LUFTHANSA GROUP

SAF Workshop- Airline Perspective

ACI & AFRAA

April 2025
Arusha

Glossary

1. Sustainable Aviation Fuel (SAF)
A low-carbon alternative to conventional jet fuel made from renewable feedstocks (e.g., waste oils, agricultural residues). SAF reduces lifecycle CO_2 emissions and is fully compatible ("drop-in") with current aircraft and fueling infrastructure.

2. Drop-in Fuel
A fuel that can be used directly in existing aircraft engines and airport fueling systems without modification. SAF is a drop-in fuel, easing its adoption.

3. Lifecycle Emissions
Total greenhouse gas (GHG) emissions from the production, transport, and combustion of a fuel. SAF can reduce lifecycle emissions by up to 80% compared to fossil jet fuel.

4. Book-and-Claim
A chain-of-custody system where the environmental benefits of SAF are traded via certificates, allowing airlines to claim SAF use even if not physically using it. Enables global access and scaling.

5. Blending Mandate
A regulation requiring a minimum percentage of SAF to be blended with conventional fuel. For example, the EU's ReFuelEU mandate increases from 2% SAF in 2025 to 70% by 2050.

6. ReFuelEU Aviation
An EU regulation mandating SAF usage in jet fuel supplied at EU airports. It aims to scale SAF adoption across Europe through gradually increasing blending targets.

7. EU ETS (Emission Trading System)
A cap-and-trade system where EU airlines must hold allowances for their CO_2 emissions. SAF use is exempt from these obligations, lowering costs for compliant airlines.

8. CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation)
ICAO's global program requiring airlines to offset growth-related emissions. SAF use reduces offset requirements, offering a cost-effective compliance route.

9. Greenhouse Gas Protocol (GHG Protocol)
A global standard for measuring and reporting GHG emissions. Airlines use it to disclose emissions and SAF-related reductions, classified under Scope 1 (direct) and Scope 3 (indirect).

10. Carbon Leakage
When environmental regulations in one region push emissions to other, less regulated regions. For example, passengers may reroute via non-EU hubs to avoid SAF costs.

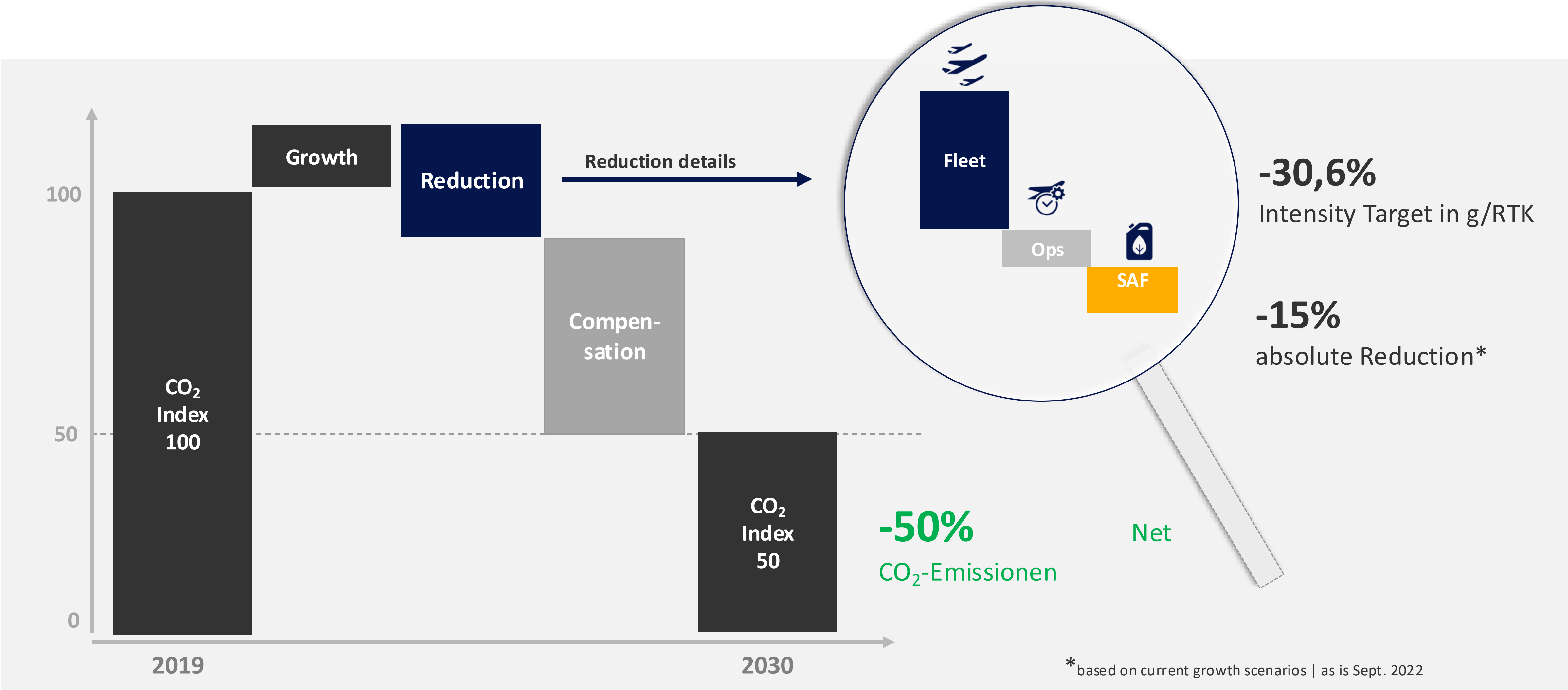
11. Proof of Sustainability (PoS)
Documentation verifying SAF's origin, feedstock, lifecycle emissions, and sustainability compliance. Required for regulatory and voluntary claims.

12. SAF Certificates
Tradable units in book-and-claim systems representing the environmental benefit of SAF use. Can be claimed by airlines or customers to report CO_2 reductions.

13. Fit for 55
An EU climate policy package aimed at reducing greenhouse gas emissions by at least 55% by 2030 (compared to 1990 levels). It includes measures affecting aviation, such as SAF mandates, revised EU ETS rules, and carbon pricing to accelerate decarbonization.

