SAFari

Core Partners:

ASG Analytik-Service

bp

CLARIANT

DLR

Fraunhofer ISE

GESAMTKONZEPT ERNEUERBARE KRAFTSTOFFE

Gefördert durch: Bundesministerium für Digitales und Verkehr

aufgrund eines Beschlusses des Deutschen Bundestages

Koordiniert durch: NOW-GMBH.DE

Projektträger: VDI|VDE|IT, FNR

Associated Partners:

AIRBUS HELICOPTERS

BDL Bundesverband der Deutschen Luftverkehrswirtschaft

SÜDZUCKER

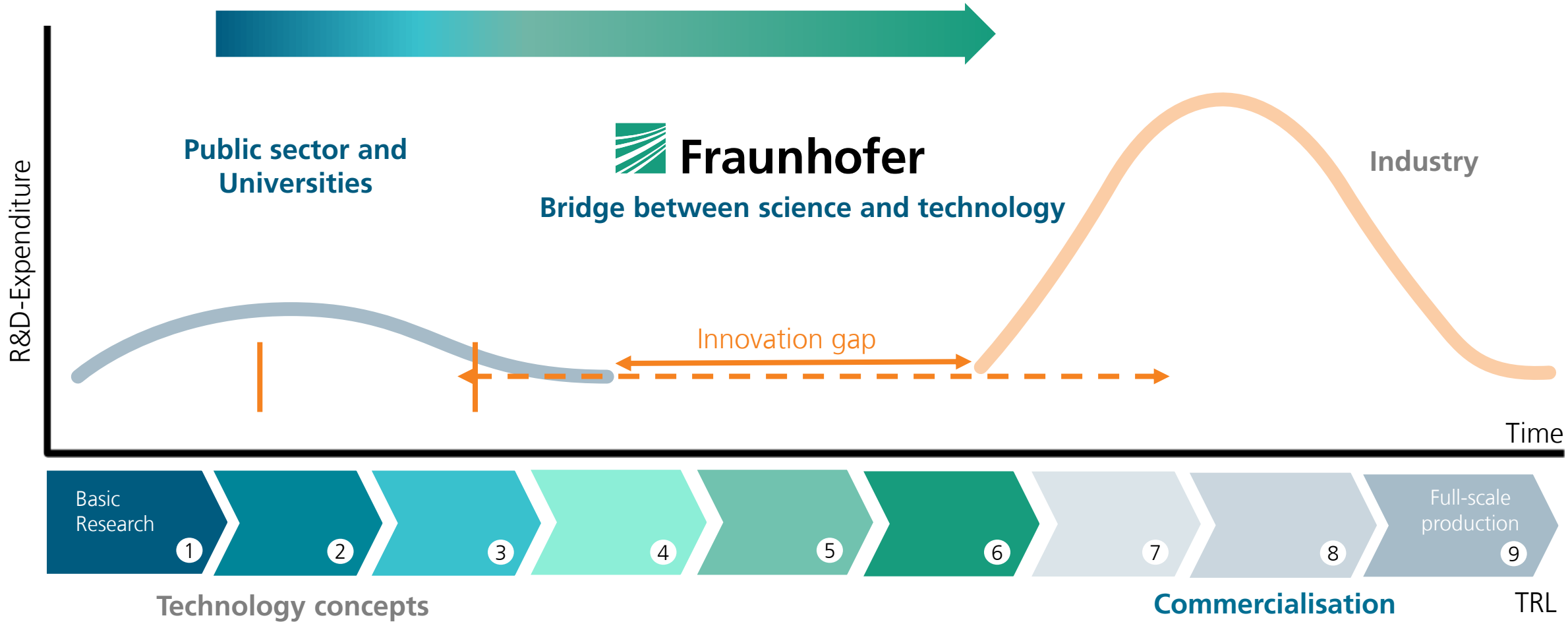
Perspectives on Methanol to Jet Fuel – SAFari Project

aireg Webinar on Sustainable Aviation, 6.11.24

Achim Schaadt
Head of Department Sustainable Synthesis Products
Division Hydrogen Technologies
Fraunhofer Institute for Solar Energy Systems, Freiburg, Germany
www.ise.fraunhofer.de

Fraunhofer Reduces the Time-to-Market

Bridging the Gap Between Conceptual Research to Commercialization along the Innovation Value Chain



