NAVIGATING THE FUTURE OF SUSTAINABLE AVIATION FUEL (SAF): GLOBAL MARKET INSIGHTS AND CHALLENGES

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CMK CENTRUM VOOR MILIEUKUNDE
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Stargate within EU Green Deal

STARGATE: Accelerating Greener Aviation

Stargate within EU Green Deal

22 Partners

2021-2026

30+ Projects

3 Goals

- Modal Shift
- Decarbonisation
- Local Environmental Quality

24,8 mio Grant EU Green Deal

30% Funding by Stargate Partners

A Strong and Diverse European Partnership

Stargate within EU Green Deal

Knowledge Institutions & Academics

Three Fellow Airports

Airport Community Partners

Specific Partners

Consultants in Energy, Mobility & Digitalisation

3 main pillars

Decarbonization & Circularity	Local Environmental Quality	Modal split & Smart Mobility
		

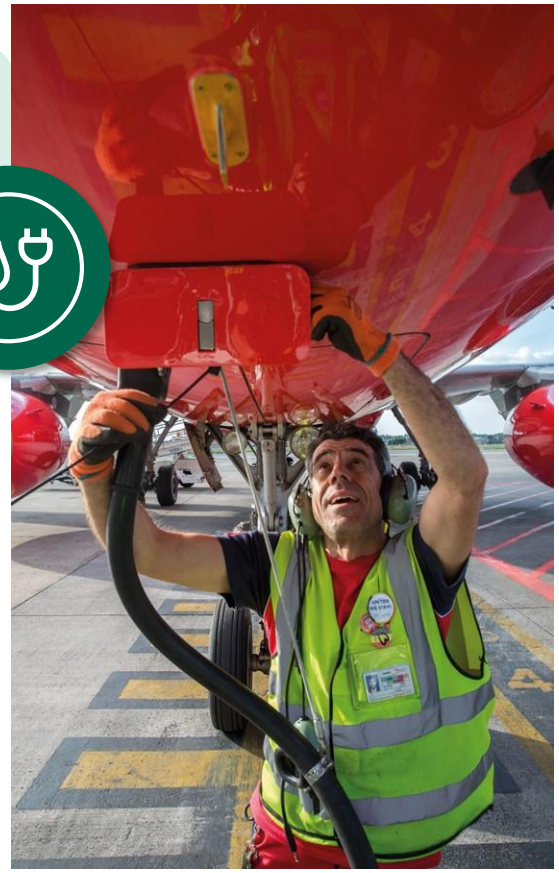
Decarbonization and Circularity

We test and develop a set of green energy solutions to further decarbonize ground & airline operations and green terminal operations.

Promote the use of **SAF at airports & enabling on airport blending at high ratios**

Testbed to demonstrate the benefits of **renewable (electric & hydrogen) alternatives** for **mobility**

Identify **opportunities** for **resource saving and waste reduction in the terminal**



Local Environment Quality

We improve air quality and reduce noise using innovative technological solutions:

- **Apply techniques to improve living quality by reducing air and noise pollution**
- **Promote collaborative projects with the local communities**
- Enhance **digitalization in the air cargo**

Modal Split and Smart Mobility

We reduce the environmental impact of airport activities and access by innovative infrastructure, technology, equipment, digitalization and human engagement.

Sustainable Airport Mobility Plan: shift to low-carbon alternative multimodal mobility

Real-time mobility management and decision-making system for seamless door-to-door mobility around the airport

14th EASN International Conference

on "Innovation in Aviation and Space towards sustainability today & tomorrow"

