# Sustainable Fuels for Aviation

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Aviation Initiative for
Renewable Energy in Germany e.V.

# Our Goals for 2030

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 %**

# 55 Members and Strong Partners

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AIRBUS | ARNECKE SIBETH DABELSTEIN | Austro Engine | AVIALLIANCE | Aviation Fuel Projects Consulting GmbH & Co. KG | Bauhaus Luftfahrt Neue Wege | BOEING | bp

Die Senatorin für Wirtschaft, Arbeit und Europa | CAPHENIA | C·A·C ALWAYS AN IDEA AHEAD | CONTINENTAL AEROSPACE TECHNOLOGIES | DEUTSCHE AIRCRAFT | DHL Group | DLR | EDL PÖRNER GRUPPE

Fraunhofer IBP | GRIESEMANN | H2FLY | Hamburg Behörde für Wirtschaft und Innovation | H·C·S GROUP | HESSEN Hessisches Ministerium für Wirtschaft, Energie, Verkehr und Wohnen | H2E | The Hong Kong Polytechnic University 香港理工大學 Department of Logistics & Maritime Studies 物流及航運學系

HORVÁTH | hynamics EDF GROUP | ISCC International Sustainability & Carbon Certification | Institut für Umwelttechnik und Energiewirtschaft IUE | JatroGreen Sustainable Energy Madagascar | JÜLICH Forschungszentrum | KIT Karlsruhe Institute of Technology | Catalysis LIKAT

MABANAFT | McKinsey & Company | MTU Aero Engines | Flughafen München | Niedersächsisches Ministerium für Umwelt, Energie, Bauen und Klimaschutz | NESTE | norsk e-fuel | OCEANERGY

OMV | PCK | PtXLab LAUSITZ | ROLLS ROYCE | RWE | sasol ecoFT | SH Schleswig-Holstein Ministerium für Wirtschaft, Verkehr, Arbeit, Technologie | SIEMENS energy

spark e-fuels | SYNTHECFUELS | Technische Universität Bergakademie Freiberg – Professur für Reaktionstechnik | Thorsten Luft Beratung für Treibstoffmanagement und Sustainable Aviation Fuels | TotalEnergies | uniper | WIWeB

## Cooperation Agreements

CAAFI | en2X | IATA

## Memberships

European Climate Foundation | RLCF Alliance | ICAO · OACI · ИКАО | ISCC International Sustainability & Carbon Certification | P2X

# 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**
Deputiy Chairman of the Board

**Melanie Form**
Member of the Board
Managing Director

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

**Prof. Dr. Jürgen Ringbeck**
President Industry and Aviation

Working Groups and Task Force

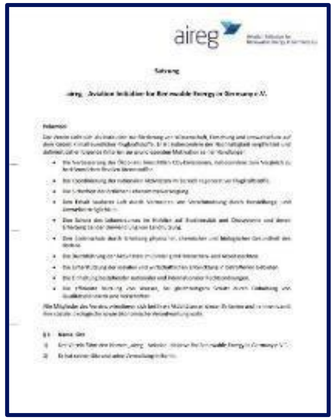
Resources and Technologies

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. !

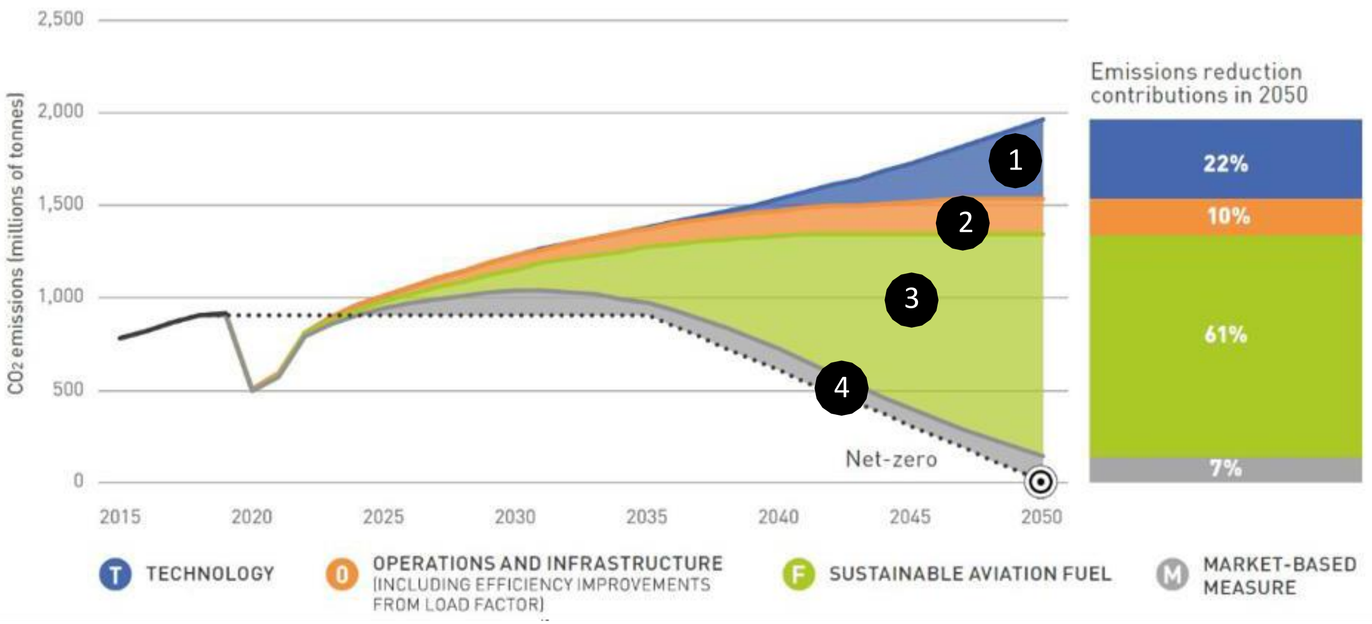
→ At least doubling of the climate impact if no measures are taken.

