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ENVIRONMENT

:

Introduction to Sustainable Aviation Fuels



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Chinga Mazhetese

Environment Officers, ICAO, ESAF, WACAF



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The role and benefits of SAF in the aviation decarbonization





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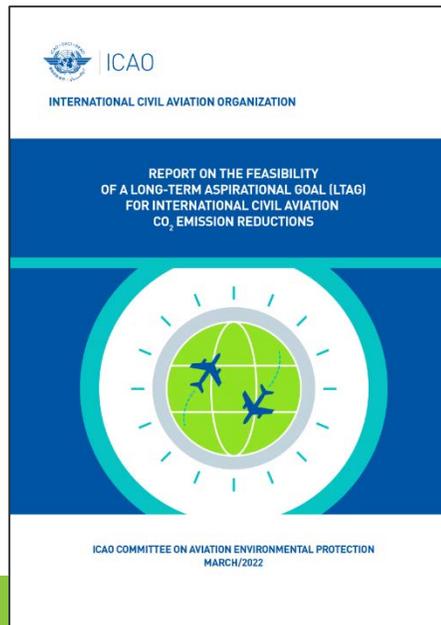
LTAG Decision



ICAO Long Term Global Aspirational Goal For International Aviation (LTAG)

Adopted by ICAO Assembly Resolution A41-21 (2022)

https://www.icao.int/environmental-protection/Documents/Assembly/Resolution_A41-21_Climate_change.pdf

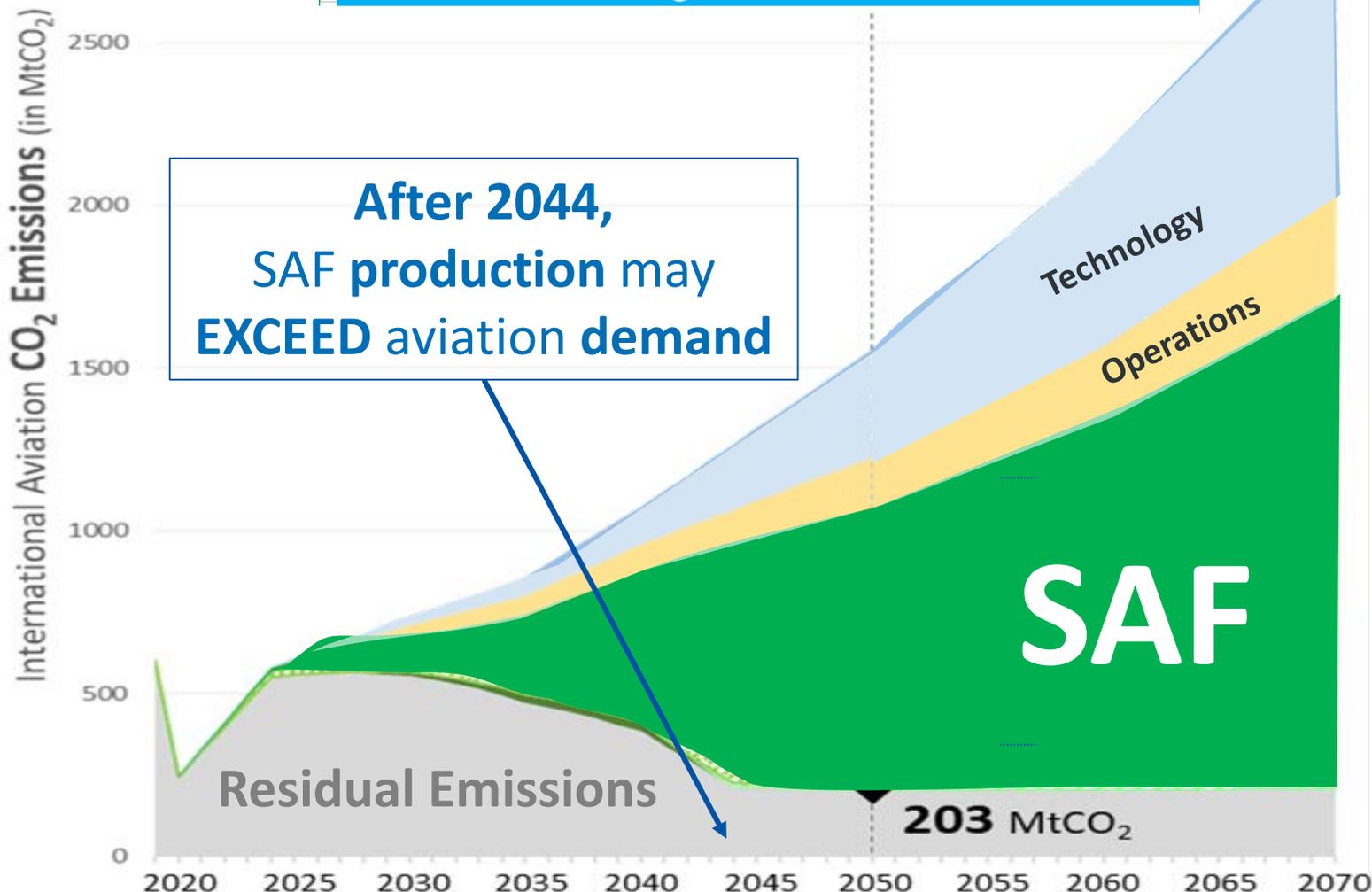


LTAG Report

SAF will play a key role in aviation decarbonization efforts

LTAG report and SAF

IS3 LTAG Integrated Scenario 3



2022: 0.15 Billion Liters of SAF being produced

2045: 636 billion liters needed to replace all fossil fuels

Need for immediate action to fully realize SAF potentials

References:

- <https://www.icao.int/environmental-protection/LTAG/Pages/LTAG-data-spreadsheet.aspx>
- <https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet---alternative-fuels/>

ICAO 2050 Vision for SAF

adopted at the Second ICAO Conference on Aviation and Alternative Fuels (CAAF/2 - 2017)



- Calls on States, industry and other stakeholders to substitute a significant proportion of conventional aviation fuels with sustainable aviation fuels by 2050.
- 2050 Vision to be revised in 2023 (CAAF/3 Conference)
- Stocktaking process supporting these goals – yearly events held since 2019





Drop-in nature of SAF makes it interchangeable and compatible with conventional aviation fuels

- SAFs can currently be blended at up to 50% with conventional jet fuel, and re-certified – it is handled in the same way as conventional aviation fuels
- No changes in aircraft or its engines, nor in infrastructure, which would imply major logistical, safety and cost issues



