Sustainable Fuels for Aviation

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Aviation Initiative for
Renewable Energy in Germany e.V.

Our Goals for 2030

aireg Aviation Initiative for Renewable Energy in Germany e.V.

Research & Development
Constructing and operating of a **PtL research, technology and demonstration platform** in Germany

Beginning Industrialization
Operation of at least one **commercial SAF production plant** in Germany

SAF-Rates
Rates for sustainable, regenerative aviation fuels

2026: 2 % → **2028: 5 %** → **2030: 10 %**

64 Members

AIRBUS	ARNECKE SIBETH DABELSTEIN	Austro Engine	AVIALLIANCE	Aviation Fuel Projects Consulting GmbH & Co. KG	Bauhaus Luftfahrt Neue Wege.	BOEING	bp	Die Senatorin für Wirtschaft, Häfen und Transformation – Freie Hansestadt Bremen	CAPHENIA Turning CO_2 into fuel
CAC ENGINEERING GMBH	CONTINENTAL AEROSPACE TECHNOLOGIES	DEKRA	DEUTSCHE AIRCRAFT	LUFTHANSA GROUP	DHL Group	DLR	EDL PÖRNER GRUPPE	eFUEL	Emirates
ENERTRAG Eine Energie voraus	EY	ETERNAL POWER	BER BERLIN BRANDENBURG AIRPORT	Fraunhofer IBP	Greenlyte	GRIESEMANN	Hamburg Behörde für Wirtschaft und Innovation	HALTERMANN CARLESS	UHASSELT
HESSEN Hessisches Ministerium für Wirtschaft, Energie, Verkehr, Wohnen und ländlichen Raum	HIF	The Hong Kong Polytechnic University Department of Logistics and Maritime Studies	HORVÁTH	hynamics EDF GROUP	INERATEC	ISCC International Sustainability & Carbon Certification	IUE Institut für Umwelttechnik und Energiewirtschaft	JÜLICH Forschungszentrum	KIT Karlsruher Institut für Technologie
Catalysis LIKAT Leibniz-Institut für Katalyse	MB Energy Our energy, your way.	McKinsey & Company	MTU Aero Engines	M	Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz	NESTE	norsk e-fuel	OCEANERGY	OMV
PCK	PtX Lab Lausitz	pwc	BRAATHENS RENAVIA	ROLLS ROYCE	RWE	spark e-fuels	SYNTHECFUELS	TU Bergakademie Freiberg Professur für Reaktionstechnik	Thorsten Luft Beratung für Treibstoffmanagement und Sustainable Aviation Fuels
			TotalEnergies	uniper	WIWeB	ZAFFRA			

Cooperation Agreements and Memberships

Cooperation Agreements

ASAFA	CAAFI FUELING SOLUTIONS FOR SECURE & SUSTAINABLE AVIATION	en2x	HAMBURG AVIATION	impact ON SUSTAINABLE AVIATION

Memberships

European Climate Foundation	ICAO OACI ИКАО	RLCF Alliance

Organizational Structure

Aviation Initiative for Renewable Energy in Germany e.V.

General Assembly

Executive Board

Six members of the Board

Advisory Council

Advisory Council members from science, industry and politics

Coordinating Committee

Consisting of the Executive Board and the chairs of the WGs

Auditors and Head Office

Our Executive Board

Siegfried Knecht
Chairman of the Board

Uwe Gaudig
Deputy Chairman of the Board

Prof. Dr.-Ing. Martin Kaltschmitt
Deputy Chairman of the Board

Melanie Form
Member of the Board
Managing Director

Prof. Dr.-Ing. Manfred Aigner
President for Science and Research

Prof. Dr. Jürgen Ringbeck
President for Industry and Aviation

Working Groups and Task Force

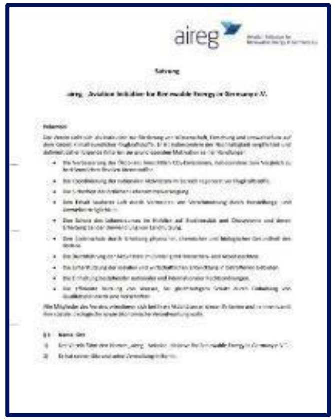
Resources and Technologies

Quality, Certification and Use

Sustainability

Task-Force Economy and Production

Our Statues



Working Groups and Task Force

Resources and Technology
Examine available feedstocks and production options for sustainable, renewable aviation fuels

Quality, Certification and Use
Practical use of sustainable, renewable aviation fuels and challenges of quality and certification

Sustainability
Considering all three pillars of sustainability – environment, social equity and economy – along the entire value chain

Task Force Economy and Production
Examination of economic aspects and potential production capacities of sustainable, regenerative aviation fuels

Climate Protection Plan of International Aviation in the face of major growth

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! Growth by 2050: ICAO expects revenue passenger kilometer (RPK) to double to triple by 2050. !