**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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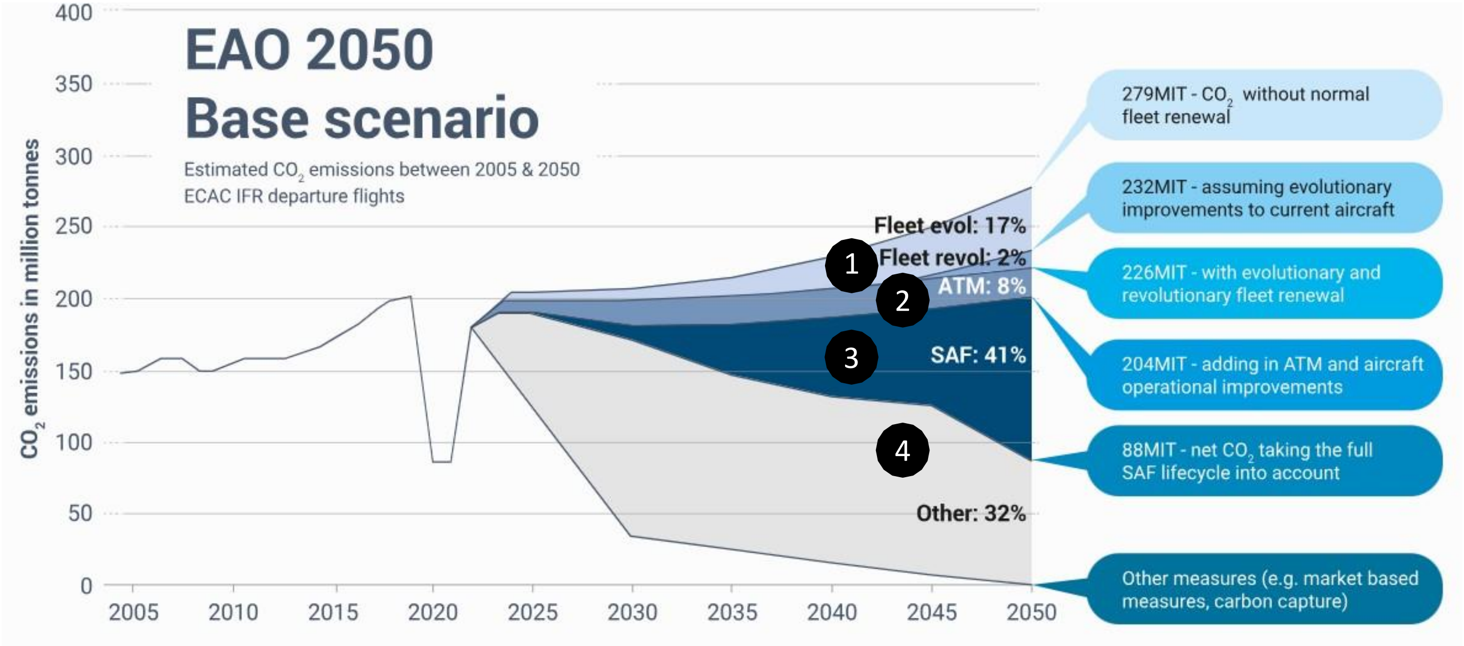
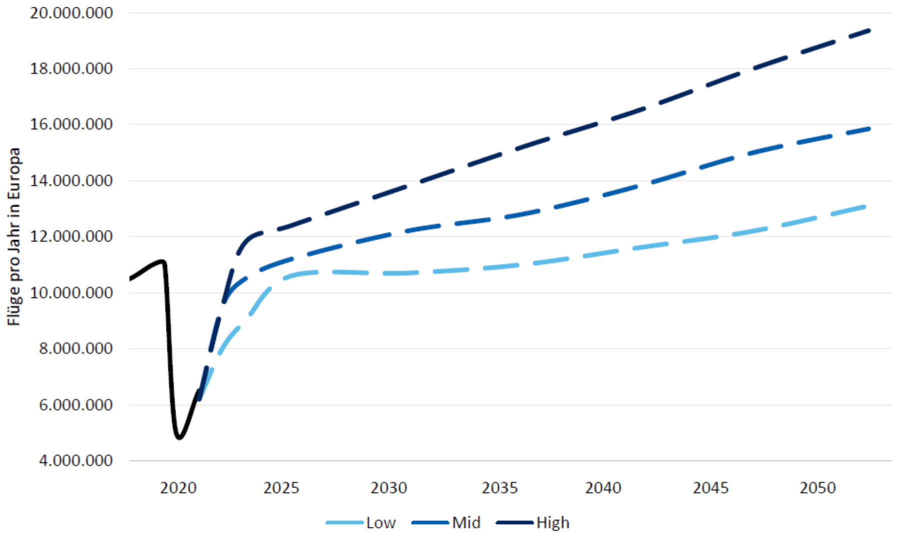