SAF industry can provide opportunities for economic growth and employment





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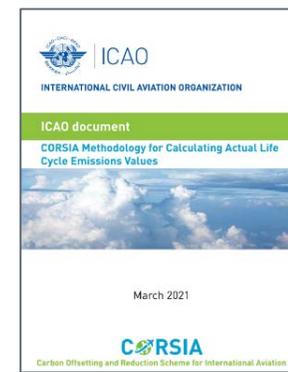
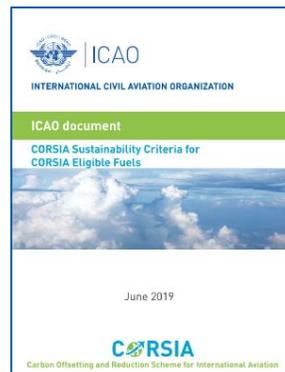
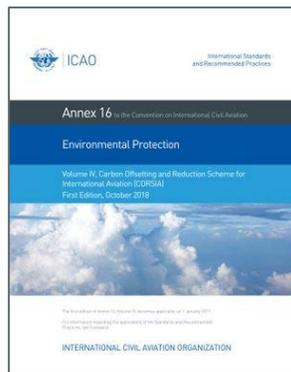
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Definition of SAF And Sustainability Criteria



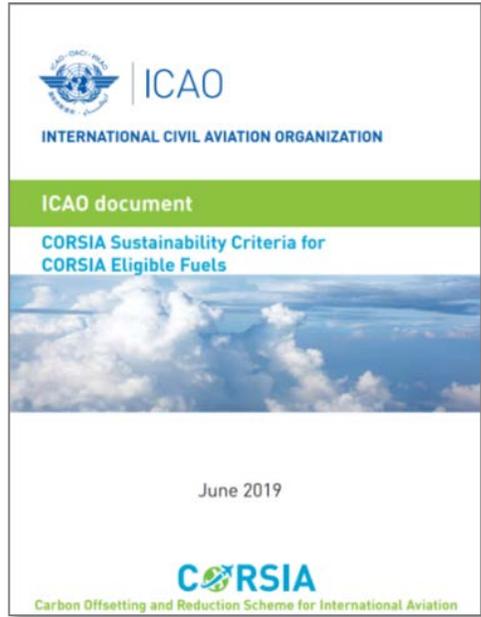
What are Sustainable Aviation Fuels (SAF)?

| Definition | Which Sustainability Criteria? | What is a waste? |
|--|---|---|
| <p>SAF is defined as a <i>renewable or waste-derived aviation fuel</i> that meets sustainability criteria. <i>reference: Annex 16 Vol IV – CORSIA</i></p> | <p>Sustainability Criteria are defined in the ICAO document <i>“CORSIA Sustainability Criteria for CORSIA Eligible Fuels”</i></p> | <p>Waste is a feedstock with inelastic supply and no economic value (e.g. municipal solid waste, used cooking oil, waste gases etc.) <i>reference: ICAO document “CORSIA Methodology For Calculating Actual Life Cycle Emissions Values”</i></p> |



All documents available at <https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx>

CORSIA sustainability criteria for CORSIA eligible fuels First global approach to sustainability for an industry sector



Sustainability Themes

1. Greenhouse Gases (GHG)
2. Carbon stock
3. Water
4. Soil
5. Air
6. Conservation
7. Waste and Chemicals
8. Human and labour rights
9. Land use rights and land use
10. Water use rights
11. Local and social development
12. Food security

Carbon-reduction themes
(CORSIA pilot phase, 2021-2023)

Environmental and socio-economic
Themes for SAF
(After CORSIA pilot phase, from 2024)

*Sustainability criteria for LCAF is
under consideration by Council*

Theme 1: Greenhouse gases

- CORSIA eligible fuel should generate lower carbon emissions on a life cycle basis

Theme 2: Carbon stock

- CORSIA eligible fuel should not be made from biomass obtained from land with high carbon stock



For more details,
please refer to [CORSIA
Sustainability Criteria
for CORSIA Eligible
Fuels \(icao.int\)](#)

Theme 3: Water

- Production of CORSIA SAFs should maintain or enhance water quality and availability

Theme 4: Soil

- Production of CORSIA SAFs should maintain or enhance soil health

Theme 5: Air

- Production of CORSIA SAF should minimize negative effects on air quality

Theme 6: Conservation

- Production of CORSIA SAF should maintain biodiversity, conservation value and ecosystem services

Theme 7: Waste and chemicals

- Production of CORSIA SAF should promote responsible management of waste and use of chemicals

Theme 8: Human and labour rights

- Production of CORSIA SAF should respect human and labour rights

Theme 9: Land use rights and land use

- Production of CORSIA SAF should respect land and land use rights including indigenous and/or customary rights

Theme 10: Water use rights

- Production of CORSIA SAF should respect prior formal or customary water use rights

Theme 11: Local and social development

- Production of CORSIA SAF should contribute to social and economic development in regions of poverty

Theme 12: Food security

- Production of CORSIA SAF should promote food security in food insecure regions



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SAF life cycle assessment



CORSIA Sustainability Theme 1 requires lower carbon emissions on a life cycle basis.



CORSIA Sustainability Criterion 1.1 requires net greenhouse gas emissions reductions of at least 10% compared to a baseline.

These requirements are met based on a Life cycle assessment of the SAF:

SAF Life cycle emission value (LSf)
Unit – gCO₂e/MJ

=

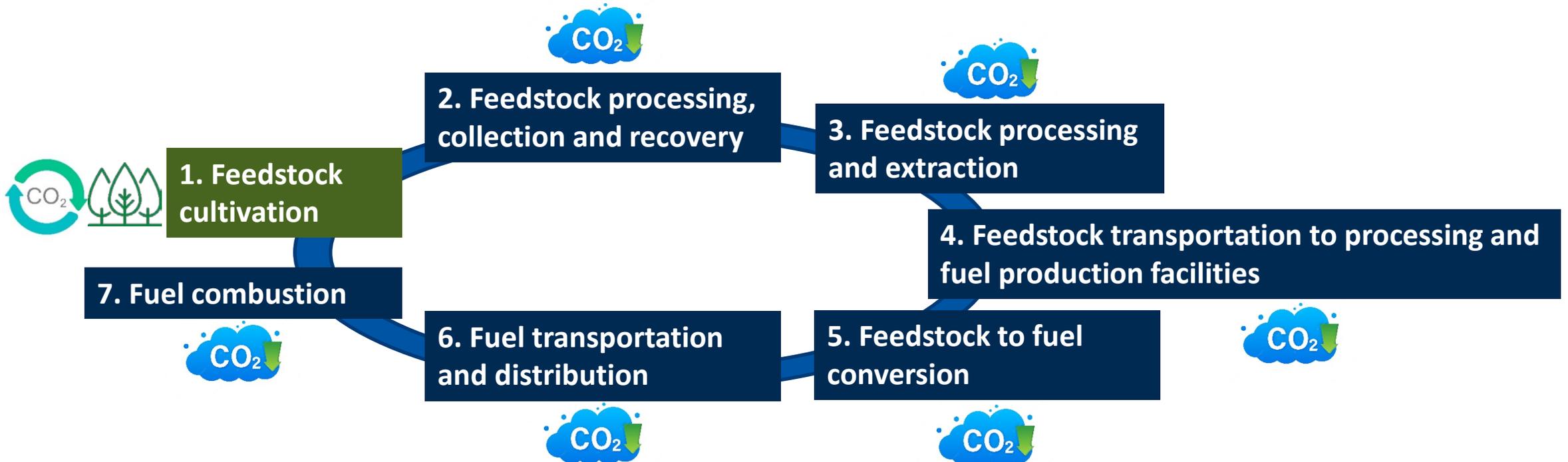
Core Life cycle assessment
(core LCA value)
emissions associated with
all steps of SAF production
and use

