ICAO

INTERNATIONAL CIVIL AVIATION ORGANIZATION

A UN SPECIALIZED AGENCY

:

Introduction to Sustainable Aviation Fuels

Blandine Ferrier

Environment Officers, ICAO, EURNAT

The role and benefits of SAF in the aviation decarbonization

ICAO ENVIRONMENT

LTAG Decision

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

Adopted by ICAO Assembly Resolution A41-21 (2022)

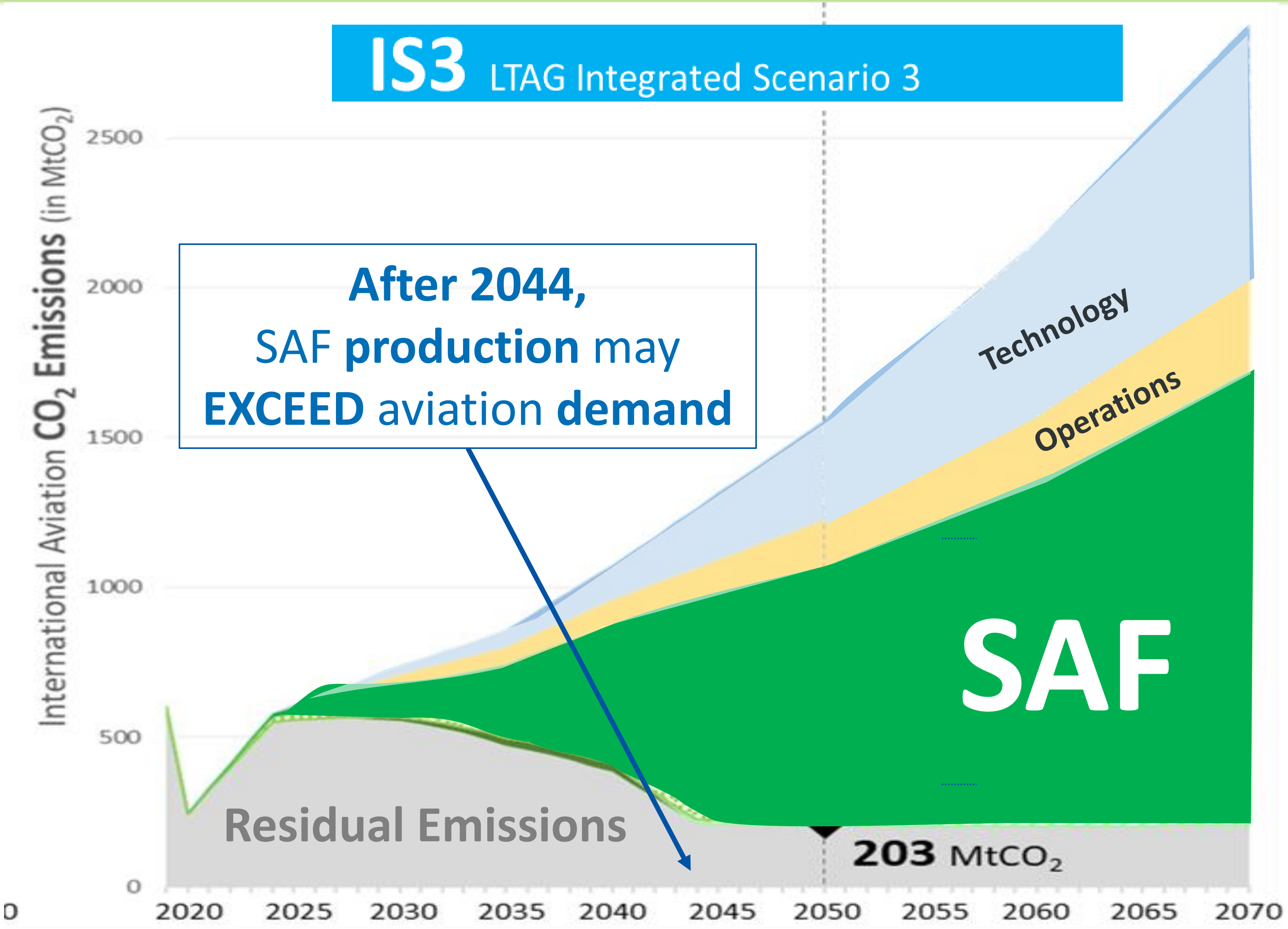
https://www.icao.int/environmental-protection/Documents/Assembly/Resolution_A41-21_Climate_change.pdf

LTAG Report

SAF will play a key role in aviation decarbonization efforts

ICAO ENVIRONMENT

LTAG report and SAF



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 work on SAF goals

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**

Benefits of SAF

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

ACT-SAF #5 SERIES

SAF industry can provide opportunities for economic growth and employment

ACT-SAF #6 SERIES

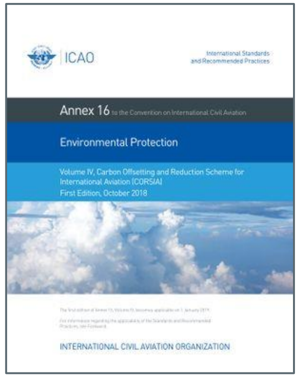
Definition of SAF

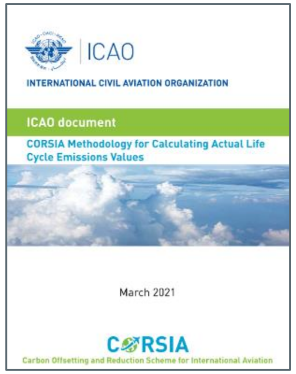
And Sustainability Criteria

SAF basic definitions

What are Sustainable Aviation Fuels (SAF)?

