Airlines for America®

We Connect the World

SAF 101

Introduction to Alternative Jet Fuels and Their Handling

Gammon Aviation Fuel Handling and Training Symposium

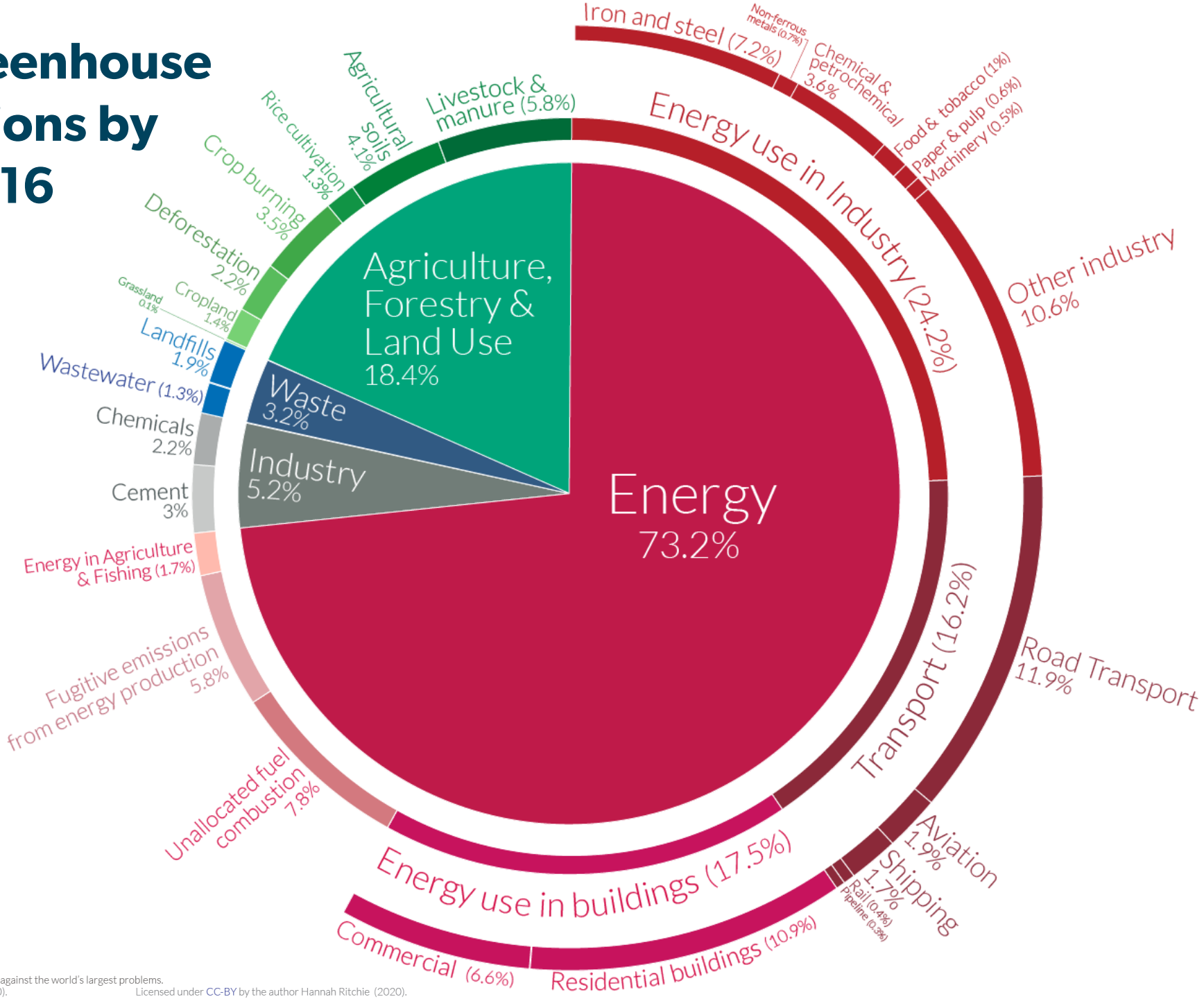
February 2025

TODAY'S SAF 101 TAKE AWAYS

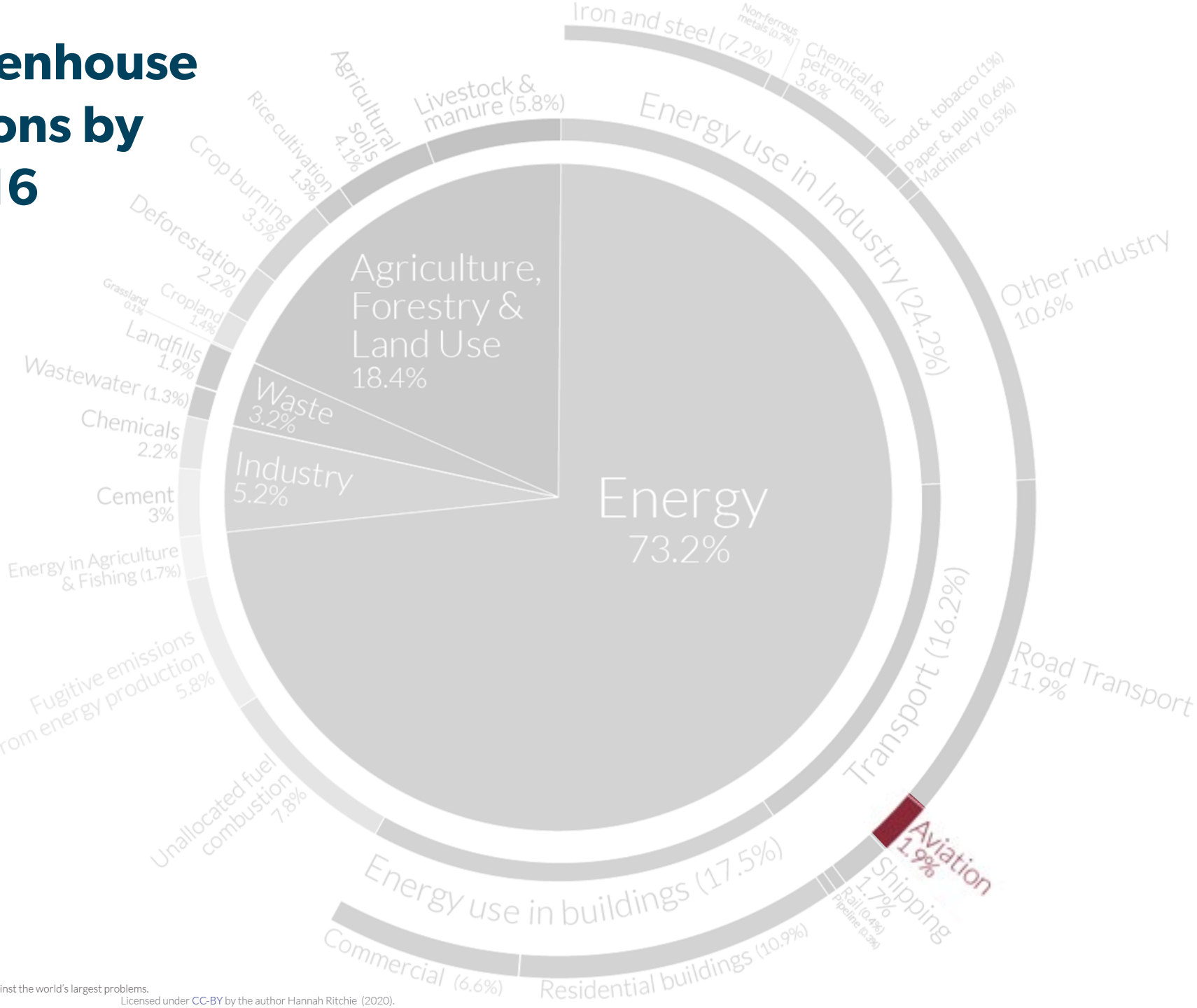
- SAF is just a different way to make the same thing we've used for the last 75+ years
- Synthetic production of jet fuel isn't new
- SAF may have/be required to have more paperwork
- By the time its at the airport, SAF is just jet fuel – treat it as such
- All aircraft certified to fly on jet fuel are certified to fly on jet fuel!

Why SAF?

Global greenhouse gas emissions by sector, 2016



Global greenhouse gas emissions by sector, 2016



AIRLINES FLY GREEN

COMMITTED TO NET-ZERO CARBON EMISSIONS BY 2050

The major U.S. airlines have committed to working across the aviation industry and with government leaders in a positive partnership to achieve net-zero carbon emissions by 2050.

What is SAF?

A different way to make the same thing

“Conventional” Beef

Source: Kitchen Swagger

Synthetic Beef

Source: The Well by Northwell

Not Beef

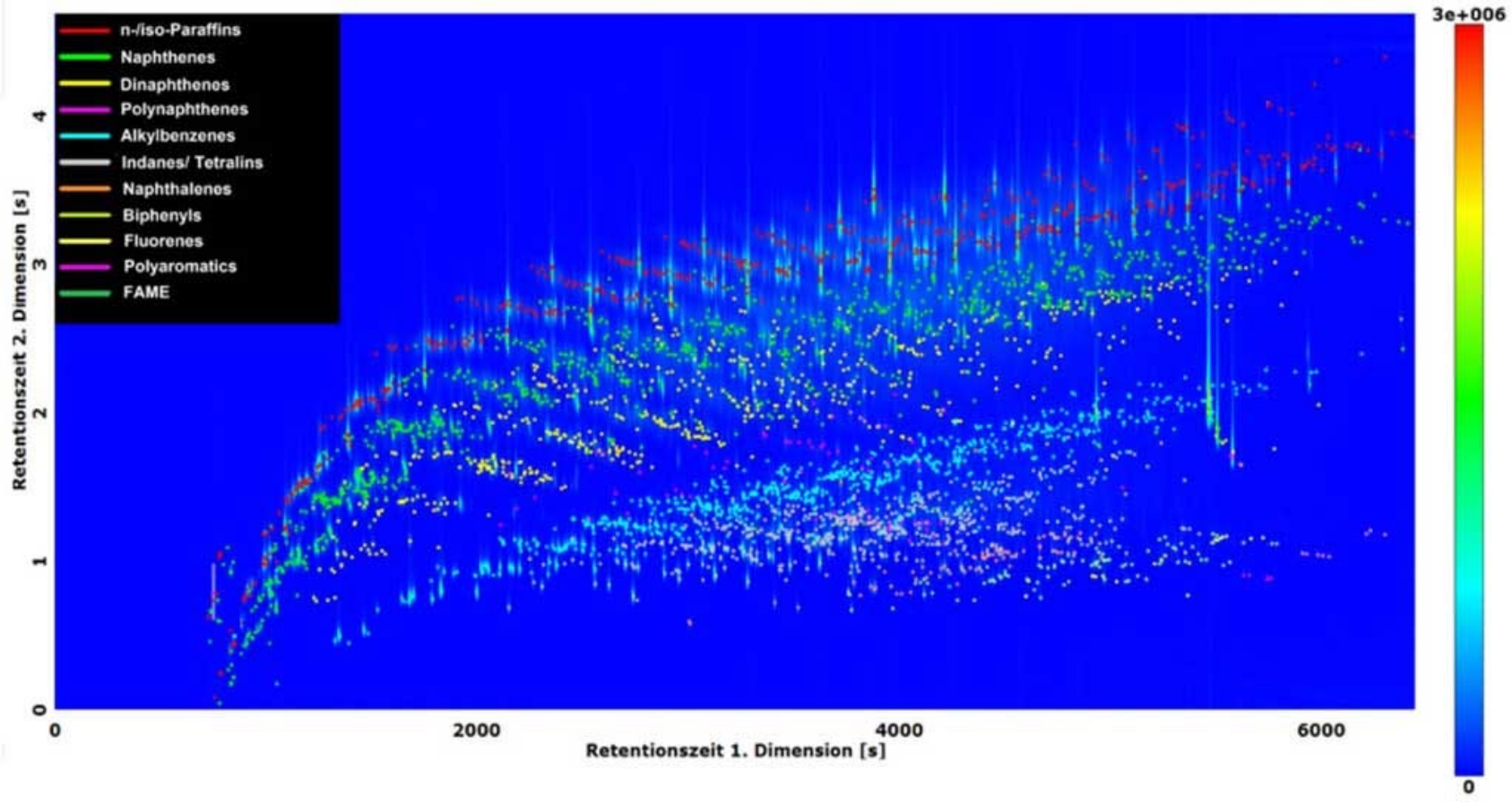
Source: Healthline

“Drop-In” Beef

Source: Kitchen Swagger

What is Jet Fuel?