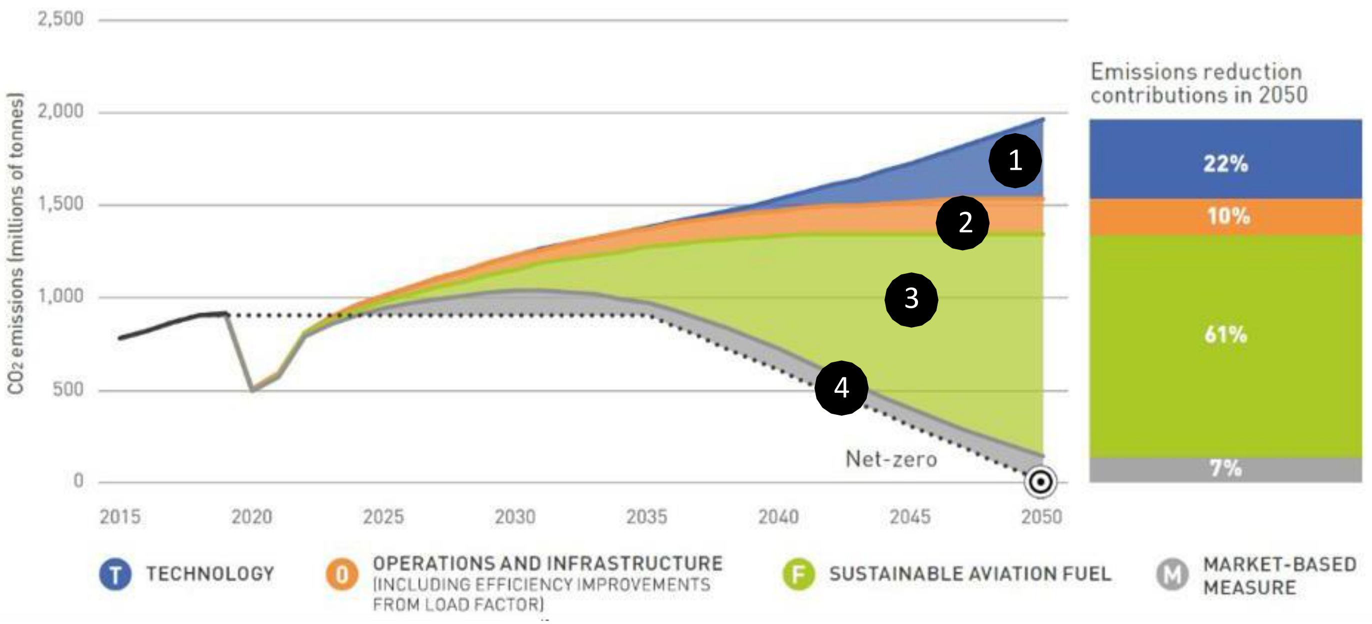
→ At least doubling of the climate impact if no measures are taken.

1. Technology: Technological improvements and the use of aircraft with hybrid and electric propulsion primarily on short-haul routes from 2035 to 2040.

2. Operations and Infrastructure: Significant investments in the efficiency of operations and infrastructure.

3. SAF: The largest contribution is to be made by sustainable aviation fuels. In 2050, 90% of fuel is to be replaced by SAF, which saves 100% emissions respectively.

Possible route to climate neutrality by 2050 from the perspective of the aviation industry:



Proportions of different measures on the way to climate neutrality in aviation

4. Market-based measures: Emissions not prevented by the previous three areas are offset through compensatory measures.

Source: ATAG (2021): Waypoint 2050.

Climate Protection Plan of European Aviation in the face of major growth

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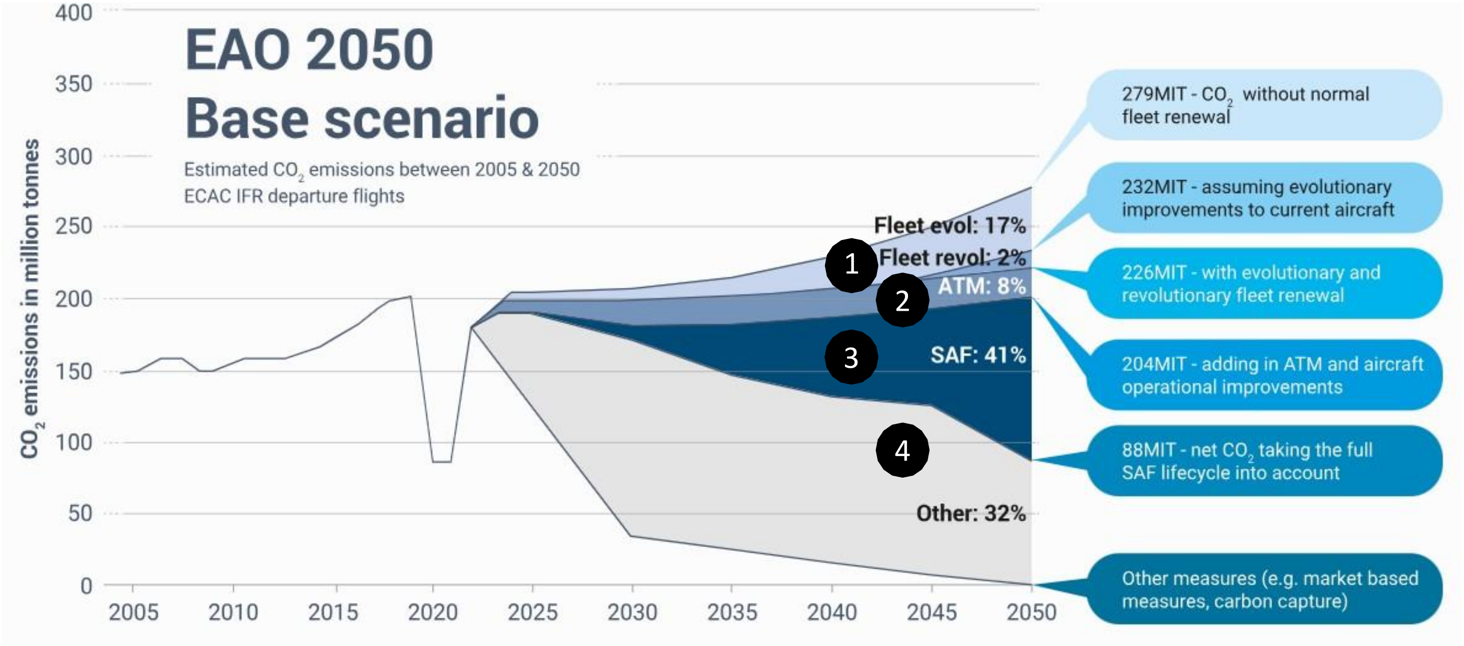
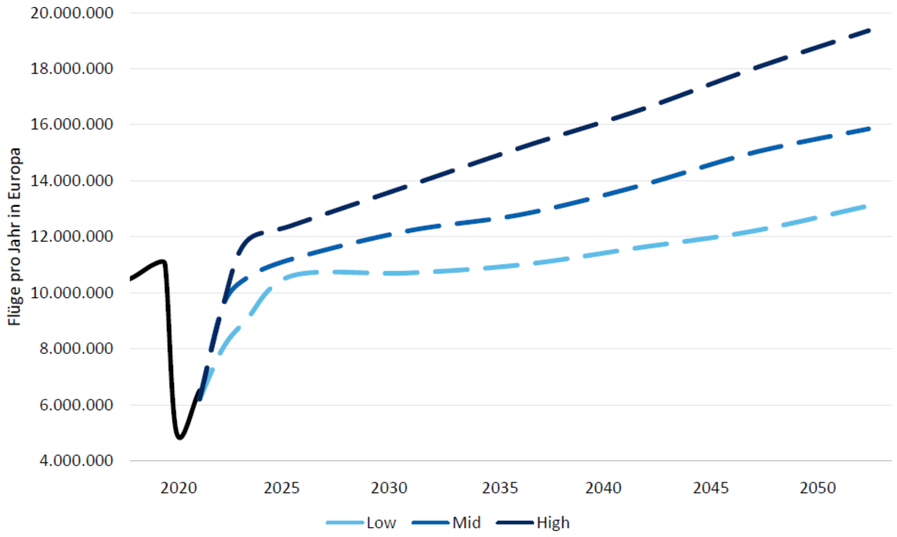


