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SUSTAINABLE AVIATION BUYERS ALLIANCE

Education Deck 1: Sustainable Aviation Fuel 101

A joint initiative of EDF Environmental Defense Fund® RMI Energy. Transformed.

With expert support from ENGIE Impact

“SAF is our biggest emissions reduction opportunity. The time is right to push it forward so that, together, we can achieve major carbon reductions on the way towards fossil fuel-free flight. ”

Alexandre de Juniac, Director General and CEO,

International Air Transport Association (IATA)

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Sustainable aviation fuel is an alternative to conventional jet fuel and is key to reducing aviation-related emissions

Today, commercial aviation is fueled primarily by kerosene-based fuel Jet-A/Jet-A1, which can be easily substituted with SAF blends.

SAF is a liquid fuel currently used in commercial aviation which reduces CO_2 emissions.

It can be produced from several feedstocks, including but not limited to waste oil and fats, municipal waste, non-food crops, CO_2 and water.

SAF is a “drop-in” fuel as it meets all the same technical and safety requirements as fossil-based jet fuel and can therefore be used safely on existing aircraft and within current airport systems.

ENVIRONMENTAL BENEFITS

Approximately 60-80% reduction in CO_2 life cycle emissions compared to fossil fuels, depending on feedstock and production pathway

DIVERSIFIED SUPPLY

Can substitute traditional jet fuel with a more diverse geographical fuel supply

ECONOMIC BENEFITS

SAF can provide economic benefits to developing nations that have land unavailable for food crops that is suitable for SAF feedstock growth

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There are four main SAF production pathways likely to scale

SAF Production Pathway	Feedstock	Feedstock availability 2050[1]	Production cost 2025[1]	Production cost 2050[1]	Technology Readiness Level[2,3]
1. Hydrogenated Esters and Fatty Acids	Waste & residue lipids	◔	◑	◕	9
	Oil crops	◑	◑	◑	9
2. Alcohol to Jet	Cellulosic crops	◑	◑	◕	5-9
	Agricultural residues	●	◕	●	
	Industrial waste gases	◔	◕	◕	
3. Gasification and Fischer-Tropsch	Municipal solid waste	◑	◑	●	5-9
4. Power to Liquid	CO2 and water	●	◔	◑	5-6

● Optimal

○ Suboptimal

1) Air Transport Action Group, 2021; 2) Umwely Bundesamt, 2016; 3) Technology Readiness Levels are a measurement system to assess the maturity of a technology, with 9 being the most mature. More information can be found here.

Deep dive on pathway 1: Hydrogenated esters and fatty acids (HEFA)

FAST FACTS

Popular Feedstock:

Waste & residue lipids, such as tallow and used cooking oil from animals and vegetables

Oil crops, including but not limited to carinata, camelina, jatropha, and algae

Chemical process[1]:
Deoxygenation followed by hydrogenation to break down fats to hydrocarbons

%Lifecycle GHG emissions reduction vs. fossil fuels[2]:
73% - 84%

Maximum blend ratio:
50%

Technology readiness level:
9: Proven through successful full-scale operations

OUTLOOK

Today's production[3]:
11.6 million tCO2 from waste & residue lipids and 13.4 from oil crops

Anticipated production[3]:
6% - 8% of total SAF volumes in 2050,with production levels hovering around 27 million tCO2 per year (9 billion gallons)

Tailwinds

- Opportunities for cost reduction and carbon intensity reduction of feedstocks

Headwinds

- Finite feedstock which comes with two major concerns: sustainability and cost
- Limited opportunities for technical improvements

1) Glossary of chemical processes listed in appendix; 2) World Economic Forum, 2021; 3) Air Transport Action Group, 2021; 4) Note: tCO2e = metric ton CO2 equivalent

Deep dive on pathway 2: Alcohol-to-jet (ethanol route)

FAST FACTS

Popular Feedstock:

Agricultural residues leftover from agricultural production, such as stalks and stems of sugarcane