8-11 October 2024

Concert Hall, Thessaloniki Greece

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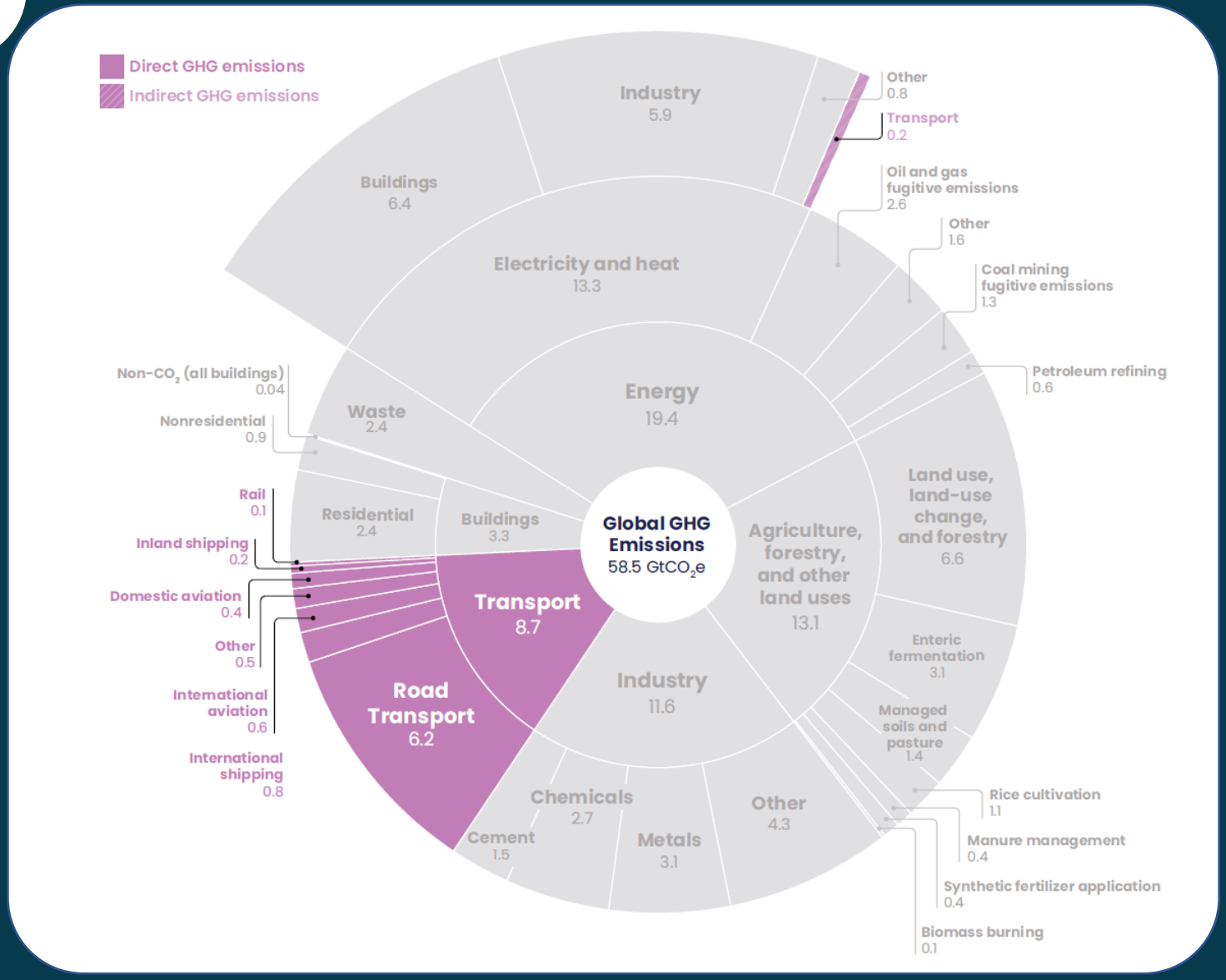
Global GHG emissions for the transport sector