Scenarios of air traffic growth in Europe



1. Savings measures by renewing aircraft fleets with modern aircraft types and improving efficiency compared with current technology, savings potential: 53 million metric tons of CO_2

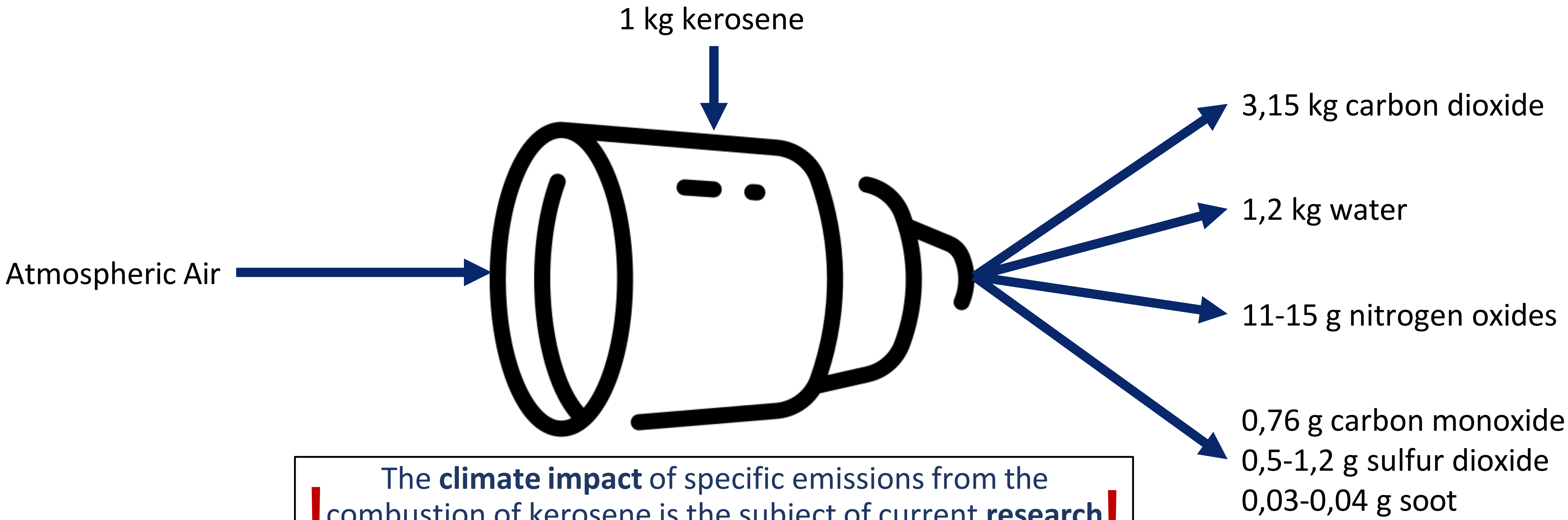
2. Savings measures through efficiency improvements in operations and infrastructure, savings potential: 24 million metric tons of CO_2

3. Savings measures through the use of SAF, savings potential: 116 million tons of CO_2

4. Further savings through market-based measures or CO_2 capture and storage, Savings potential: 88 million metric tons of CO_2

Source: Eurocontrol (2022)

Emissions from the Combustion of Kerosene



! The **climate impact** of specific emissions from the combustion of kerosene is the subject of current **research projects**, for example at the DLR. !

BAZL (2020): CO2-Emissionen des Luftverkehrs: Grundsätzliches und Zahlen.
Lee et al., Atmos. Environ., https://doi.org/10.1016/j.atmosenv.2020.117834, 2020