## Scenarios of air traffic growth in Europe




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

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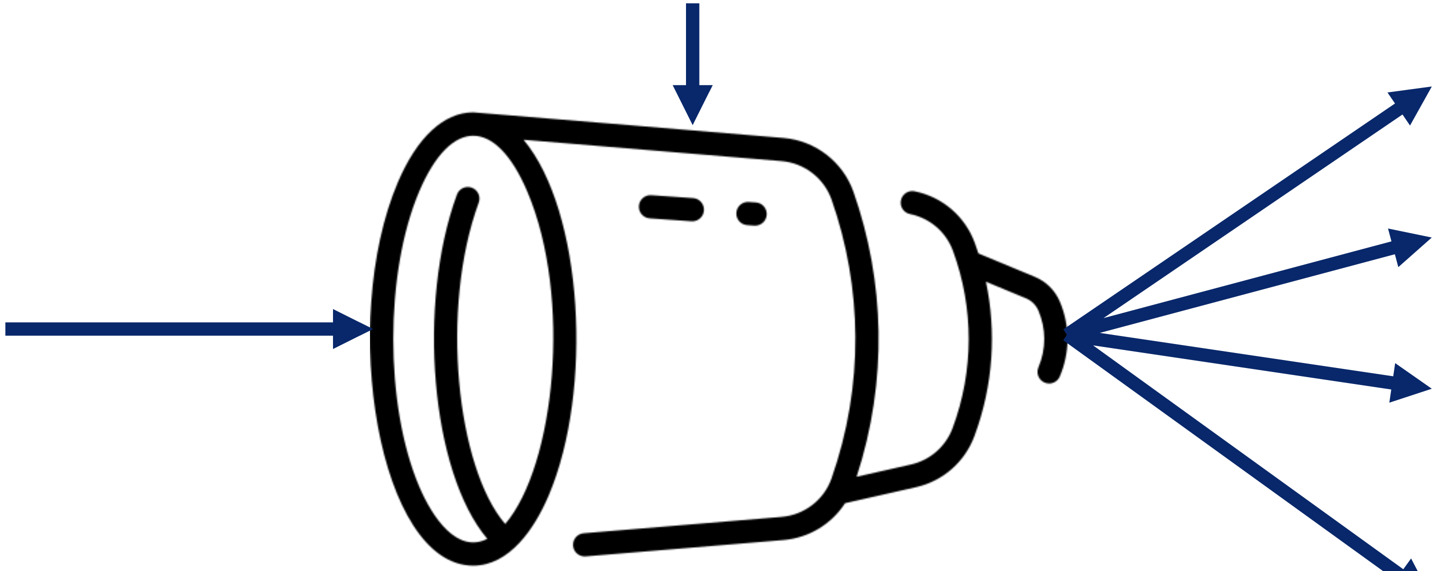


! The **climate impact** of specific emissions from the combustion of kerosene is the subject of current **research projects**, for example at the DLR. !