The CO^2 Target

The Lufthansa Group reduction path until 2030



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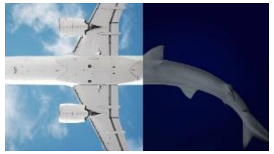
Lufthansa Group especially focuses on environmental aspects

Non exhaustive

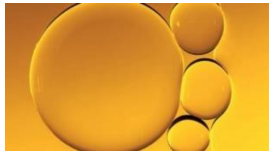
ENVIRONMENT

Low emission Flight Ops

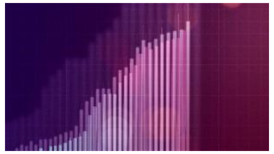
NEW AND EFFICIENT FLEET



SUSTAINABLE AVIATION FUELS



OPS & ATM EFFICIENCY



CO_2-OFFSETTING

Circularity and Waste

SUSTAINABLE PACKAGING

RECYCLING

CIRCULAR FREIGHT PACKAGING

CIRCULAR TEXTILES

CO_2-neutral Ground Ops

ELECTRIC GROUND OPERTIONS

ELECTRIC FLEET

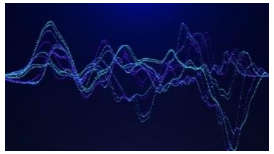
ENERGY EFFICIENCY IN OWNED BUILDINGS

Minimize local environmental footprint

MODERN AND CALM AIRCRAFT

OPTIMIZED ROUTING

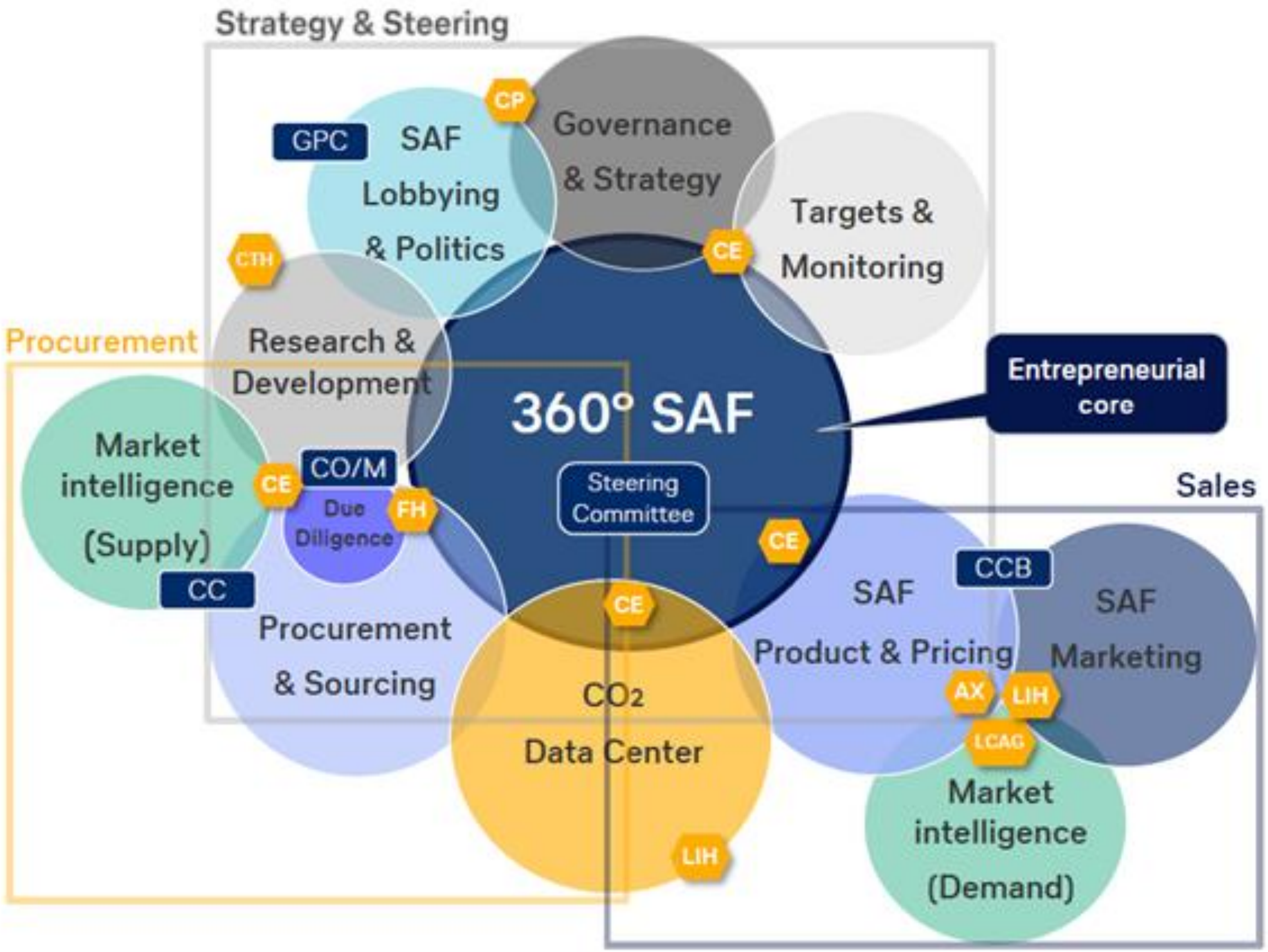
NOISE SCIENCES



STAKEHOLDER DIALOGUE

The SAF Plan exiting Covid

Setup to bundle and steer all SAF activities at LHG



SAF 360º

- Cross functional team to coordinate info and interests
- Technical/commercial team to analyze viable pathways and commercial predictions
- Fuel procurement and deal structure as key focus
- Targets and penalties into calculations and business modeling.

Strategic Partnerships & SAF Supply Agreements

Situation
2025

Oct 2021- Kuehne+Nagel and Lufthansa Cargo agree to offtake 25.000 liters/year x 5 years from NGO atmosfair, world's first PtL production in Werlte, Germany.
Nov 2021 – $250m USD biogenic SAF from Neste - its largest sustainability investment to date.

Sep 2022– Expanded partnership with OMV to supply more than 800,000 tons of SAF between 2023 and 2030.
Aug 2022– Signed a Memorandum of Understanding (MoU) with Shell for the supply of up to 1.8 million metric tons of SAF from 2024 to 2030.
Dec 2022- SWISS acquires a financial stake in Swiss-based solar fuel company Synhelion, which uses concentrated sunlight to produce carbon-neutral kerosene.

Feb 2023– Launched "Green Fares," offering passengers the option to fly more sustainably by including 20% SAF and contributing to climate protection projects.
May 2023– Passengers offset approximately 43,900 tons of CO_2 through the use of SAF and climate protection projects in the first 100 days of "Green Fares."
Jul 2023 –DER Touristik- first tour operator to sign SAF offtake with Lufthansa Group.
Aug 2023 – LHG signs LOI with HCS Group to produce and supply SAF "Made in Germany," with production starting in 2026 at a volume of 60,000 tons per year.
Jun 2023 - Nippon Express Europe and Lufthansa Cargo sign SAF offtake for airfreight, to reduce CO_2 emissions by ~ 3,150 tons per year.

Nov 2024 - Lufthansa Cargo signs offtake with Maersk for 400 metric tonnes of SAF in late 2024, aiming to reduce CO_2 emissions by at least 1,200 metric tonnes.

PtL fuels

THE GAP BETWEEN VISION AND REALITY IS WIDENING

The production of PtL kerosene is making little progress. The EU's policy toolbox is not sufficient to achieve the technological breakthrough. New ways of thinking are needed.

Sustainable aviation fuels (SAF) are a key lever for decarbonizing aviation. Today, biogenic materials such as used cooking oils and animal fats account for about 90 percent of SAF production. For many years, the Power-to-Liquid (PtL) process has been seen as a promising technology. In this process, hydrogen and CO_2 are converted into synthetic PtL kerosene (eFuels) using renewable energy. eFuels are almost climate-neutral and reduce dependence on fossil fuels. At least that is the vision.

eFuels gap
In 2030, eFuels supply will fall 45 percent short of targets.