Non-CO_2 Effects

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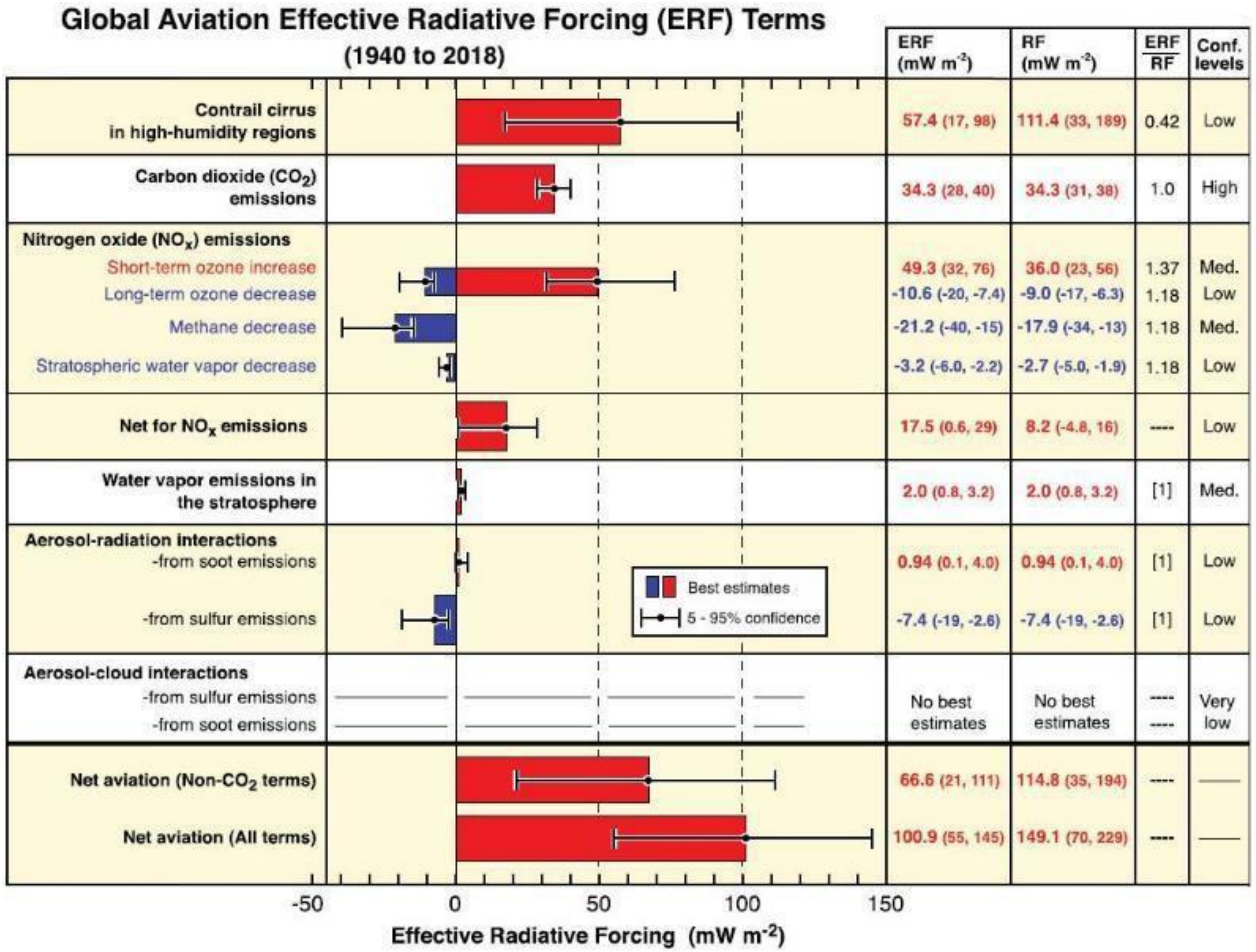
- In addition to CO_2, **other climate-impacting** substances are emitted
- These include water vapor, soot particles, sulfate particles and nitrogen oxides emitted at high altitudes
- Their complex interaction and the resulting climate impact are the subject of current research
- Non-CO_2 effects account for about **2/3 of the total climate impact** of aviation
- Click here for more information o non-CO_2 effects

! **SAF burn cleaner than fossil kerosene** and thus also reduce non-CO_2 effects. Further information in this regard can be found in the aireg roadmap. !



Effect of climate-impacting emissions. Warming effects in red and cooling effects in blue, with confidence intervals indicated.[1]

[1]EASA Final Report: Updated analysis of the non-CO2 climate impacts of aviation and potential policy measures pursuant to the EU Emissions Trading System Directive Article, p. 28, fig. 2, November 2020

Why SAF to reduce Climate Impact?

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Lower GHG emissions

- Already up to 80% less GHG emissions with HEFA-SAF compared to fossil kerosene
- With electricity-based SAF potentially up to 100% CO_2 emission reduction

Reduction of non-CO_2 effects

- Result from the formation of soot particles and other climate-impacting substances
- SAF burns cleaner with reduced formation of particles

Lack of Alternatives

- Other climate-friendly propulsion systems (electric/hydrogen) will be available from 2030 at the earliest
- Duration of market ramp-up very high due to long service life of aircraft

Drop-in solution

- No adaption of engines and tank infrastructure necessary
- Commercially available and in use today
- Already approved in admixtures up to 50%

Biogenic SAF Production Pathways

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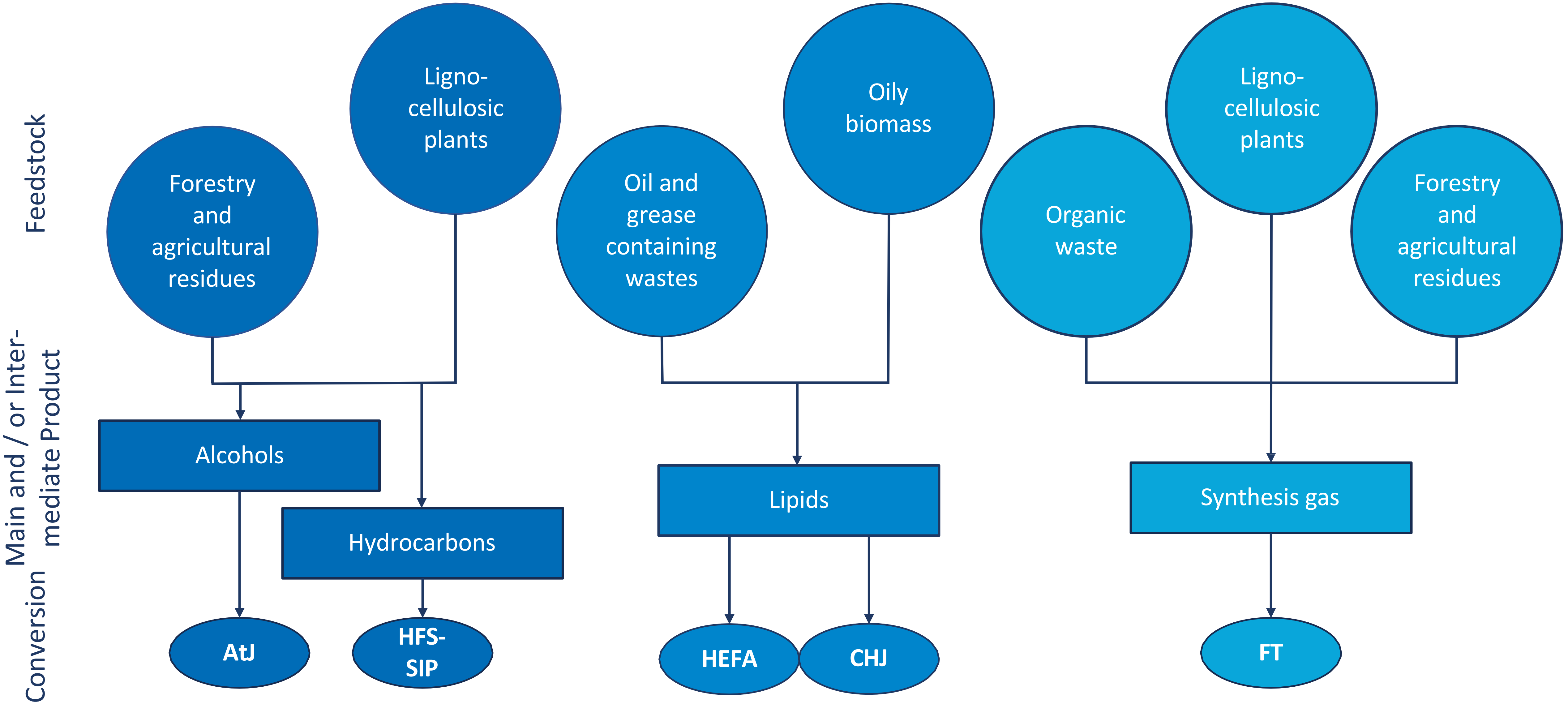