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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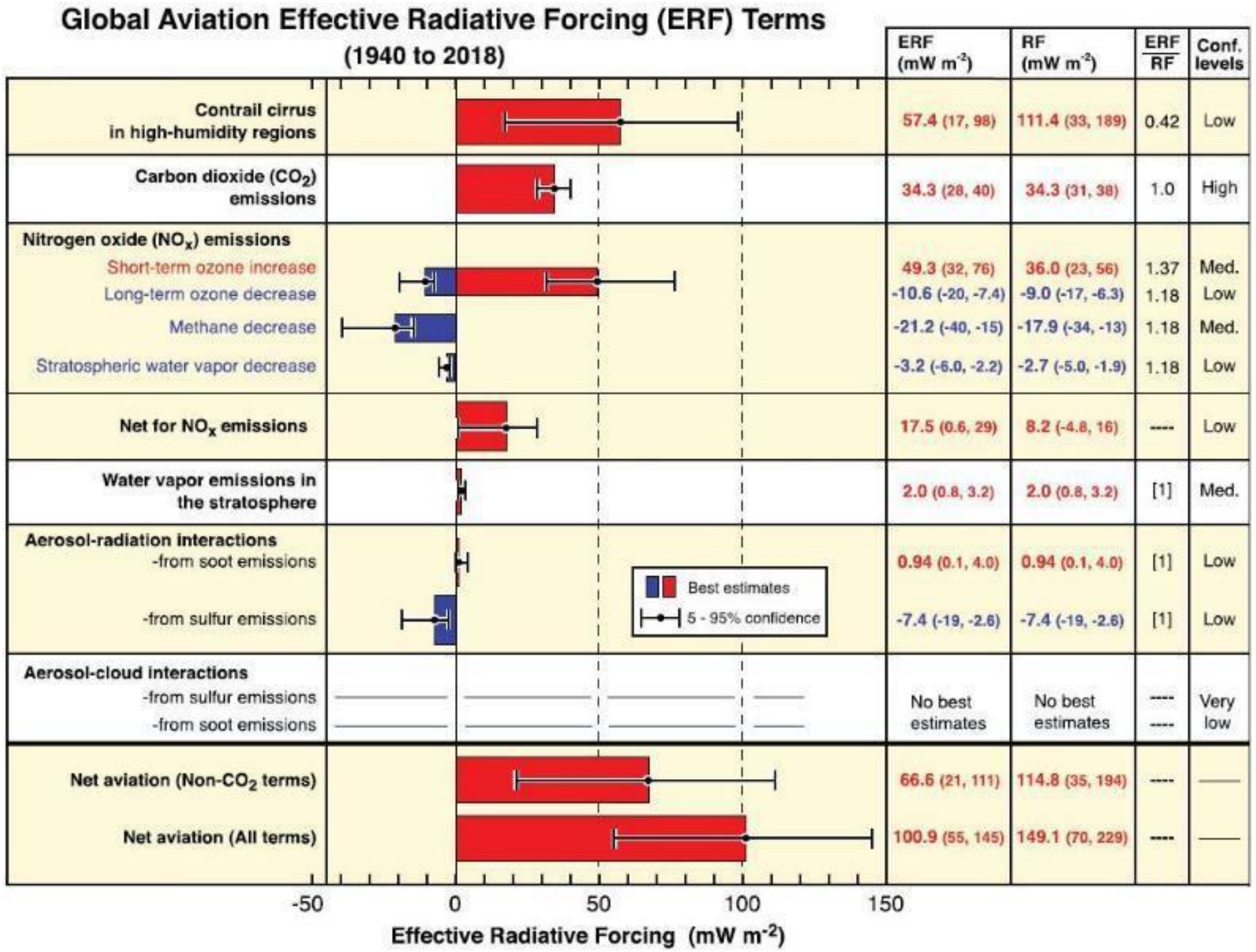
- In addition to $CO_2$, **other climate-impacting** substances are emitted
- These include water vapor, soot particles, sulfate particles and nitrogen oxides emitted at high altitudes
- Their complex interaction and the resulting climate impact are the subject of current research
- Non-$CO_2$ effects 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?

## 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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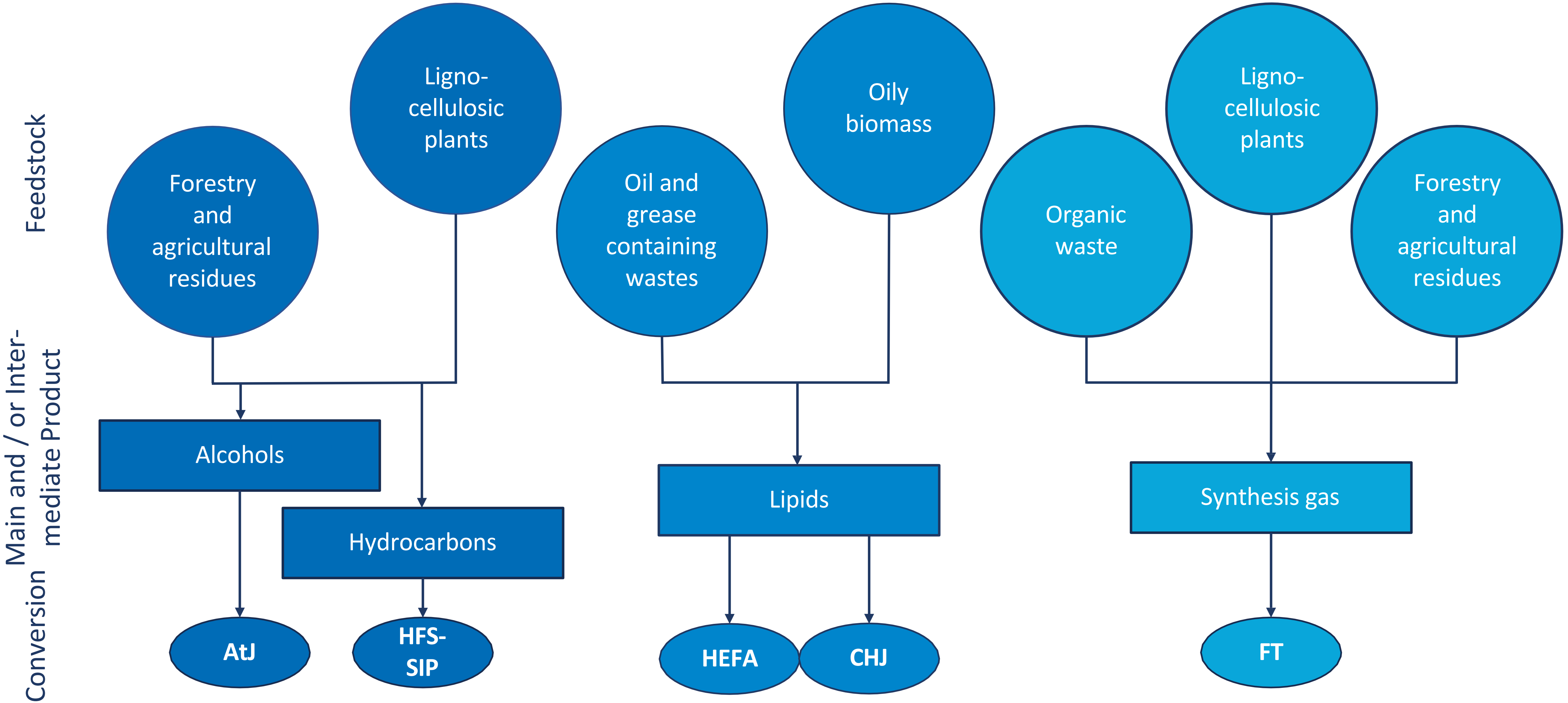