+

Induced Land use Change
(ILUC value)
Emissions associated with
possible land use change
generated by SAF feedstock
production

Core Life cycle assessment (core LCA value)

Emissions associated with all steps of SAF production and use



Example: life cycle emissions of sugarcane ethanol ATJ in Brazil

| Production step | Associated emissions (gCO ₂ e/MJ) |
|---|--|
| Feedstock growth | -74 |
| Feedstock cultivation Feedstock processing, collection and recovery Feedstock processing and extraction | 16.9 |
| Feedstock transportation to processing and fuel production facilities | 1.6 |
| Feedstock to fuel conversion | 5.2 |
| Fuel transportation and distribution | 0.4 |
| fuel combustion on aircraft engine | 74 |
| total (core LCA value) | 24.1 |
| Induced Land use Change (ILUC value) | 8.7 |
| SAF Life cycle emission value (LSf) = core LCA + ILUC | 32.8 |



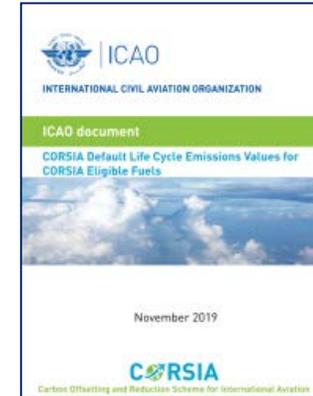
**63% emission reduction
on a life cycle basis**
(Compared with Baseline emission value of 89 gCO₂e/MJ)

CORSIA allows two options to obtain the life cycle emissions of SAF

DEFAULT Life Cycle Emissions

ICAO document “CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels”

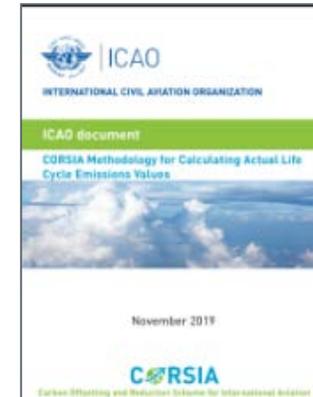
Default emission values, as a function of the feedstocks and conversion processes.



ACTUAL Life Cycle Emissions

ICAO document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values”

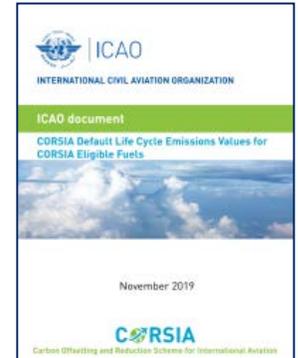
Allows calculation of specific emissions values to a given SAF or LCAF



First Global Approach to life cycle assessment

Table 1. CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels produced with the Fischer-Tropsch Fuel Conversion Process

| Region | Fuel Feedstock | Pathway Specifications | Core LCA Value | ILUC LCA Value | LS _r (gCO ₂ e/MJ) |
|--------|--|--|-----------------|----------------|---|
| Global | Agricultural residues | Residue removal does not necessitate additional nutrient replacement on the primary crop | 7.7 | 0.0 | 7.7 |
| Global | Forestry residues | | 8.3 | | 8.3 |
| Global | Municipal solid waste (MSW), 0% non-biogenic carbon (NBC) | | 5.2 | | 5.2 |
| Global | Municipal solid waste (MSW) (NBC given as a percentage of the non-biogenic carbon content) | | NBC*170.5 + 5.2 | | NBC*170.5 + 5.2 |
| USA | Poplar (short-rotation woody crops) | | 12.2 | -5.2 | 7.0 |
| Global | Poplar (short-rotation woody crops) | | 12.2 | 8.6 | 20.8 |
| USA | Miscanthus (herbaceous energy crops) | | 10.4 | -32.9 | -22.5 |
| EU | Miscanthus (herbaceous energy crops) | | 10.4 | -22.0 | -11.6 |
| Global | Miscanthus (herbaceous energy crops) | | 10.4 | -12.6 | -2.2 |



For more details, please refer to [ICAO document 06 - Default Life Cycle Emissions - June 2022.pdf](#)

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

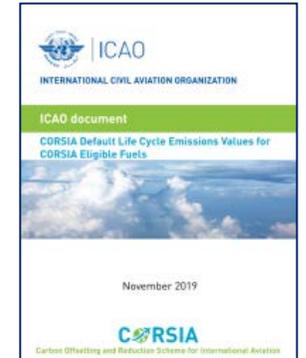
| Region | Fuel Feedstock | Pathway Specifications | Core LCA Value | ILUC LCA Value | LSr (gCO ₂ e/MJ) |
|----------------------|----------------------------|--|----------------|----------------|-----------------------------|
| Global | Tallow | | 22.5 | 0.0 | 22.5 |
| Global | Used cooking oil | | 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 |



For more details, please refer to [ICAO document 06 - Default Life Cycle Emissions - June 2022.pdf](#)

Table 3. CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels produced with the Alcohol (isobutanol) to jet (ATJ) Fuel Conversion Process