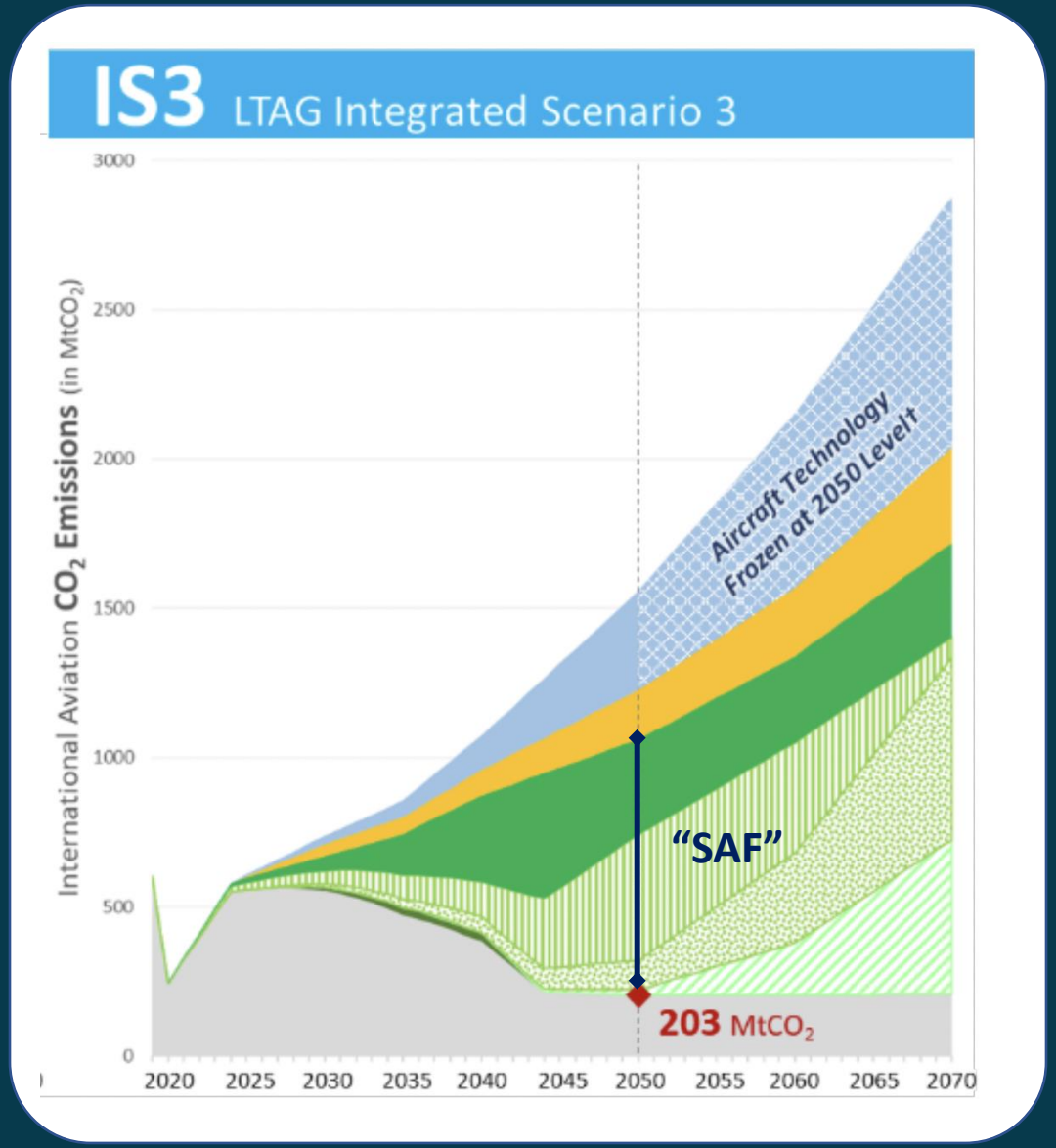


12% Transport Sector

2.5% Global

Source: State of Climate Action 2022, The role of sustainable aviation fuels in decarbonizing air transport

Net Zero CO_2 goal of ICAO and role of SAF



There is general agreement across industry and governmental actors that SAF is the biggest lever to drastically reduce aviation GHG emissions.

Source: https://www.icao.int/environmental-protection/LTAG/Documents/REPORT%20ON%20THE%20FEASIBILITY%20OF%20A%20LONG-TERM%20ASPIRATIONAL%20GOAL_en.pdf

SAF Production Pathways: ASTM D7566

ASTM Ref	Conversion Process	Abbreviation	Possible Feedstocks	Blending Ratio	Year
Annex 1	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene	FT	Coal, natural gas, biomass	50%	2009
Annex 2	Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids	HEFA	Bio-oils, used cooking oils, animal fats	50%	2011
Annex 3	Synthesized iso-paraffins from hydroprocessed fermented sugars	SIP	Biomass used for sugar production	10%	2014
Annex 4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	FT-SKA	Coal, natural gas	50%	2015
Annex 5	Alcohol to jet synthetic paraffinic kerosene	ATJ-SPK	Biomass from ethanol or isobutanol production	50%	2016
Annex 6	Catalytic hydrothermolysis jet fuel	CHJ	Triglycerides	50%	2020
Annex 7	Synthesized paraffinic kerosene from hydrocarbon-hydroprocessed esters and fatty acids	HC-HEFA-SPK	Algae	10%	2020
Annex 8	Synthetic paraffinic kerosene with aromatics	ATJ-SKA	C2-C5 alcohols from biomass	50%	2023

Source: ASTM

Fuel Certification Process

Aircraft are certified to operate on specified fuel, defined in ASTM D1655.

D1655

Is new fuel equivalent to CAF? Go through industry process D4045.

D4045

If equivalent, a new annex is added to D7566, including max blend ratio.

D7566

When added in D7566, it is automatically approved in D1655 when blended at allowed ratio.