**AtJ**: Alcohol to Jet, **HFS-SIP**: Hydroprocessed Fermented Sugars to Synthetic Isoparaffins, **CHJ**: Catalyctic Hydrothermolysis Jet, **HEFA**: Hydroprocessed Esters and Fatty Acids, **FT**: Fischer-Tropsch



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

# Overview of Approved Biogenic SAF Options

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Overview of approved SAF options (as of April 2023) according to ASTM D7566 and ASTM 1655

| ASTM | Annex | Year of Approval | Process | Blending Limit | Possible Feedstock | Producers |
|---|---|---|---|---|---|---|
| D7566 | 1 | 2009 | FT-SPK | 50 Vol.-% | fats/oil (e.g. plant-based oils, used cooking oils) | 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.-% | Fats/oils (e.g. plant-based oils, used cooking oil) | Sasol |
| D7566 | 5 | 2016 | ATJ-SPK | 50 Vol.-% | sugar, starch, lignocellulose | Gevo, Cobalt |
| D7566 | 6 | 2020 | CH-SK | 50 Vol.-% | fat/oils (e.g. plant-based oils, used cooking oil) | 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 |
| D1655 | 1 | 2018 | Co-Processing | 5 Vol.-% | fats/oils (e.g. plant-based oils, used cooking oil) | |
| D1655 | 1 | 2020 | Co-Processing | 5 Vol.-% | FT-biocrude (primary feedstocks like FT-SPK, FT-SPK/A) | |
| D1655 | 1 | | Co-Processing | 5 Vol.-% | | |