Fraunhofer ISE

Fraunhofer-Gesellschaft

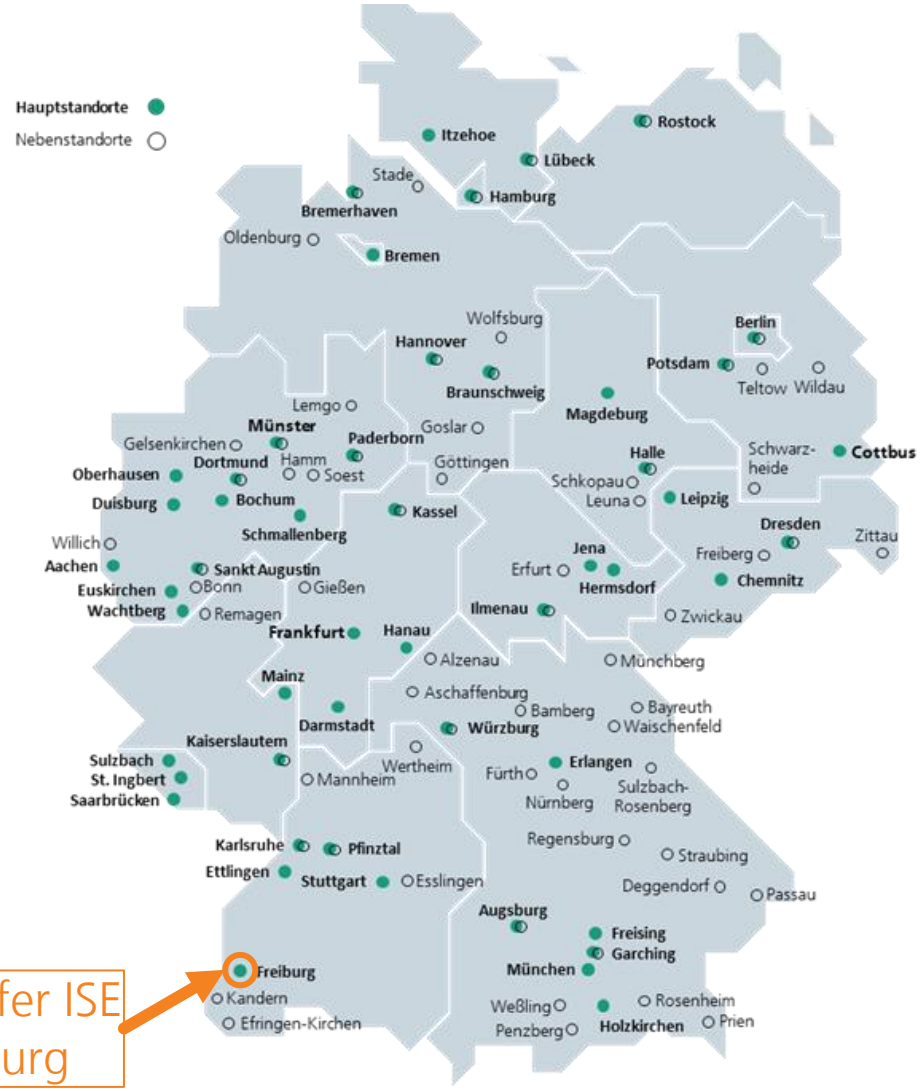
At a Glance

Applied research organization prioritizing key future-relevant technologies and the commercialization of its findings in business and industry. A trailblazer and trendsetter in innovative developments and research excellence.

> 30,000 staff

76 institutes and research units

€2.9 billion
Finance volume 2021



Fraunhofer ISE
In Freiburg

Fraunhofer ISE

Department Sustainable Synthesis Products

PtX Products - Production, Transport and Utilisation

From Catalyst to Industrial Reactors / Processes

- Techno-economic feasibility studies assessing the potential of PtX processes for your business cases
- Ecological evaluation of processes (Life-Cycle-Assessment, LCA)
- Design, test and characterisation of tailor-made catalysts (e.g. HT-NAP-XPS)
- Process development of more efficient, cost optimized processes using CO_2/CO or N_2 and H_2 as feeds
- In-house design, construction, programming and operation of miniplants
- **Unique selling points: π-COMET®, CatVap®, etc.**

Enjoy our virtual lab tour:
https://s.fhg.de/LabTourTCP

About 50 employees work on these topics:

Power to **Methanol**

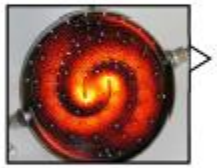
INDIGO
DME Technology

Clean **OME** Technology (π-COMET®)

Methanol to **Jet fuel** (SAFari)