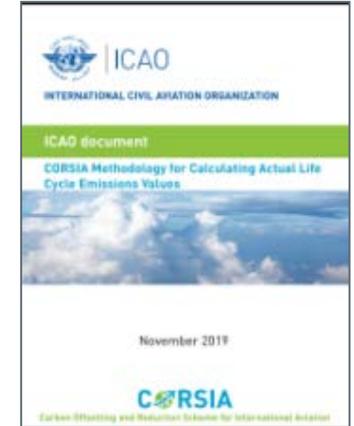
| Region | Fuel Feedstock | Pathway Specifications | Core LCA Value | ILUC LCA Value | LSr (gCO _{2e} /MJ) |
|--------|---------------------------------------|---|----------------|----------------|-----------------------------|
| Global | Agricultural residues | Residue removal does not necessitate additional nutrient replacement on the primary crop. | 29.3 | 0.0 | 29.3 |
| Global | Forestry residues | | 23.8 | | 23.8 |
| Brazil | Sugarcane | Standalone or integrated conversion design | 24.0 | 7.3 | 31.3 |
| Global | Sugarcane | Standalone or integrated conversion design | 24.0 | 9.1 | 33.1 |
| USA | Corn grain | Standalone or integrated conversion design | 55.8 | 22.1 | 77.9 |
| Global | Corn grain | Standalone or integrated conversion design | 55.8 | 29.7 | 85.5 |
| USA | Miscanthus (herbaceous energy crops) | | 43.4 | -54.1 | -10.7 |
| EU | Miscanthus (herbaceous energy crops) | | 43.4 | -31.0 | 12.4 |
| Global | Miscanthus (herbaceous energy crops) | | 43.4 | -23.6 | 19.8 |
| USA | Switchgrass (herbaceous energy crops) | | 43.4 | -14.5 | 28.9 |
| Global | Switchgrass (herbaceous energy crops) | | 43.4 | 5.4 | 48.8 |
| Brazil | Molasses | | 27.0 | 7.3 | 34.3 |
| Global | Molasses | | 27.0 | 9.1 | 36.1 |



For more details, please refer to [ICAO document 06 - Default Life Cycle Emissions - June 2022.pdf](#)

ICAO Document “CORSlA Methodology for Calculating Actual Life Cycle Emissions Values” allow for the calculation of specific emissions values to a given CORSlA SAF

- Document provides further details on the methodology, such as:
 - Technical report requirements
 - Feedstock categories (wastes, residues, byproducts = zero ILUC),
 - Low land use change risk practices (zero ILUC)
 - Emissions credits



For more details,
please refer to ICAO
document 07 -
Methodology for Actual
Life Cycle Emissions -
June 2022.pdf



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SAF sustainability certification



ICAO-approved ‘Sustainability Certification Schemes (SCS)’ are responsible for

- Ensuring compliance with the sustainability criteria for CORSIA eligible fuels (including CORSIA SAF)
- Ensuring that the life cycle emissions values of the fuel have been applied/calculated correctly
- To date, the International Sustainability and Carbon Certification (ISCC) and Roundtable on Sustainable Biomaterials (RSB) are the two CORSIA approved SCSs





Questions?



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SAF specifications, feedstocks and conversion pathways



ASTM International defines technical specifications for SAF

- Ensure SAF are safe for use in aircraft
- Specify necessary chemical properties
- 9 conversion processes currently approved for SAF production (ASTM D7566 and D1655)
- Other technical specifications include the UK DEF STAN 91-091, China CTSO-2C701, among others.

For more details
Conversion
processes ([icao.int](https://www.icao.int))



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Standard Historical Last Updated: Aug 02, 2022

ASTM D7566-21 ⓘ

Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Scope

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

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

SAF can be produced from a variety of feedstocks

Oils and fats



Lignocellulose



Sugars



Wastes



Examples of conversion pathways:

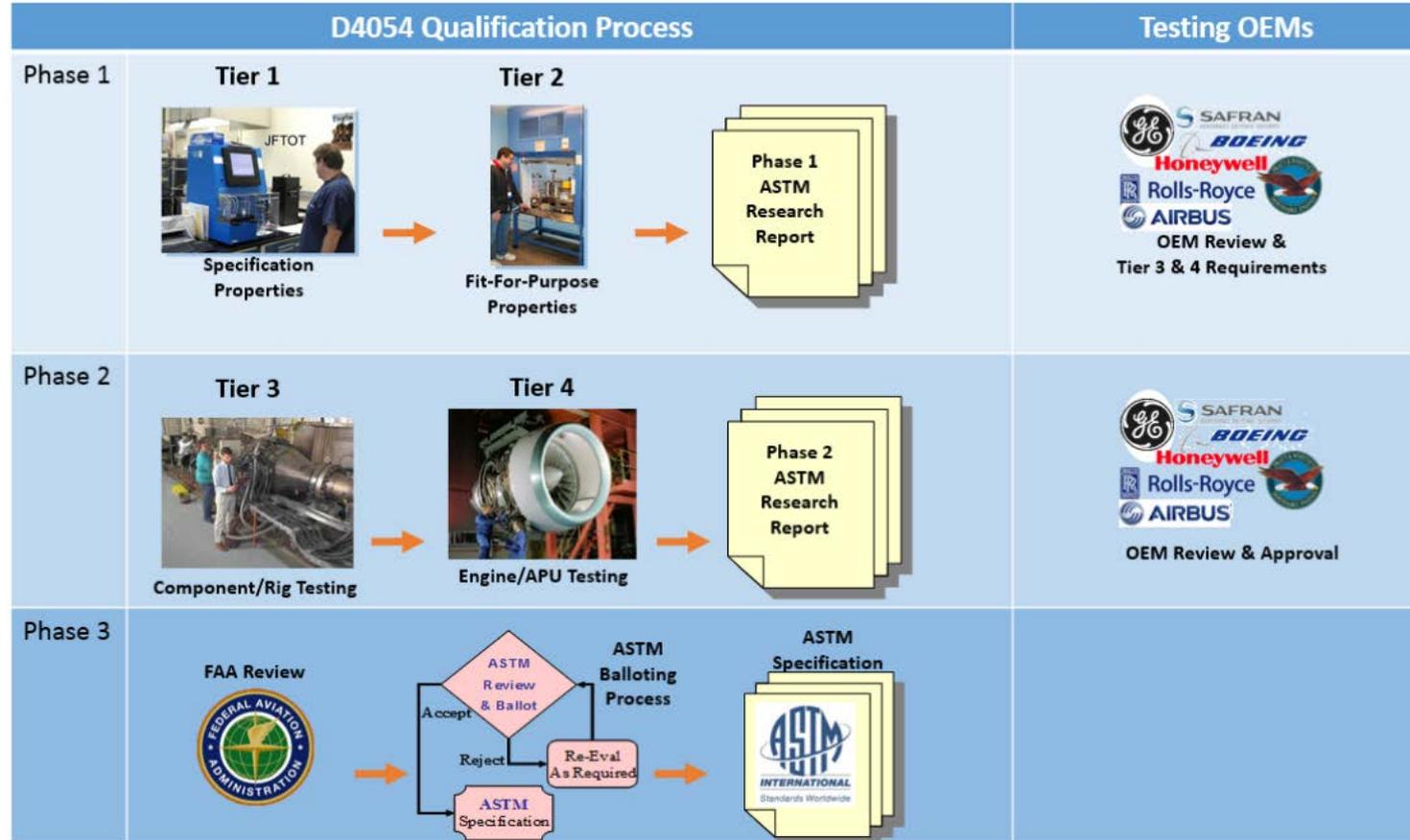
| | Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids (HEFA) | Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene (FT) | Alcohol to jet synthetic paraffinic kerosene (ATJ-SPK) |
|--------------------|--|--|---|
| Description | Conversion of oils/fats to hydrocarbons via deoxygenation with hydrogen and cracking | Gasification of carbon containing material to syngas, then converted to SAF through FT synthesis | Sugars (from syngas or cellulosic material) converted to SAF through alcohol intermediate |
| Blend ratio | 50% | 50% | 50% |
| Possible feedstock | Animal tallow Used cooking oil | Municipal solid waste Miscanthus | Sugar cane Waste gases |
| Existing programs | Neste, WorldEnergy, Honeywell UOP, etc. | Fulcrum, Redrock, Sasol, Shell, etc. | Gevo, Lanzatech, Swedish biofuels, etc. |