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

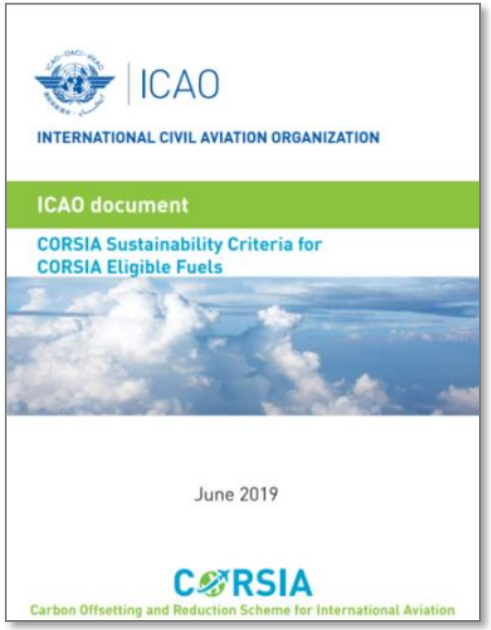




All documents available at https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

CORSIA Sustainability Criteria

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



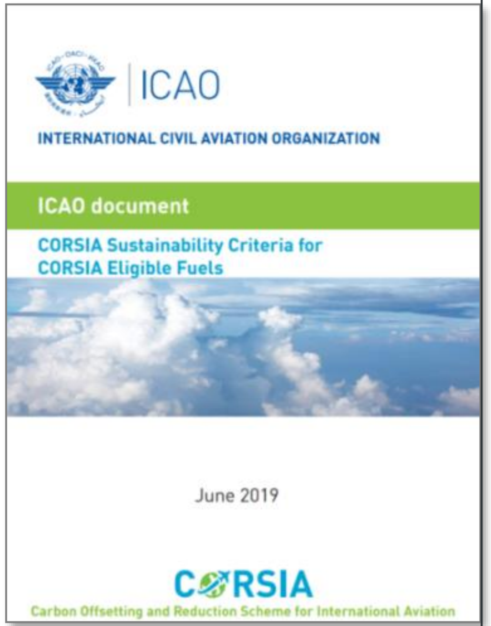
Sustainability Themes
1. Greenhouse Gases (GHG)
2. Carbon stock
3. GHG reduction permanence
4. Water
5. Soil
6. Air
7. Conservation
8. Waste and Chemicals
9. Seismic and Vibrational Impacts
10. Human and labour rights
11. Land use rights and land use
12. Water use rights
13. Local and social development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

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

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

CORSIA Sustainability Criteria

CORSIA sustainability criteria for CORSIA eligible fuels



For **next CORSIA Phases**:

✓ **13 themes applicable <u>for SAF</u> with specific criteria <u>(Chapter 2)</u> :**

- ➢ **Environmental: GHG, Carbon Stocks, GHG savings permanence, Water; Soil; Air; Conservation; Waste and Chemicals;**
- ➢ **Socio-Economic: Human and labor rights; Land use rights and land use; Water use rights; Local and social development; and Food security**

✓ **Same 14 themes <u>for LCAF</u> with specific criteria <u>(Chapter 3)</u>**

Theme	Principle	Criteria
1. Greenhouse Gases (GHG)	Principle: CORSIA SAF should generate lower carbon emissions on a life cycle basis.	Criterion 1.1: CORSIA SAF will achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis.
2. Carbon stock	Principle: CORSIA SAF should not be made from biomass obtained from land/aquatic systems with high biogenic carbon stock.	Criterion 2.1: CORSIA SAF will not be made from biomass that is either obtained/extracted from land or aquatic ecosystems converted after 1 January 2008 that was primary forest, wetlands, peat lands, coral reefs, kelp forests, seagrass meadows, estuaries, tidal salt marshes or mangrove forests or contributes to degradation of the carbon stock in primary forests, wetlands, peat lands, coral reefs, kelp forests, seagrass meadows, estuaries, tidal salt marshes or mangrove forests as these systems all have high carbon stocks.
		Criterion 2.2: In the event of land use conversion after 1 January 2008, as defined based on the Intergovernmental Panel on Climate Change (IPCC) land categories, direct land use change (DLUC) emissions will be calculated. If DLUC greenhouse gas emissions exceed the default induced land use change (ILUC) value, the DLUC value will replace the default ILUC value.
3. Greenhouse gas Emissions Reduction Permanence	Principle: Emissions reductions attributed to CORSIA SAF should be permanent.	Criterion 3.1: Operational practices will be implemented to monitor, mitigate and compensate any material incidence of non-permanence resulting from carbon capture and sequestration (CCS) activities.
4. Water	Principle: Production of CORSIA SAF should maintain or enhance water quality and availability.	Criterion 4.1: Operational practices will be implemented to maintain or enhance water quality.
		Criterion 4.2: Operational practices will be implemented to use water efficiently and to avoid the depletion of surface or groundwater resources beyond replenishment capacities.

Chapter 2 and 3 : APPLICABLE FOR **SAF** PRODUCED **ON OR AFTER 1 JANUARY 2024**

Carbon Reduction Themes

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

Theme 3: GHG reduction permanence

- Emissions reductions attributed to CORSIA SAF should be permanent.

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

Environmental themes

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

Socio-economic themes

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

SAF life cycle assessment

SAF Life cycle emissions 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 with a **Life cycle assessment of the CEF:**