DAC Material and Process Characterisation

NH_3 Technology (PICASO)



Electrically Heated Catalyst Carrier for **Reforming** Reactions (CatVap®, e.g. DME-, NH_3 Reforming)

LOHC as H_2-carrier

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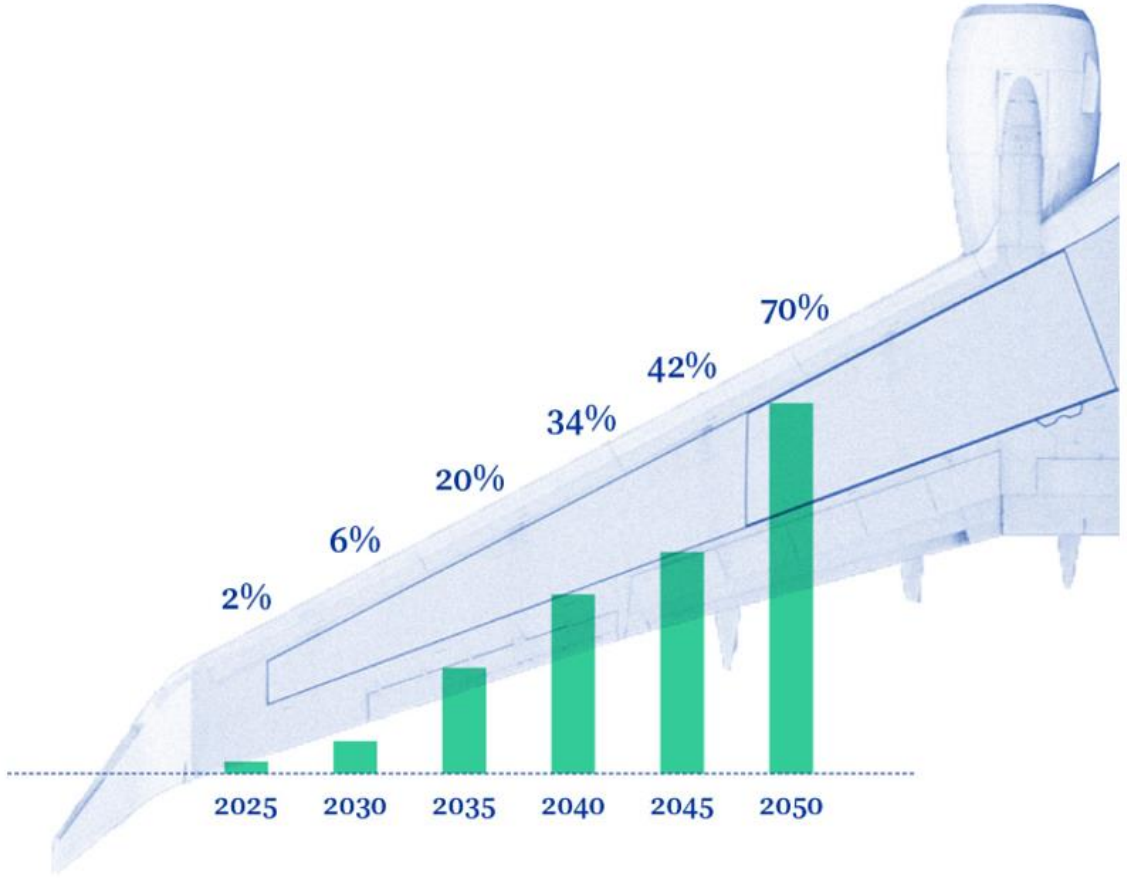
Sustainable Aviation Fuels (SAF) Mitigate the Climate Impact of Aviation

The EU Requires a 70% Share of SAF by 2050

Obligation to gradually increase the share of SAF (ReFuelEU Aviation) in flights leaving the EU

- 2 % SAF by 2025
- 6 % SAF by 2030



Aircraft fuel suppliers at EU airports, minimum share of supply of sustainable aviation fuel. [1]

[1] European Council Infographic. 2023. https://www.consilium.europa.eu/en/infographics/fit-for-55-refueleu-and-fueleu/, accessed 7.10.2024