SAF – conversion processes and specifications

ASTM D4054 provides a framework for approval of new SAFs

- guidance on testing and necessary properties
- fast track process for fuel approval



Source: https://www.caafi.org/focus_areas/fuel_qualification.html#streamlining



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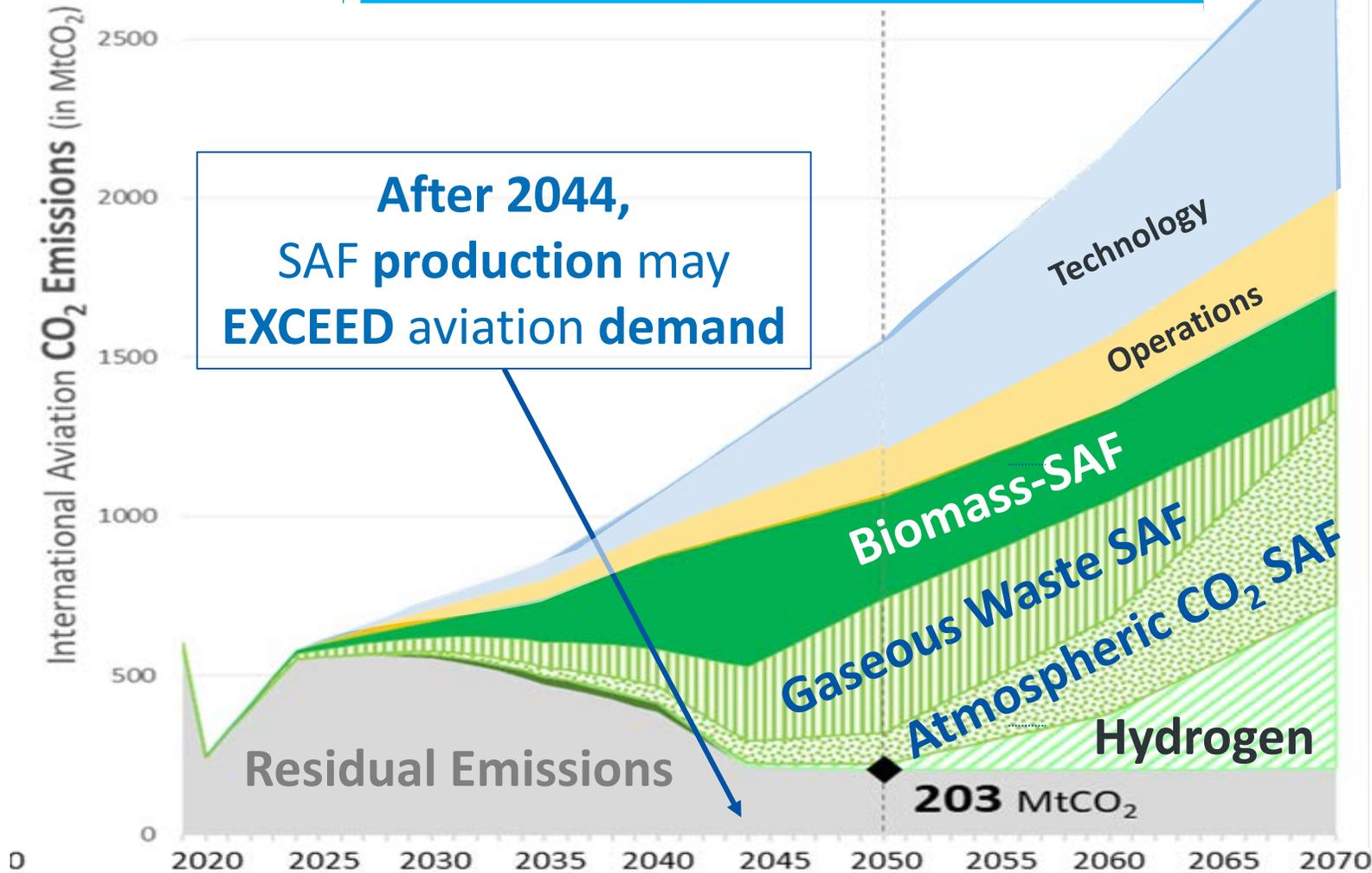
ASTM D4054-22

Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives

Significance and Use

5.1 This practice is intended to describe the data requirements necessary to support the review of new aviation turbine fuels or additives by ASTM members for the developers or sponsors of these new products.