CEF Life cycle emission value (L_{CEF})
Unit – gCO2e/MJ

=

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

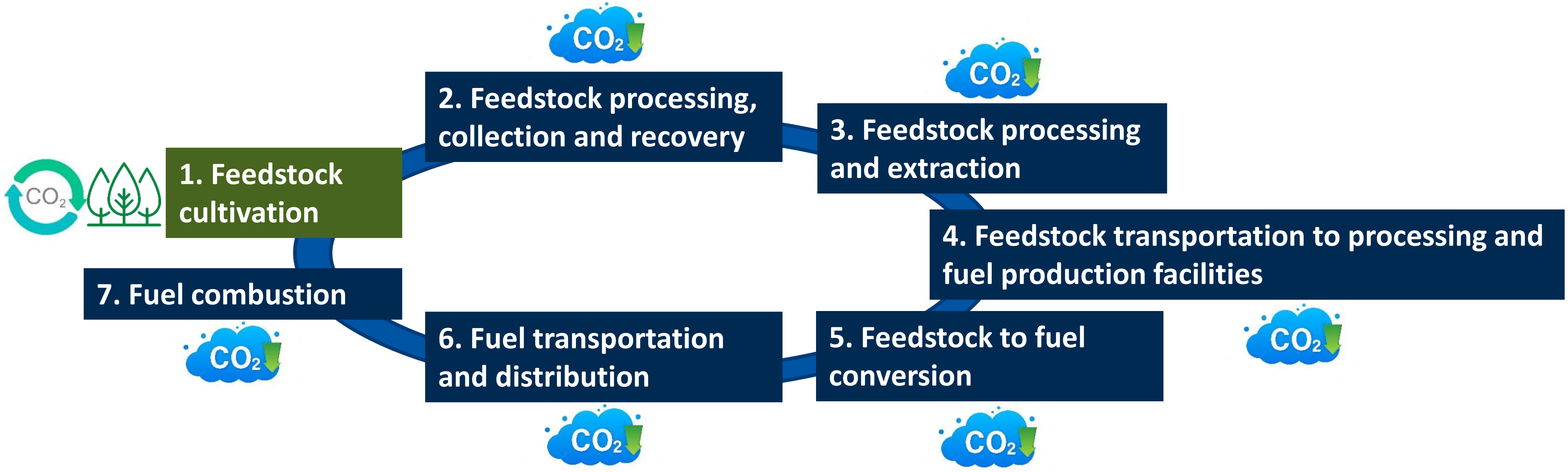
+

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

For LCAF, only core LCA values are considered (ILUC is considered zero).

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_2e/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 gCO_2e/MJ)

Life Cycle Assessment

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

ICAO ENVIRONMENT

Default life cycle emissions values

ACT-SAF #2 SERIES

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_f (gCO_2e/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


ICAO
INTERNATIONAL CIVIL AVIATION ORGANIZATION
ICAO document
CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels
November 2019
CORSIA

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

Default life cycle emissions values

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

<table>
<tr><th>Region</th><th>Fuel Feedstock</th><th>Pathway Specifications</th><th>Core LCA Value</th><th>ILUC LCA Value</th><th>LS_f (gCO_2e/MJ)</th></tr>
<tr><td>Global</td><td>Tallow</td><td></td><td>22.5</td><td rowspan="4">0.0</td><td>22.5</td></tr>
<tr><td>Global</td><td>Used cooking oil</td><td></td><td>13.9</td><td>13.9</td></tr>
<tr><td>Global</td><td>Palm fatty acid distillate</td><td></td><td>20.7</td><td>20.7</td></tr>
<tr><td>Global</td><td>Corn oil</td><td>Oil from dry mill ethanol plant</td><td>17.2</td><td>17.2</td></tr>
<tr><td>USA</td><td>Soybean oil</td><td></td><td>40.4</td><td>24.5</td><td>64.9</td></tr>
<tr><td>Brazil</td><td>Soybean oil</td><td></td><td>40.4</td><td>27.0</td><td>67.4</td></tr>
<tr><td>Global</td><td>Soybean oil</td><td></td><td>40.4</td><td>25.8</td><td>66.2</td></tr>
<tr><td>EU</td><td>Rapeseed oil</td><td></td><td>47.4</td><td>24.1</td><td>71.5</td></tr>
<tr><td>Global</td><td>Rapeseed oil</td><td></td><td>47.4</td><td>26.0</td><td>73.4</td></tr>
<tr><td>Malaysia & Indonesia</td><td>Palm oil</td><td>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.</td><td>37.4</td><td>39.1</td><td>76.5</td></tr>
<tr><td>Malaysia & Indonesia</td><td>Palm oil</td><td>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.</td><td>60.0</td><td>39.1</td><td>99.1</td></tr>
</table>

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

Default life cycle emissions values

ACT-SAF #2 SERIES

ICAO ENVIRONMENT

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	LS_f (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

Actual life cycle emissions values

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

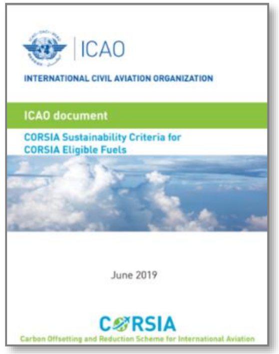
- **Document provides further details on the methodology, such as:**
  - Technical report requirements
  - Feedstock categories (wastes, residues, byproducts = zero ILUC),
  - Low land use change risk practices (zero ILUC)
  - Emissions credits

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

SAF sustainability certification

CORSIA Sustainability Criteria

CORSIA sustainability criteria for CORSIA eligible fuels


ICAO
INTERNATIONAL CIVIL AVIATION ORGANIZATION
ICAO document
CORSIA Sustainability Criteria for CORSIA Eligible Fuels
June 2019
CORSIA
Carbon Offsetting and Reduction Scheme for International Aviation


Guidance to Sustainability Certification Schemes (SCS) for application of CORSIA Sustainability Criteria, Themes 3 to 7, for CORSIA Sustainable Aviation Fuel produced on or after 1 January 2024
CORSIA
Version 1 – November 2021

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

Not all the themes are to be assessed in the same way

Compliance with Themes 1 to 8 is granted on independent attestation by approved Sustainability Certification Schemes (SCS)
Themes 4 to 8, also considering the guidance approved by the Council

Compliance with themes 10-12 can be **demonstrated to the SCS by a national attestation from the State in whose territory the SAF is produced**, without further assessment by the SCS

Compliance with 13-14 will be demonstrated by **reporting to the SCS the actions being taken to meet the related criteria,** without further judgement of those actions by the SCS

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


ICAO
INTERNATIONAL CIVIL AVIATION ORGANIZATION
ICAO document
CORSIA Approved Sustainability Certification Schemes
November 2020
CORSIA
Carbon Offsetting and Reduction Scheme for International Aviation

ISCC
International Sustainability & Carbon Certification

RSB

Questions?