D1655

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

Benefits of SAF

Climate Benefits

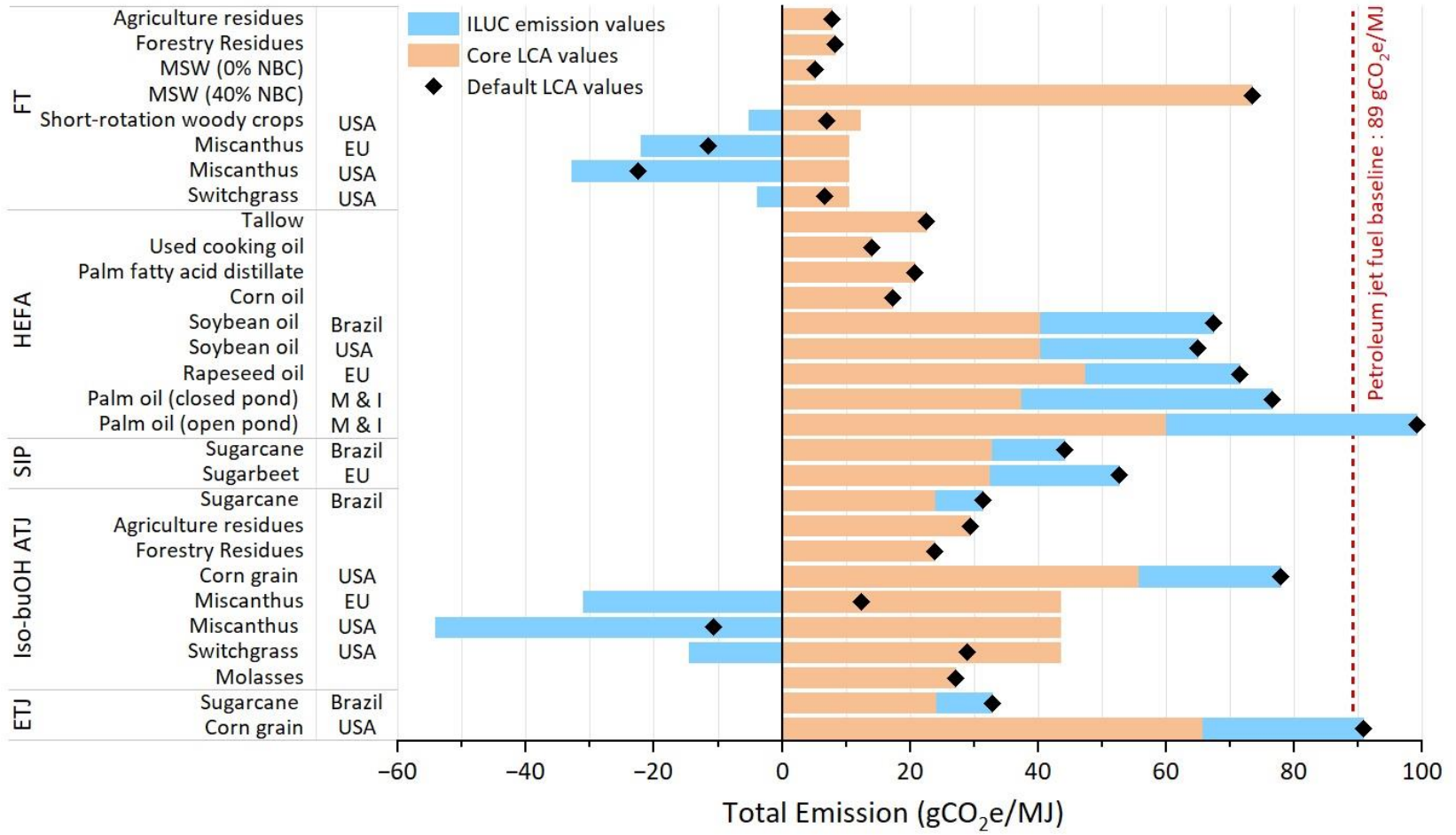
Air Quality

Industrialization

Employment

Energy Security

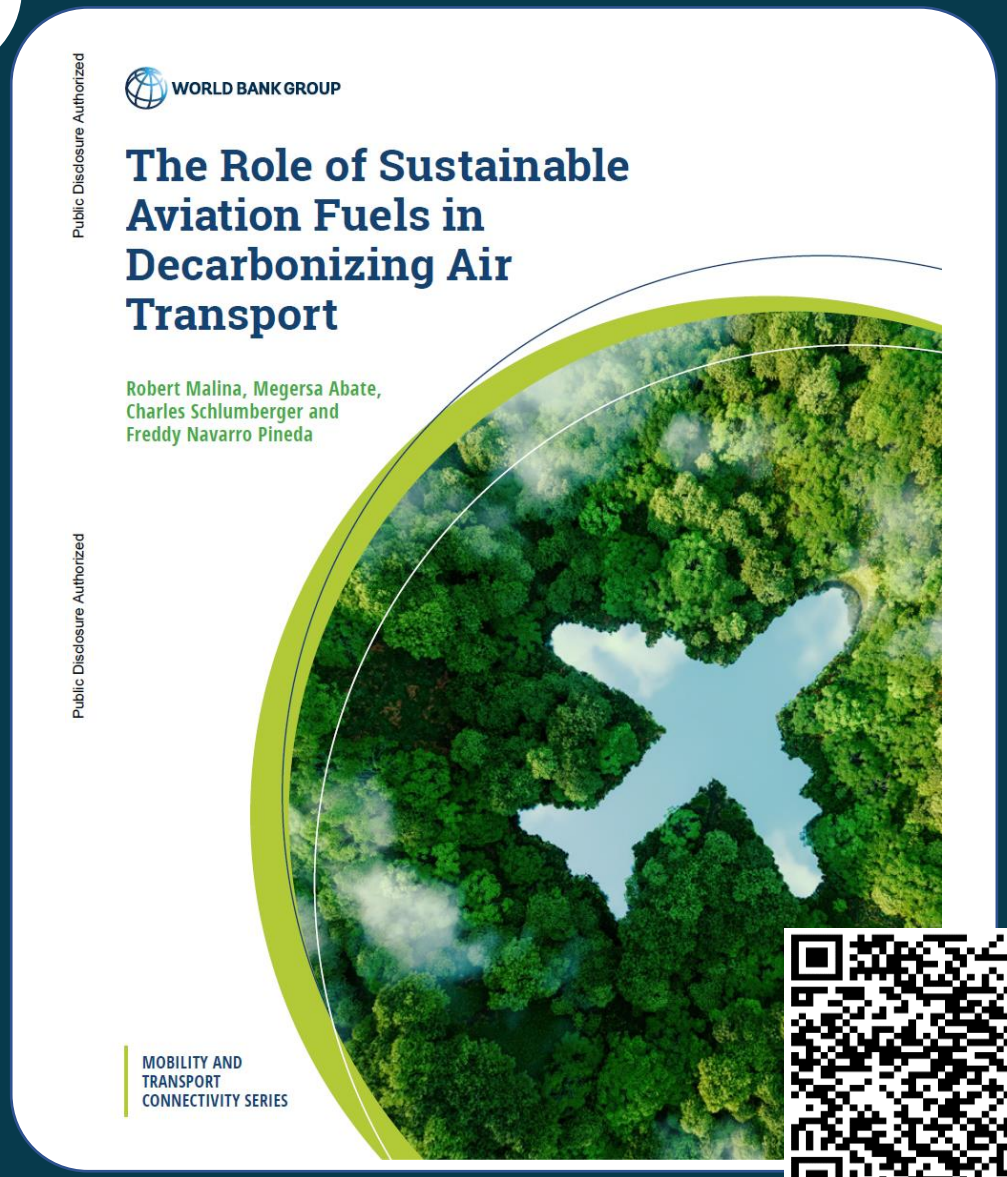
Life Cycle GHG emissions



Large emission reductions possible with SAF, compared to conventional jet fuel, but:
Which type is used MATTERS!

Source: Prussi et. Al (2021)

World Bank Report



Key Messages

SAF will need to play a major role in the decarbonization mix as it is the only option that can generate significant GHG emissions reduction in the medium-term already.

SAF production can reduce up to 58% of aviation CO_2 emissions compared to business as usual in 2050 – this will require significant policy support.

Success Stories

BOEING 747

AIR NEW ZEALAND

Test Flight
50 % blend
Dec 2008

London to Amsterdam
20 % blend
Feb 2008

virgin atlantic

2008

BRA

virgin atlantic

Success Stories

ATR 72-600

Braathens Regional Airlines
Malmo – Bromma (1hr 20min)
100 % SAF
June 2022

BRA

Success Stories

BOEING 787

Heathrow – New York
100 % SAF
Dec 2023

virgin atlantic

AIR NEW ZEALAND

BRA

virgin atlantic

2023

Success Stories

As of June 2023 ~ 499,000 flights powered by SAF

Airlines are operating ~ 200 SAF flights per day

Global SAF production ~300 million liters in 2022

Production is expected to reach ~ 1.9 billion liters in 2024

Source: https://www.iata.org/en/pressroom/2023-releases/2023-12-06-02/

Offtake Agreements

Summary per fuel producer

	Fuel producer	Total offtake volume (million liters)	Number of offtake agreements
1.	Gevo	9,550.03	14
2.	Fulcrum	6,719.1	3
3.	Alder Fuels	5,678.12	1
4.	Cemvita	3,785.41	1
5.	USA BioEnergy	3,255.45	1
6.	Shell	2,793.37	8
7.	Neste	2,474.9	24
8.	DG Fuels	2,300.67	3
9.	Raven SR	1,561.64	1
10.	OMV	1,436.57	7
11.	Aemetis	1,272.43	9
	Grand total	**53,180**	**134**