AtJ: Alcohol to Jet, **HFS-SIP**: Hydroprocessed Fermented Sugars to Synthetic Isoparaffins, **CHJ**: Catalyctic Hydrothermolysis Jet, **HEFA**: Hydroprocessed Esters and Fatty Acids, **FT**: Fischer-Tropsch

Source: Based on Thomson et al. 2020): Sustainable Aviation Fuels. The Best Solution to Large Sustainable Aircraft

Overview of Approved SAF Options

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ASTM	Annex	Year of Approval	Process	Blending Limit	Possible Feedstocks	Producers
D7566	1	2009	FT-SPK	50 Vol.-%	flexible (biogen, fossil, synthetic, e.g. PtL or BtL)	Velocys, Sasol, Shell
D7566	2	2011	HEFA-SPK	50 Vol.-%	fats/oils (e.g. plant-based oils, used cooking oils)	UOP, Neste
D7566	3	2014	HFS-SIP	10 Vol.-%	sugar, starch, lignocellulose	Amyris
D7566	4	2015	FT-SPK/A	50 Vol.-%	flexible (biogen, fossil, synthetic, e.g. PtL or BtL)	Sasol
D7566	5	2016	ATJ-SPK	50 Vol.-%	sugar, starch, lignocellulose	Gevo, Cobalt
D7566	6	2020	CH-SK	50 Vol.-%	fats/oils (e.g. plant-based oils, used cooking oils)	ARA
D7566	7	2020	HC-HEFA-SPK	10 Vol.-%	fats/oils (algae oil)	IHI
D7566	8	2023	ATJ-SKA	50 Vol.-%	sugar, starch	Swedish BioFuels, Byogy
D1655	1	2018	Co-Processing	5 Vol.-%	fats/oils (e.g. plant-based oils, used cooking oils)	
D1655	1	2020	Co-Processing	5 Vol.-%	FT-biocrude (primary feedstocks see FT-SPK, FT-SPK/A)	
D1655	1	2023	Co-Processing	10 Vol.-%	hydroprocessed biomass	

ATJ-SPK (Alcohol to Jet Synthetic Paraffinic Kerosene), **ATJ-SKA** (Alcohol to Jet Synthetic Paraffinic Kerosene with Aromatics), **CH-SK** (Catalytic Hydrothermolysis Synthesized Kerosene), **FT** (Fischer-Tropsch), **HC** (Hydrocarbons), **HEFA** (Hydroprocessed Esters and Fatty Acids), **HFS-SIP** (Hydroprocessed Fermented Sugars to Synthetic Isoparaffins), **PtL** (Power-to-Liquid), **SPK** (Synthetic Paraffinic Kerosene), **SPK/A** (Synthetic Paraffinic Kerosene with Aromatics)

In addition to **biogenic SAF** and **electricity-based SAF**, there is the option of combining these pathways. These SAF are called **hybrid SAF**.

Source: based on CAAFI (2023)

Electricity-based SAF – Power to Liquid (PtL)