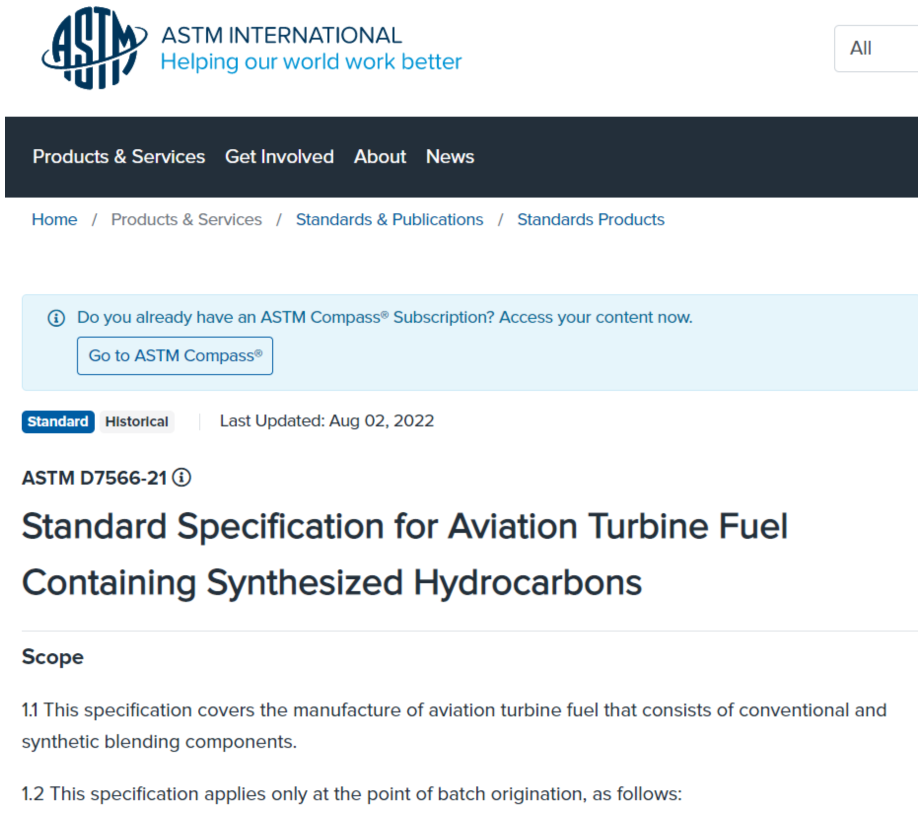
SAF specifications, feedstocks and conversion pathways

SAF specifications

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)



SAF – conversion pathways and feedstocks

SAF can be produced from a variety of feedstocks

Oils and fats

Lignocellulose

Sugars

Wastes

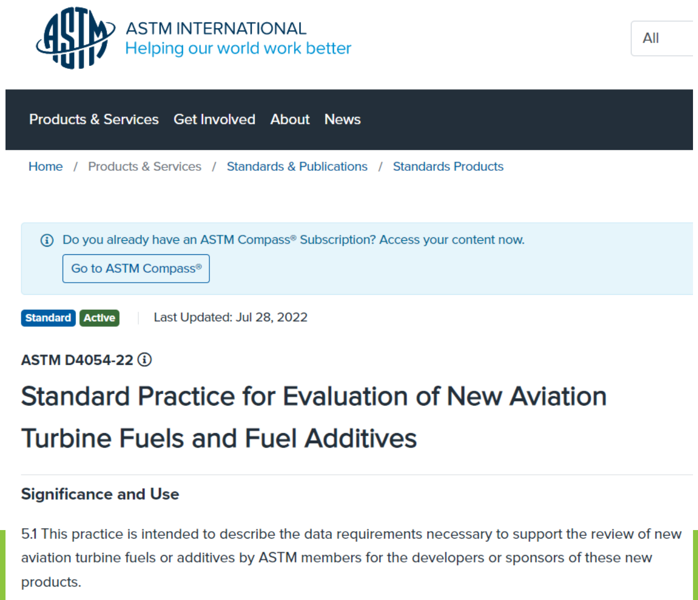
Examples of conversion pathways:

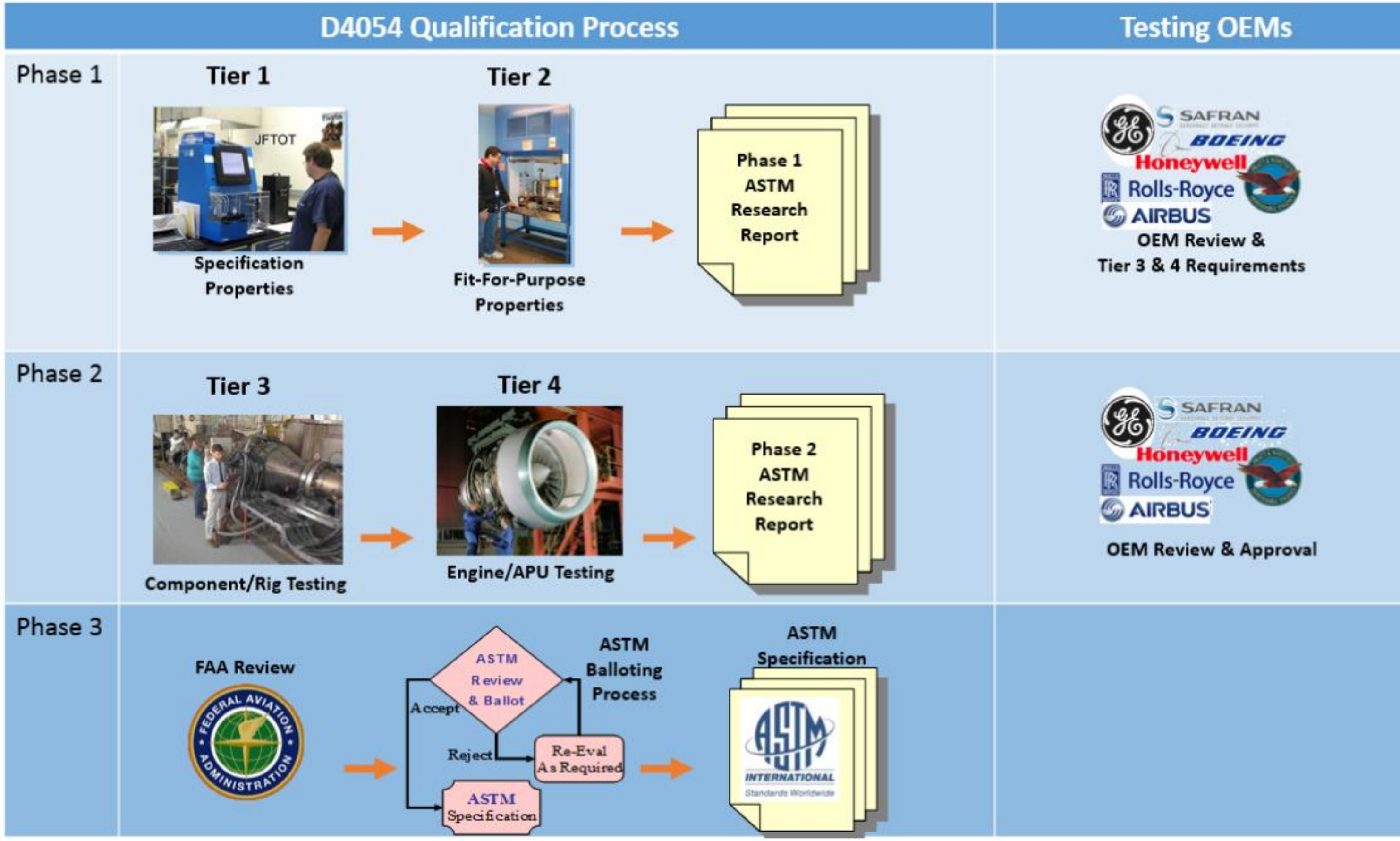
	Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids (HEFA)	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene (FT)	Alcohol to jet synthetic paraffinic kerosene (ATJ-SPK)
Description	Conversion of oils/fats to hydrocarbons via deoxygenation with hydrogen and cracking	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