**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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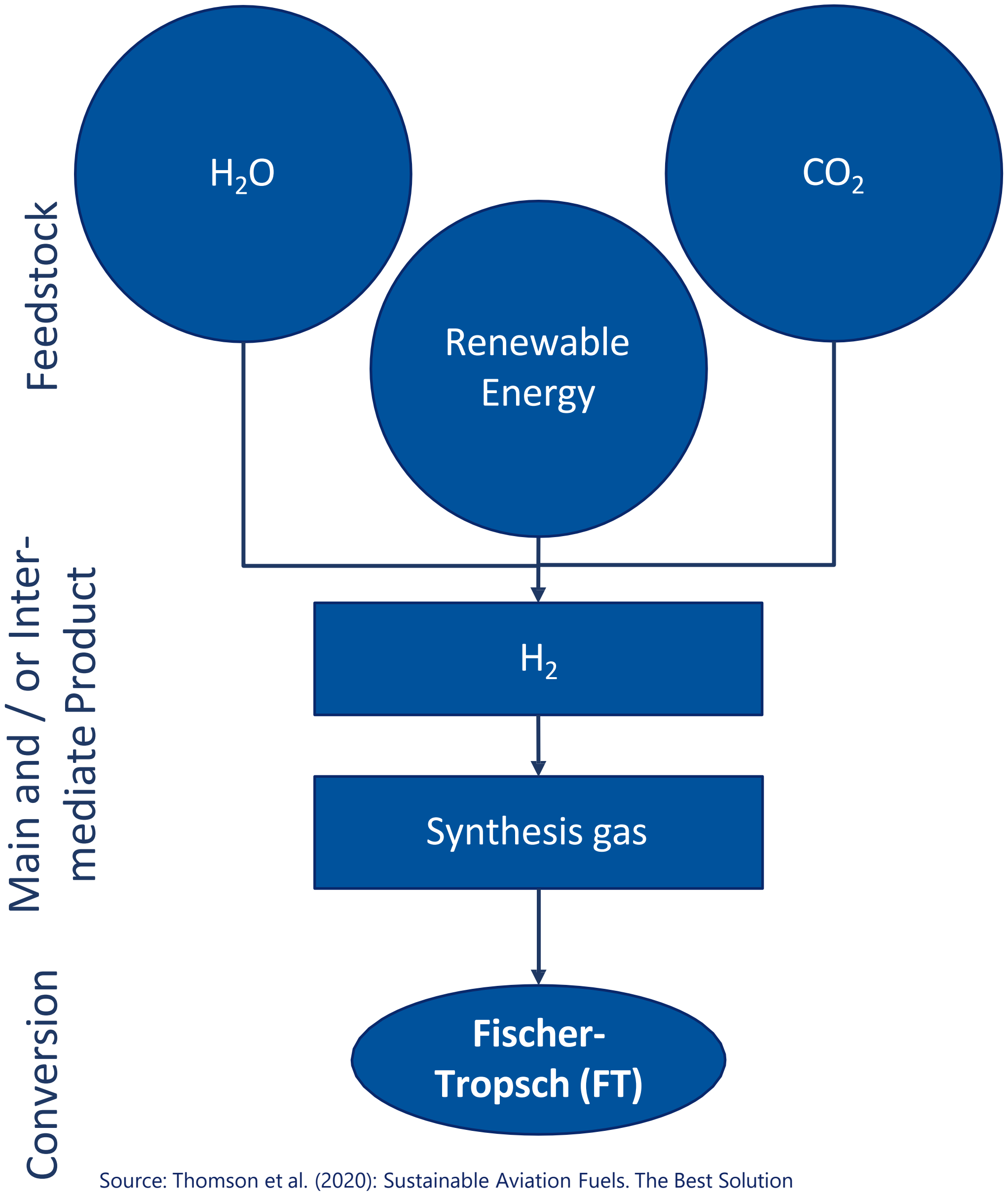
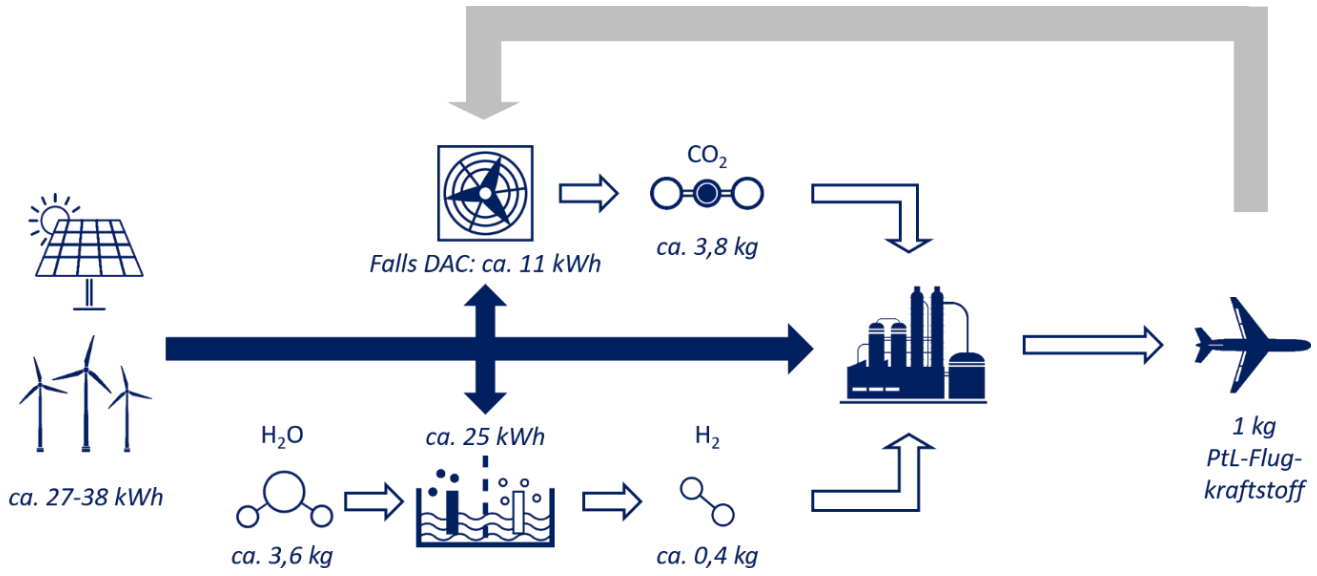



Source: Thomson et al. (2020): Sustainable Aviation Fuels. The Best Solution to Large Sustainable Aircraft