2030
-45%
eFuels

Prognosis: BCG, 2025

Market ramp-up is faltering
The Lufthansa Group is working with partners from science and industry around the globe to further develop SAF. The challenge is enormous – and reality shows that the production costs for small PtL volumes are still far too high for a broad market launch. Although the first demonstration plants are in operation in the United States and Germany, they only produce minimal quantities of PtL kerosene. Many production facilities are behind schedule. The lack of a business case is hindering the scale up.

Political instruments ineffective
It is no longer possible to gloss over the economic reality. Political targets are increasingly receding into the distance. At the EU level, a PtL quota of 1.2 percent will apply from 2030, rising to 35 percent by 2050. The theory behind this is that a quota will generate sufficient demand to create an economic supply. It is now becoming clear that this rather simplistic mechanism is not working. Current projections show that without a change of

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One thing is clear: the aviation industry cannot create a competitive market for sustainable fuels on its own. That is why the EU needs to take a new regulatory approach. How can PtL production be launched outside Europe? Can forces be unleashed across modes of transport? How can effective market-based incentives be created? What flexibility mechanisms are needed?

It will hardly be economically feasible to implement PtL production in Germany – energy prices are too high, and renewable resources are too limited. The national PtL quota, which already applies from 2026, cannot change this either. Its abolition is only a first step. Half-hearted promises of support won't help either. From an airline perspective, it is clear that policymakers must finally come clean. The energy transition in aviation is a global mammoth task. It will not be enough to use a regulatory straitjacket to place the onus on the demand side alone.

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Missing Book-and-Claim & Policy Challenges

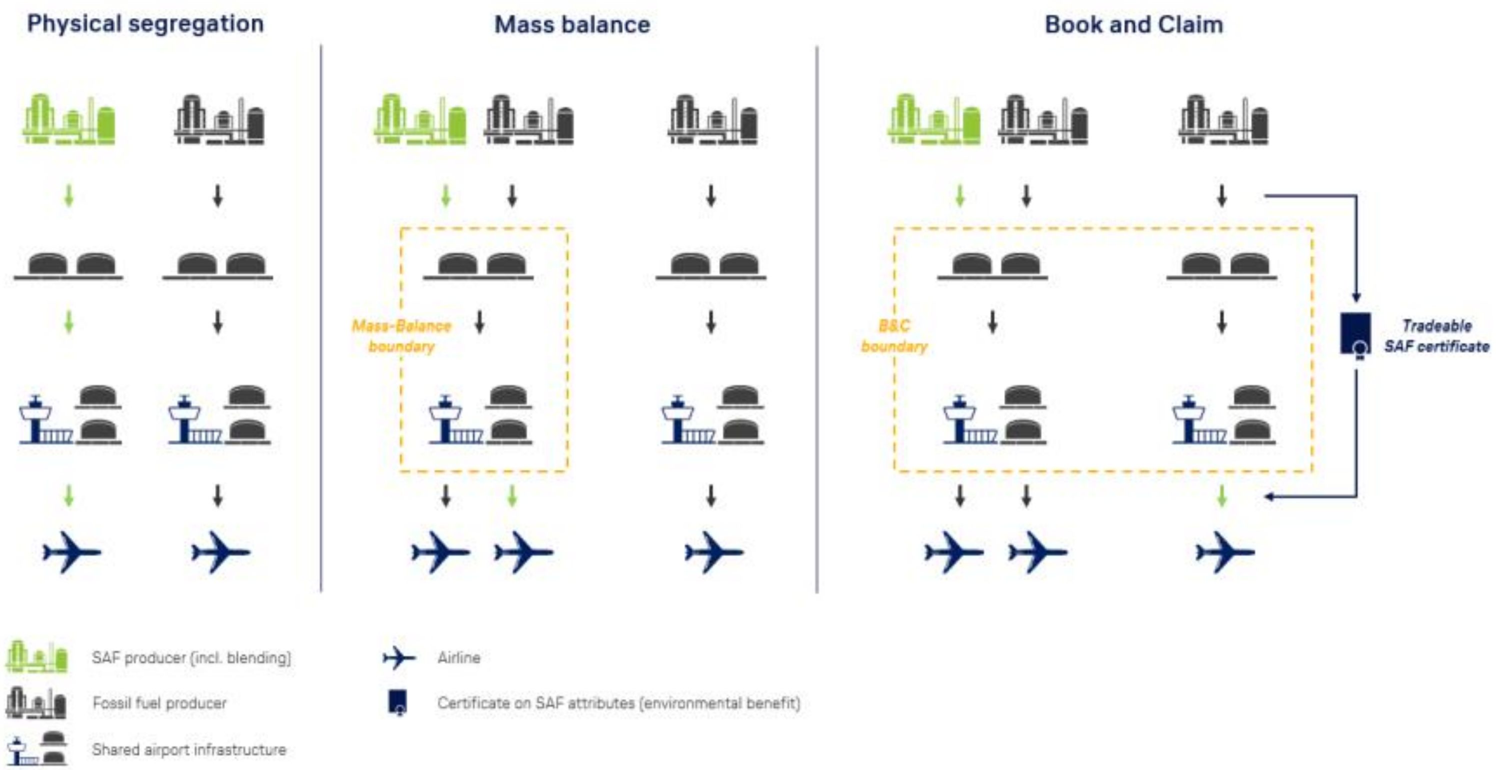
The problem with SAF investments: the missing Book-and-Claim system

Book-and-Claim Explained:

- SAF is used somewhere
- Environmental benefit is issued as a certificate
- Certificate is traded/claimed elsewhere (airline, customer, etc.)

Chain-of-Custody Options:

- Physical Segregation – costly and logistica complex
- Mass Balance – more efficient but still constrained to physical infrastructure
- Book-and-Claim – decouples geography fr environmental benefit



Global registry ensures transparency and prevents double-counting

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SAF Regulation and Voluntary Reporting along the Value Chain

Regulatory drivers:

- **ReFuelEU Aviation**: SAF mandate with flexibility
- **EU RED II**: Sustainability criteria and national targets
- **EU ETS** & **CORSIA**: SAF reduces emissions obligations

Voluntary frameworks:

- **GHG Protocol** (Scope 1, 3)
- **SBTi** (Science-Based Targets)