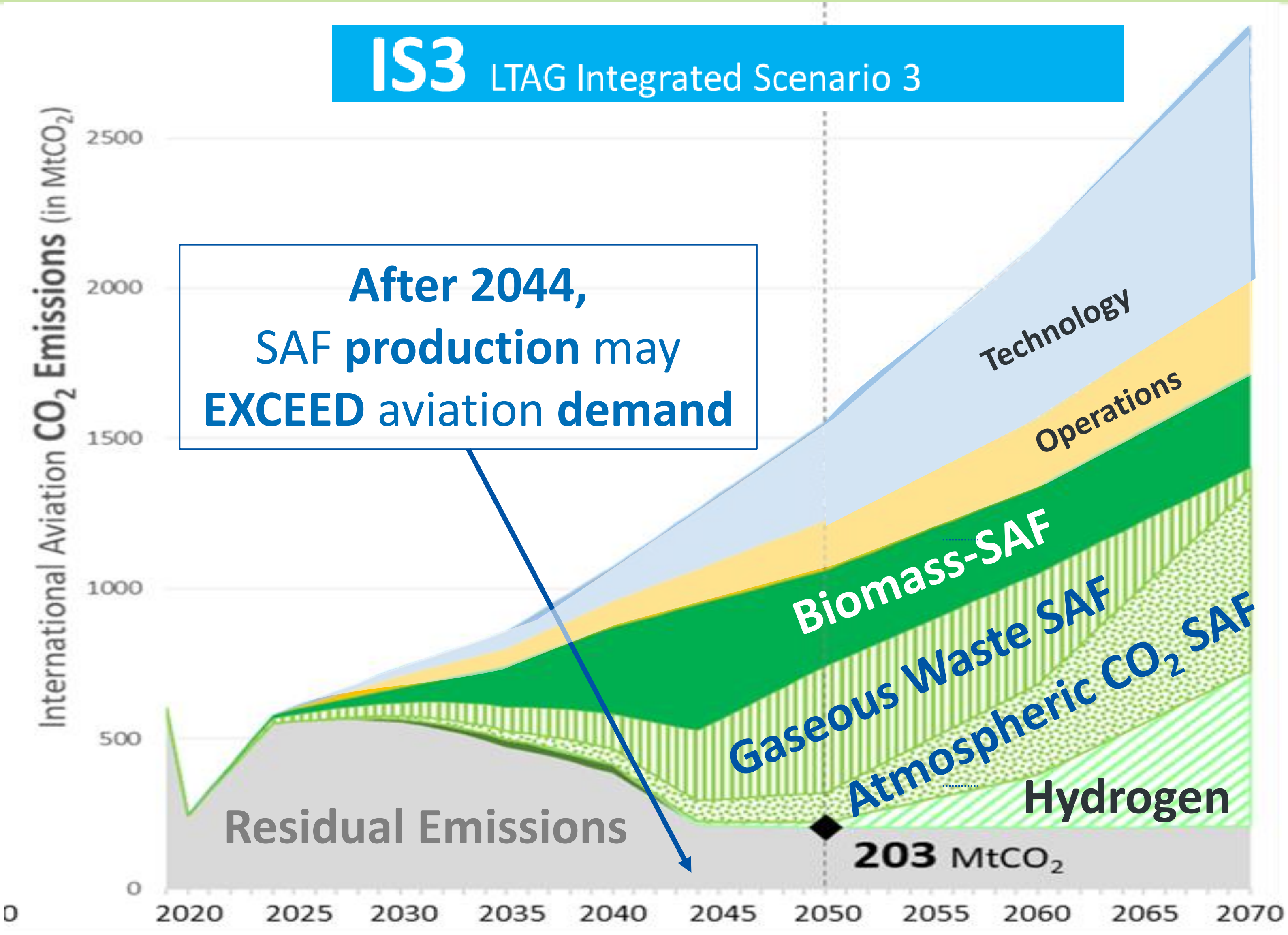




Source: https://www.caafi.org/focus_areas/fuel_qualification.html#streamlining

LTAG and SAF

•



All types of SAF will contribute to the LTAG of net zero CO_2 emissions by 2050

Developments in the SAF market

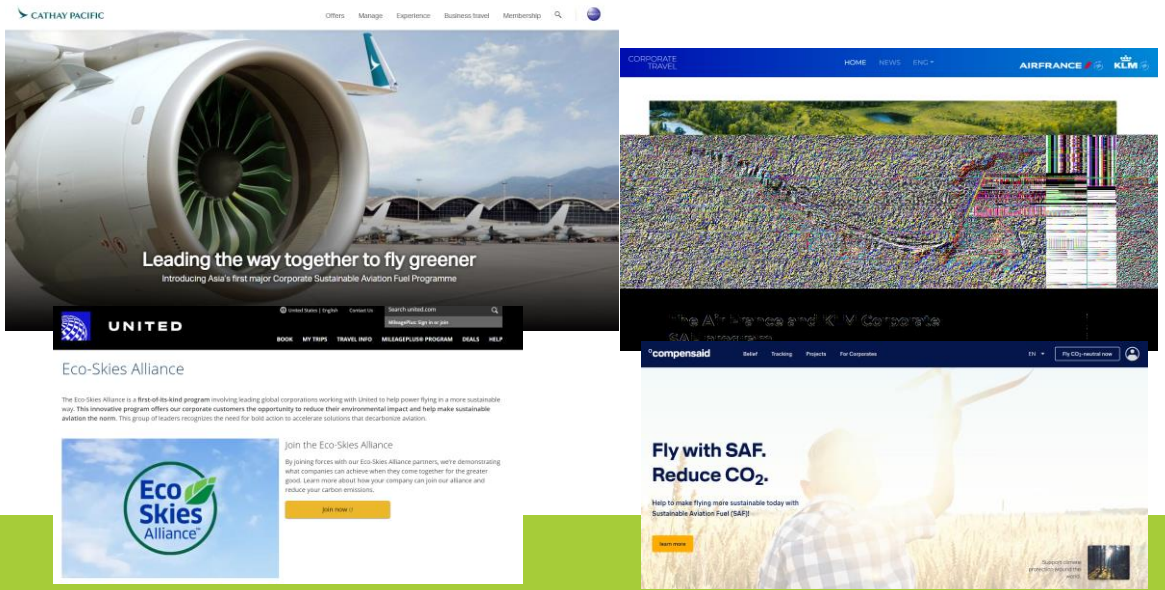
ICAO ENVIRONMENT

Developments in the SAF market - demand

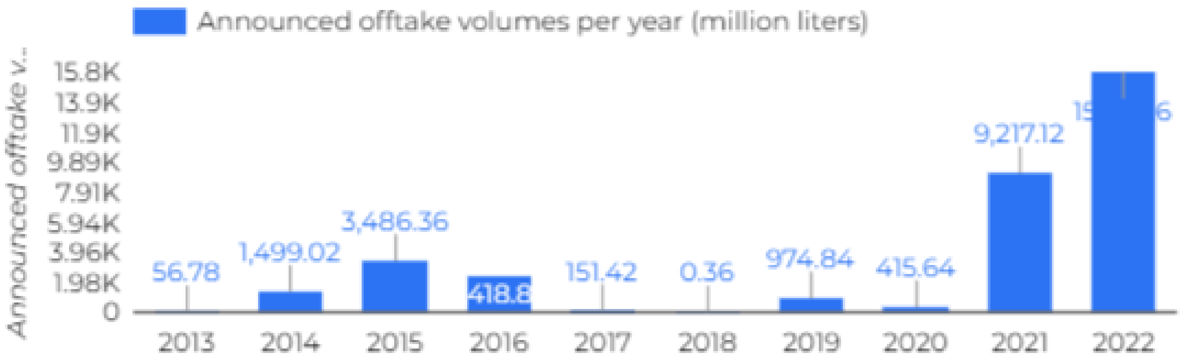
ACT-SAF #4 SERIES

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