Cellulosic crops, including but not limited to miscanthus, switchgrass, and reed canary grass

Industrial waste gases leftover from industrial production including H2 and CO

Chemical process[1]:
Fermentation to convert feedstock to alcohol then upgraded to hydrocarbons via processes such as dehydrogenation, oligomerization, and hydrogenation

%Lifecycle GHG emissions reduction vs. fossil fuels[2]:
85% - 94%

Maximum blend ratio: 50%

Technology readiness level:
5-9: Some pathways are still being tested at scale and others are already system proven and in operational environment

OUTLOOK

Today's production[3]:
52.5 million tCO2 from agricultural residues and 24.8 from cellulosic crops and 9.5 million tCO2e from industrial waste gases

Anticipated production[3]:
35% - 47% of total SAF volumes in 2050, with production levels hovering around 155 million tCO2e (52 billion gallons)

Tailwinds

- Ethanol production is a long-established process that is already globally at commercial production levels

Headwinds

- Ethanol is an important component for gasoline
- Low yield associated with bio-alcohol production

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1) Glossary of chemical processes listed in appendix; 2) World Economic Forum, 2021; 3) Air Transport Action Group, 2021; 4) Note: tCO2e = metric ton CO2 equivalent

Deep dive on pathway 3: Gasification + Fischer-Tropsch

FAST FACTS

Popular Feedstock:

Municipal solid waste that comes from households and businesses such as product packaging, furniture, clothing, food scraps and paper

Chemical process[1]:
Gasification of feedstock to form CO and H2 followed by Fischer-Tropsch to generate hydrocarbons

%Lifecycle GHG emissions reduction vs. fossil fuels[2]:
85% - 94%

Maximum blend ratio:
50%

Technology readiness level:
5-9: Some pathways are still being tested at scale and others are already system proven and in operational environment

OUTLOOK

Today's production[3]:
22 million tCO2e from municipal solid waste

Anticipated production[3]:
35% - 47% of total SAF volumes in 2050,with production levels hovering around 155 million tCO2e per year (52 billion gallons)

Tailwinds

- It has a great variety of available feedstock that do not compete with food supply

Headwinds

- Much of the current progress of Fischer-Tropsch is still based on coal and natural gas as the feedstock

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1) Glossary of chemical processes listed in appendix; 2) World Economic Forum, 2021; 3) Air Transport Action Group, 2021; 4) Note: tCO2e = metric ton CO2 equivalent

Deep dive on pathway 4: Power to liquids (Fischer-Tropsch route)

FAST FACTS

Popular Feedstock:

CO2 sourced via direct air capture (DAC) or bio-energy with carbon capture (BECCS)

Water obtained from sustainable sources

Chemical process[1]:
H2O electrolysis to form H2 and reverse water gas shift to convert CO2 to CO, followed by Fischer-Tropsch to generate hydrocarbons

%Lifecycle GHG emissions reduction vs. fossil fuels[2]:
99%

Maximum blend ratio:
50%

Technology readiness level:
5-8: Some pathways are still being tested at scale and others are already complete and qualified but still not at commercial scale

OUTLOOK

Today's production[3]:
The high costs of production limit scale, so not yet commercial

Anticipated production[3]:
42% - 57% of total SAF volumes in 2050,with production levels hovering between 139 million tCO2 – 252 million tCO2 (47- 85 billion gallons)

Tailwinds

- Significant potential for scaleup and production of nearly 100% emissions reduction when compared to fossil jet fuel

Headwinds

- High total costs of fuel production
- The supply for renewable CO2 is low and costly

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1) Glossary of chemical processes listed in appendix; 2) World Economic Forum, 2021; 3) Air Transport Action Group, 2021; 4) Note: tCO2e = metric ton CO2 equivalent