IS3 LTAG Integrated Scenario 3



After 2044,
SAF production may
EXCEED aviation demand

All types of SAF will contribute to the LTAG of net zero CO₂ emissions by 2050



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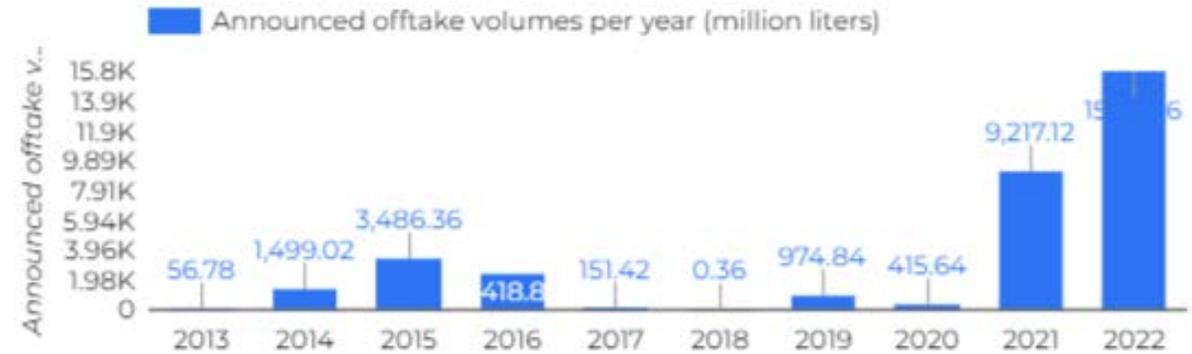
Developments in the SAF market



Demand for SAF is growing exponentially

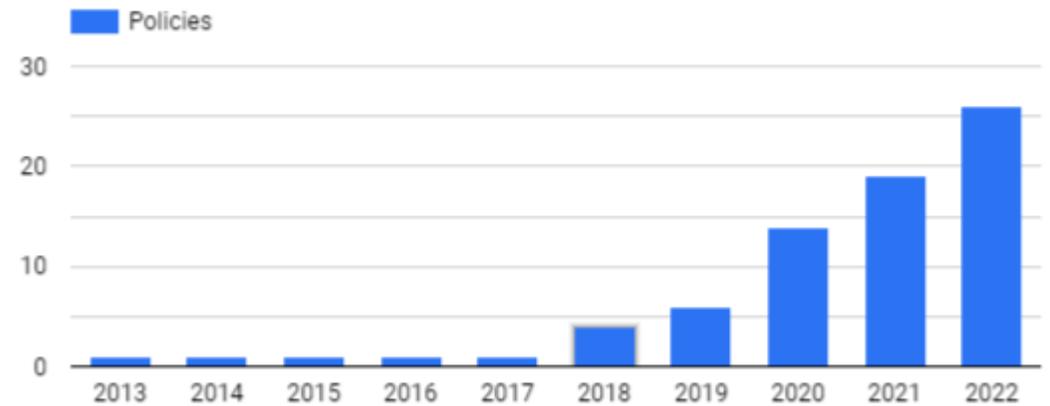
- Airlines signing multi year offtake agreements
- States are implementing supporting policies
- Programmes allow corporates and travelers to purchase SAF

Offtake agreements



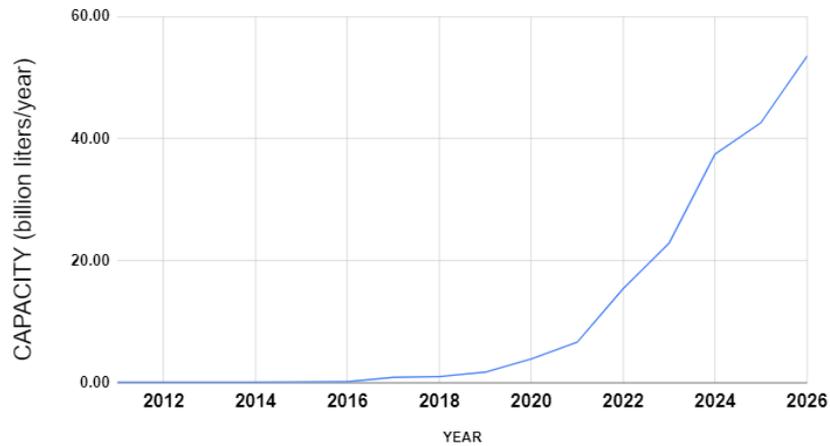
Source: <https://www.icao.int/environmental-protection/GFAAF/Pages/Offtake-Agreements.aspx>

Policies



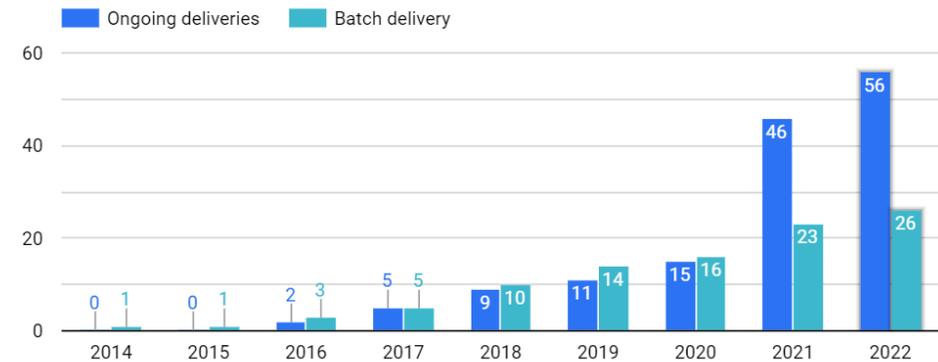
SAF production volumes and distribution also growing

Announced Production capacity



ICAO SAF Tracking Tools provide regular updates on SAF market

Airports distributing SAF



SAF policies are supporting supply and demand

United States SAF Grand Challenge

- Government wide effort to reduce cost, enhance sustainability, expand production and use of SAF
- Scale up SAF production to at least 3 billion gallons per year by 2030
- Sufficient SAF to meet 100% aviation fuel demand by 2050
- SAF Grand Challenge Roadmap
- Incentives (SAF blenders tax credit, Clean Fuel Production Credit, Grant Programs)

UK Jet Zero Strategy

- Vision and approach for aviation sector to reach net-zero by 2050 – SAF is one of six core policy measures
- SAF mandate setting obligation on fuel suppliers for at least 10% SAF use by 2030
- Funding support to kickstart domestic SAF industry
- Joint industry/government work through Jet Zero Council SAF Delivery Group

Fit-for-55: ReFuelEU Aviation

- Regulatory proposal to transition from fossil fuels to SAF
- Proposal to introduce EU wide SAF blending mandate
 - Advanced biofuels and E-fuels
 - From 2% by 2025 to 63% by 2050
 - Sub-obligation on e-fuels (0.7% by 2030 to 28% by 2050)
- Legislative process is ongoing



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Additional SAF resources from ICAO



ICAO provides guidance material to support SAF development and deployment

Guidance on potential policies and coordinated approaches for the development of SAF