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Summary per fuel purchaser

	Fuel purchaser	Total offtake volume (million liters)	Number of offtake agreements
1.	United Airlines	14,299.39	7
2.	Southwest Airlines	4,163.95	3
3.	Delta	3,862.25	8
4.	OneWorld	3,785.41	1
5.	Lufthansa	3,399.4	4
6.	Air France - KLM	3,094.54	6
7.	AirBP	2,192.71	2
8.	American Airlines	2,134.21	5
9.	Japan Airlines	1,661.95	2
10.	Cathay Pacific	1,477.07	2
11.	DHL Express	1,466.72	2
	Grand total	**53,180**	**134**

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

SAF Demand Based on Mandates and Ambitions

Country	Year	SAF %	Fuel Volume
Japan	2030	10%	
EU	2030	6%	
UK	2030	10%	
India	2025	1%	
China	2025		50,000 tons
Turkey	2030	5%	
Brazil	2027	1%	
Sweden	2030	27%	
Finland	2030	30%	
Indonesia	2025	5%	
Australia	2030	10%	
Kenya	2030	10%	
Canada	2030		12gCO_2e/MJ
Philippines	2030		175,000 tons

~23 billion liters

Production
~21.6 billion liters

(Some) Challenges

1. Production delays and failures
2. High Investment needs and speed of ramp-up
3. Geographical imbalances
4. Feedstock availability issues
5. Large, persistent cost premiums

Production delays and failures

Rate of SAF capacity expected to be in service by end of 2024 and currently operational, by process and facility type

SAF conversion process	Commercial	Demo	Pilot	Not indicated
Total	47%	9%	37%	54%
Synthesized iso-paraffins	20%	0%	100%	0%
Solar Thermochemistry	0%	100%	0%	0%
Pyrolysis	0%	0%	0%	0%
Power-to-Liquid	0%	2%	100%	0%
Not indicated	0%	0%	100%	0%
Methanol-to-jet	0%	0%	0%	0%
Hydrothermal Liquefaction	0%	0%	0%	0%
HEFA	44%	10%	100%	80%
Fischer-Tropsch	0%	3%	0%	0%
Distillation	100%	0%	0%	0%
Co-processing	74%	0%	0%	0%
Catalytic hydrothermolysis (CH-SK)	0%	100%	100%	0%
Alcohol-to-Jet	24%	8%	100%	0%

Share of announced SAF capacity expected to be in service by 2024 and currently operational:

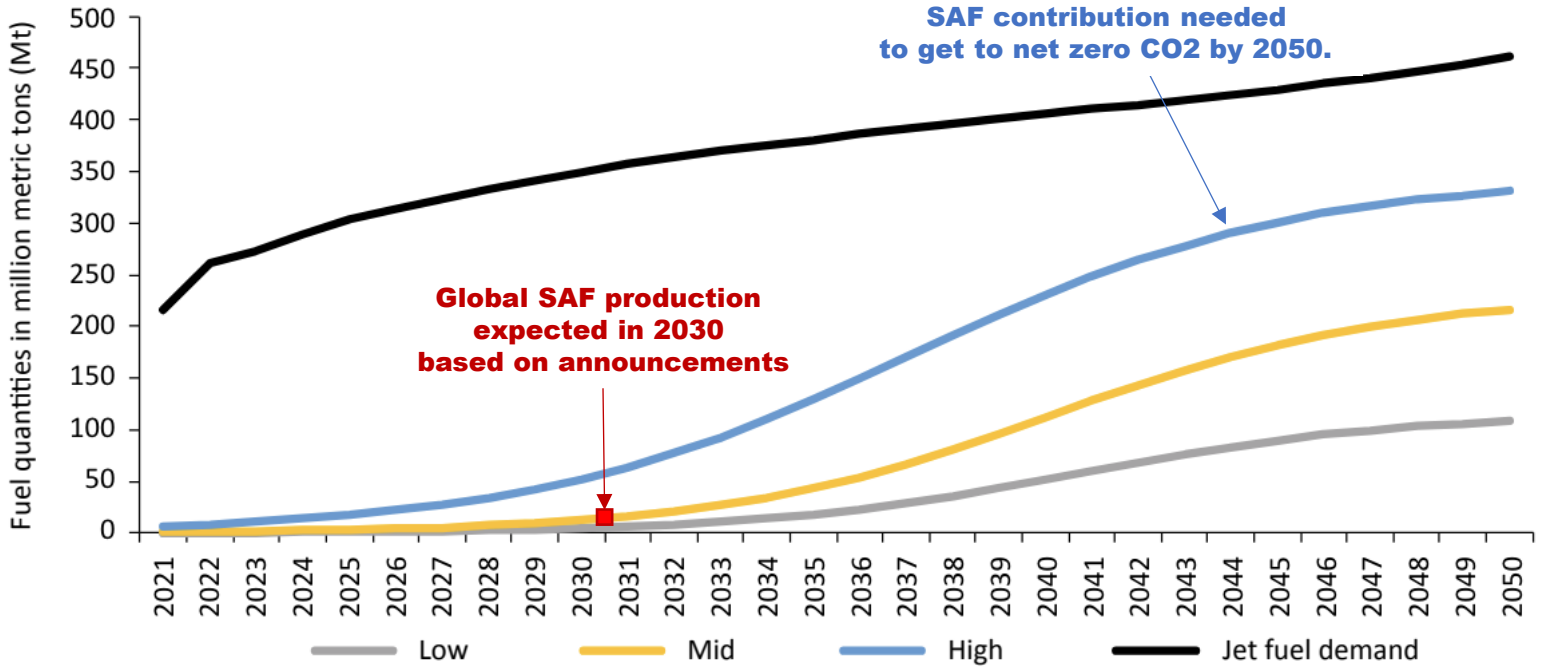
46.75 %

Number of SAF project abandoned or paused:

115

Investment needs and speed of ramp-up

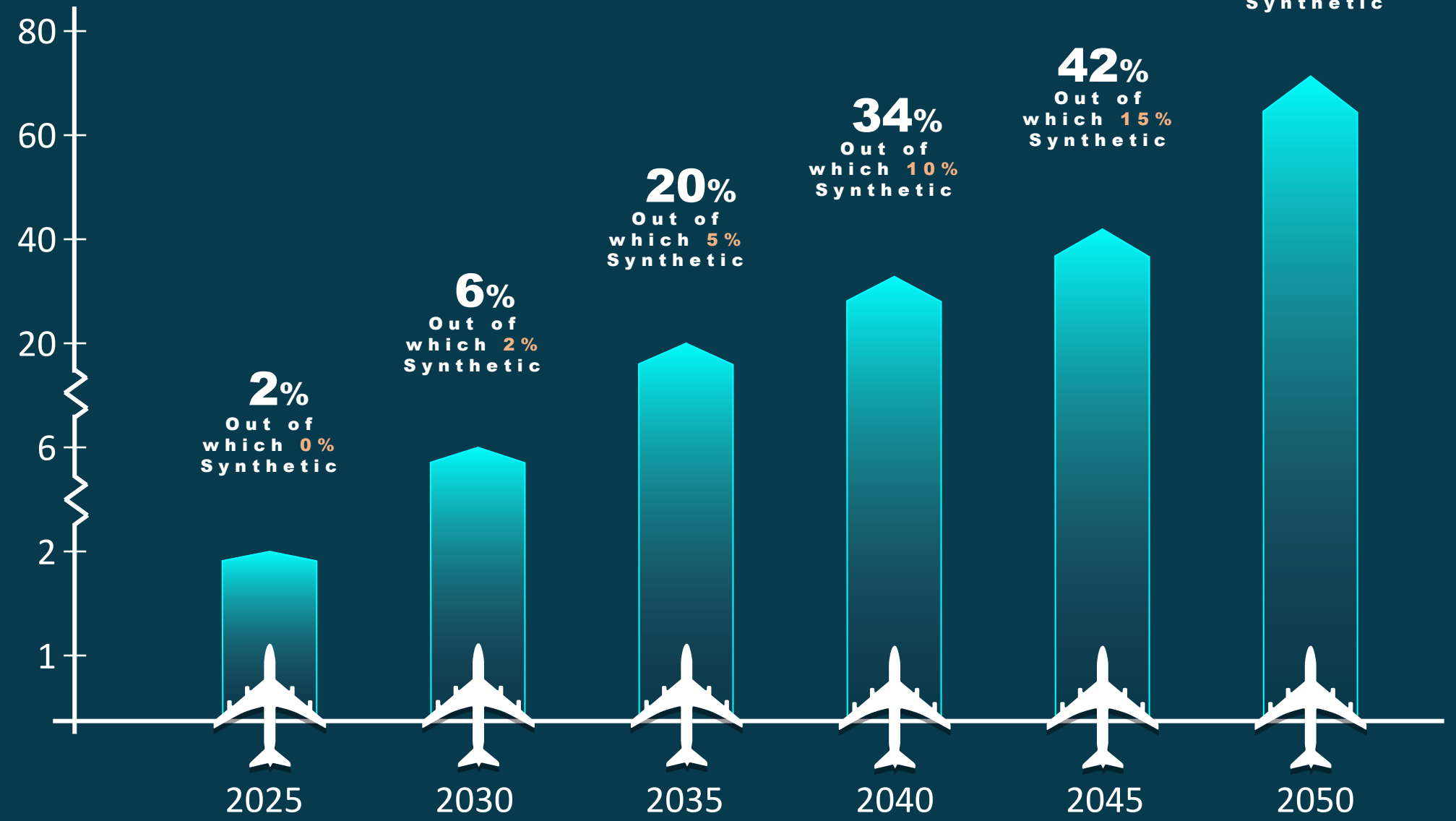
Figure 3.4. SAF Production Projection, by SAF Scenario, out to 2050, Compared to Projected Jet Fuel Demand