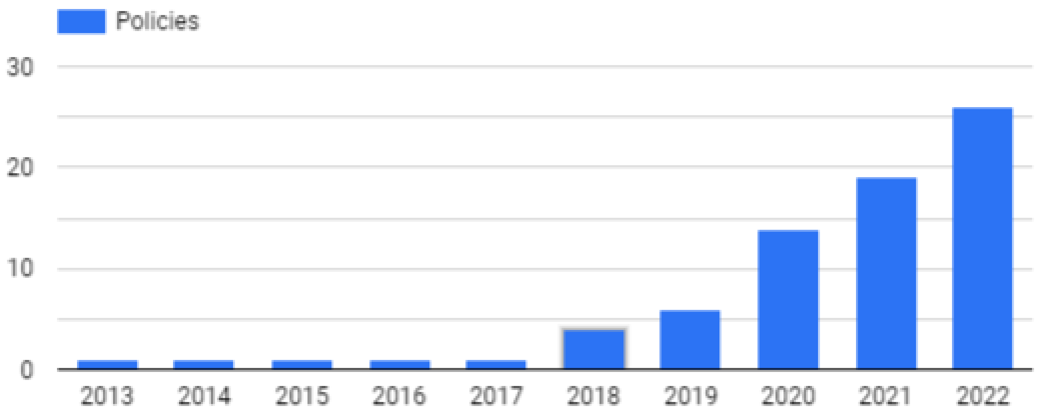


Offtake agreements



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

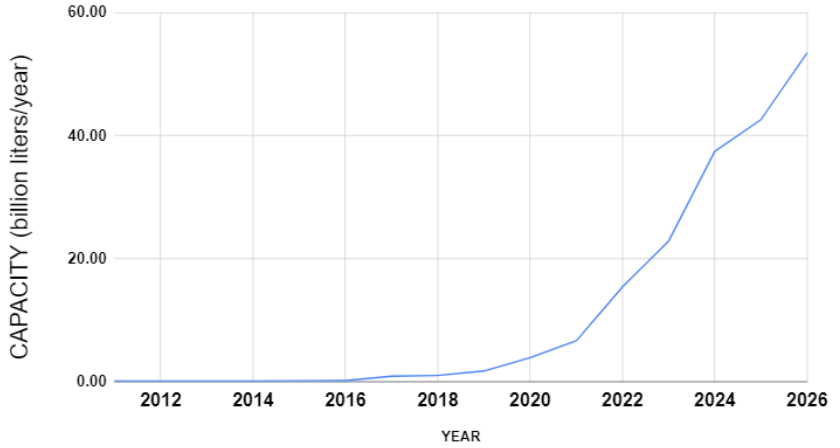
Policies



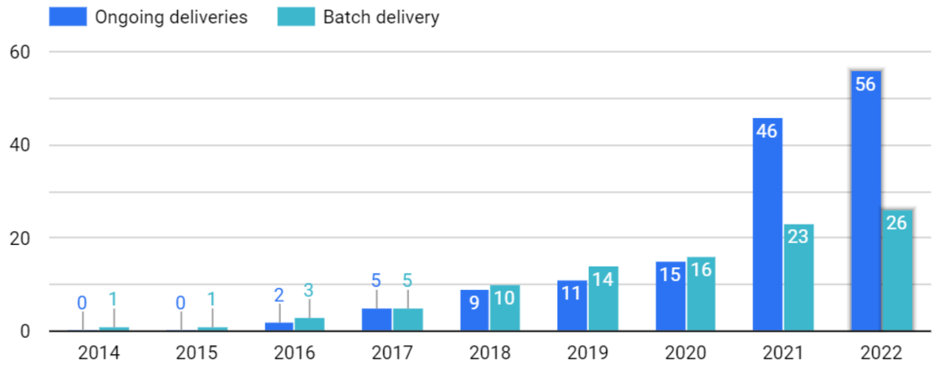
Developments in the SAF market - supply

SAF production volumes and distribution also growing

Announced Production capacity



Airports distributing SAF



ICAO SAF Tracking Tools provide regular updates on SAF market

Policy Examples

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)