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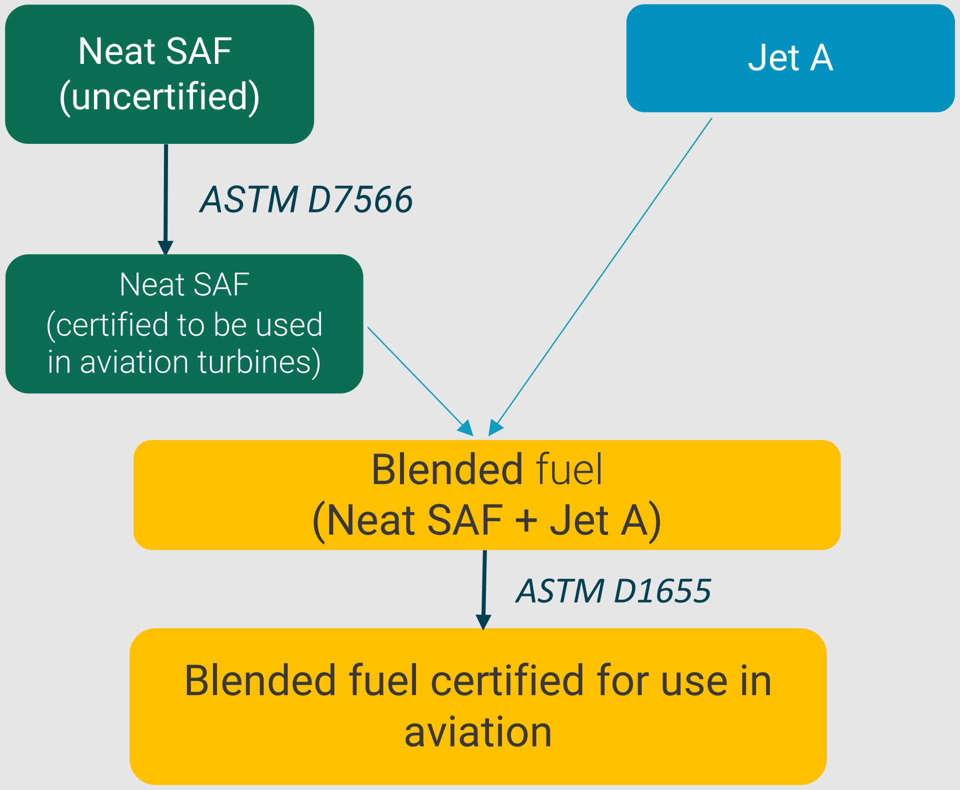
SAF must follow strict regulations to qualify as a safe, "drop in" fuel

SAF must follow strict specifications to be an eligible aviation fuel. The standard regulating the technical certification of SAF produced from different technical pathways in ASTM[1] D7566[2].

After SAF has been produced and blended with Jet-A / Jet-A1 up to specified limits, the blended fuel is recertified by ASTM's standard for aviation turbine fuel ASTM D1655[3], which certifies all the world's jet fuel prior to usage.



1. ASTM is an international standards organization that develops and publishes technical standards for a wide range of materials, products, systems, and services. ASTM's standard sets requirements for criteria such as composition, volatility, fluidity, combustion, corrosion, thermal stability, contaminants, and additives1, to ensure that the fuel is compatible when blended.
2. IATA Sustainable Aviation Fuel: Technical Certification
3. ASTM D1655 Standard Specification for Aviation Turbine Fuels

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CORSIA certifications help ensure that SAF is sustainable

The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is a market-based mechanism put in place by the International Civil Aviation Organization (ICAO) to cap emissions from international aviation at 85% of the 2019 level. Airlines are required to buy and retire carbon offsets or use SAF in order to keep global aviation emissions under the cap. SAF must meet certain sustainability criteria to be used towards a CORSIA obligation. ICAO has approved two "sustainability certification schemes" to verify that the SAF meets the required criteria – RSB and ISCC. (See next slides)