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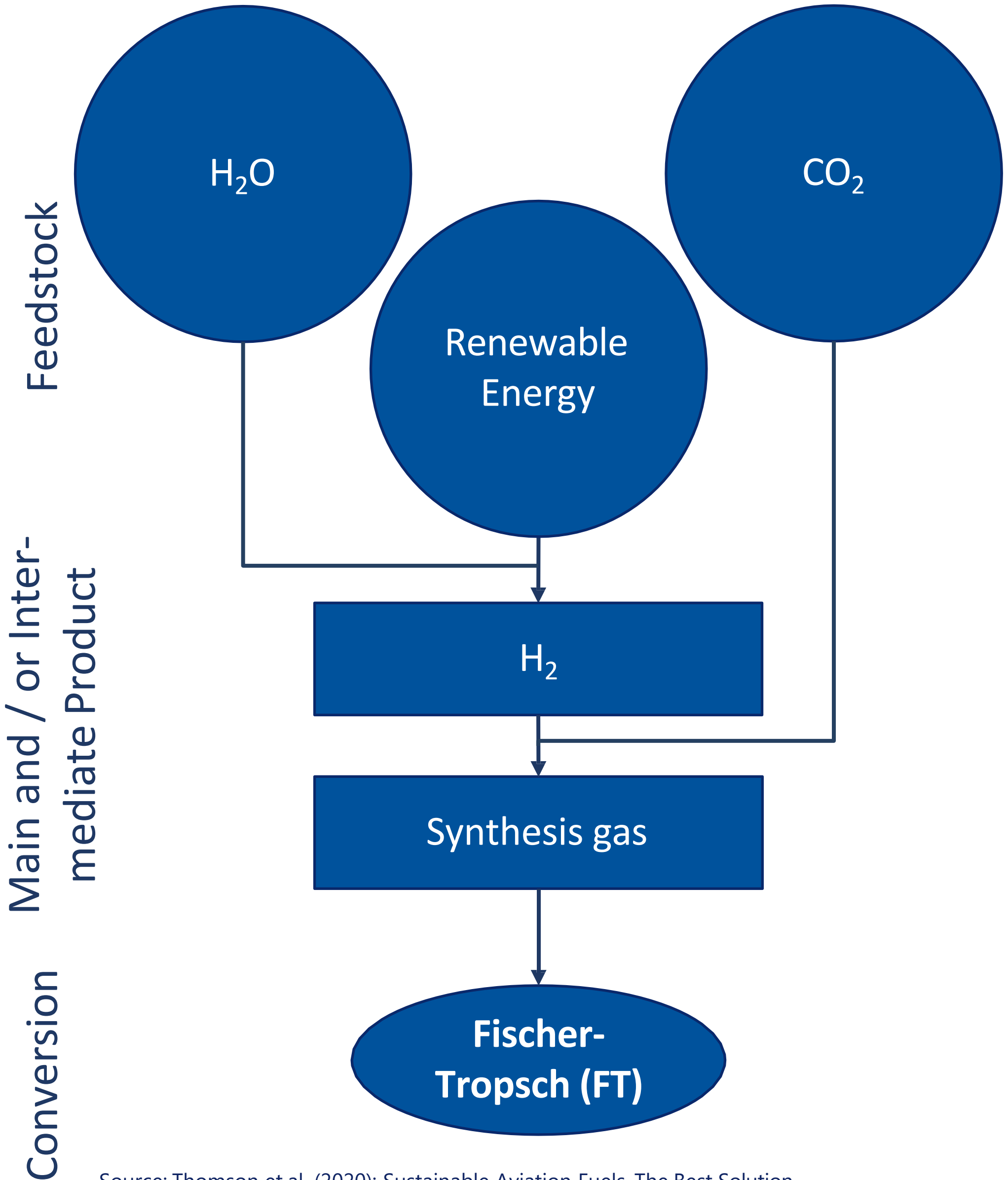
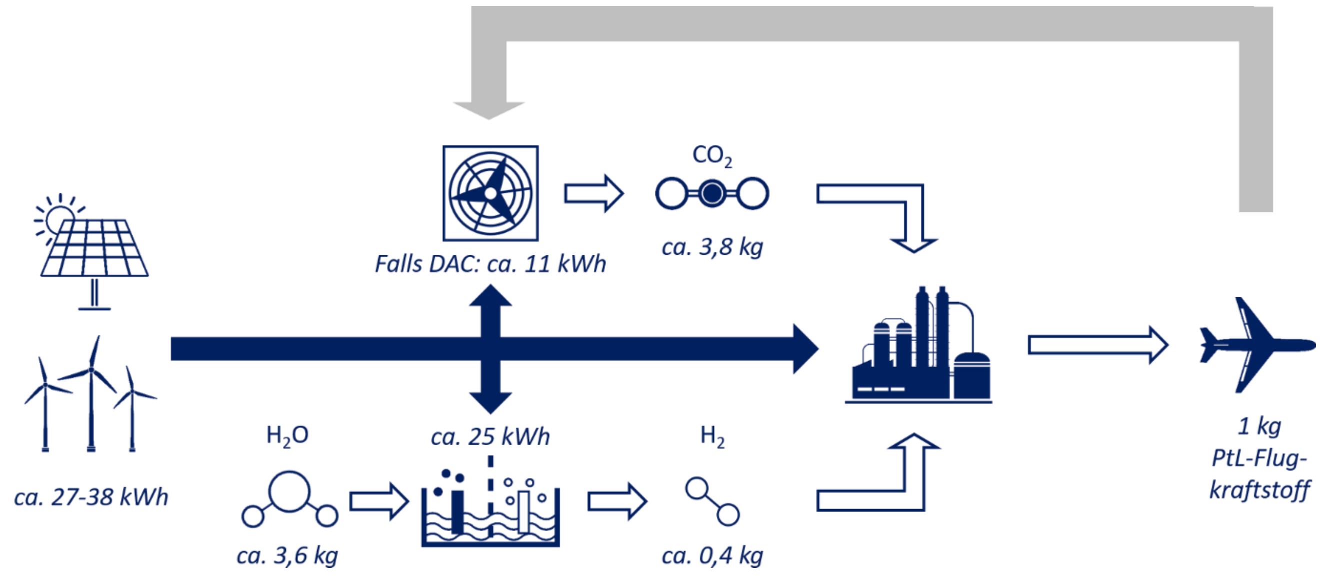


Source: Thomson et al. (2020): Sustainable Aviation Fuels. The Best Solution to Large Sustainable Aircraft

Quantitative overview of required feedstocks in the PtL production pathway:



Feedstock required to operate all domestic German flights with PtL:

- Demand of about 700,000 tons of kerosene (comparison year 2019).
- At least 19,000 GWh of renewable energy -> 750 to 2,500 wind turbines
- 280,000 tons of hydrogen ≙ 9 TWh hydrogen -> 10% of Germany's hydrogen demand in 2030 according to hydrogen strategy of the Federal Government of Germany
- 2.7 million tons of biogenic CO2 -> potential of CO2 capture of approx. 13 million tons from biogas, biomethane and bioethanol production in Germany

Source: aireg e.V. / TUHH (2023): Ptl Factsheet

Electricity-based SAF – Power to Liquid (PtL)

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PtL-Aviation Fuels Strategic Evaluation

Strengths:

→ Certification for use in all aircraft types is available

→ Blending with conventional kerosene is readily possible ("drop-in fuel"); no need for adjustment at aircraft or airports

→ High potential for climate impact mitigation (up to 90% CO_2 and further mitigation of some non-CO_2 effects)

Weaknesses:

→ Large-scale commercial availability of non-fossil CO_2 is currently limited to biogenic sources (e.g., biogas plants); direct-air capture processes are still under development

→ High supply / fuel costs, for example, compared to HEFA kerosene

→ PtL plants are still in laboratory and pilot scale today; large-scale commercial implementation is still pending