- Stimulate growth of SAF supply
- Create SAF demand
- Enable a SAF marketplace

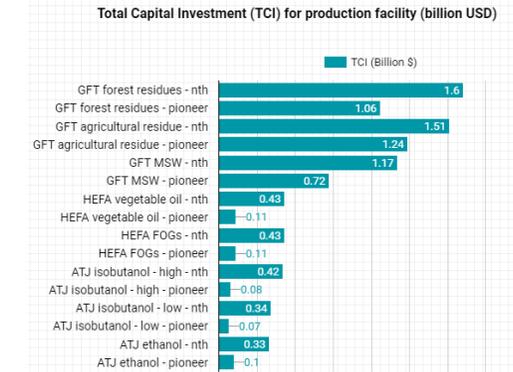
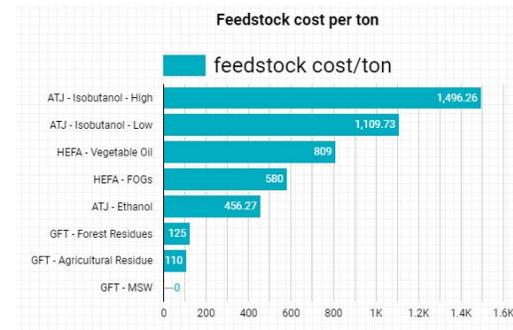
For more details



SAF Rules of Thumb – what does it take to produce SAF?



- Estimations on SAF costs, investment needs and production potential
- Tradeoffs between variables

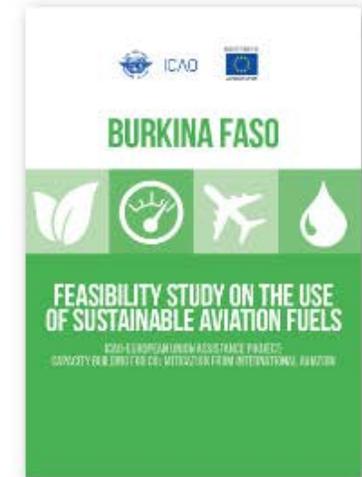
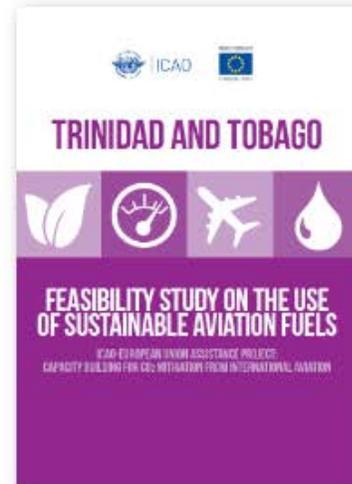
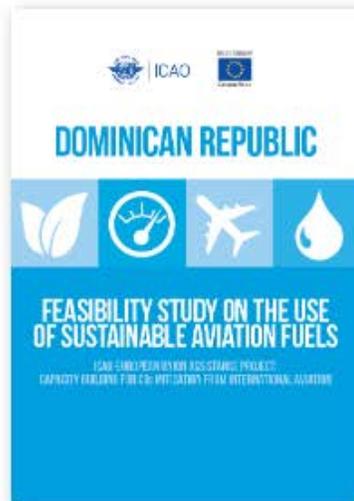


For more details



Four SAF feasibility studies are freely available on the ICAO website*

ACT-SAF
#7
SERIES



*developed under the ICAO-EU assistance project 'Capacity building for CO₂ mitigation from international aviation'

SAF tracker tools are also available in the ICAO website

Provides updated information on

- SAF offtake agreements from airlines
- SAF production facilities
- Airports offering SAF
- Policies fostering SAF market developments
- Latest news



For more details, please refer to [ICAO SAF Tracking Tools](#)

Sustainable Aviation Fuels (SAF)

SAF Tracking tools (click on the drops for details)



Latest news (click for details)

Search Filter by State

| Date | Link |
|--------------|---|
| Nov 7, 2022 | Neste joins forces with ITOCHU and Fuji Oil on SAF blending project |
| Nov 3, 2022 | BA, LanzaJet and Nova move closer to large-scale SAF production with Project Speedbird |
| Nov 2, 2022 | Iberia Airlines Enters Into New Fuel Sales Agreement with Gevo for 6 Million Gallons of Sustainable Aviation Fuel Per Year for Five Years |
| Oct 31, 2022 | Qatar Airways Signs Deal For 25 Million Gallons Of SAF From 2028 |
| Oct 31, 2022 | Topsoe supports SGP BioEnergy in renewable fuels production in Panama |
| Oct 28, 2022 | JetBlue launches new SAF partnership |
| Oct 27, 2022 | First Etihad Airways flight using sustainable aviation fuel |

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SAF facilities map
see the facilities (existing and announced) that can produce SAF





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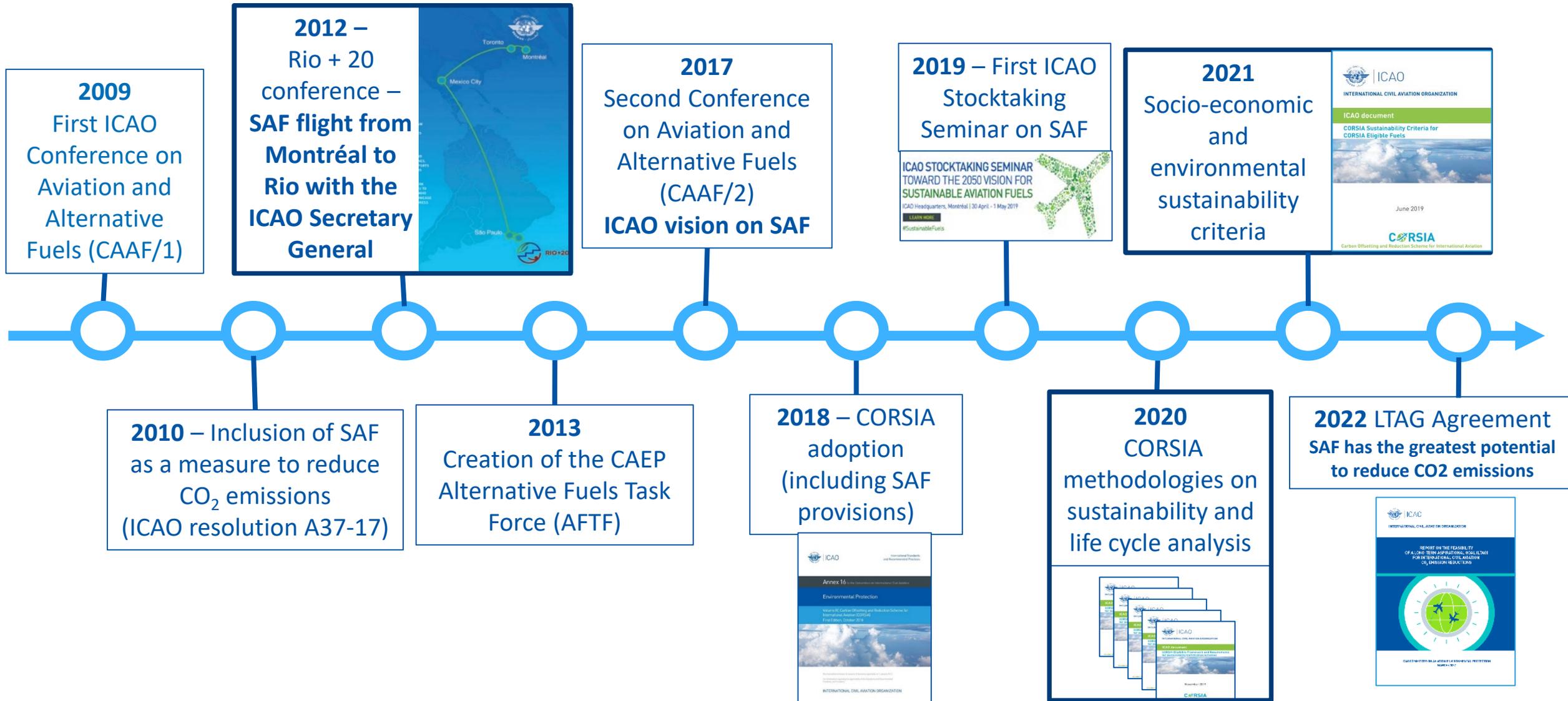
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ACT-SAF