CORSIA Sustainability Criteria

1. **Greenhouse gases:** SAF should generate lower carbon emissions on a life cycle basis
2. **Carbon stock:** SAF should not be made from biomass obtained from land with high carbon stock
3. **Water:** Production of SAF should maintain or enhance water quality and availability
4. **Soil:** Production of SAF should maintain or enhance soil health
5. **Air:** Production of SAF should minimize negative effects on air quality
6. **Conservation:** Production of SAF should maintain biodiversity, conservation value, and ecosystem services
7. **Waste and chemicals:** Production of SAF should promote responsible management of waste and use of materials
8. **Human and labor rights:** Production of SAF should respect human and labor rights
9. **Land use rights and land use:** Production of SAF should respect land rights and land use rights including indigenous and / or customary rights
10. **Water use rights:** Production of SAF should respect prior formal or customary water use rights
11. **Local and social development:** Production of SAF should contribute to social and economic development in regions of poverty
12. **Food security:** Production of SAF should promote food security in food insecure regions

RSB CORSIA CERTIFICATION

The Roundtable on Sustainable Biomaterials (RSB)'s CORSIA Certification is for use by feedstock producers, refineries and traders globally to certify CORSIA-eligible SAF

Details on RSB

RSB has members from a worldwide movement of businesses, NGOs, academics, government and UN organizations that all have the same goal of supporting and driving best practice for sustainable biomaterial production

The RSB CORSIA Certification enables the certification of SAF made from:

- Primary biomass, such as oil or sugar crops and energy grasses
- Biomass from end-of-life products and production residues, such as used cooking oil, agricultural and forestry residues, and animal fats
- Municipal solid waste

ISCC CORSIA CERTIFICATION

The International Sustainability & Carbon Certification (ISCC)'s CORSIA Certification is for use by feedstock producers, refineries and traders globally to certify CORSIA-eligible SAF

Details on ISCC

ISCC is a multi-stakeholder initiative governed by an association of more than 100 members from over than 30 countries. The program began operations in 2010 and has issued more than 20,000 certificates over the past eight years. Currently, more than 3,300 companies in 100 countries are ISCC certified.

The ISCC CORSIA Certification enables the certification of SAF made from:

- Agricultural feedstocks for SAF, such as corn, palm and soy
- Wastes, residues and by-products, such as used cooking oil, municipal solid waste, bark, and tallow

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The Sustainable Aviation Buyers Alliance is accelerating the path to net-zero aviation

MISSION STATEMENT

The Sustainable Aviation Buyers Alliance (SABA) is committed to **accelerating the path to net zero air transport** by driving investment in high quality SAF, catalyzing new SAF production and technological innovation, and supporting member engagement in SAF policymaking.

3 KEY OBJECTIVES

- Expand SAF Investment Opportunity
- Provide Education & Policy Support
- Accelerate Technology Innovation

SABA works with partners to build a system that will enable organizations to invest in SAF with confidence

Four main priorities for 2022:

1 SUSTAINABILITY FRAMEWORK

Supporting buyers to invest in high integrity SAF and prevent unintended environmental consequences

2 SAF CERTIFICATE REGISTRY

Creating a universal SAF certificate registry, on the back of RSB's book and claim standard, that will allow buyers to make credible claims about the emission reductions from their investment in SAF

3 DEMAND AGGREGATION

Producing competitive RFPs and standardized contracts to help unlock investment, reduce costs, and drive rapid growth in SAF production