A complex mixture of hundreds of unique molecules



Source: ASG Analytik Service

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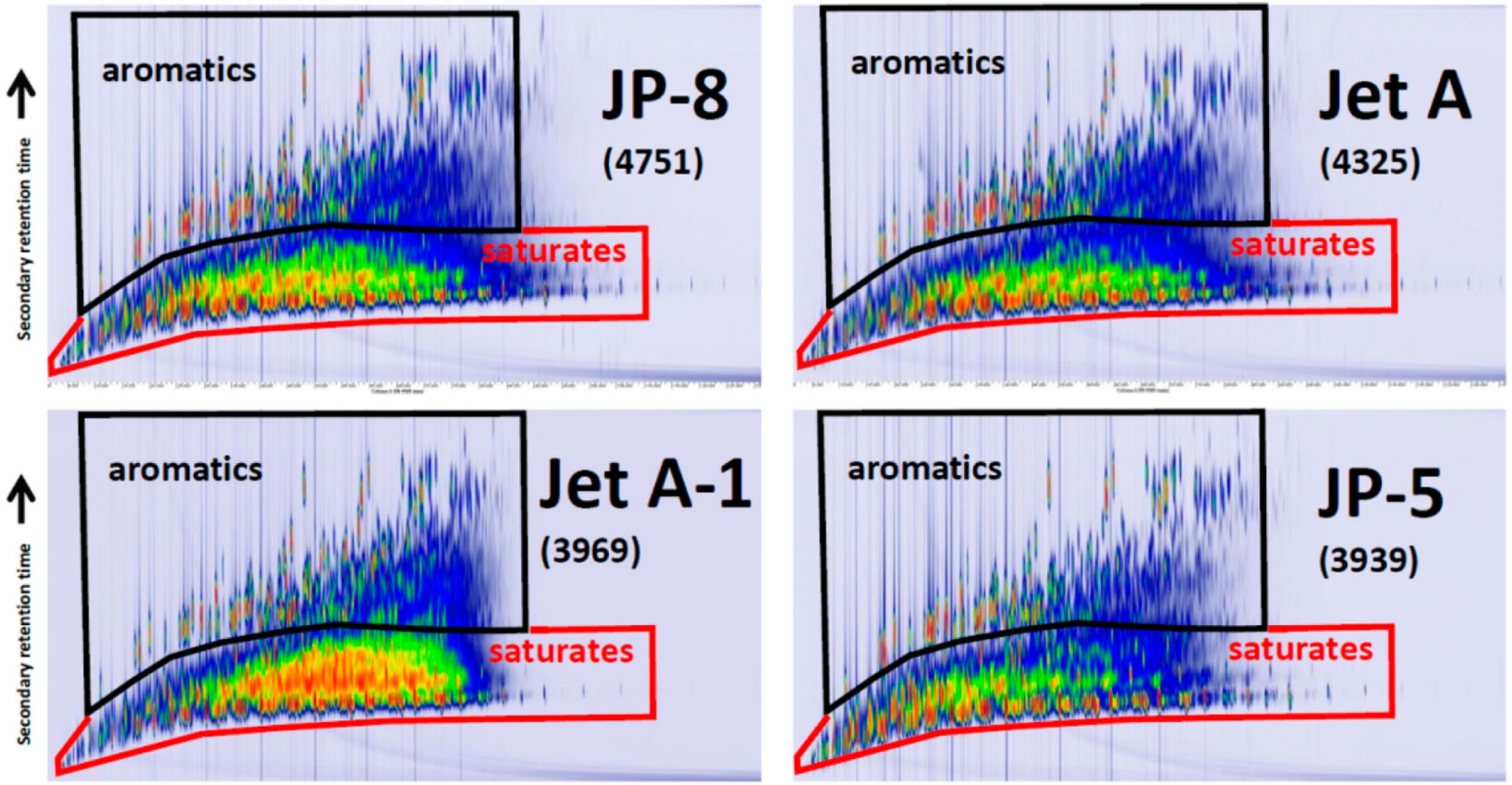
What is Jet Fuel?

Each batch is unique based on the crude slate and refinery processing



Source: Energy Fuels 2014, 28, 9, 5696–5706, with permission

Tentative Specifications for

AVIATION TURBINE FUELS[1]

ASTM Designation: D 1655 – 59 T

ISSUED, 1959.[2]

These Tentative Specifications have been approved by the sponsoring committee and accepted by the Society in accordance with established procedures, for use pending adoption as standard. Suggestions for revisions should be addressed to the Society at 1916 Race St., Philadelphia 3, Pa.

Scope

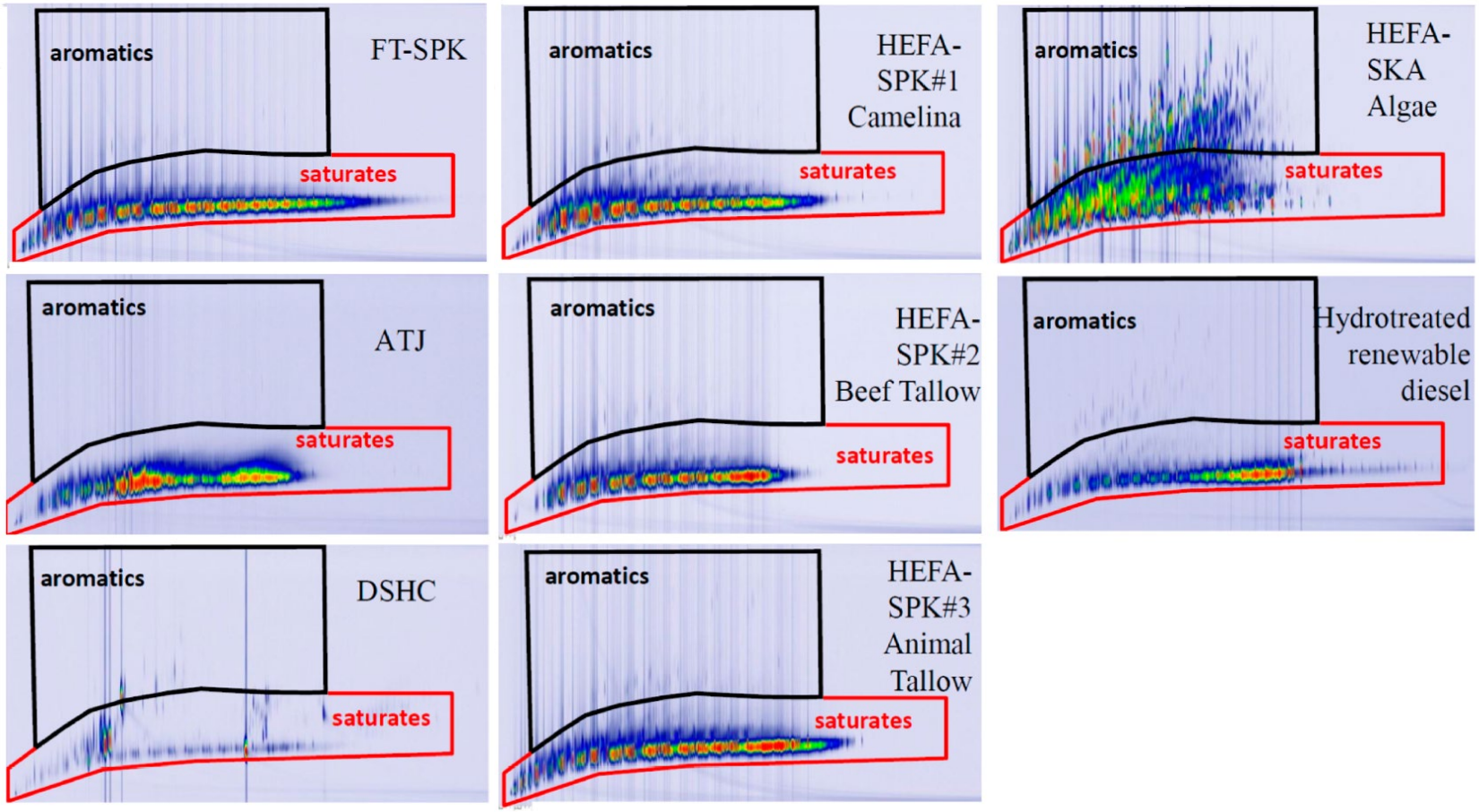
1. (*a*) These specifications are for the use of purchasing agencies in formulating

low temperature characteristics for certain operations.

General

What are Synthetic Blending Components

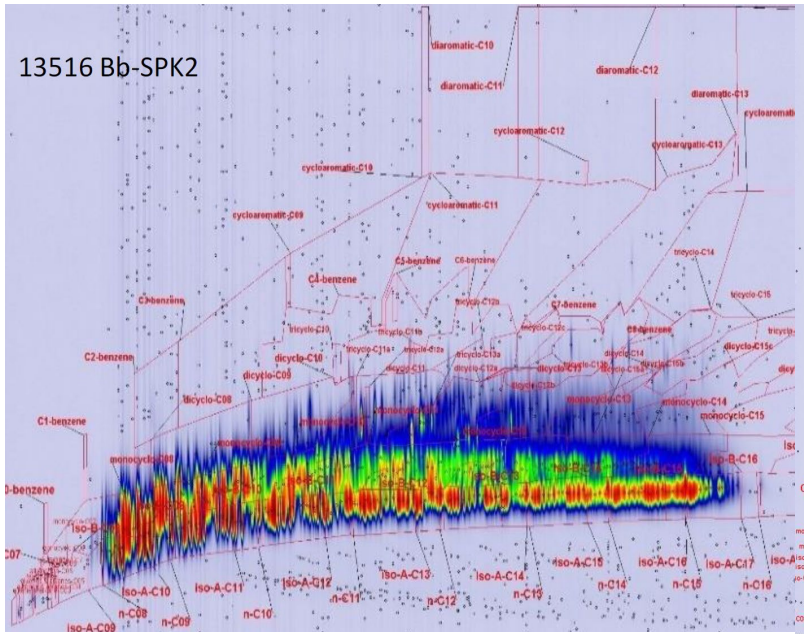
A feedstock processed and converted into one or many unique molecules

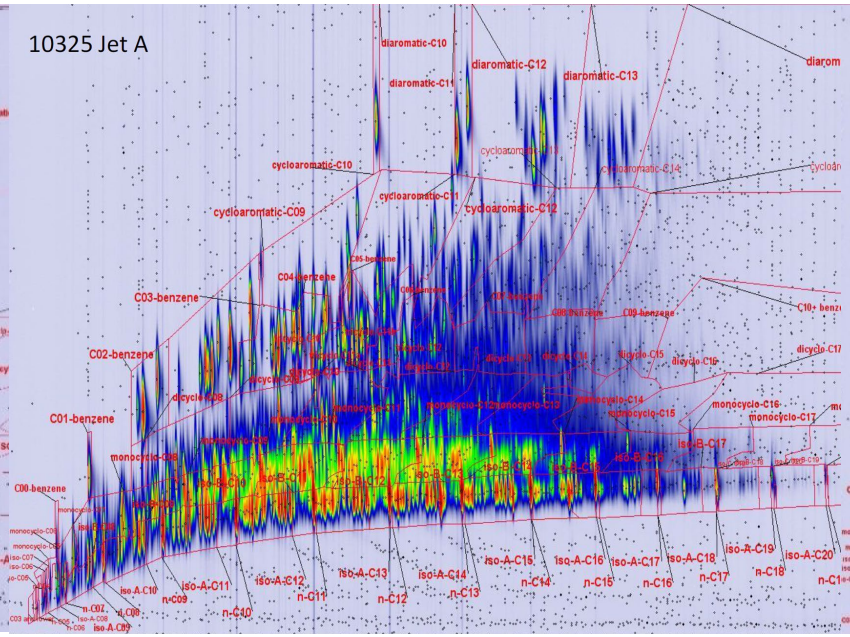


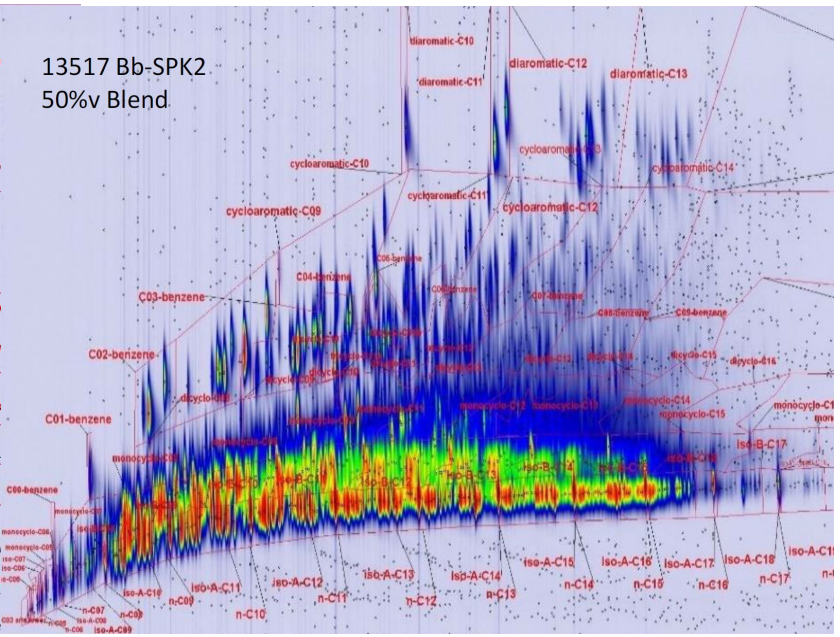
Source: Energy Fuels 2014, 28, 9, 5696–5706, with permission

What is Semi-Synthetic Aviation Turbine (Jet) Fuel?