Introduction and updates



ICAO action on Sustainable Aviation Fuels (SAF)



ICAO ACT-SAF

ICAO Assistance, Capacity-building and Training for Sustainable Aviation Fuels



Launched on 1 June 2022, in an event Associated to the Stockholm+50 Conference

<https://www.icao.int/environmental-protection/Pages/act-saf.aspx>



What is ICAO ACT-SAF?

- An ICAO initiative to facilitate the development and deployment of SAF
- Tailored support for States
- Facilitate cooperation under ICAO coordination
- A Platform to facilitate knowledge sharing and progress monitoring

Why ICAO ACT-SAF programme?

- Builds on existing ICAO “ACT” experience, through partnerships and cooperation amongst States
- ICAO LTAG report foresees largest CO2 reductions coming from fuels/cleaner energy sources
- Need for immediate action to fully realize SAF potentials



How does ACT-SAF work

| 1) Interested party* expresses interest in becoming an ACT-SAF Partner | 2) ICAO coordinates with the interested party to detail the offers and requests, and suggest possible projects | 3) ICAO connects ACT-SAF Participants | 4) Agreement is signed and projects defined |
|--|--|--|--|
| <p>Supporting State / Organization can participate by providing experts and/or resources</p> <p>Requesting State can participate by providing a focal point for coordination</p> | <p>Possible projects:</p> <ul style="list-style-type: none">• Feasibility Studies• Training programmes• Support for SAF certification• Support for Policy implementation | <p>Criteria for connection:</p> <ul style="list-style-type: none">• Matching expertise• Language, cultural and geographical aspects• Resources availability | <p>Agreement will contain:</p> <p>Details on the cooperation terms, including the roles and responsibilities of ICAO and each participant</p> |

ACT-SAF platform provides most recent information

- States and International Organizations that are on ACT-SAF
- Latest news
- ACT-SAF Terms and Conditions (available to any State or Organization)



ICAO ACT-SAF Platform

Here you will find more information on our ACT-SAF Participants*



States

Acceptance to ... Pending Yes



International Organizations

Acceptance T&C (Blank) Pending Yes



Latest news on ACT-SAF

| Date | Latest news | Link |
|------------|--|----------------------|
| 11/17/2022 | ICAO launches the ACT-SAF Series of training events on SAF | Link |
| 10/20/2022 | Argentina signs the ACT-SAF Terms and Conditions | Link |
| 10/7/2022 | Equatorial Guinea signs the ACT-SAF Terms and Conditions | Link |
| 10/4/2022 | Brazil signs the ACT-SAF Terms and Conditions | Link |
| 10/4/2022 | Singapore signs the ACT-SAF Terms and Conditions | Link |



Key request - conceptual training on SAF

ACT-SAF Series (preliminary list of sessions)

#1 Introduction to SAF

#2 SAF sustainability and reporting under CORSIA

#3 SAF technology and certification

#4 SAF market outlook and policies

#5 SAF logistics

#6 SAF economics and financing

#7 Feasibility Assessment

← Today's Session

- Future sessions on specific aspects
- Subject to review – **feedback welcome**





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Conclusion: ACT-SAF next steps



ACT-SAF next steps

1) Interested party* expresses interest in becoming an ACT-SAF Partner

2) ICAO coordinates with the interested party to detail the offers and requests, and suggest possible projects

3) ICAO connects ACT-SAF Participants

4) Agreement is signed and projects defined

Ongoing

Identification of needs and offers

- Coordination calls being held
- European Commission offered €1.6m towards ACT-SAF Projects
- Various ACT-SAF partners offered technical support

Identification of financing opportunities

4 Informal Exchanges on SAF financing

Next steps

Facilitate the match of opportunities and needs from States



Coordination of specific **ACT-SAF projects** (Q1 2023)



ACT-SAF Series (provisional list of next sessions)

#1 Introduction to SAF

#2 SAF sustainability and reporting under CORSIA

#3 SAF technology and certification

#4 SAF market outlook and policies

#5 SAF logistics

#6 SAF economics and financing

#7 Feasibility Assessment

ACTIONS FOR ACT-SAF Partners:

- Invite other States and Stakeholders to join ACT-SAF and participate on these events
 - Any State or Organization can fill out the ACT-SAF Terms and Conditions available on the ACT-SAF website)
- Provide feedback and suggest other subjects for the ACT-SAF Series (email officeenv@icao.int)

ICAO ACT-SAF platform will consolidate the actions and results



ICAO ACT-SAF Platform

Here you will find more information
on our ACT-SAF Participants*



Expected actions for 2023

- Outreach of Financing opportunities
- Assessment of SAF policy approaches
- 2023 Stocktaking (date TBC)
 - dedicated session on SAF policies and financing
- ICAO to continue to coordinate and get views from Member States and Stakeholders
- Development of ICAO SAF Accounting and Reporting System
 - Monitor progress on SAF implementation (Assembly Resolution A41-21)
 - Consolidate available information (e.g. Book and Claim systems; CORSIA CCR public information, State Action Plans).

All activities will support the CAAF/3 Conference in 2023 (date TBC)



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THANK YOU