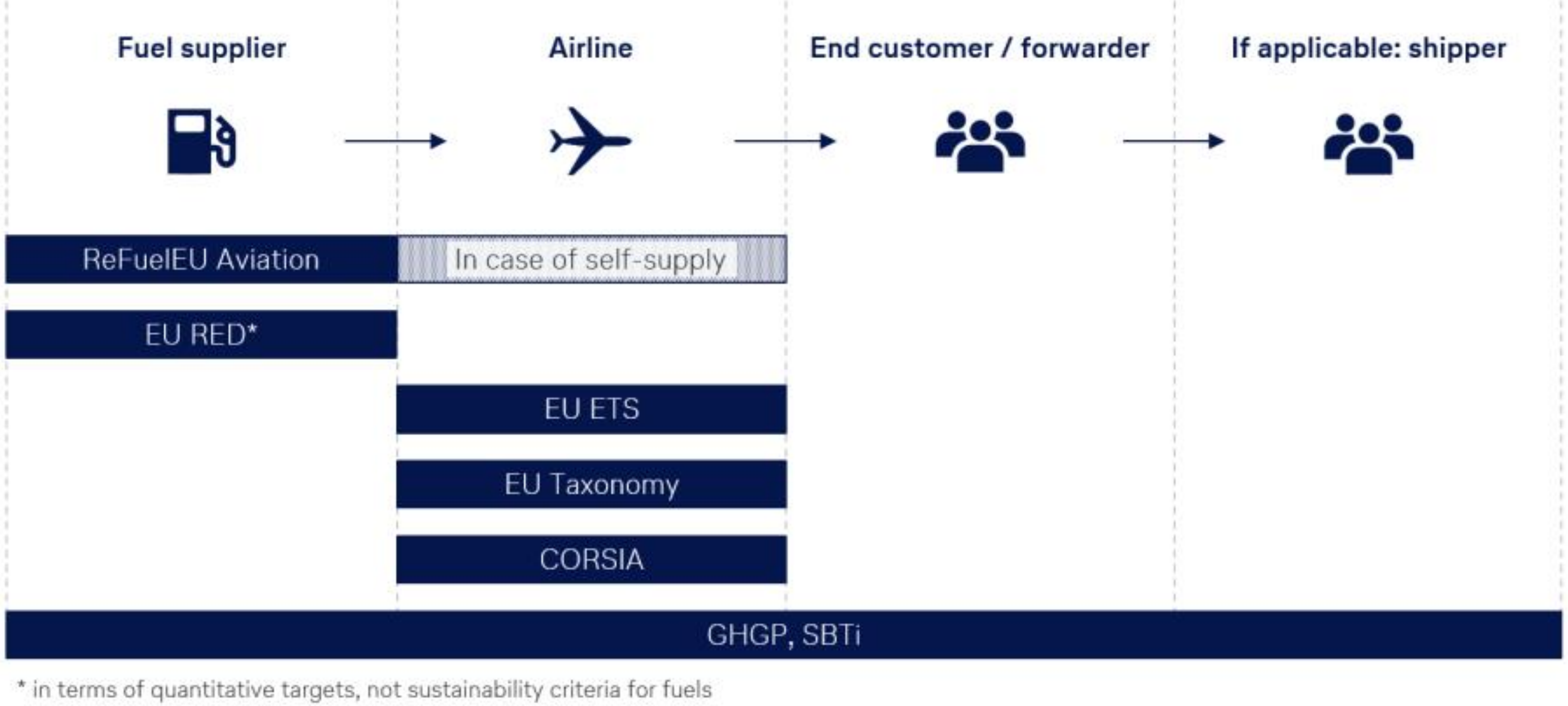

Figure 2: Regulatory and reporting systems affected by book-and-claim.

Design of the new proposed Book-and-Claim System

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Geographical differences mean different opportunities for EU and Africa

What Book-and-Claim Means for Europe

•Access SAF benefits without on-site fuel delivery

•Promote SAF adoption while infrastructure develops

•Transparent emissions reporting across stakeholders

- Airlines
- Airports (Scope 3)
- Leasing companies

•Potential to attract climate-conscious partners and customers

Assess opportunity to become SAF producer

•Leverage cheaper green energy i.e. PV in sun belt, wind farms, hydro from Ethiopia, geothermal in Kenya to become SAF producer

•Leverage large funds (i.e. sovereign wealth funds, debt financing, international grants, climate funds) to invest into local infrastructure

•Sell SAF directly to EU carriers and load in tank

•Mix into fuel and charge a surcharge but balanced with credits to levelized price.

•Sell carbon credits on CORSIA market

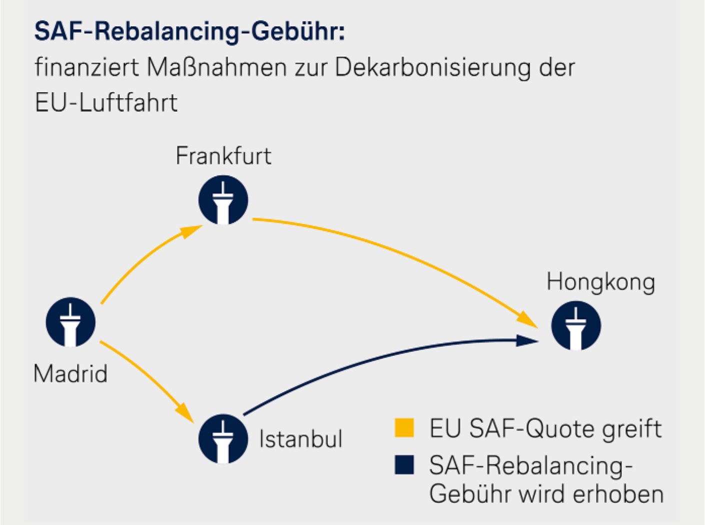
"ReFuelEU Aviation“ and competitive disadvantage for European Airlines

Under the EU "ReFuelEU Aviation" regulation, the SAF blending mandate will increase from 2% today to 6% in 2030 and 70% by 2050. This will significantly raise airline costs, as SAF is three to five times more expensive than conventional jet fuel, with no major price drops expected.
The SAF mandate also distorts international competition, as it only applies to flights departing the EU. Connecting flights via non-EU countries like Turkey or Gulf states are exempt, allowing non-EU airlines to offer lower fares. This shifts emissions outside the EU without reducing them—a phenomenon known as *carbon leakage*.

Possible Remedy:

SAF Levy: A uniform ticket surcharge on all flights departing the EU, applied to the entire journey regardless of stopovers. Revenues would help offset SAF costs.

SAF Rebalancing Charge (SRC): A targeted fee on routes not covered by the EU SAF mandate, such as non-EU connecting flights. Proceeds would support aviation decarbonization but generate less revenue than the general SAF levy.



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What SAF do we want?

A quick 101 on fuel types…

Fossil Kerosene

Synthetic Fuels

Fossil Synthetic Fuels

Sustainable Aviation Fuels (SAF)

Biogenic SAF

Renewable fuel of non-biogenic origin (RFNBO)

Fossil Kerosene	Fossil Synthetic Fuels		Biogenic SAF			RFNBO	
	Coal-to-Liquid	Gas-to-Liquid	Biomass-to-Liquid (Oils, fats)	Biomass-to Liquid (sugar, starch)	Biomass-to Liquid (Lignocellulose)	Power-to-Liquid	Sun-to-Liquid
							
Oil refining Hydrocracking	Gasification & FT Alcohol to Jet	Steam reforming & FT Alcohol to Jet	HEFA	Alcohol to Jet Direct Sugar to Hydrocarbons	Sacchar. / Gasification & FT Alcohol to Jet	Electrolysis, RWGS & FT Alcohol to Jet	Thermochemistry & FT Alcohol to Jet
			Most relevant today			Long-term, theoretically scalable without limitations	

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There are several options to produce SAF – while current options are aceled-up, renewable fuels of non-biogenis sources are promising

Global demand 2019
~300 Mio. t

Currently most important process

	 **Biomass-to-Liquid** oils and fats	 **Biomass-to-Liquid** sugar, starch	 **Biomass-to-Liquid** lignocellulose	 **Power-to-Liquid** electricity, H_2O, CO_2	 **Sun-to-Liquid** sunlight, H_2O, CO_2
Max. potential (Mio. t kerosene)	10 - 100	up to 100	up to 500	> 4000	more than PtL
CO_2 reduction[1] vs oil production	35 – 80 %	50 – 80 %	70 – 85 %	80 – 99 %	90 – 99 %
Challenges	FvF[2], sustainability and additionality	FvF[2], limited scalability	Low TRL[3], feedstock logistics	Low TRL[3], carbon source	No proof of concept, carbon source
Upsides	Instant availability	High TRL[3], reasonable cost	High acceptance, high waste share	Highest acceptance, scalability	Highest acceptance, more efficient than PtL

1) WTW Basis 2) FvF = Food versus Fuel 3) TRL = Technology Readiness Level

How we evaluate SAF along the supply chain

Excursus portfolio: The „SAF universe“ is complex and will require decisions and positioning along the whole supply chain

non-exhaustive

Feedstocks

- Availability?
- Food vs. fuel?
- Land grabbing?
- Land use change?
- Public acceptance?
- Political acceptance?
- Customer acceptance?
- Sustainability certification?
- RED compliant?