A mixture of synthetic blending component with conventional jet fuel







Synthetic Blending Component

Conventional Jet

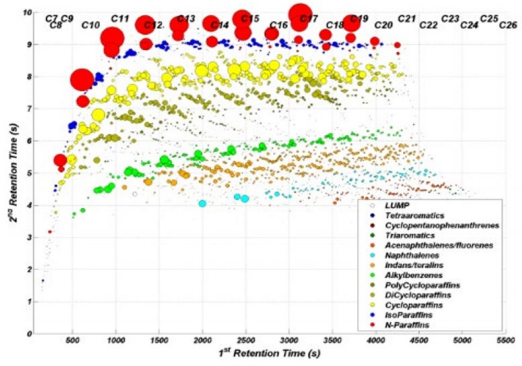
Semi-Synthetic Jet Fuel

Source: ASTM Research Report RR:D02-1925

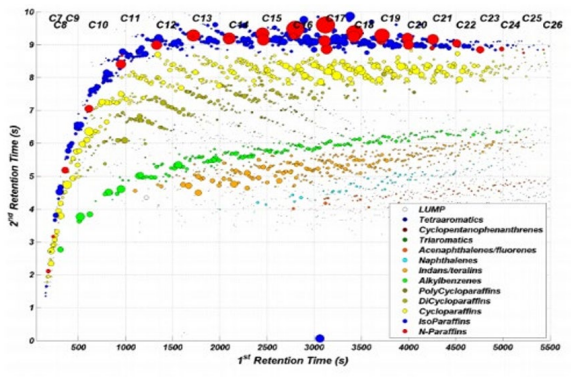
Source: KLM

What is Fully-Synthetic Aviation Turbine (Jet) Fuel?

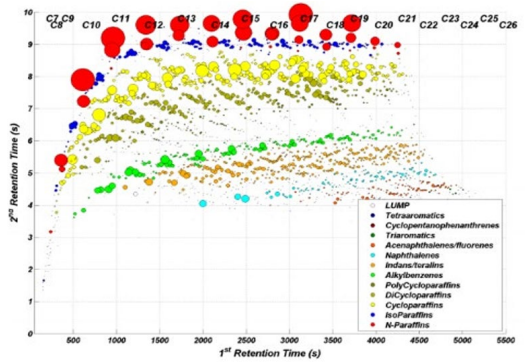
A synthetic mixture of molecules that without blending is already identical to conventional jet fuel



Synthetic Blending Component



Conventional Jet



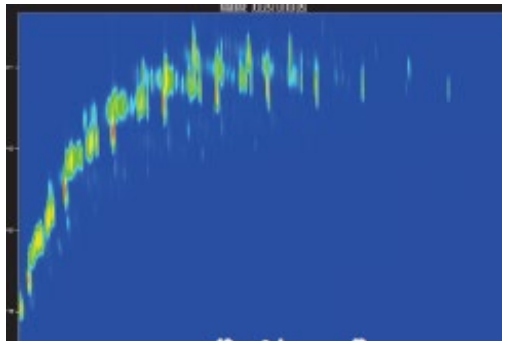
Fully-Synthetic Jet Fuel

Source: Chevron Lummus Global, ARA

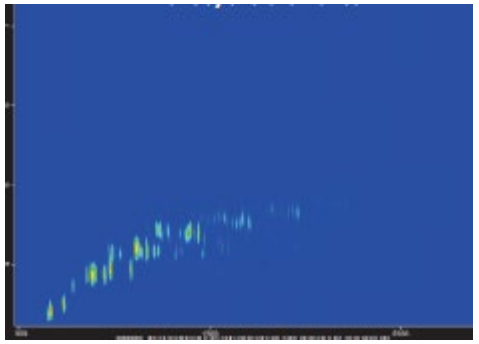
Source: U.S. Navy

What is Fully-Synthetic Aviation Turbine (Jet) Fuel?

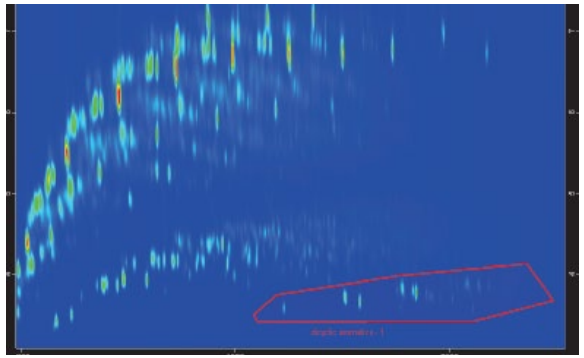
A synthetic mixture of molecules that with blending is already identical to conventional jet fuel



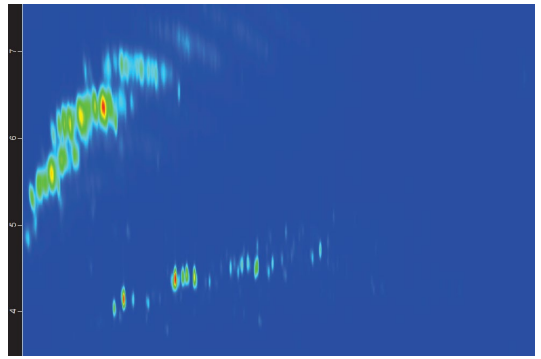
Synthetic Blending Component



Synthetic Blending Component



Conventional Jet



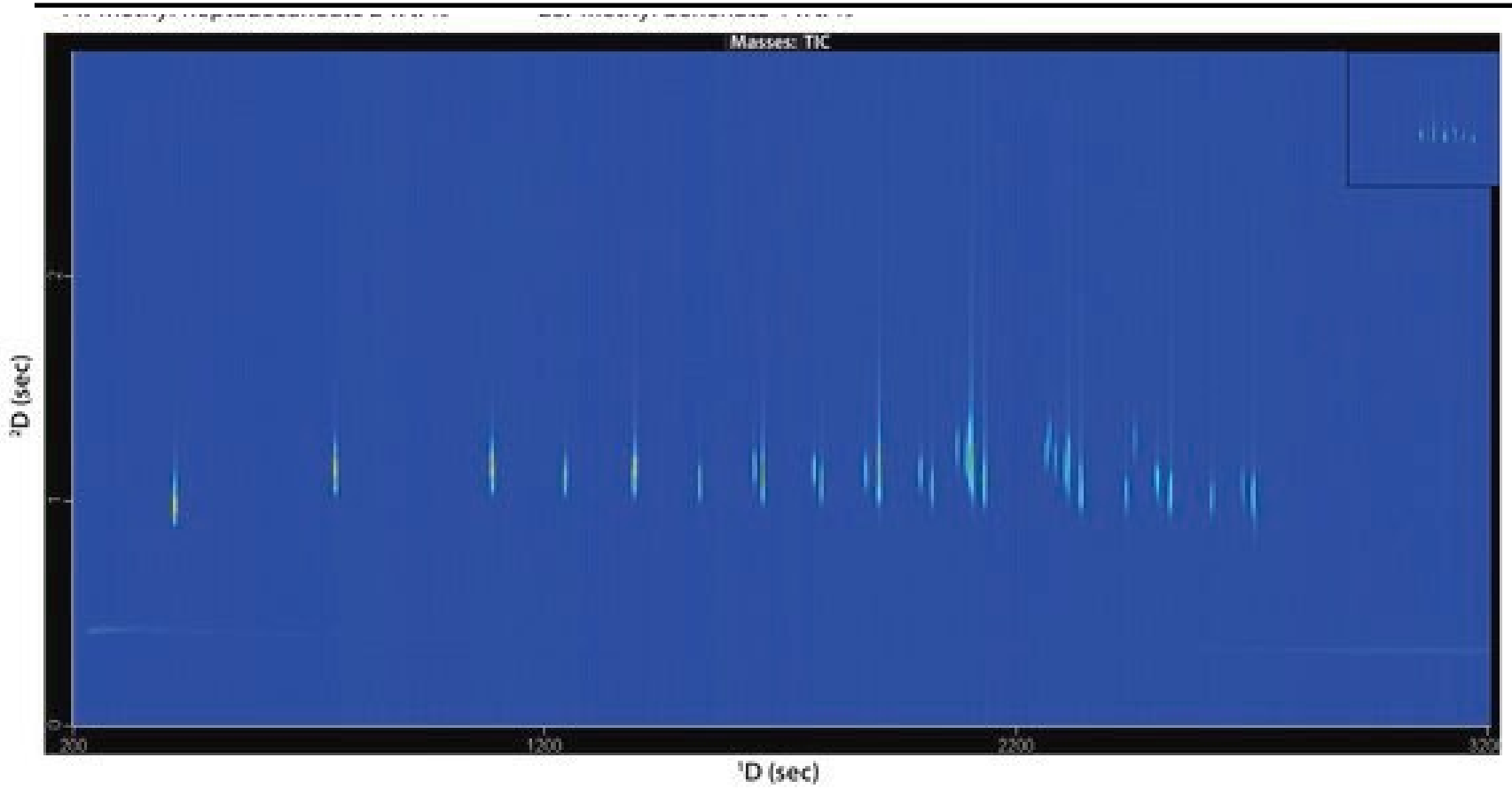
Fully-Synthetic Jet Fuel

Source: LECO Corporation

Source: United Airlines

What is not jet fuel?