*"Translating the SAF production volumes into CAPEX estimates shows that annual investment in the high scenario peaks at approximately **US$125 billion**. This is equivalent to more than **370 SAF** producing facilities coming online during the peak year in the late 2030s or early 2040s—as the periods of highest SAF production growth"*

Source: Malina et. Al, world bank report

ReFuelEU Mandate



Incentives for SAF Uptake

Incentive 1: SAF zero emissions under EU ETS

SAF that qualifies under the EU RED is assumed to have zero emissions under the EU ETS, so if an airline uses SAF, it does not need to surrender allowances.

Incentive 2: Free Allowances for SAF use

The EU has created a reserve of 20 million ETS allowances until 31 December 2030 that will be reserved to incentivize the transition of aircraft operators from using fossil fuels. These are free for airlines if they use SAF to partially compensate for the cost difference between SAF and conventional jet fuel.

Incentives for SAF Uptake

The level of support will vary depending on the sustainability of the purchased SAF (based on a yearly report by aircraft operators). It will cover:

- **50% of the price gap between fossil kerosene and other eligible fuels under ReFuelEU Aviation (RED Annex IX, Part B):**

  For example Used cooking oil, Animal fats

- **70% of the price gap between fossil kerosene and renewable hydrogen for aviation and advanced biofuels (RED Annex IX, Part A):**

  For example, Algae, animal manure,sewage sludge

- **95% of the price gap between fossil kerosene and RFNBOs:**

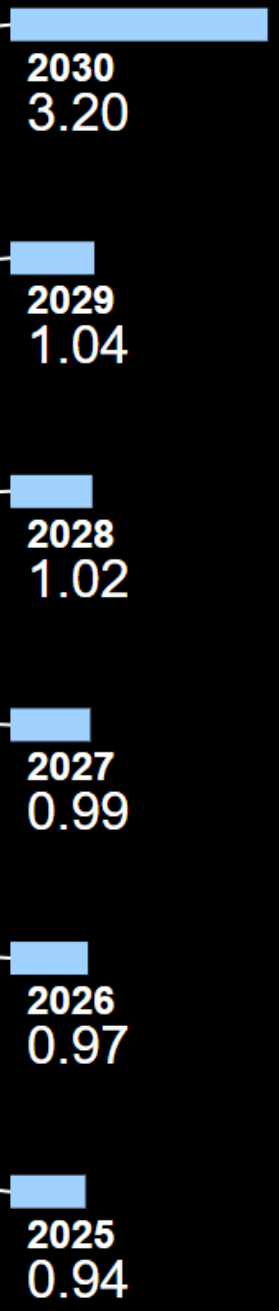
  For Example: PtL

SAF mandate

2025-2029: 2 %, 2030: 6 %

Cumulative SAF Mandate (bn lit.)
8.16

The volume of neat SAF that SAF mandate will create an obligation to supply cumulatively between 2025 and 2030.



Zero CO_2 rating for SAF
(Estimated at
€100 / tCO_2)

20 Million EU-ETS
allowances provided for free for SAF use

€ 0.253/L

€2 bn

~8.16 bn lit.
Neat SAF to be supplied for 2025 -2030

Incentive assuming SAF cost to be 3 times:
~ € 0.6/L neat SAF

Under these assumptions, SAF's monetary incentive from EU-ETS allowances amounts to 0.6 EUR per litre of neat SAF.

Incentives for SAF Uptake

SAF cost multiplier	Part B Feedstocks (50 %)			Airline Cost (CAF in €/L)
	Incentive (€/L)	Airline Cost (SAF in €/L)	SAF Covered (Bn Lit)	
2.0	0.02	1.07	108.11	1.30 (0.92)
2.5	0.19	1.24	10.75	1.30 (0.92)
3.0	0.35	1.40	5.66	1.30 (0.92)
3.5	0.52	1.57	3.84	1.30 (0.92)
4.0	0.69	1.74	2.90	1.30 (0.92)
4.5	0.86	1.91	2.34	1.30 (0.92)
5.0	1.02	2.07	1.95	1.30 (0.92)
5.5	1.19	2.24	1.68	1.30 (0.92)
6.0	1.36	2.41	1.47	1.30 (0.92)

Thank you for your attention!

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Stargate
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