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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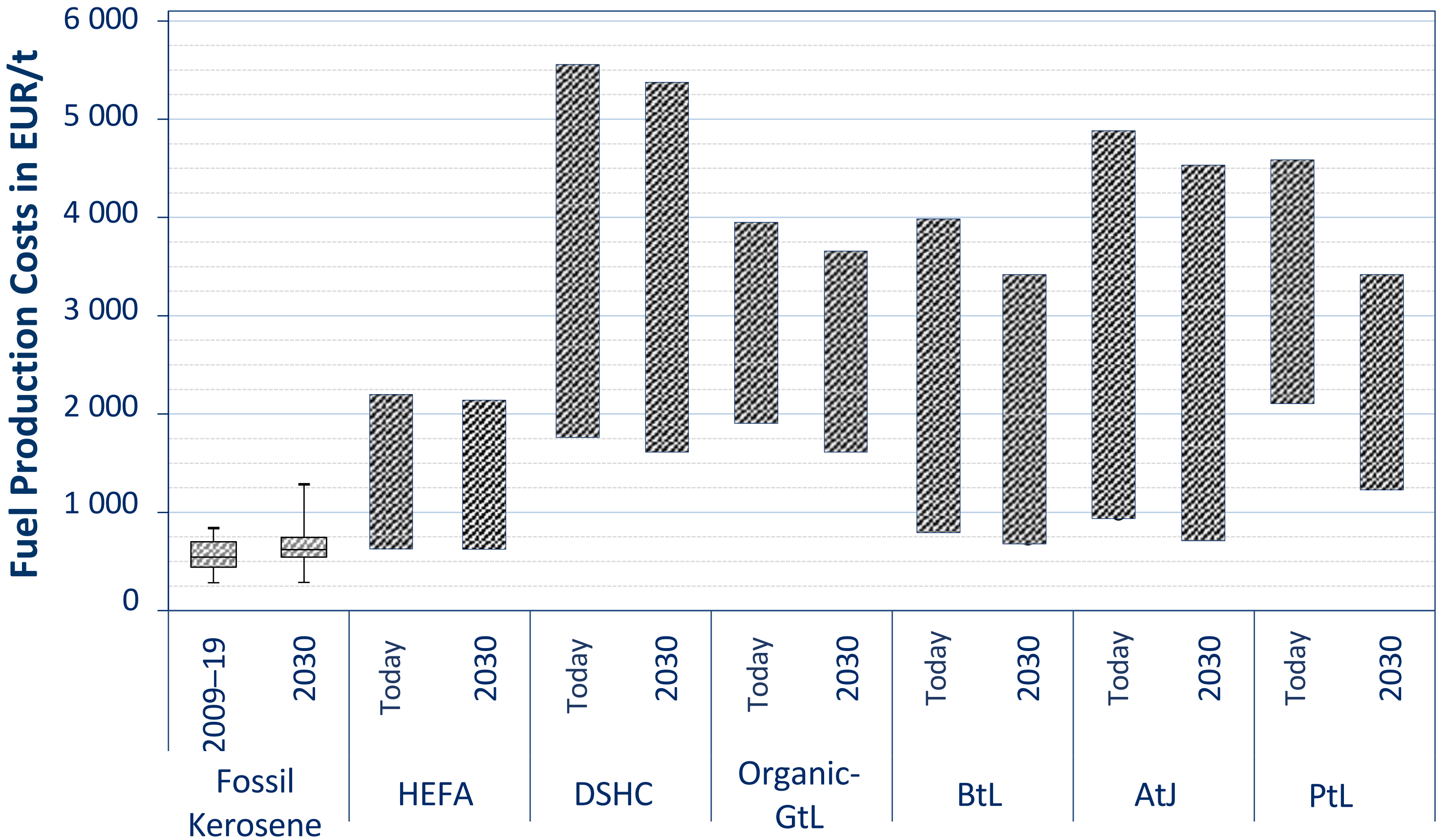