Molecules that aren't found in conventional jet fuel



Source: Millipore Sigma

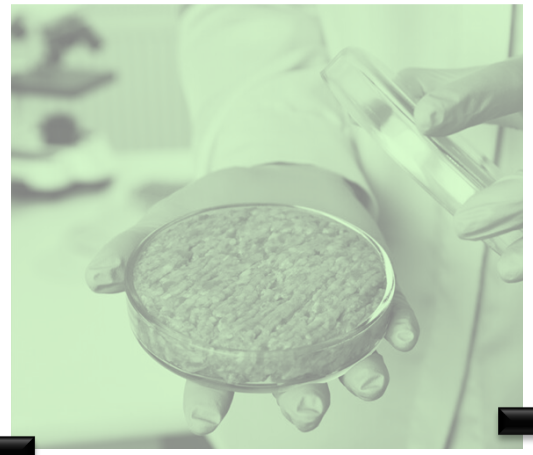
SAF: Sustainable Aviation Fuel

Conventional Jet Fuel

Jet A

+

Synthetic Blend Component



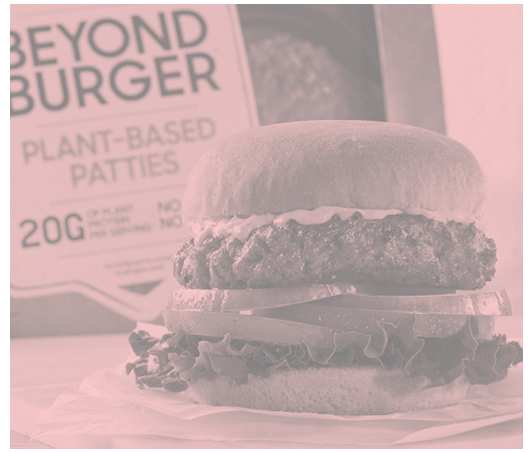
SBC

=

Drop-In Jet Fuel

SSATF

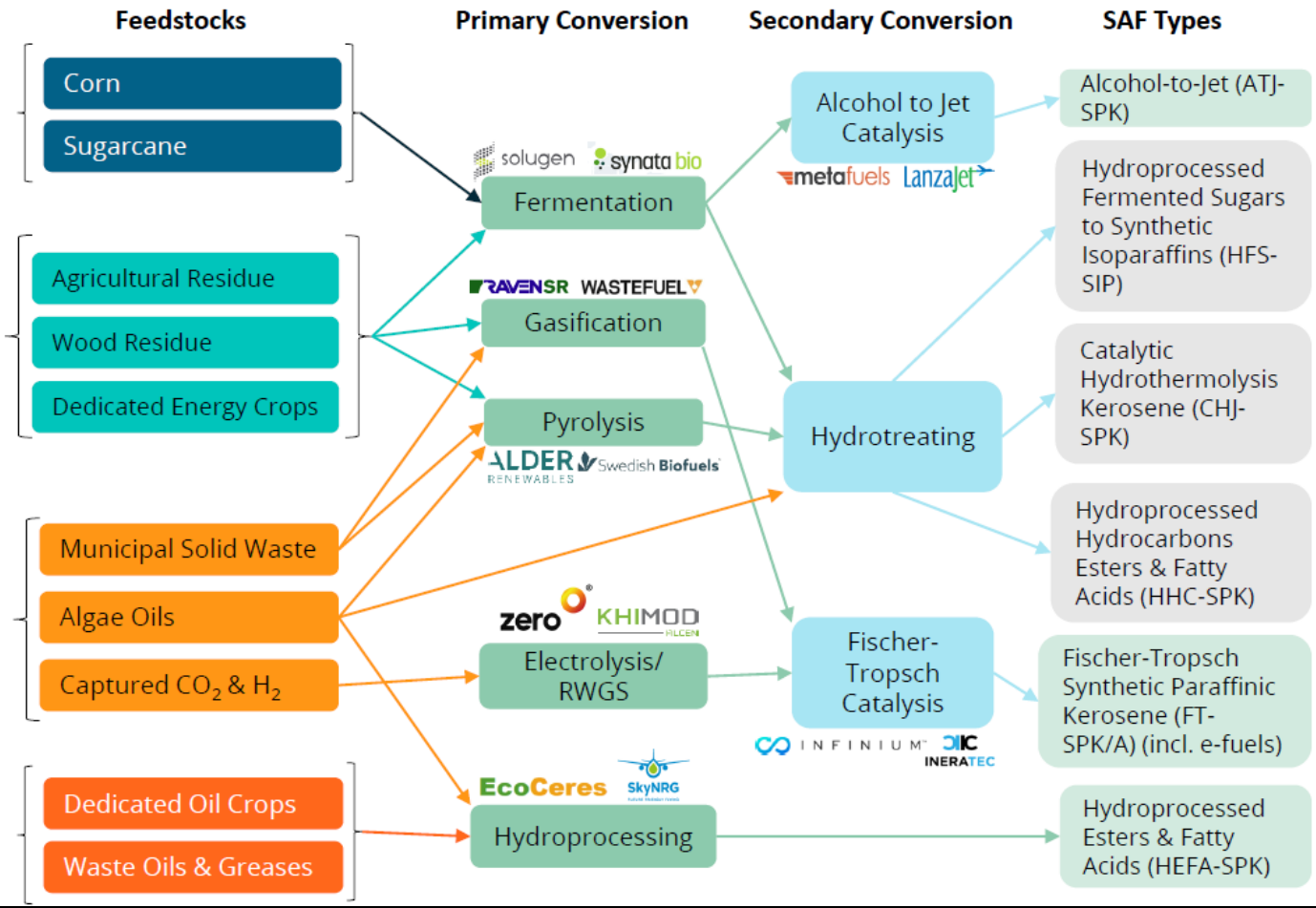
Not Jet Fuel



Biodiesel

SAF Production

How we make (synthesize) SAF



Source: Cleantech Group

Cleantech Group

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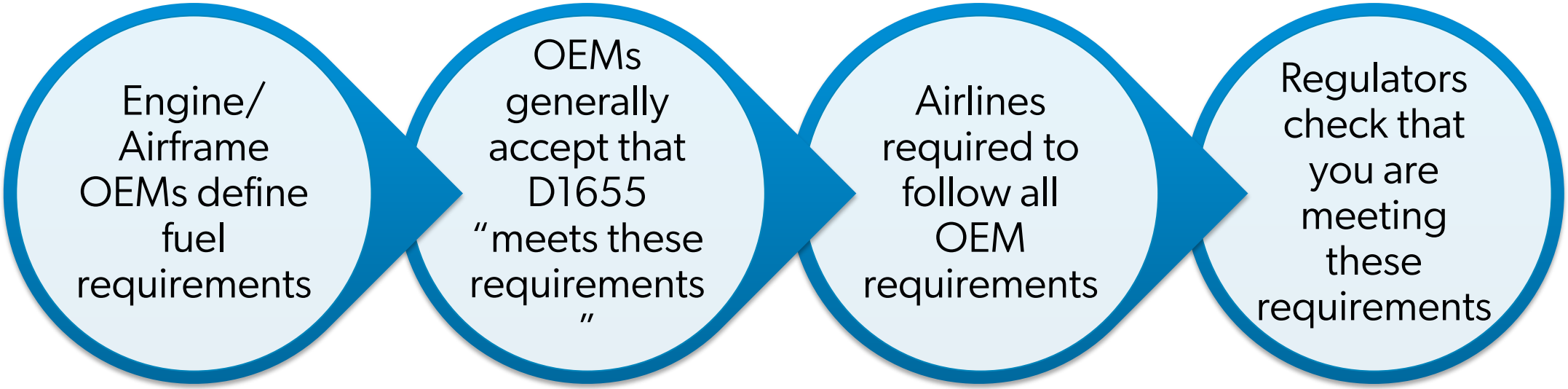
What is Co-Processing?

Processing the SAF feedstock together with crude oil in a conventional refinery

SAF Approval Process

SAF Approval Tenets

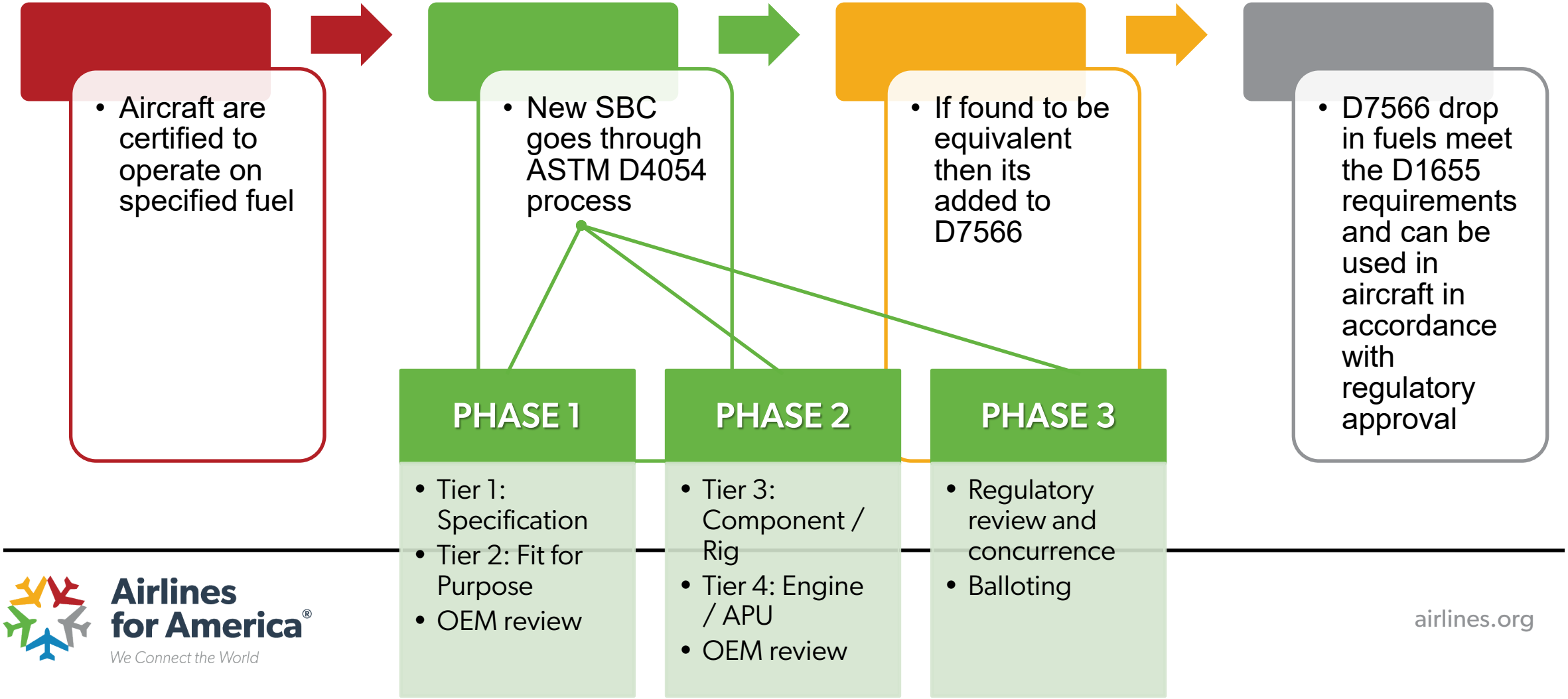
ASTM does NOT approve fuels for use in civil aircraft



FAA Approval/Acceptance of SAF

- Aircraft are certified to operate on specified fuel
- New SBC goes through ASTM D4054 process
- If found to be equivalent then its added to D7566
- D7566 drop in fuels meet the D1655 requirements and can be used in aircraft in accordance with regulatory approval

FAA Approval/Acceptance of SAF

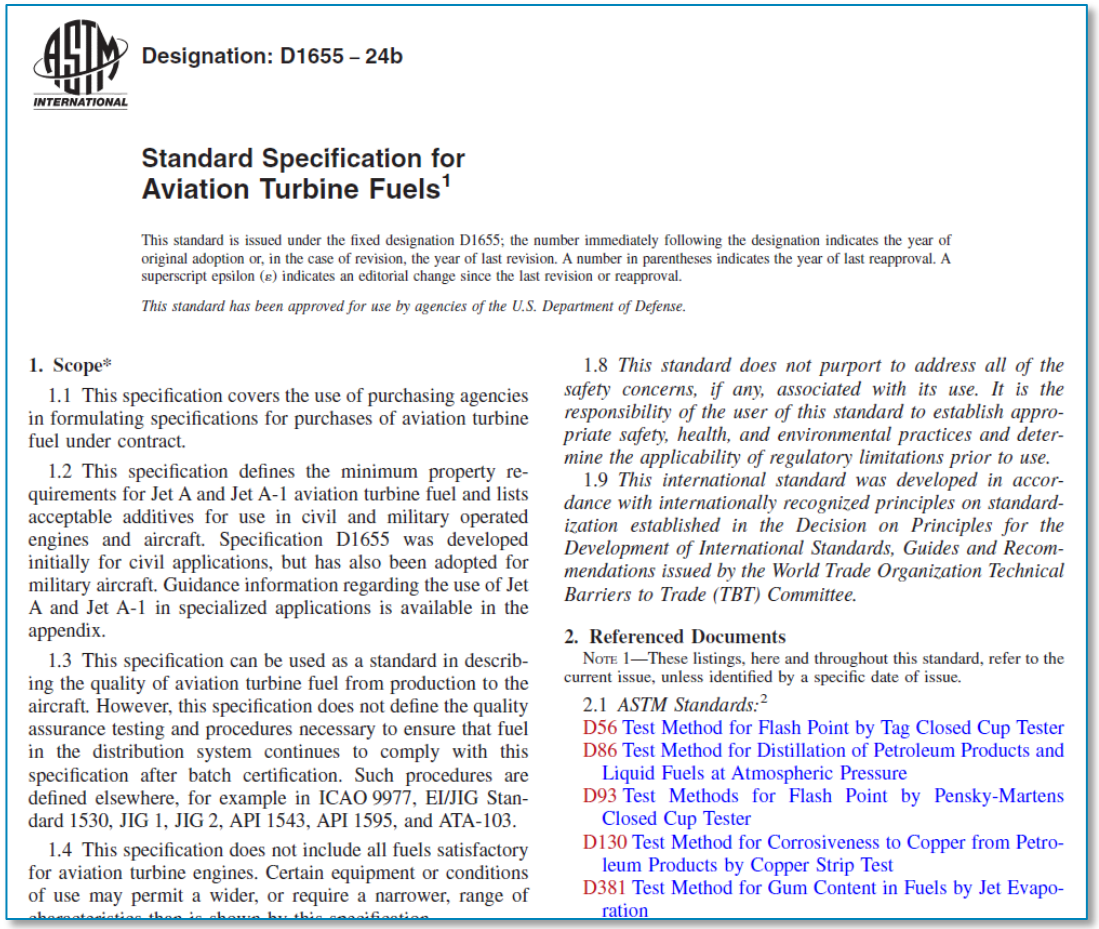


SAF Specifications

ASTM D1655: Aviation Turbine Fuel

Conventional jet fuel

- Jet fuel defined in ASTM D1655 (or DEFSTAN 91-091)
- Includes properties and refinery processing requirements
- Defines acceptable additives and limits for incidental contaminants