Manufacture

- First-of-a-kind plant?
- Approved technology?
- Subsidies for production?
- Harmful byproducts?
- ESG chain-of-custody?
- Blending requirements?
- Sustainability certification?

SAF properties

- Properties (e.g. gumming)?
- Composition (aromatics)?
- Complies to specification?
- Blending assured?
- Quality control? (start-ups)
- TTW emission factor?
- WTW emission factor?
- Sustainability allocation?
- Add. „customer value“?

Logistics

- Into-plane or self-supply?
- Physical delivery or B&C?
- Airport in network?
- Means of transport?
- Distance of transport?
- Emissions of transport?
- Cost of transport?
- Delivery on time assured?

Uplift, combustion and accounting

- Accounting methodology?
- Claimable CO_2 reduction?
- Non-CO_2 climate effect?
- Local emission effect?
- SBTi eligibility?
- Proof, audit & certificate?
- Suitable for LHG’s SAF product portfolio?

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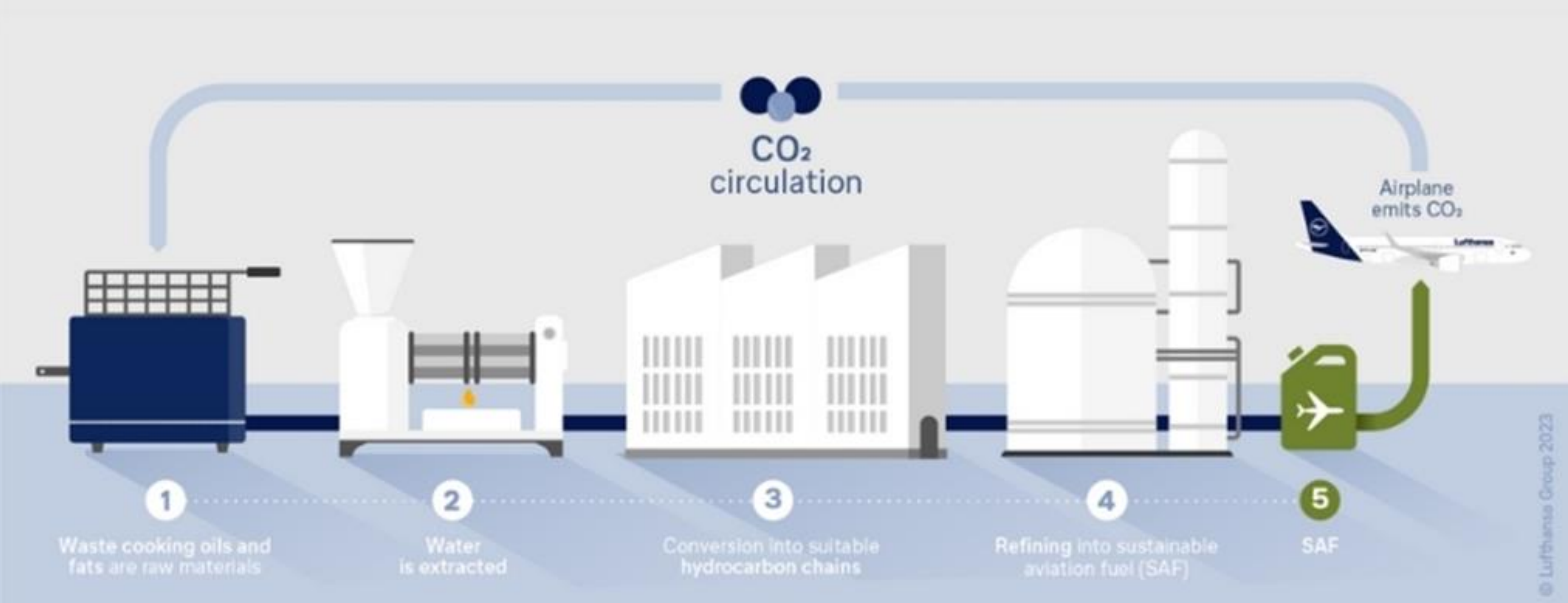
How used cooking oil becomes SAF



However the energy demand to SAF alternatives is pretty high – some calculations around Power to Liquid

10 Mio t

Fuel Consumption

=

250 TWh for

production eFuels

~40%

of German Power Demand

2x

DE Wind Energy

130 TWh in 2020

23 Nuclear Power Plants with 11 TWh

5x DE Solar

50 TWh in 2020

380 qkm

100x FRA

Area of Airport Frankfurt 20 qkm

2-3x energy output per qm in regions like Chile, Australia, MENA

Quellen: DECHEMA White Paper eFuels, Statistisches Bundesamt, Wikipedia, Pholtovotaik Kompetenzzentrum, Stromreport DE

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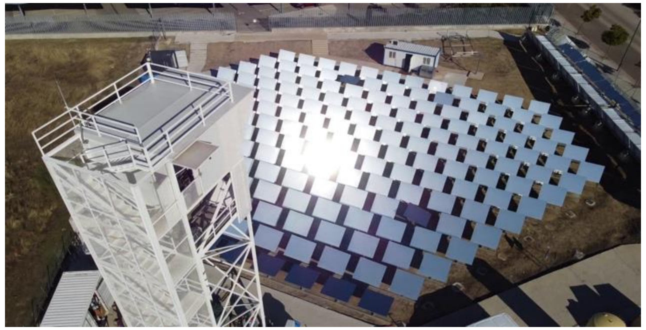
Some calculations about Sun-to-Liquid (StL)

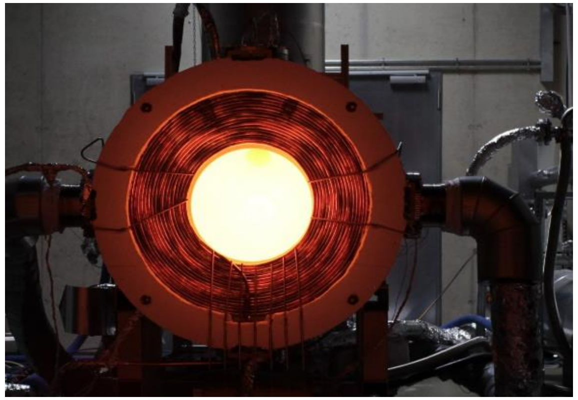
Mirror surface of **1500qm** correspond to the length and width of an A321