Additional SAF resources from ICAO

Additional resources

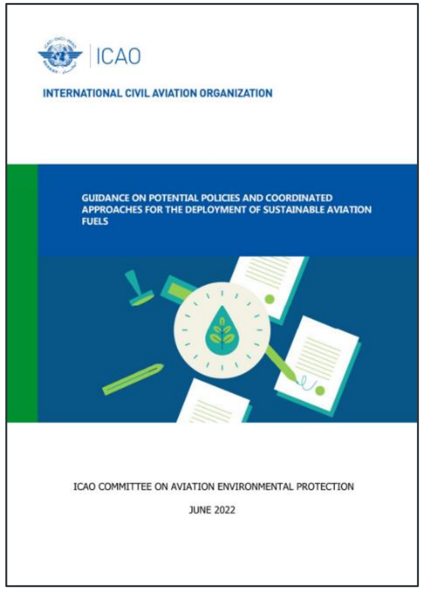
ICAO provides guidance material to support SAF development and deployment

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

ACT-SAF #4 SERIES

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

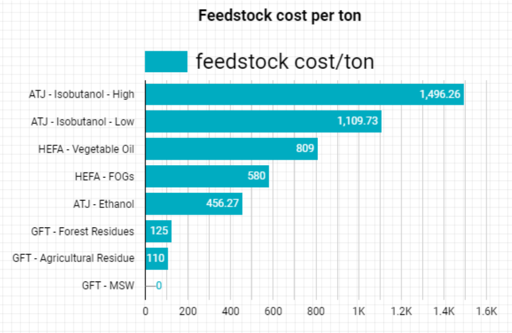
For more details

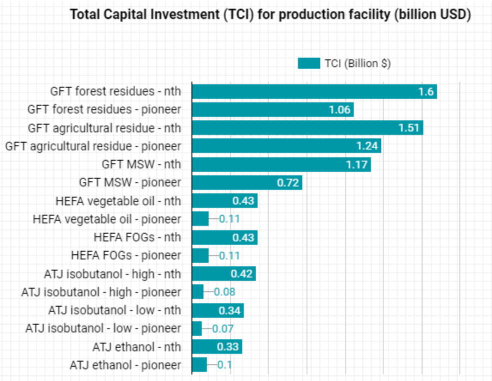


SAF Rules of Thumb – what does it take to produce SAF?