Designation: D1655 – 24b

Standard Specification for Aviation Turbine Fuels[1]

This standard is issued under the fixed designation D1655; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification covers the use of purchasing agencies in formulating specifications for purchases of aviation turbine fuel under contract.

1.2 This specification defines the minimum property requirements for Jet A and Jet A-1 aviation turbine fuel and lists acceptable additives for use in civil and military operated engines and aircraft. Specification D1655 was developed initially for civil applications, but has also been adopted for military aircraft. Guidance information regarding the use of Jet A and Jet A-1 in specialized applications is available in the appendix.

1.3 This specification can be used as a standard in describing the quality of aviation turbine fuel from production to the aircraft. However, this specification does not define the quality assurance testing and procedures necessary to ensure that fuel in the distribution system continues to comply with this specification after batch certification. Such procedures are defined elsewhere, for example in ICAO 9977, EI/JIG Standard 1530, JIG 1, JIG 2, API 1543, API 1595, and ATA-103.

1.4 This specification does not include all fuels satisfactory for aviation turbine engines. Certain equipment or conditions of use may permit a wider, or require a narrower, range of characteristics than is shown by this specification.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

NOTE 1—These listings, here and throughout this standard, refer to the current issue, unless identified by a specific date of issue.

2.1 *ASTM Standards:*[2]

D56 Test Method for Flash Point by Tag Closed Cup Tester

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure

D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test

D381 Test Method for Gum Content in Fuels by Jet Evaporation

ASTM D1655: Aviation Turbine Fuel

Conventional jet fuel

TABLE 1 Detailed Requirements of Aviation Turbine Fuels[A]

Property		Jet A or Jet A-1	Test Methods[B] Referee	Alternative
COMPOSITION				
Acidity, total mg KOH/g	max	0.10	D3242/IP 354	
Aromatics				
(1) percent by volume, or	max	25	D1319	IP 156[C] or D8267 or D8305[D]
(2) percent by volume	max	26.5		D6379/IP 436
Sulfur, mercaptan,[E] percent by mass	max	0.003	D3227/IP 342	
Sulfur, total percent by mass	max	0.30		D1266, D2622, D4294, D5453, or IP 336
VOLATILITY				
Distillation temperature, °C:			D86[F]	D2887 or IP 406,[G] D7344,[H, I] D7345,[H] IP 123[J]
10 % recovered, temperature	max	205		
50 % recovered, temperature		report		
90 % recovered, temperature		report		
Final boiling point, temperature	max	300		
Distillation residue, %	max	1.5		
Distillation loss, %	max	1.5		
Flash point, °C	min	38[J]	D56	D93,[K] D3828,[K] D7236,[K] IP 170,[K] IP 523,[K] or IP 534[K]
Density at 15 °C, kg/m³		775 to 840		D1298 or IP 160 or D4052 or IP 365
FLUIDITY[L]				

5

D1655 – 24b

TABLE 1 *Continued*

Property		Jet A or Jet A-1	Test Methods[B] Referee	Alternative
Freezing point, °C	max	–40 Jet A[M,N]	D2386/IP 16	D5972/IP 435, D7153/IP 529, or D7154 or IP 528
		–47 Jet A-1[M,N]		
Viscosity –20 °C, mm²/s[O]	max	8.0	D445 or IP 71, Section 1	D7042[P] or D7945
COMBUSTION				
Net heat of combustion, MJ/kg	min	42.8[Q]	D4809	D4529, D3338, or IP 12
One of the following require-ments shall be met:				
(1) Smoke point, mm, or	min	25.0	D1322/IP 598	

6.1 Aviation turbine fuel is a complex mixture predominantly composed of hydrocarbons and varies depending on crude source and manufacturing process. **Consequently, it is impossible to define the exact composition of Jet A/A-1**. This specification has therefore evolved primarily as a performance specification rather than a compositional specification. It is acknowledged that this largely **relies on accumulated experience**; therefore the specification limits aviation turbine fuels to those made from conventional sources or by specifically approved processes.

ASTM D7566: Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Designation: D7566 – 23

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons[1]

This standard is issued under the fixed designation D7566; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification covers the manufacture of aviation turbine fuel that consists of conventional and synthetic blending components.

1.2 See Appendix X2 for an expanded description of the procedure for the production and blending of synthetic blend components.

1.3 This specification applies only at the point of batch origination, as follows:

1.3.1 Aviation turbine fuel manufactured, certified, and released to all the requirements of Table 1 of this specification (D7566), meets the requirements of Specification D1655 and shall be regarded as Specification D1655 turbine fuel. Duplicate testing is not necessary; the same data may be used for both D7566 and D1655 compliance. Once the fuel is released to this specification (D7566) the unique requirements of this specification are no longer applicable: any recertification shall be done in accordance with Table 1 of Specification D1655.

1.3.3 Once a fuel is redesignated as D1655 aviation turbine fuel, it can be handled in the same fashion as the equivalent refined D1655 aviation turbine fuel.

1.4 This specification defines the minimum property requirements for aviation turbine fuel that contain synthesized hydrocarbons and lists acceptable additives for use in civil operated engines and aircrafts. Specification D7566 is directed at civil applications, and maintained as such, but may be adopted for military, government, or other specialized uses.

1.5 This specification can be used as a standard in describing the quality of aviation turbine fuel from production to the aircraft. However, this specification does not define the quality assurance testing and procedures necessary to ensure that fuel in the distribution system continues to comply with this specification after batch certification. Such procedures are defined elsewhere, for example in ICAO 9977, EI/JIG Standard 1530, JIG 1, JIG 2, API 1543, API 1595, and ATA-103, and IATA Guidance Material for Sustainable Aviation Fuel Management.

SYNTHETIC jet fuel defined in ASTM D7566 (or 91-091)

Includes properties and processing requirements

Defines acceptable additives and limits for incidental contaminants

ASTM D7566 ANNEXES

Each annex defines a process for synthesizing hydrocarbons that can be blended with jet fuel

ANNEXES

(Mandatory Information)

A1. FISCHER-TROPSCH HYDROPROCESSED SYNTHESIZED PARAFFINIC KEROSINE

A1.1 Scope

A1.1.1 This annex defines hydroprocessed synthesized paraffinic kerosine (SPK) for use as a synthetic blending component in aviation turbine fuels for use in civil aircraft and engines. The specifications in this annex can be used for contractual exchange of synthetic blending components.

A1.1.2 The synthetic blending components defined in this annex are not satisfactory for aviation turbine engines unless blended with conventional fuel or conventional blending components in accordance with the limitations described in 6.1.1.

A1.1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

A1.2 General

A1.2.1 All requirements of the main body of this specification apply except as detailed in this annex.

A1.3 Terminology

A1.3.1 *Definitions of Terms Specific to This Annex:*

A1.3.1.1 *Fischer-Tropsch hydroprocessed synthesized paraffinic kerosine (FT-SPK), n*—SPK produced from one or more precursors synthesized by Fischer-Tropsch processing.

A1.4 Materials and Manufacture

A1.4.1 FT-SPK synthetic blending components shall be comprised of hydroprocessed synthesized paraffinic kerosine wholly derived from:

A1.4.1.1 Paraffins and olefins derived from synthesis gas via the Fischer-Tropsch (FT) process using Iron or Cobalt catalyst.

A1.4.1.2 Subsequent processing of the product shall include hydrotreating, hydrocracking, or hydroisomerization and is expected to include, but not be limited to, a combination of

TABLE A1.1 Detailed Batch Requirements; Fischer–Tropsch Hydroprocessed SPK[A]

Property		FT–SPK	Test Method[B]
COMPOSITION			
Acidity, total mg KOH/g	Max	0.015	D3242/IP 354
VOLATILITY			
Distillation—both of the following requirements shall be met:			
1. Physical Distillation			D86[C] or IP 123[C] or D7344 or D7345
Distillation temperature, °C:			
10 % recovered, temperature (T10)	Max	205	
50 % recovered, temperature (T50)		report	
90 % recovered, temperature (T90)		report	
Final boiling point, temperature	Max	300	
T90-T10, °C	Min	22	
Distillation residue, percent	Max	1.5	
Distillation loss, percent	Max	1.5	
2. Simulated Distillation			D2887[J, K]/IP 406
Distillation temperature, °C:			
10 % recovered, temperature (T10)		report	
20 % recovered, temperature (T20)		report	
50 % recovered, temperature (T50)		report	
80 % recovered, temperature (T80)		report	
90 % recovered, temperature (T90)		report	
Final boiling point, temperature		report	
Flash point, °C	Min	38[D]	D56 or D3828[E], D7236[E], IP 170[E], IP 523[E] or IP 534[E]
Density at 15 °C, kg/m³		730 to 770	D1298 / IP 160, D4052 or IP 365
Freezing point, °C	Max	–40	D5972 / IP 435, D7153/IP 529, D7154/IP 528, or D2386/IP 16
Thermal Stability (2.5 h at control temperature)			
Temperature, °C	Min	325[F]	D3241[G] /IP 323[G]
Filter pressure drop, mm Hg	Max	25	
Tube rating: One of the following requirements shall be met:[H]			
(1) Annex A1 VTR, VTR Color Code	Less than	3 No peacock or abnormal color deposits	
(2) Annex A2 ITR or Annex A3 ETR, nm avg over area of 2.5 mm²	Max	85	
ADDITIVES			
Antioxidants, mg/L[I]	Min	17	
	Max	24	

ASTM D7566 ANNEXES

Each annex defines a process for synthesizing hydrocarbons that can be blended with jet fuel

ANNEXES

(Mandatory Information)

A1. FISCHER-TROPSCH HYDROPROCESSED SYNTHESIZED PARAFFINIC KEROSINE

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A1.1.2 The synthetic blending components defined in this annex are not satisfactory for aviation turbine engines unless blended with conventional fuel or conventional blending components in accordance with the limitations described in 6.1.1.

A1.1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

A1.2 General

A1.2.1 All requirements of the main body of this specification apply except as detailed in this annex.

A1.3 Terminology

A1.3.1 *Definitions of Terms Specific to This Annex:*

A1.3.1.1 *Fischer-Tropsch hydroproc*
affinic kerosine (FT-SPK), n—S
precursors synthesized by Fische

A1.4 Materials and Manuf

A1.4.1 FT-SPK synthetic b
comprised of hydroprocessed syn
wholly derived from:

A1.4.1.1 Paraffins and olefi
via the Fischer-Tropsch (FT) pr
catalyst.