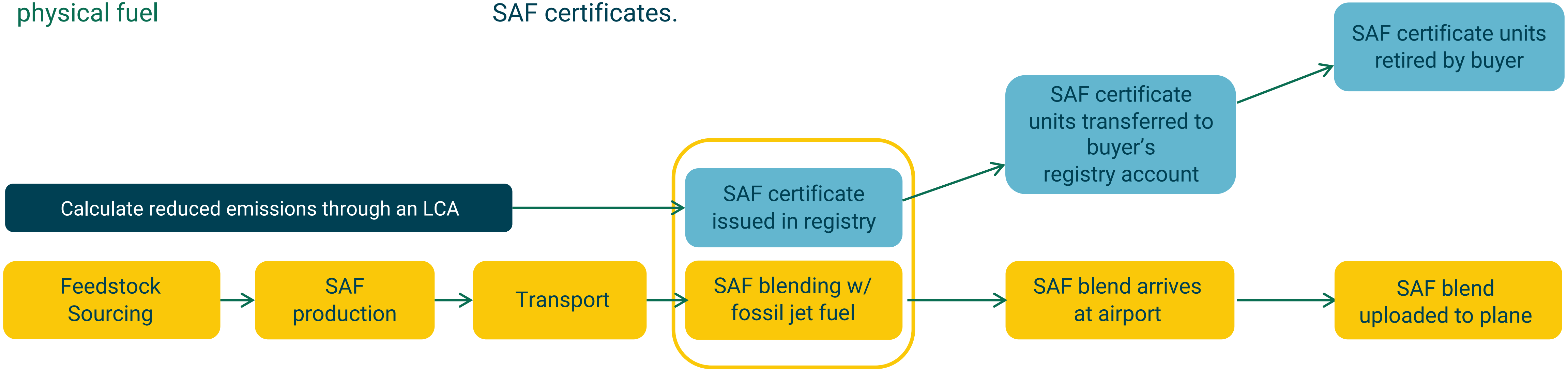
4 ACCOUNTING GUIDANCE

In collaboration with WEF CST, developing guidance on how to measure and report aviation emissions involving SAF

SAF certificates will enable anyone to support the purchase of SAF

MASS BALANCE SYSTEM
Environmental attributes are carried with the physical fuel

BOOK AND CLAIM SYSTEM
Environmental attributes are decoupled from the physical fuel and tracked as SAF certificates.



Saba is working with key partners to develop the necessary tracking and verification infrastructure

MASS BALANCE SYSTEM

RSB
SAF standard

SAF certified to
RSB standard

ISCC
SAF standard

SAF certified to
ISCC standard

There are two SAF standard holders, also known as **Sustainability Certification Schemes** (SCSs), recognized by ICAO today

Accredited third party certification bodies (i.e., auditors) certify SAF to the SCS standards.

SAF
Blending

BOOK AND CLAIM SYSTEM

RSB Book and Claim Manual

Detailed rules for how “credits” can be booked and claimed

SAF certificate rulebook

Detailed rules for how the SAF certificate and its registry will work

SAF certificate registry

The SAF certificate registry will be fully transparent and open for use by any organization, not only SABA members

RSB is developing a book and claim manual, in close collaboration with SABA. The environmental attributes from RSB and ISCC-certified SAF can be “booked” and “claimed” according to the rules outlined in the RSB manual.

SABA is collaborating with RSB, WEF/CST, and other partners to design and build an electronic ledger, or registry, compatible with the RSB book and claim system.

Appendix

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Glossary of SAF production process steps (1/2)

PROCESS	DESCRIPTION
Dehydration	The process where a reacting molecule loses water
Deoxygenation	The reaction of removing oxygen atoms from a molecule
Distillation	The process of separating materials through heating and cooling
Electrolysis	The process of using electricity to decompose water into oxygen and hydrogen gas
Fermentation	The process of converting sugars to alcohol in the presence of enzymes
Fischer- Tropsch	A collection of reactions that converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons in the presence of catalysts
Gasification	A process that converts biomass or fossil fuel-based materials into gases consisting of nitrogen, carbon monoxide, hydrogen, and carbon dioxide

Glossary of SAF production process steps (2/2)

PROCESS	DESCRIPTION
Hydrogenation	A reaction between hydrogen and another molecule in the presence of catalyst that saturates* the molecule *Saturation is when the number of double and triple bonds in a molecule are reduced
Isomerization	The process in which a molecule transforms into an isomer* *Isomers are molecules that has the same chemical formula but different arrangement of atoms
Oligomerization	A process that converts multiple small molecules (monomers) to a larger molecule (macromolecular complex) with a finite number of monomer units
Reverse water gas shift	The reaction of carbon dioxide and hydrogen to form carbon monoxide and water