Source: aireg e.V. – TU HH / Institut für Umwelttechnik und Energiewirtschaft

- 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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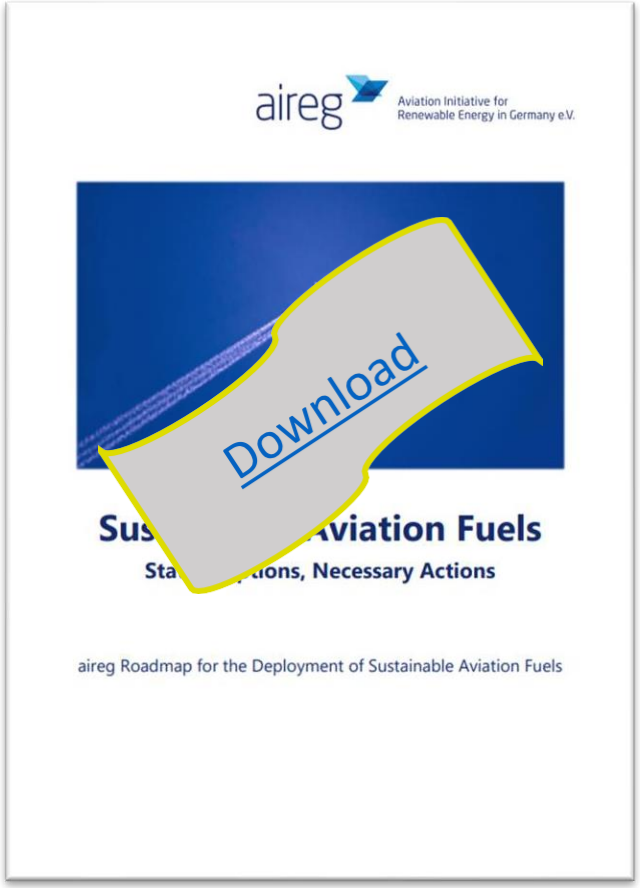
- The aireg **Roadmap** presents measures and incentives to achieve **a significant share of sustainable fuels** in aviation.
- This includes measures in the field of research and development (R&D) of corresponding manufacturing technologies, milestones for technological development and implementation 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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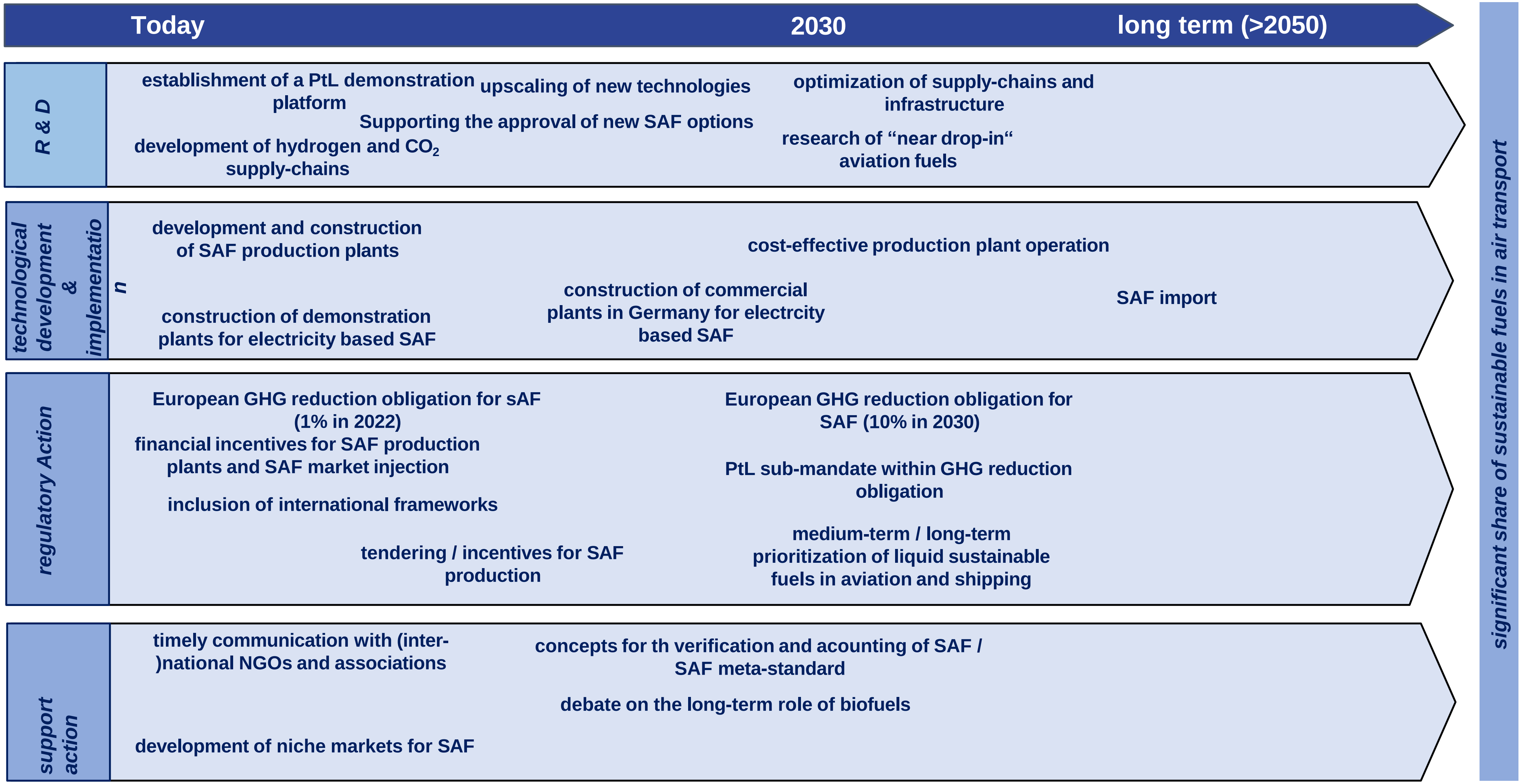

# Selection of commitments: Climate protection in aviation of different countries

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**Canada**

Carbon neutrality by 2050

**Norway**

30% sustainable fuel by 2030

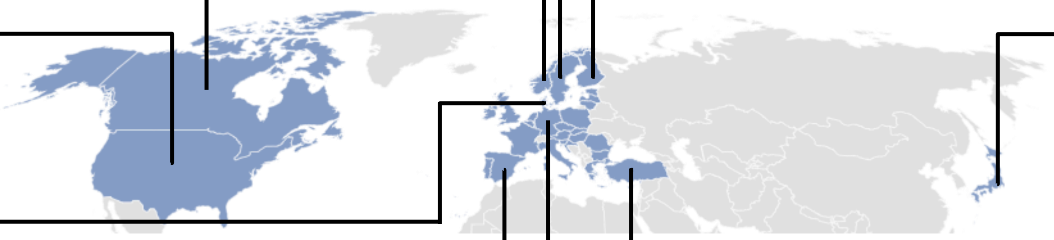
**Sweden**

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

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| | |
|---|---|
| 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 | 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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