A1.4.1.2 Subsequent processing
hydrotreating, hydrocracking, or
expected to include, but not be

8 approved annexes

TABLE A1.1 Detailed Batch Requirements; Fischer–Tropsch Hydroprocessed SPK[A]

Property		FT–SPK	Test Method[B]
COMPOSITION			
Acidity, total mg KOH/g	Max	0.015	D3242/IP 354
VOL TY			
Dis –both e following requirements shall be met:			
Di			D86[C] or IP 123[C] or D7344 or D7345
re, °C:			
(T10)	Max	205	
e (T50)		report	
ure (T90)		report	
	Max	300	
	Min	22	
	Max	1.5	
	Max	1.5	
			D2887[J, K]/IP 406
		report	
		report	
		report	
		report	
		report	
		report	
	Min	38[D]	D56 or D3828[E], D7236[E], IP 170[E], IP 523[E] or IP 534[E]
		730 to 770	D1298 / IP 160, D4052 or IP 365
	Max	–40	D5972 / IP 435, D7153/IP 529, D7154/IP 528, or D2386/IP 16
trol temperature)			
	Min	325[F]	D3241[G] /IP 323[G]
p, mm	Max	25	
ing: the following requirements shall be met:[H]			
nex A1 R, VTR Color Code	Less than	3	
		No peacock or abnormal color deposits	
(2) Annex A2 ITR or Annex A3 ETR, nm avg over area of 2.5 mm^2	Max	85	
ADDITIVES			
Antioxidants, mg/L[I]	Min	17	
	Max	24	

ASTM D7566 SAF Pathways Approved

As of January 2025

D7566 Annex	Process Name	Abbreviation	Feedstocks	Max Blend
A1	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene	FT	Coal, Natural Gas, Biomass	50%
A2	Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids	HEFA	Bio-oils, Animal fat, Recycled oils	50%
A3	Synthesized iso-paraffins from hydroprocessed fermented sugars	SIP	Biomass for sugar	10%
A4*	Synthesized kerosene with aromatics derived by alkylation of light aromatics	FT-SKA	Coal, Natural Gas, Biomass	50%
A5	Alcohol to jet synthetic paraffinic kerosene	ATJ-SPK	Biomass from ethanol, isobutanol, isobutene	50%
A6*	Catalytic hydrothermolysis	CHJ	Triglycerides	50%
A7	Synthesized paraffinic kerosene from hydrocarbon-hydroprocessed esters and fatty acids	HC-HEFA-SPK	Algae	10%
A8*	Alcohol to jet synthetic kerosene with aromatics	ATJ-SKA	Starch/Sugars, Cellulosic Biomass	50%

*Have the potential to be approved as a 100% SAF in the future

ASTM D1655, Annex A1: Co-Processing

Processing the SAF feedstock together with crude oil in a conventional refinery

A1. FUELS FROM NON-CONVENTIONAL SOURCES

A1.1 Introduction

A1.1.1 Jet fuel has contained synthesized hydrocarbons since the inception of Specification D1655. However, these synthesized materials are generated from petroleum, oil sand or shale derived feedstocks in the refinery and exhibit properties substantially similar to historically refined kerosene. The fuel property requirements defined in Specification D1655, Table 1 are batch-to-batch quality control tests which historically have provided fit-for-purpose jet fuel but assume that the jet fuel has a composition that is substantially similar to historical compositions. There is no basis to assume that fuels having novel compositions provide fit-for-purpose performance in current aviation hardware even if they appear to satisfy Specification D1655, Table 1 requirements. While the use of synthesized hydrocarbons is known and an acceptable practice, the use of synthesized hydrocarbon blend stocks from new sources requires specific guidance. This guidance can be found in Specification D7566.

A1.1.2 Specification D7566 was developed by Subcommittee D02.J0 to provide control for jet fuel produced with non-petroleum, non-shale, non-oil sands derived synthesized components. This specification guides the preparation of fuel blends that are compositionally similar to the refined fuels generated to Specification D1655 and can be controlled thereby in the distribution system. Aviation turbine fuels with synthetic components produced in accordance with Specification D7566 meet the requirements of Specification D1655. Specification D7566 does not yet include all fuels from non-conventional sources, so as an interim solution, it has been deemed necessary to recognize, on an individual basis, fuels from non-conventional sources whose performance complies with the intent of this specification and that have been approved by a coordinated specification authority.

A1.2.1.2 The SASOL fully synthetic fuel, a blend of up to five synthetic streams, specified in B.3 of Defence Standard (Def Stan) 91-091, is recognized as meeting the requirements of Specification D1655.

A1.2.2 *Co-processing*[16,17,18]—Feedstocks other than those defined in A1.2.2.1, A1.2.2.2, or A1.2.2.3 are excluded from jet fuel co-processing.

A1.2.2.1 Co-processing of mono-, di-, and triglycerides, free fatty acids, and fatty acid esters producing co-hydroprocessed synthesized kerosene is recognized as being acceptable for jet fuel manufacture. The process streams used for jet fuel production in co-processing refinery units shall not exceed 5 % by volume of mono-, di-, and triglycerides, free fatty acids, and fatty acid esters in feedstock volume with the balance (≥ 95 % by volume) being conventionally sourced hydrocarbons as described in 6.1. Co-processing shall include hydrocracking or hydrotreating and fractionation. Processing may also include other conventional refinery processes. The final product is limited to 5 % by volume of co-hydroprocessed synthesized kerosene derived from mono-, di-, and triglycerides, free fatty acids, and fatty acid ester feedstock in any jet batch. Refer to X1.15.5 for a discussion of biobased carbon content and identification of the applicable test method.

A1.2.2.2 Co-processing of hydrocarbons derived from synthesis gas via the Fischer-Tropsch process using iron or cobalt catalyst producing co-hydroprocessed synthesized kerosene is recognized as being acceptable for jet fuel manufacture. The process streams used for jet fuel production in co-processing refinery units shall not exceed 5 % by volume of Fischer-Tropsch hydrocarbons in feedstock volume with the balance

[16] A task force studied the impact of co-hydroprocessing esters and fatty acids at up to 5 % by volume with crude oil derived middle distillates following Specification D7566 Annex 2 approval. Supporting data have been filed at ASTM Interna-

Jet fuel defined in ASTM D1655 (or DEFSTAN 91-091)

Includes ADDITIONAL properties and refinery processing requirements

Includes limits of how much co-processed material can be in the final jet fuel product

ASTM D1655, Annex A1: Co-Processing

Processing the SAF feedstock together with crude oil in a conventional refinery

TABLE A1.1 Extended Requirements of Aviation Turbine Fuels Containing Co-hydroprocessed Esters and Fatty Acids, Fischer-Tropsch Hydrocarbons, or Hydrocarbons from Esters and Fatty Acids[A, B]

Property		Jet A or Jet A-1	Test Methods[C] Referee	Alternative
THERMAL STABILITY[D, E] (2.5 h at control temperature of 280 °C min)				
Filter pressure drop, mm Hg	max	25	D3241/IP 323	
Tube rating: One of the following requirements shall be met:[F]				
(1) Annex A1 VTR, VTR Color Code	Less than	3 No peacock or abnormal color deposits		
(2) Annex A2 ITR or Annex A3 ETR, or Annex A4 MWETR, nm average over area of 2.5 mm^2	max	85		
Viscosity –40 °C mm^2/s[G]	max	12.0	D445 or IP 71, Section 1[H]	D7042[I] or D7945
Freezing point °C		Table 1 freezing point limits apply	D5972/IP 435	D7153/IP 529 or D7154 or IP 528
Unconverted esters and fatty acids, mg/kg[J]	max	15	D7797/IP 583[J,K]	
Aromatics: One of the following requirements shall be met:[L]				
1. Aromatics, volume percent	min[M]	8	D1319[N]	IP 156,[N] D8267, or D8305[O]
2. Aromatics, volume percent	min[M]	8.4		D6379/IP 436
VOLATILITY				
Distillation			D86[P]	D2887 or IP 406,[Q] D7344,[R] D7345,[R] IP 123[P]
T50-T10, °C[L]	min	15		
T90-T10, °C[L]	min	40		
LUBRICITY				
Lubricity, mm[L]	max	0.85	D5001	

[A] Applies at the point of manufacture only.
[B] Applies for the finished batch of jet fuel as opposed to the product of the refinery hydroprocessing unit which is used to blend the finished batch of jet fuel.
[C] Where applicable, the referee test methods are identified in Table A1.1.
[D] A D3241 test temperature of 280 °C has been selected to help ensure that reactive compounds introduced through co-hydroprocessing of esters and fatty acids are limited. Research is ongoing on the actual requirement for a more restrictive thermal stability limit.
[E] Metal Deactivator (MDA), as described in Table 2 and the associated footnotes, may not be used to meet this requirement.
[F] Refer to Table 1, Footnote U.
[G] The kinematic viscosity specification of 12.0 mm^2/s at –40 °C maximum mitigates the potential risk of increased viscosity due to n-paraffin enrichment. Compared to conventional hydrocarbons, a co-hydroprocessed esters and fatty acids stream may contain a higher concentration of n-paraffins. Research is ongoing on how n-paraffin enrichment from co-hydroprocessed esters and fatty acids impact low temperature viscosity. The results of that research will be used to confirm the necessity of and

- Must be noted on the Refinery Certificate of Quality that the product was co-processed and noting the final volume of co-processed material in the finished product
- Additional tests are required to be listed on the Certificate in addition to the standard COA

91-091 Annex B4: Co-Processing

Processing the SAF feedstock together with crude oil in a conventional refinery

B.4.1.1.1 In the case of hydrotreating, the feed into the final hydrotreating unit, where process streams are used for jet production, shall not exceed 5% by volume in approved feedstock derived volume with the balance (≥ 95% by volume) being conventional sources as described in **Clause 4.1.1**. The final jet batch is limited to 5% by volume of co-hydroprocessed synthesized kerosene derived from co-hydrotreated mono-, di-, and triglycerides, free fatty acids and fatty acid esters.

B.4.1.1.2 In the case of hydrocracking, a hydrogen partial pressure of greater than 7000 kPa (70 bar or 1015 psi) shall be present. The feed into the final hydrocracking unit, where process streams are used for jet production, shall not exceed 30% by volume in approved feedstock with the balance (≥ 70% by volume) being conventional sources as described in **Clause 4.1.1**. The resultant stream shall:

a) not exceed 30 % by volume of co-hydroprocessed synthesized kerosene derived from mono-, di-, and triglycerides, free fatty acids, and fatty acid esters.
b) be blended at 50 % by volume maximum with conventional kerosene derived from sources as described in **Clause 4.1.1** when more than 5 % by volume of co-hydroprocessed synthesized kerosene derived from co-hydrocracked mono-, di-, and triglycerides, free fatty acids, and fatty acid ester feedstock is present, and in such cases, the finished blend shall include antioxidant of the type specified in **A.2.4** at a concentration of 17.0 to 24.0 mg/l.

The final jet batch is limited to 15% by volume of co-hydroprocessed synthesized kerosene derived from co-hydrocracked mono-, di-, and triglycerides, free fatty acids and fatty acid esters.

B.4.1.2 Co-hydroprocessing of Fischer-Tropsch hydrocarbons shall include hydrocracking or hydrotreating and fractionation. Processing may also include other conventional fuel manufacturing processes. The feed into the final hydrocracking or hydrotreating unit, where process streams are used for jet production, shall not exceed 5% by volume in approved feedstock with the balance (≥ 95% by volume) being conventional sources as described in **Clause 4.1.1**. The final jet batch is limited to 5% by volume of co-hydroprocessed synthesized kerosene derived from Fischer-Tropsch hydrocarbons.

B.4.1.3 Co-processing of hydrocarbons from hydroprocessed mono-, di-, and triglycerides, free fatty acids and fatty acid esters shall include fractionation. Processing may also include other conventional fuel manufacturing

- Co-hydrocracked feedstocks can be up to 30% of the volume in and out of the refinery stream
- Must be blended 50% max with conventional fuel so its 15% max final volume

ASTM D1655 SAF Co-Processing Pathways Approved

As of January 2025

D1655 Annex	Process Name	Abbreviation	Feedstocks	Max Blend
A1	Co-hydroprocessing of esters and fatty acids in a conventional petroleum refinery		Fats, oils, and greases (FOG)	5% or 15%†
A1	Co-hydroprocessing of Fischer-Tropsch hydrocarbons in a conventional petroleum refinery		FT Biocrude	5%
A1	Co-processing of already hydroprocessed esters and fatty acids in a conventional petroleum refinery		Hydroprocessed Biomass	10%*

† DEFSTAN 91-091 allows up to 30% coprocessing of esters and fatty acids of the refinery input stream but final jet cannot exceed 15%; ASTM D1655 remains limited to 5%
*Previously hydroprocessed FOGs /Biomass can be up to 24% of the refinery input stream but the final jet cut cannot exceed 10% synthetic compounds

SAF Terminology

What do people mean when they say “SAF”?