15 mio. Tons water for 10 mio Tons StL Fuel

Up to 1.500 °C process heat

20,8 mio kWh for 10 mio. Tons StL fuel per year



187,5 km² mirror field

for 10 mio. Tons StL Fuel per year

1500 m² mirror field

=

(80kg SAF/m² per year)

Quellen: Synhelion

Selling SAF effectively

Lufthansa Group offers for CO_2-neutral flying achieved good market position

Sustainable Choices

Not exhaustive

Private

Book // **Fly** // **Engage**

"Deep Integration"
"Green Fare"

"Compensation
on the fly"

"mindfulflyer"
"Sustainability Booster"

Corporate & Cargo

On bulk

"Partner Plus
Benefit"

"Corporate Value Fund"

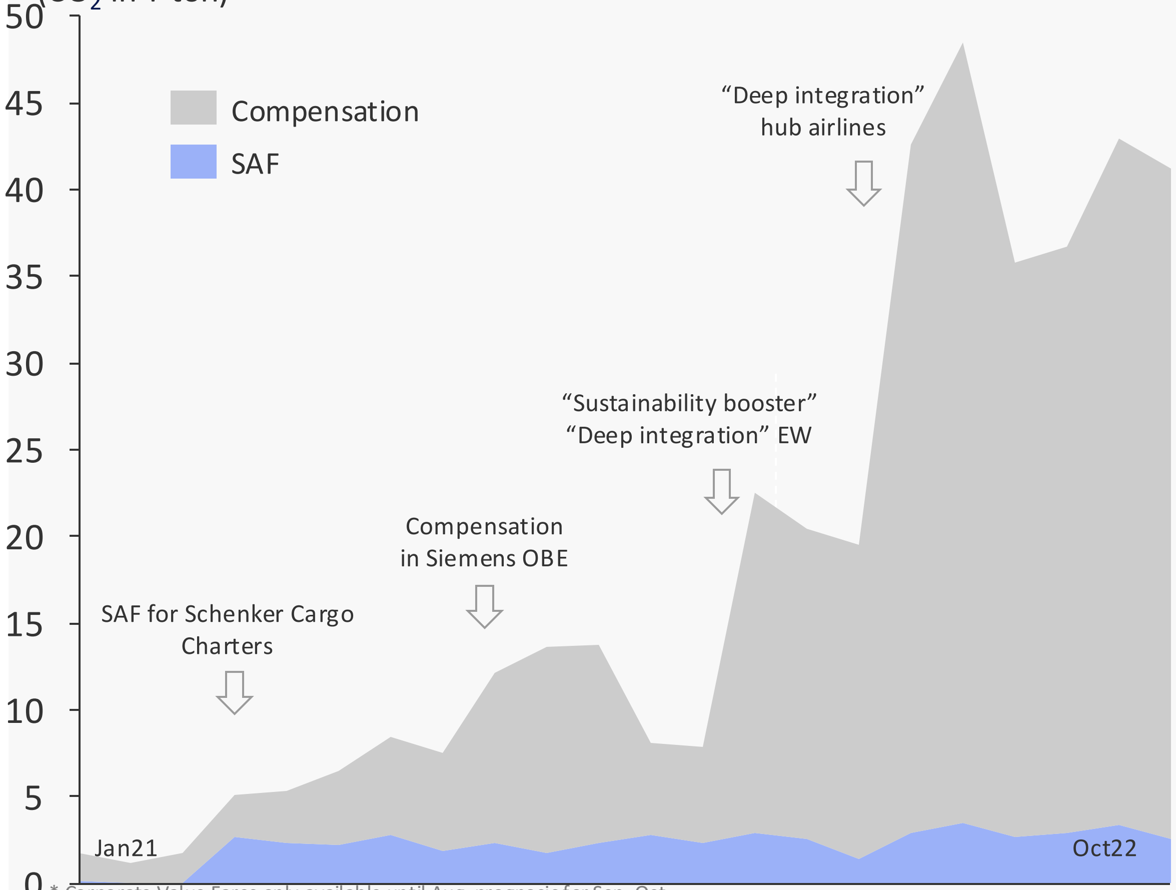
On route

"Corporate
Value Fares"

"Tour Operator offer"

SAF / compensation with customer contribution *

(CO_2 in T ton)



* Corporate Value Fares only available until Aug, prognosis for Sep, Oct

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Packaging green travel- make it easy

BOOK — FLIGHT — ENGAGE

B2C Customers

Sustainable choices at point of sale

Green Fares Europe

Compensaid on the fly

Mindful-flyer program

Green selection

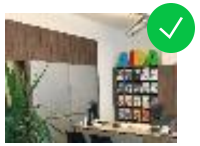
B2B Customers and Agencies

SAF PACKAGES

Partner Plus Benefit (SAF)

Corporate Value Fund (SAF)

Third-party purchase (SAF)