ACT-SAF #6 SERIES

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



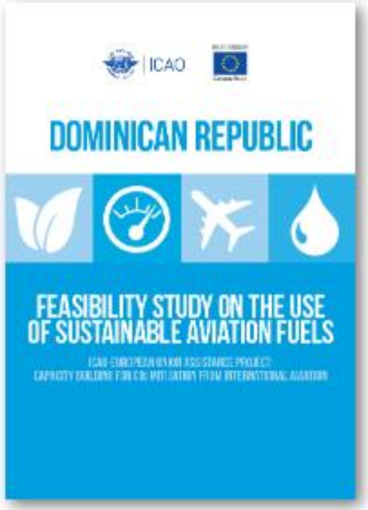


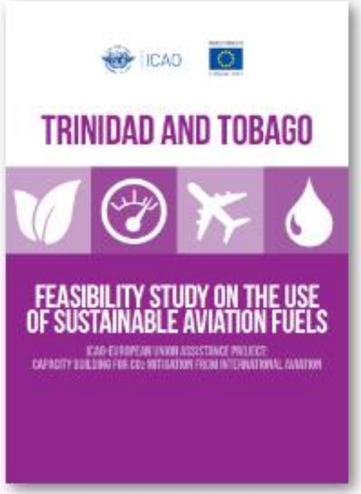
For more details

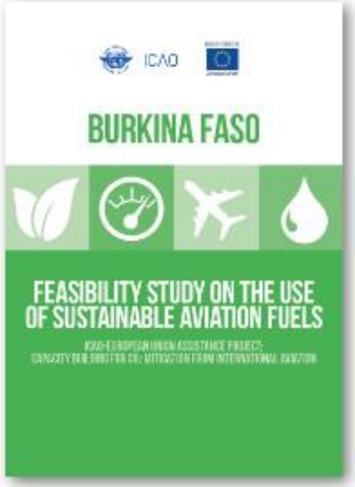
Additional resources

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

ACT-SAF #7 SERIES







3 more studies on SAF for Cote d’Ivoire, Rwanda and Zimbabwe

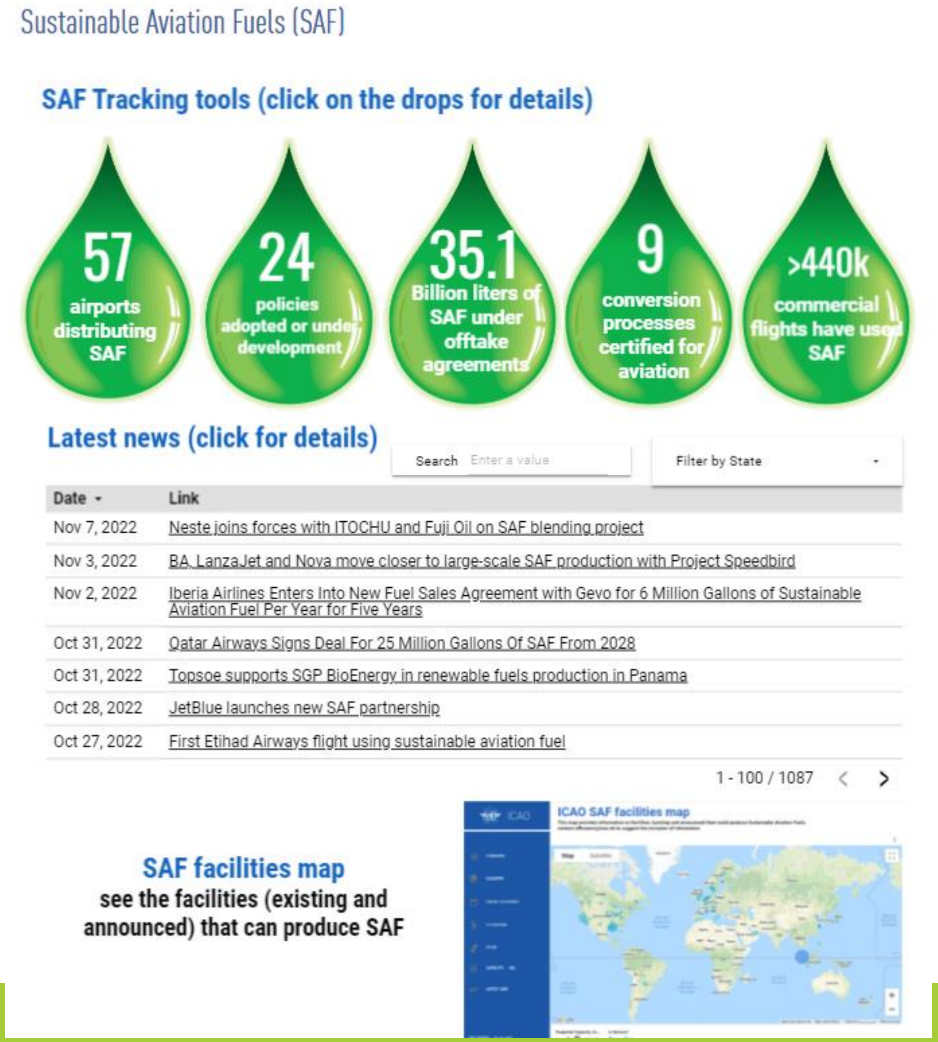
***developed under the ICAO-EU assistance project ‘Capacity building for CO_2 mitigation from international aviation**

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



SAF as a key future element of State Action Plans

Why develop a State Action Plan?

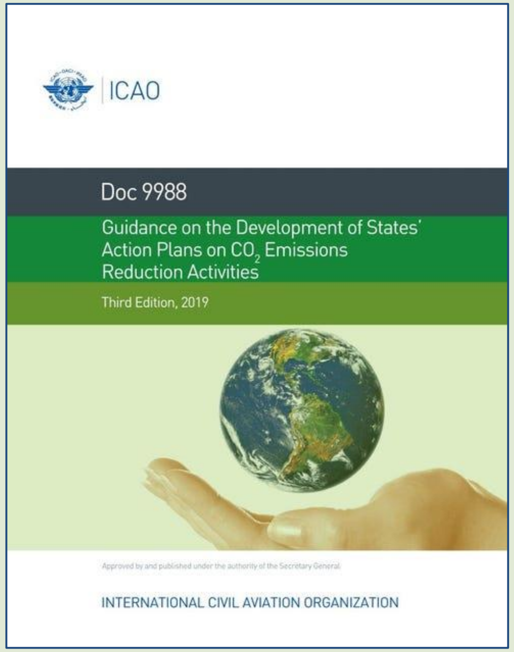
A State Action Plan can help States:

- Report international aviation CO2 emissions
- Outline their policies and actions
- Provide information on their basket of measures and any specific assistance needs

A State Action Plan will help ICAO:

- Compile information on achieving the global aspirational goals
- Provide guidance and technical assistance on preparing action plans
- Identify and respond to States' needs for technical and financial assistance

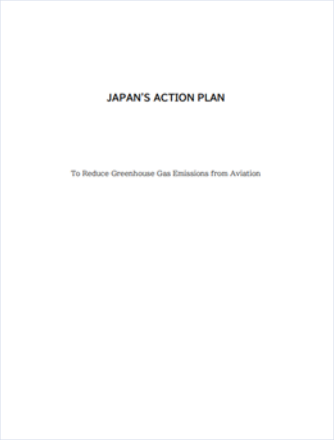
ICAO Doc 9988 provides guidance to develop a State Action Plan



SAF in State Action Plans

- Out of the 140 action plans that were submitted, 84 States in total consider SAF as one of the mitigation measures to reduce CO_2 emissions. SAF in the action plans considered in the following ways:
  - SAF Policies in place
  - SAF Policies planned to be implemented
  - SAF development and deployment
  - Research and Development (R&D)
  - Pilot projects
  - Feasibility studies

SAF and Cleaner Energy initiatives from SAPs


JAPAN'S ACTION PLAN

To Reduce Greenhouse Gas Emissions from Aviation

United Kingdom

Renewable Transport Fuel Obligation - fuel suppliers to ensure a proportion of fuel from renewable origin

Canada

Identification of local SAF feedstocks (Canola, forestry residues, carinata, used cooking oil, poplar, camelina)

Dominican Republic

Use of photovoltaic energy in airports

Japan

Target of replacing 10% of fuel consumption by Japanese airlines with SAF by 2030

United States

SAF grand challenge - commitment to increase the production of SAF to at least 3 billion gallons per year by 2030

ICAO CAAF/3 process and timeline

ICAO ENVIRONMENT

ICAO CAAF/3 PROCESS AND TIMELINE

28 March 2023
Council Informal Meeting
(Financial Institutions)

April - May 2023
ENV Regional
Seminars (5 events)

- 13-14 Apr: EUR-NAT
- 18-19 Apr: ESAF/WACAF
- 24-25 Apr: NACC/SAM
- 3-4 May: APAC
- 7-8 May: MID

24 May 2023
Launch of ICAO-EU
ACT-SAF Project

15 and 20 June 2023
Council Informal Meetings
(Banks/Investors and
Energy Companies)

11-13 July 2023
Pre-CAAF/3 Stocktaking,
and Policy / Finance
Consultations

25-26 Sept 2023 (TBC)
Pre-CAAF/3 Outcomes
Consultations

21-24 Nov. 2023
CAAF/3
Discussions on a
global
framework for
aviation



ICAO

THANK YOU