Opportunities:

→ Potential for efficient storage of electrical energy from fluctuating renewable sources

→ Potentially high cost reduction potential through innovative processes, optimized system integration and large-scale scaling

→ Significant market potential for national and international plant engineering and construction

Challenges:

Large-scale industrial production has yet to be tested

Some process components (e.g., reverse water-gas shift reaction) have not yet been demonstrated on a large industrial scale

Cost reduction potential strongly dependent on innovation dynamics and global market development

Source: aireg e.V. / TUHH (2023): Ptl Factsheet

SAF price remains high in the medium term due to high production costs

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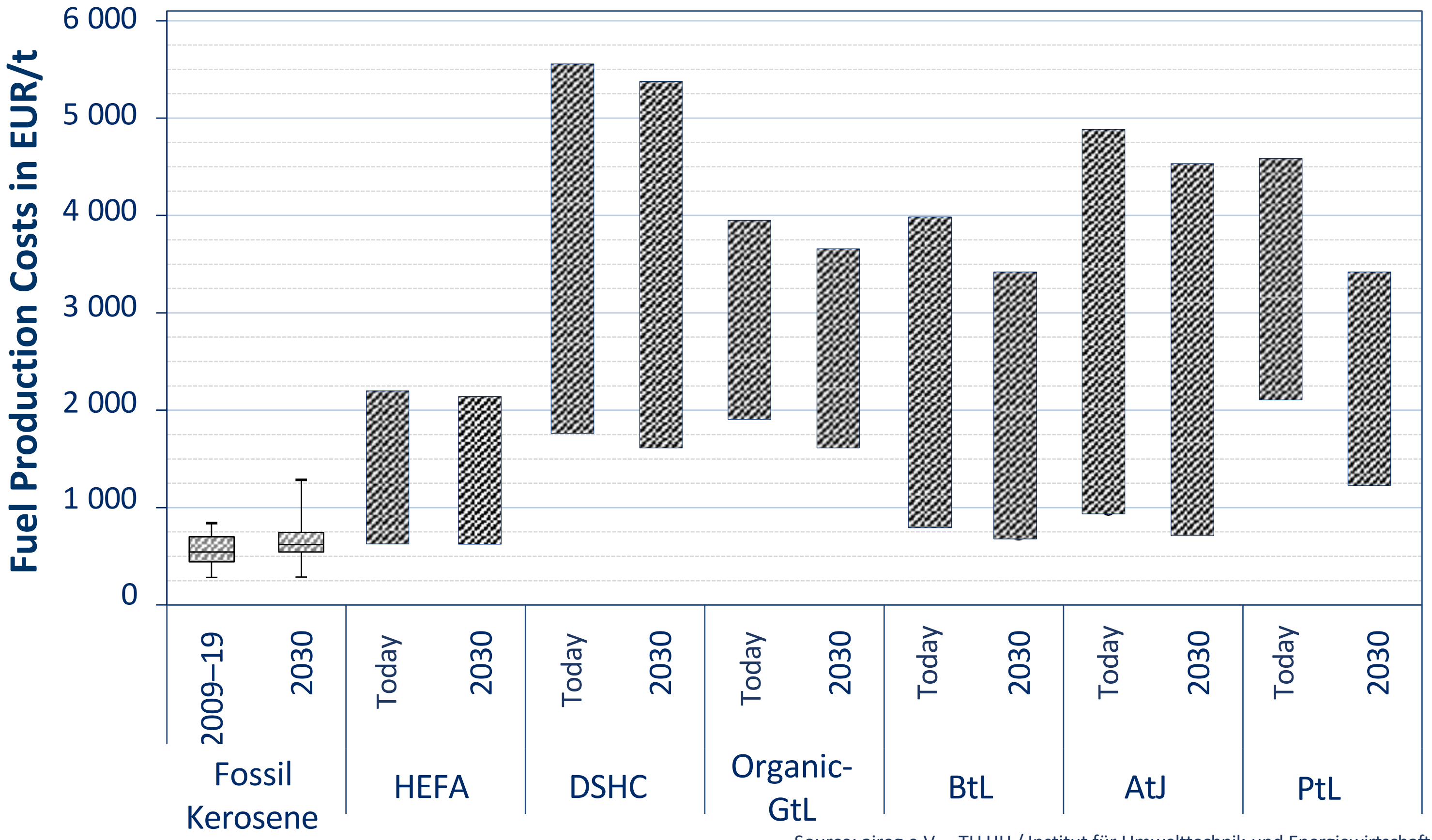

Source: aireg e.V. – TU HH / Institut für Umwelttechnik und Energiewirtschaft

- Sustainable aviation fuels have been and will continue to be very expensive compared to fossil kerosene, **severely hampering their market entry**
- Cost reduction through innovation and scaling of the entire value chain.
- Price parity is more likely to be achieved through government incentive programs

Roadmap for the Development and Introduction of Sustainable Aviation Fuels

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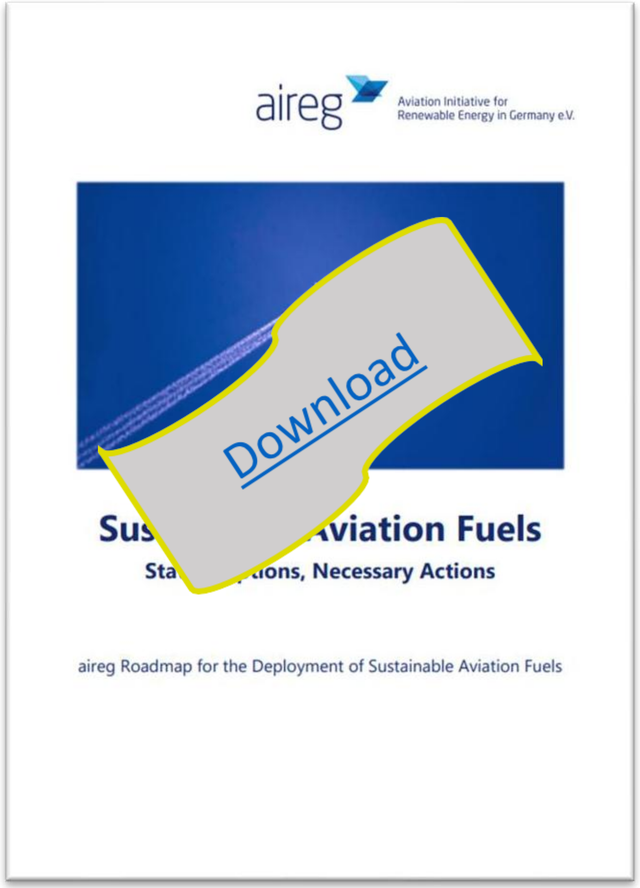
- The aireg **Roadmap** presents measures and incentives to achieve **a significant share of sustainable fuels** in aviation.
- This includes measures in the field of research and development (R&D) of corresponding manufacturing technologies, milestones for technological development and implementation as well as regulatory and other supporting measures.
- The Roadmap contains
  - establishment of a PtL Demonstration and Research Centre in Germany
  - Research and development (R&D) of corresponding manufacturing technologies
  - Milestones for technical development
  - regulatory and other supporting measures