There is no one definition…

Only the synthetic molecules	Synthetic molecules blended with conventional molecules	Only fuel that is certified sustainable
• NOT ok to fly • NOT ok to receive onto airport per ATA103, JIG, etc. • “Neat SAF” • D7566 Annex	• Ok to fly • Ok to receive onto airport per ATA103 • “Blended SAF” • D7566 or D1655	• Could be ok or NOT ok to fly • Only refers to fuel with enough total lifecycle GHG or CO_2 reductions

Synthetic Blend Component (SBC)

Synthetic blend component (SBC) is the industry accepted technical term referring to a finished neat product meeting one of the ASTM D7566 annexes

SBCs are NOT approved as finished fuels and CANNOT be used in aircraft

SBCs require blending with conventional jet fuel prior to testing/certification as ASTM D1655 compliant jet fuel

Synthetic Blend Components (SBC)

Some Examples

HEFA

ATJ

FT

CHJ

Semi-Synthetic Aviation Turbine Fuel (SSATF)

Also Semi-Synthetic Jet Fuel (SSJF)

Semi-synthetic aviation turbine fuel (SSATF) is the industry accepted technical term for a fuel that is a blend of an SBC (synthetic blend component) and conventional jet fuel

SSATFs are approved as finished fuels and can be used in aircraft

SSATFs are already blended and is treated as any other jet fuel

Semi-Synthetic Aviation Turbine Fuel (SSATF)

Some Examples

15% HEFA with 85% jet

10% HC-HEFA-SPK with 90% jet

50% FT with 50% jet

35% ATJ with 65% jet

Fully-Synthetic Aviation Turbine Fuel (FSATF)

Also Fully-Synthetic Jet Fuel (FSJF)

Fully-synthetic aviation turbine fuel (FSATF) is the industry accepted technical term for a finished fuel that is made wholly of synthetic components (no conventional jet fuel)

FSATFs may contain fuel produced using only a single method of production or may be multiple approved D7566 annexes/production processes blended with each other

FSATFs are molecularly identical to conventional jet fuel (also meet ASTM D1655) and contain aromatic molecules

NO fully-synthetic jet fuels have been approved for use on commercial aircraft YET

Note: FSATF does not refer to “Jet X” or “100% Paraffinic” fuels – these products do not contain any aromatics

Fully-Synthetic Aviation Turbine Fuel (FSATF)

90% HEFA with 10% SAK

100% CHJ

50% FT with 50% FT-SKA

100% ATJ-SKA

3 Types of 100% SAF – only 2 are FSATFs

The term "100% SAF" is used interchangeably to mean different things

100% NEAT SAF (SBC)

- Molecularly identical to jet
- No blending required

BLENDS OF SBCs

- Molecularly identical to jet
- Blending required

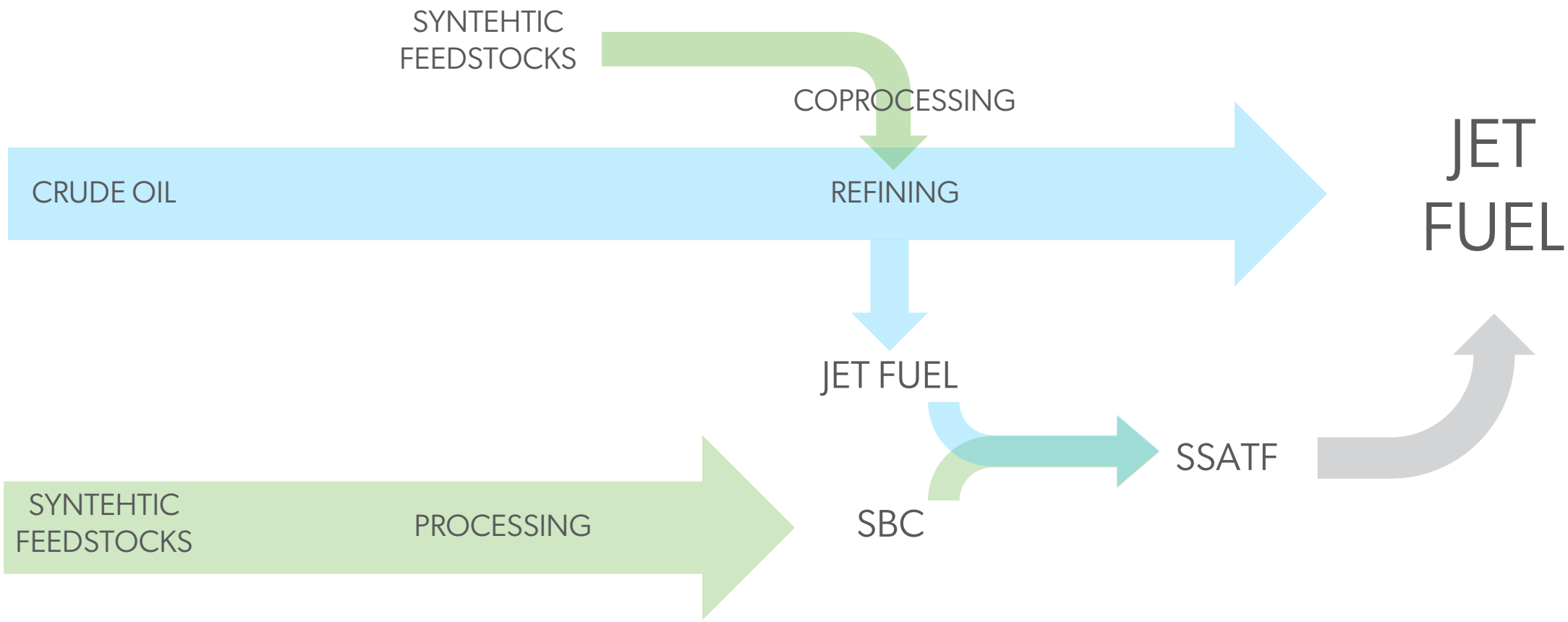
100% PARAFFINIC

Sometimes called "Jet X"

- Not Airworthy for all aircraft
- Segregated grade of fuel

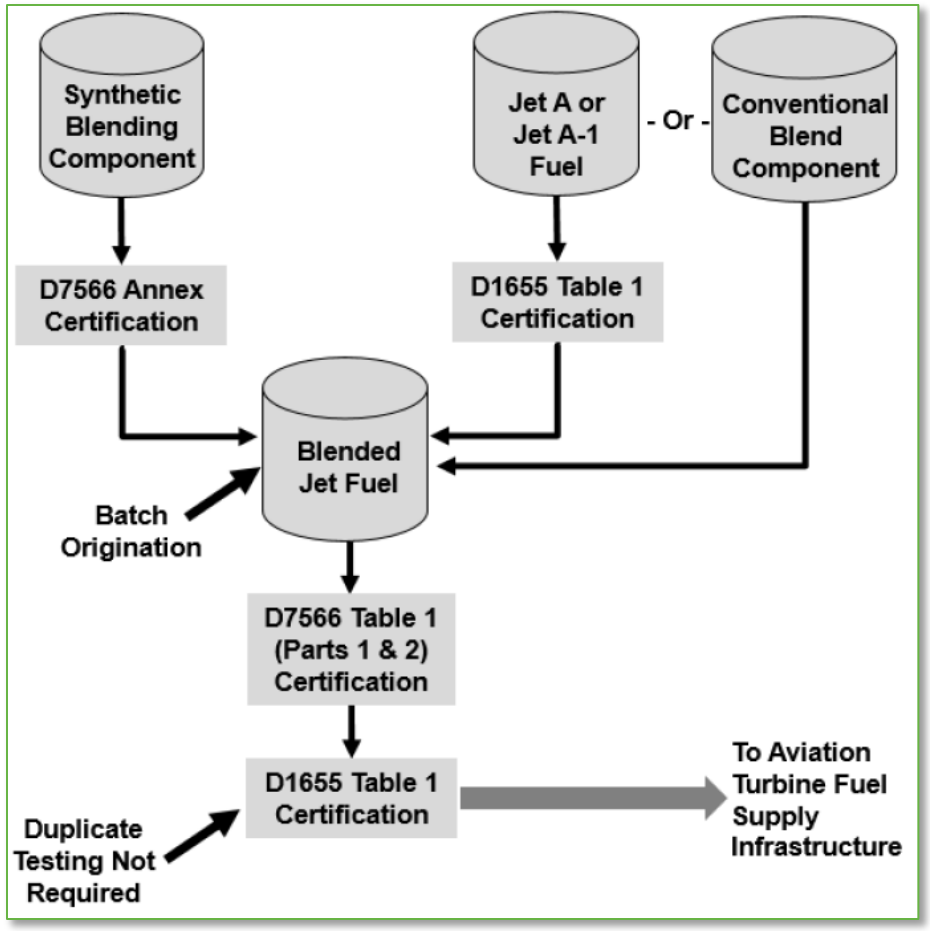
SAF Certification and Logistics

SUSTAINABLE AVIATION FUEL



Requirements for Certifying SAF Blends

What ASTM D7566 says:



X 2.3 Production of Jet A or Jet A-1 Aviation Turbine Fuel Containing Synthetic Blend Components

X 2.3.1 This a two-step process, where the synthetic blend component is first produced and tested in accordance with the applicable annex, followed by blending with a conventional Jet A or Jet A-1 fuel or conventional blend components to the prescribed blending limits of 6.1 and the property requirements of Table 1 (see Figure X2.1). Note: Blending of the synthetic blend components with Jet A or Jet A-1 fuel or conventional blend components is necessary either to meet Table 1 property requirements (applies to Annexes A1, A2, A3, A5, A7), or to use a conservative and gradual approach to introducing these components into service (applies to Annexes A4 and A6).

X 2.3.2 The testing results and properties of the synthetic blend component shall be documented and certified to show compliance to the applicable annex.

X 2.3.3 Blending of the synthetic blend component with Jet A or Jet A-1 fuel or conventional blend components cannot exceed the concentration specified in 6.1 for the applicable annex.

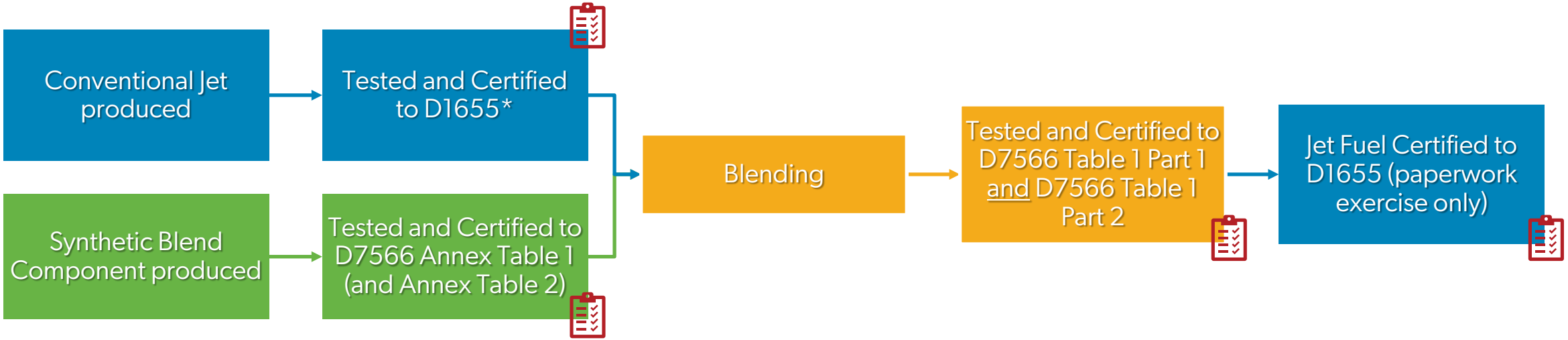
X 2.3.4 The resulting Jet A or Jet A-1 fuel shall meet the property requirements of Table 1. These property requirements may limit the synthetic blend concentration to less than the maximum concentration specified in 6.1.