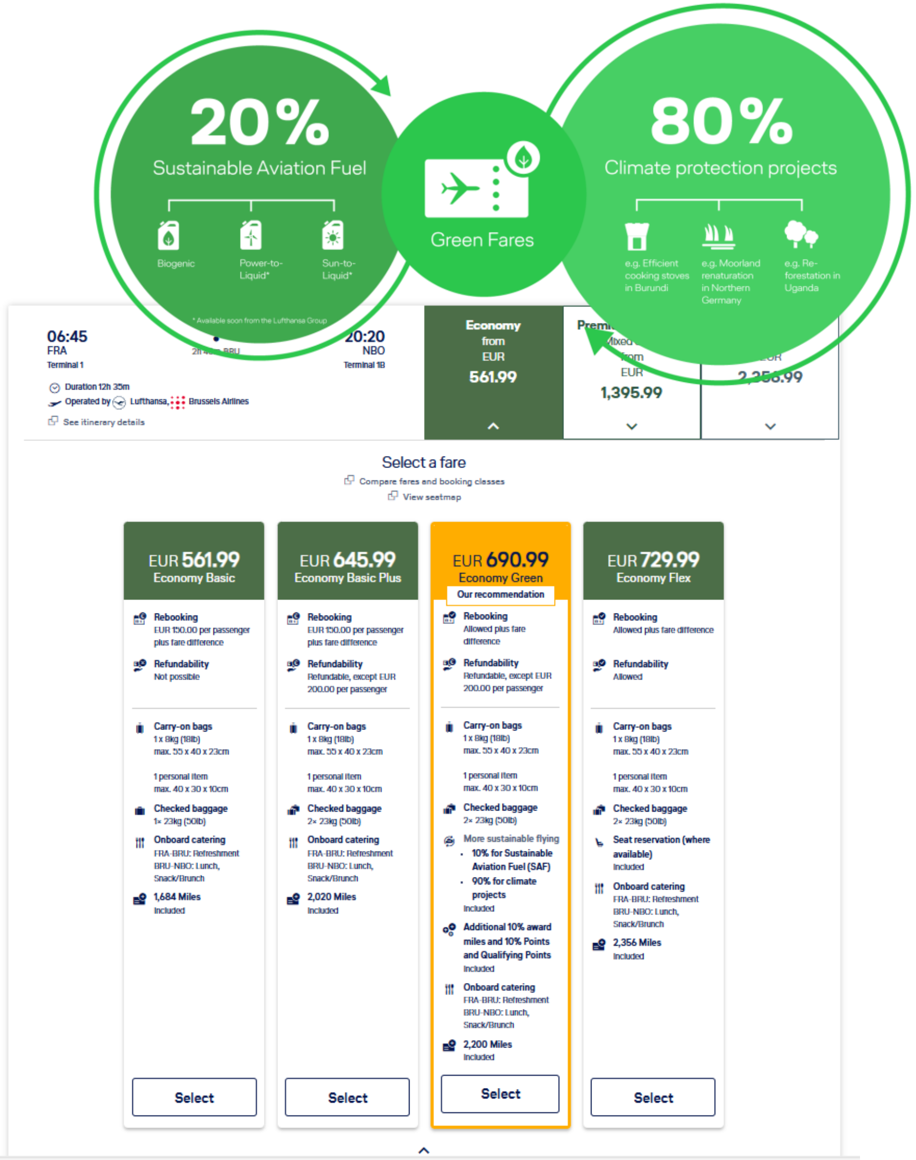


FLIGHT RELATED SAF

Corporate Value Fares Europe

Tour Operator Offers

Corporate Value Fares (incl. SAF)



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Projects: ongoing and starting

#	Ongoing	Until
1	**Climate Research**	Event Name
2	• IAGOS	Continuous
3	• CARIBIC	Date
4	**Non-CO2 Climate**	
5	• D-Kult	
6	• CoCIP	
7	**SAF Process**	
8	• Manual Certificate issue	
9	• CO2 Database migration	
10	• SAF partnership migration	
11	**CO2 Emissionsmodell**	
12	• Marginal Abatement Cost Curve Update	
13	• Migration or Calculations to AO	
	Memberships	
	• GAP (Power Fuels)	
	• RSB	
	• ISCC	
	• BDL	
	• Clean Tech in der Luftfahrt	
	• HyNeat	

#	Starting	From
1	**CO2 Calculation**	Event Name
2	• Google / EASA, or	Continuous
3	• MyClimate Update	Date
4	**SAF Lighthouses**	
5	• Swiss Re	
6	• Synhelion	
7	• DLR EPP	
8	**Neue Mitgliedschaften:**	
9	• ICAO / IATA Fuel Task Group	
10	• Arbeitskreis Klimaschonender Luftverkehr	
11	**Richtlinien**	
12	• CO2 Accounting	
13	• Umweltrichtline	
	• Umweltmanagementrichtlinie	
	Grünes Produkt (ISO Zertifizierung)	
	SAF 360° Vol 2 (Blackrock und ähnliches)	
	Innofuels (CENA – KIT)	
	SAF Klagen	

Other

Political and public

- Conferences and panels (at least 1 per month)
- Position Papers for CP

The Lufthansa Group targets

-50% net CO_2 by 2030

compared to 2019

CO_2-neutral by 2050

SCIENCE BASED TARGETS

DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

- Reduction part of near term climate targets in line with framework of the **Science Based Targets Initiative**
- **First European Airline to be SBTi validated**
- In line with **Paris Climate Agreement**

SAF Adoption- Where do we stand?

PtL fuels

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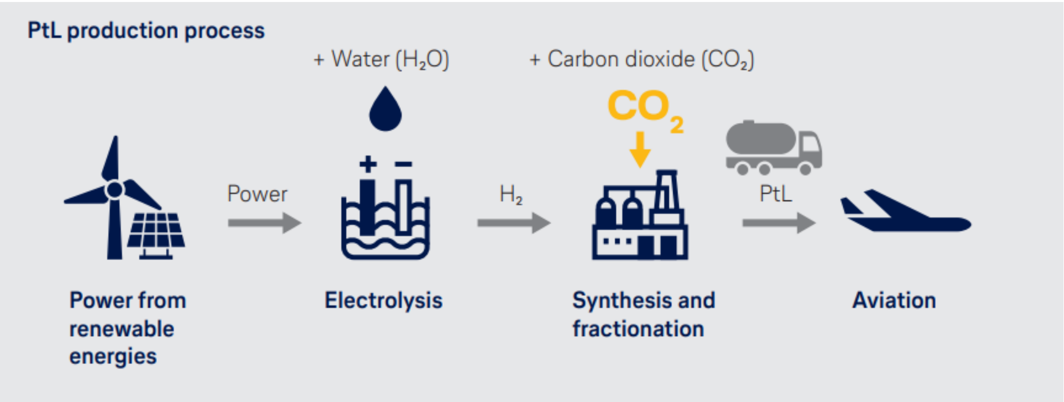
FIVE LEVERS FOR MORE SUSTAINABLE FLYING

1. Fleet modernization
2. The use of Sustainable Aviation Fuel (SAF)
3. Efficiency improvements in flight operations
4. A broad customer offer for more sustainable flying
5. Expanding intermodality



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Fuel Readiness Levels (FRL)

FRL	Description	Toll Gate	Fuel Quantity+
1	Basic Principles Observed and Reported	Feedstock /process *principles* identified.	
2	Technology Concept Formulated	Feedstock /*complete* process identified.	
3	Proof of Concept	Lab scale fuel sample produced from realistic production feedstock. Energy balance analysis executed for initial environmental assessment. Basic fuel properties validated.	0.13 US gallons (500 ml)
4.1 4.2	Preliminary Technical Evaluation	System performance and integration studies entry criteria/specification properties evaluated (MSDS/D1655/MIL 83133)	10 US gallons (37.8 litres)
5	Process Validation	Sequential scaling from laboratory to pilot plant	80 US gallons (302.8 litres) to 225,000 US gallons (851,718 litres)
6	Full-Scale Technical Evaluation	Fitness, fuel properties, rig testing, and engine testing *	80 US gallons (302.8 litres) to 225,000 US gallons (851,718 litres)
7	Fuel Approval	Fuel class/type listed in international fuel standards**	
8	Commercialization Validated	Business model validated for production airline/military purchase agreements – Facility specific GHG assessment conducted to internationally accepted independent methodology	
9	Production Capability Established	Full scale plant operational++	

FRL 1-5

FRL 6-7

FRL 8-9

Balance tech scouting with viable offtake options and commercially viable supply sources

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Lufthansa Group is a leader in Sustainable Aviation Fuel deployment

past

- 1st generation SAF
- Mainly based on crops such as Jatropha plant
- Extensive flight test campaign

State of the art

- 2nd generation SAF
- Mainly based on used cooking oils and animal fat residuals
- Fully compliant with EU REDII
- Mainly deployed at Frankfurt Airport and (still limited) Vienna airport*

2023 - future

- Future SAF scenario based procurement with major suppliers such as:

  NESTE · Shell · OMV

- Renewable energy based SAFs sourcing

  atmosfair · Synhelion

- New technology openness

  (better performing fuels with potentially higher energy density)

  cleanjoule

Meeting own 2030 reduction targets and mandates

* OMV VIE airport trial with plastic cup re-usage not included

The use of Sustainable Aviation Fuel (SAF)