- The aireg members offer cooperation to politicians at the federal and state level as well as other stakeholders from industry, business and science in order to accelerate the urgently needed market launch and production ramp-up of SAF.

Roadmap for the Development and Introduction of Sustainable Aviation Fuels

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Today → **2030** → **long term (>2050)**

R & D

- establishment of a PtL demonstration platform
- development of hydrogen and CO_2 supply-chains
- upscaling of new technologies
- Supporting the approval of new SAF options
- optimization of supply-chains and infrastructure
- research of “near drop-in“ aviation fuels

technological development & implementation

- development and construction of SAF production plants
- construction of demonstration plants for electricity based SAF
- cost-effective production plant operation
- construction of commercial plants in Germany for electrcity based SAF
- SAF import

regulatory Action

- European GHG reduction obligation for sAF (1% in 2022)
- financial incentives for SAF production plants and SAF market injection
- inclusion of international frameworks
- tendering / incentives for SAF production
- European GHG reduction obligation for SAF (10% in 2030)
- PtL sub-mandate within GHG reduction obligation
- medium-term / long-term prioritization of liquid sustainable fuels in aviation and shipping

support action

- timely communication with (inter-)national NGOs and associations
- development of niche markets for SAF
- concepts for th verification and acounting of SAF / SAF meta-standard
- debate on the long-term role of biofuels

significant share of sustainable fuels in air transport

Selection of commitments: Climate protection in aviation of different countries

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Canada

Carbon neutrality by 2050

Norway

30% sustainable fuel by 2030

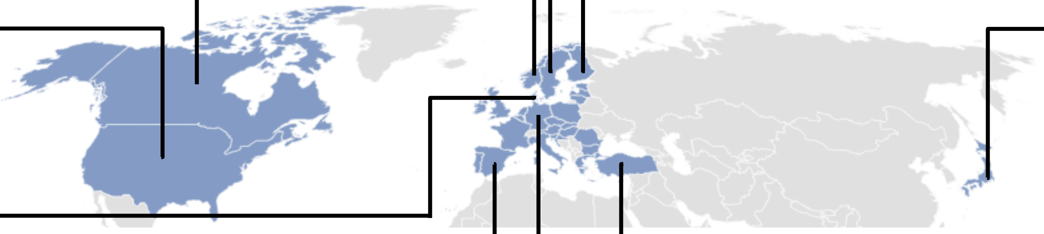
Sweden

27% reduction in greenhouse gases from aviation fuel in 2030 vs. 2019
Carbon neutrality by 2045

Finland

30% sustainable fuel by 2030

Global aviation commitments in the face of climate change



United States

Approximately 9 million tons of SAF by 2030
Carbon neutrality by 2050

Japan

Roadmap for carbon neutrality by 2050

Denmark

100% sustainable fuel by 2050

Spain

20% sustainable fuel by 2030

Turkey

1% sustainable fuel

Germany

Quotas for fuel from renewable, non-biogenic sources: 0,5% in 2026, 1% in 2028, 2% in 2030
Quotas for reduction of GHG emissions (selection): 10,5% in 2025, 25% in 2030

European Union

Reduction of 55% in greenhouse gas emissions compared to 1990 by 2030
At least 6% SAF in 2030 and 70% SAF by 2050
thereof 1.2% e-fuels in 2030 and 35% e-fuels in 2050 (ReFuelEU)

Source: nach https://www.linkedin.com/posts/ifp-energies-nouvelles_parisairlab-daezcarbonation-parisairshow-activity-7077218307723907072-kwSV?utm_source=share&utm_medium=member_ios

SAF Efforts Airlines

UNITED	5% SAF by 2030, ca. 22,000 tons of SAF since 2016, 50% reduction in GHG emissions from 2019 levels by 2035, USD 100 million fund for the promotion of SAF SBTi-validated
Lufthansa	5% - 10% SAF by 2030, reduction of CO_2 intensity (CO_2 emissions per transported ton kilometer) by 30% compared with 2019 by 2030, SBTi-validated
AIRFRANCE KLM	10% SAF by 2030, at least 1% SAF on each flight from France and the Netherlands, CO_2 emissions reduction by 30% per RPK until 2030 compared to 2019, SBTi-validated
virgin atlantic	10% SAF by 2030, first transatlantic flight with 100% SAF, 40% net reduction in CO_2 emissions by 2040
BRITISH AIRWAYS	10% SAF by 2030, 70% SAF by 2050 at IAG
DHL Group	30% SAF by 2030 in the area of air freight, SBTi-validated
American Airlines	10% SAF by 2030, SBTi-validated
RYANAIR	12.5% SAF by 2030, 70% of which is already contractually secured, 26% lower CO_2 impact compared with 2019 in 2031, SBTi-validation is in progress
SAS	17% SAF by 2030, reduction of CO_2 intensity by 40% compared with 2019 by 2035 (SBTi-compliant), separate booking classes with 50% SAF for each flight

Source: own research

Thank you for your Interest!

Aviation Initiative for Renewable Energy in Germany e.V.

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