X 2.3.5 The testing results and properties of the blended Jet A or Jet A-1 fuel should be documented and certified to show compliance to Table 1 of D7566.

X 2.3.6 Certification to D1655 may then be accomplished without retesting.

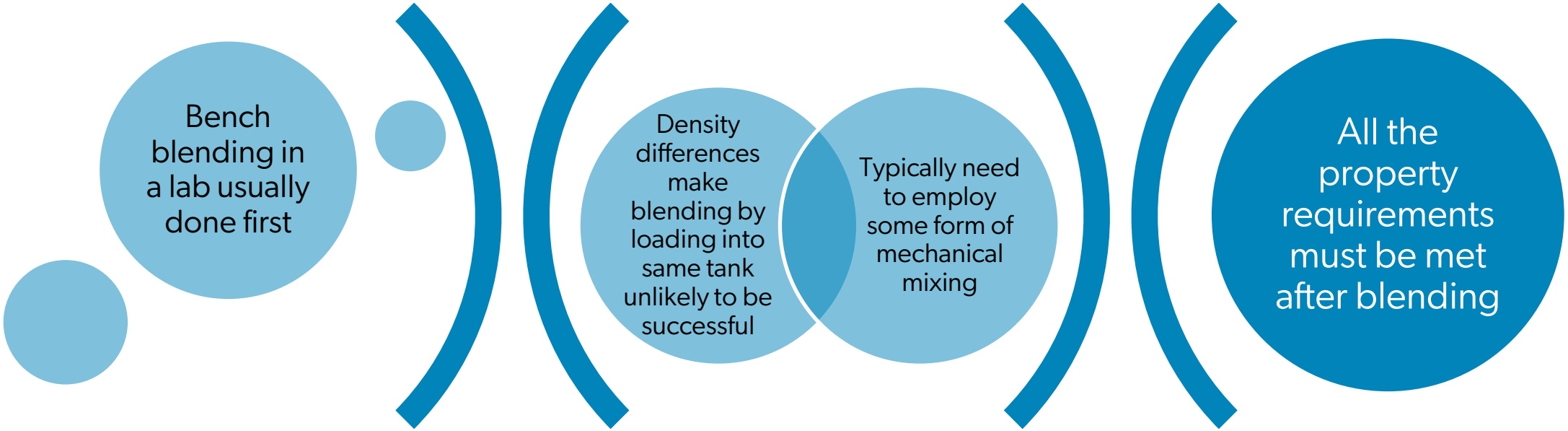
Requirements for Certifying SAF Blends

Each SAF Blend should have 3 or 4 COAs!



*Except when the conventional jet portion is a conventional blend component, then no COA

Important Points About Blending



Not all testing properties blend linearly

Blending tends to takes more energy than you think

The blend percentages specified in ASTM D7566 are *maximum* limits

2025 SAF Logistics in the US

Most SBC production facilities are not adjacent to standard refining facilities

SBCs are going to need to be transported neat (prior to blending)

Pipelines are the safest, most efficient, most economical way to transport liquid fuels

Almost all jet fuel moves by pipeline

Today, no pipelines move SBCs

Only SSATF can go into a pipeline

Vast majority of pre-airfield tanks are not equipped to conduct a proper blend

Infrastructure investments are needed

Today's vision is strategically placed SAF blending hubs

EI 1533

Quality assurance requirements for semi-synthetic jet fuel and synthetic blending components

Describes issues associated with blending

Defines handling procedures, testing and controls for various types of transportation and equipment used for import, export and shipping of SBCs

Produced through collaboration of the world's leading subject matter experts

THE global standard for handling of SBCs

Download it for FREE

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SAF On Airport

2.2.1. Specification Requirements

Jet fuel shall conform to [ASTM D1655], Latest Revision, “Standard Specification for Aviation Turbine Fuel”, Jet A or Jet A-1 Kerosene Type. Alternatively, jet fuel shall conform to [DEFSTAN 91-091], Latest Revision, “Turbine Fuel, Aviation Kerosine Type, Jet A-1; NATO Code: F-35; Joint Service Designation: AVTUR”.

Accepting SAF into JIG Airports

Issue 13

4.2.2 For reasons of fuel quality, cleanliness and traceability, only aviation fuel products (Jet fuel and Aviation Gasoline) shall be received into storage for delivery to aircraft fuel systems.

SAF Blending on Airport per DEFSTAN 91-091

Issue 18

B.5.3 The location at which a semi-synthetic Aviation Turbine Fuel meeting this Standard is blended shall be upstream of the airport fuel storage depot except in the development phase where the volumes involved are small (no more than the capacity of one or two fuellers for example). In this case the blending could be done at the airport depot in a dedicated tank or dedicated fueller. In this case the synthetic component shall be segregated to ensure that this product shall not be provided to an aircraft. After blending the fuel shall be quarantined until a Certificate of Analysis is provided according to all the requirements of **Table 1** and **Annex B** of this Standard.

Handling SAF on Airports

Once blended, SAF (SSATF) is just jet fuel!

- No special handling
- No additional checks
- No equipment mods

Last Thoughts

“Drop-In” Beef

Source: Kitchen Swagger

properties of aviation turbine fuel at the time and place of delivery.

Material

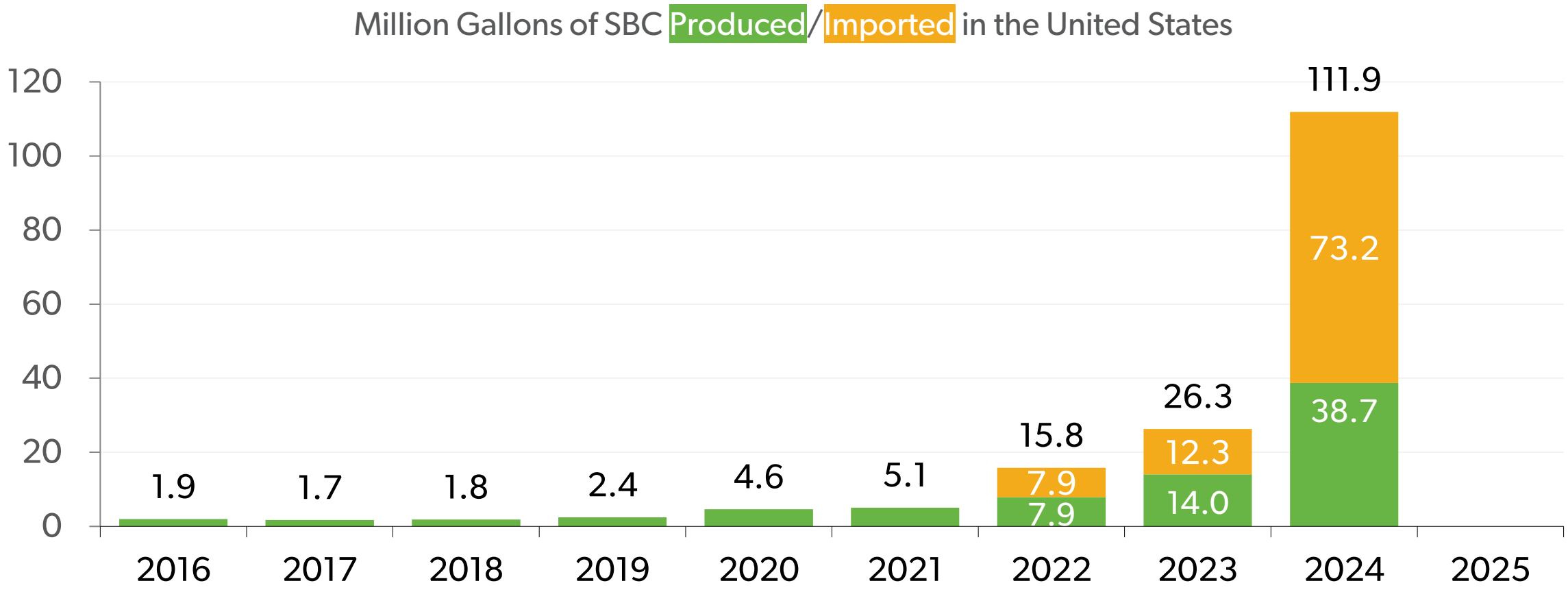
4. Aviation turbine fuel, except as otherwise specified herein, shall consist of blends of refined hydrocarbons derived from crude petroleum, natural gasoline, or blends thereof with synthetic hydrocarbons.

Detailed Requirements

5. The aviation turbine fuel shall conform to the requirements prescribed in

U.S. Domestic SBC Volumes

SBC= Synthetic Blend Component = Neat SAF (not yet blended with conventional jet)



Source: Environmental Protection Agency

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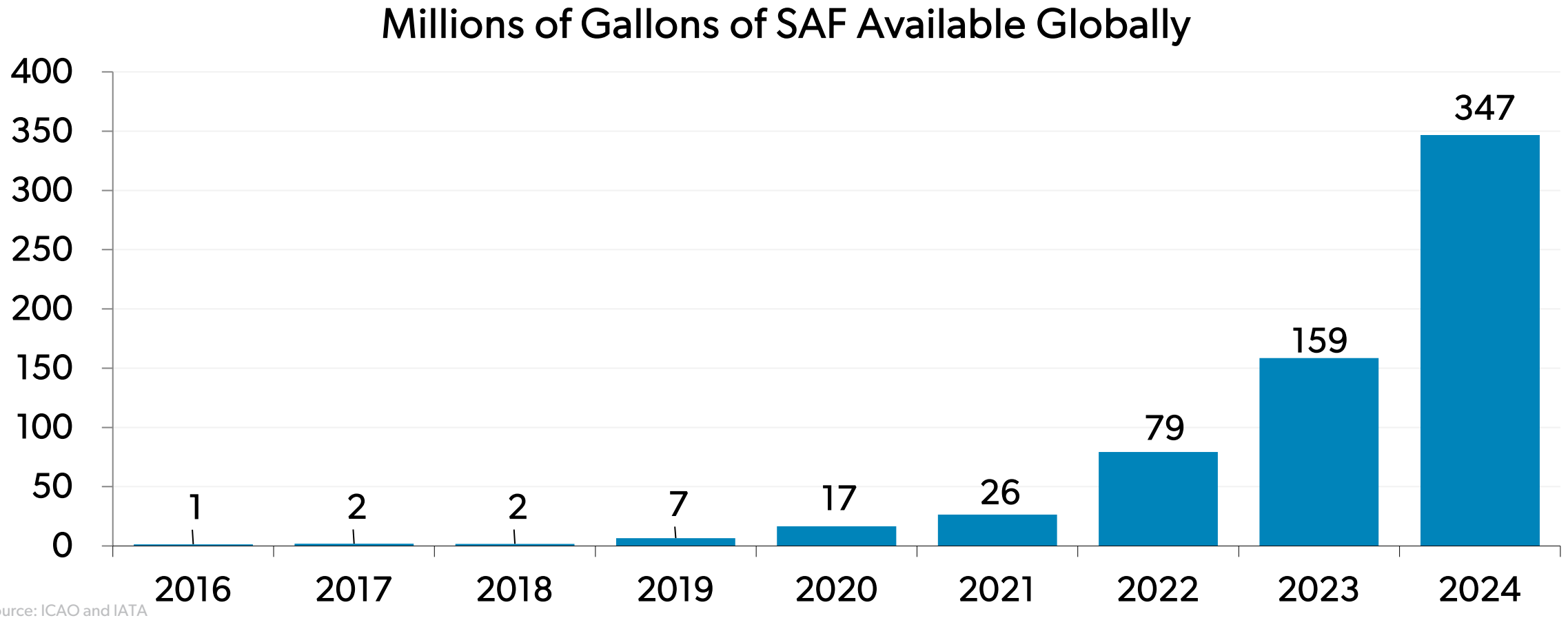
Global SBC Availability



Source: ICAO and IATA

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We Connect the World

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TODAY'S SAF 101 TAKE AWAYS

- SAF is just a different way to make the same thing we've used for the last 75+ years
- Synthetic production of jet fuel isn't new
- SAF may have/be required to have more paperwork
- By the time its at the airport, SAF is just jet fuel – treat it as such
- All aircraft certified to fly on jet fuel are certified to fly on jet fuel!

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