- SAF is a key technology for sustainable aviation and vital to the energy transition. Lufthansa is deeply committed to its research, testing, and use.
- Lufthansa was among the first airlines to use biogenic SAF in regular flights, starting in 2011.
- Today, Lufthansa is a top-five global SAF customer and plans to invest up to $250 million in SAF procurement.
- It is involved in global projects to expand SAF supply, signing MoUs and exploring long-term purchase deals.
- Current SAF used by Lufthansa is made from biogenic waste like used cooking oil.
- In 2022, Lufthansa used 13,000 tonnes of SAF, covering just 0.2% of its fuel needs but making up 5% of global SAF use.
- Lufthansa aims to reach 1 million tonnes by 2030, though global SAF supply remains low—just 0.1% of the airline industry's needs.
- In 2022, only 240,000 tonnes of SAF were globally available, against a total fuel demand of 254 million tonnes.
- If Lufthansa used all available SAF today, it would last under two weeks of operations.
- SAF is still 3–5 times more expensive than fossil fuel.
- Scaling SAF requires urgent expansion of supply and production.
- strong policy strategy is needed to support SAF growth, especially with the EU's increasing blending targets (2% by 2025, 70% by 2050).
- As a drop-in fuel, SAF is fully compatible with fossil jet fuel and is pre-blended before airport delivery.
- Lufthansa is investing in future SAF technologies, with a focus on Power-to-Liquid (PtL) and Sun-to-Liquid (StL).

	Permission (ASTM D7566)	Blending-limit (Max.)	Feedstock	Production way
Sunlight-to-Liquid			Sunlight, renewable resources	solar radiation is reflected by a field of mirrors (heliostats) -> concentrated onto the receiver and converted into high-temperature process heat. The generated heat is fed to the thermochemical reactor that produces syngas, a mixture of H2 and CO. In this reactor, a series of oxidation-reduction reactions (REDOX) takes place at high temperature, in which H2 is obtained from the H2O, and carbon from the CO2. The syngas is then processed by standard gas-to-liquids technology into fuels, such as gasoline, diesel, or jet fuel. Excess heat is saved in the thermal energy storage (TES) to enable continuous 24/7 operation.
Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)	Yes	up to 50%	Biomass, municipal solid waste (MSW), agricultural and forest wastes	Syngas is typically produced from the gasification of biomas etc. The feedstock is gasified at high temperatures -> deconstruction of the feedstock into carbon monoxid, hydrogen and CO2 + some ash. Afterwards the gas mixture is separated and cleaned to produce pure Syngas. The FTS-Process is a catalyzed chemical reaction: Syngas is converted into liquid hydrocarbons. The wax is then cracked and isomerized to produce drop-in fuels (identical to petroleum-based jet fuel)
FT-SPK with Aromatics	Yes	up to 50%	Biomass, municipal solid waste (MSW), agricultural and forest wastes	same as above + the alkylation of light aromatics (primarily benzene) to create a hydrocarbon blend that includes aromatic compounds that are required to ensure elastomer seal swell in aircraft components to prevent fuel leaks. FT-SPK/A introduces the migration toward fuels that offer a full spectrum of molecules found in petroleum-based jet fuel, rather than just paraffins.
Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA-SPK)	Yes	up to 50 %	fatty acids, lipids from plant & animal fats, oils	Oils are converted from lipids to hydrocarbons by treating the oil with green hydrogen to remove oxygen and other less desirable molecules. The hydrocarbons are cracked and isomerized, creating a synthetic jet fuel blending component comprised of paraffins.
Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK)	Yes	up to 50 %	needs Ethanol or Isobutanol made from 1.) Fermentation of starches/sugars (field corn, sugar beets, cane OR lignocellulose) 2.) biochemical conversion -> organisms that convert CO, H2 and CO2 to alcohol)	Isobutanol or Ethanol first goes though the process of dehydration, followed by Oligomerization, Hydrogenation and Fractination -> prdouct: hydrocarbon jet fuel blend component
Catalytic Hydrothermolysis Synthesized Kerosene (CH-SK OR CHJ)	Yes	up to 50 %	fatty acids, fatty acid esters, lipids from plants and animal fats	Conversion of oils/fats into unsaturated hydrocarbons (alkenes) by a Catalytic Hydrothermolysis (CH). Further processing to aviation fuel.
Hydroprocessed Fermented Sugars to Synthetic Isoparaffins (HFS-SIP)	Yes	up to 10%	Sugars	The process uses modified yeasts to ferment sugars into a hydrocarbon molecule. This produces a C15 hydrocarbon molecule called farnesene, which after hydroprocessing to farnesane, can be used as a blendstock in jet fuel.
Hydroprocessed Hydrocarbons, Esters and Fatty Acids Synthetic Paraffinic Kerosene (HHC-SPK or HC-HEFA-SPK)	Yes	up to 10 %	fatty acid esters, free fatty acids and bio-derived hydrocarbons (includes present only the tri-terpenes produced by the Botryococcus braunii species of algae)	Feedstock is converted to hydrocarbons by treating it with hydrogen to remove oxygen and other less desirable molecules. Afterwards, the hydrocarbons are cracked and isomerized to creat a synthetic jet fuel blending component comprised of paraffins.
Methanol-to-Jet	No	-	Lignocellulose (straw, wood residues)	1-a.) thermochemical gasification with Lignocellulose -> Gas purification, upgrading and conversion processes to produce Syngas OR 1-b.) Fermentation (sugar, starch): anaerobic fermentation -> Biogas (contains Methane and CO2) --> purification and upgrading processes to produce very pure methane (biomethane), which is then converted into synthesis gas via reforming processes. 1-c.) via renewable energy, CO2 from DAC/biogenic -> rWSR to produce Syngas

SAF Production Pathways – Summary Table

SAF Type	ASTM Certified	Max Blend	Feedstock	Production Summary
Sunlight-to-Liquid (StL)	No	–	Sunlight, renewable resources	Solar heat used to create syngas, then converted into fuels via gas-to-liquids. Still under development.
Fischer-Tropsch SPK (FT-SPK)	Yes	Up to 50%	Biomass, MSW, forest/agri waste	Biomass gasified to syngas, then catalytically converted to liquid fuels.
FT-SPK with Aromatics	Yes	Up to 50%	Same as FT-SPK	Similar to FT-SPK, but includes aromatics for fuel compatibility in aircraft seals.
HEFA-SPK	Yes	Up to 50%	Plant & animal oils, fats	Oils are hydroprocessed and isomerized into jet fuel blendstocks. Most common SAF today.
ATJ-SPK	Yes	Up to 50%	Sugars/starches (via ethanol/isobutanol)	Fermentation to alcohols → chemical conversion to hydrocarbons.
CHJ (CH-SK / CHJ)	Yes	Up to 50%	Fats, oils, fatty acid esters	Hydrothermal processing of fats/oils to hydrocarbons, then refined to jet fuel.
HFS-SIP	Yes	Up to 10%	Sugars	Sugars are modified and converted to farnesane, a high-density molecule used as jet fuel.
HHC-SPK / HC-HEFA-SPK	Yes	Up to 10%	Algae oils, fatty esters	Algae-based oils hydroprocessed and isomerized into synthetic jet fuel.
Methanol-to-Jet	No	–	Lignocellulose (straw, wood)	Methanol converted to jet fuel via olefins → oligomerization → hydrotreating. Still in development.

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