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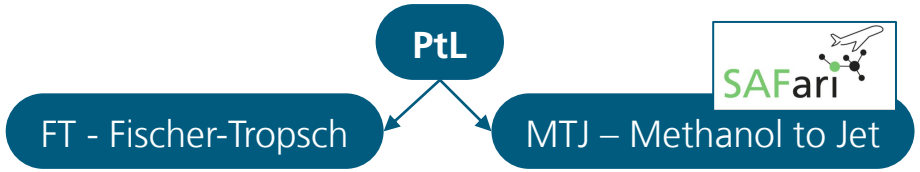
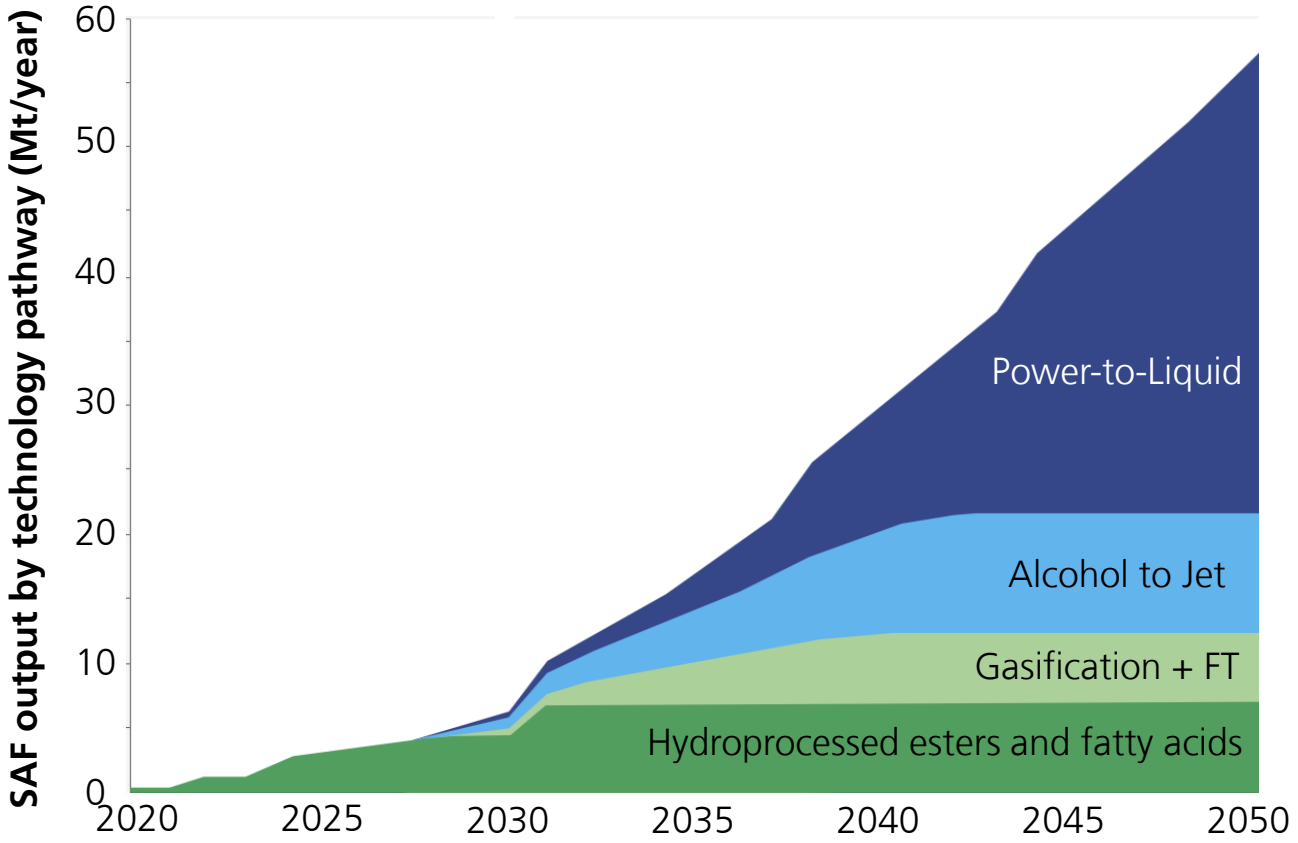
- 6 % SAF by 2030

Currently, the majority of SAF is produced via hydrotreating biobased feedstocks, such as used cooking oils

SAF produced via power-to-liquid (PtL) processes is becoming increasingly important, as the production capacity is not limited by the availability of biomass





Predicted SAF output by technology pathway. Adapted from [2].

[1] European Council Infographic. 2023. https://www.consilium.europa.eu/en/infographics/fit-for-55-refueleu-and-fueleu/, accessed 7.10.2024
[2] Clean Skies for Tomorrow. 2021. https://www3.weforum.org/docs/WEF_CST_EU_Policy_2021.pdf, accessed 7.10.2024

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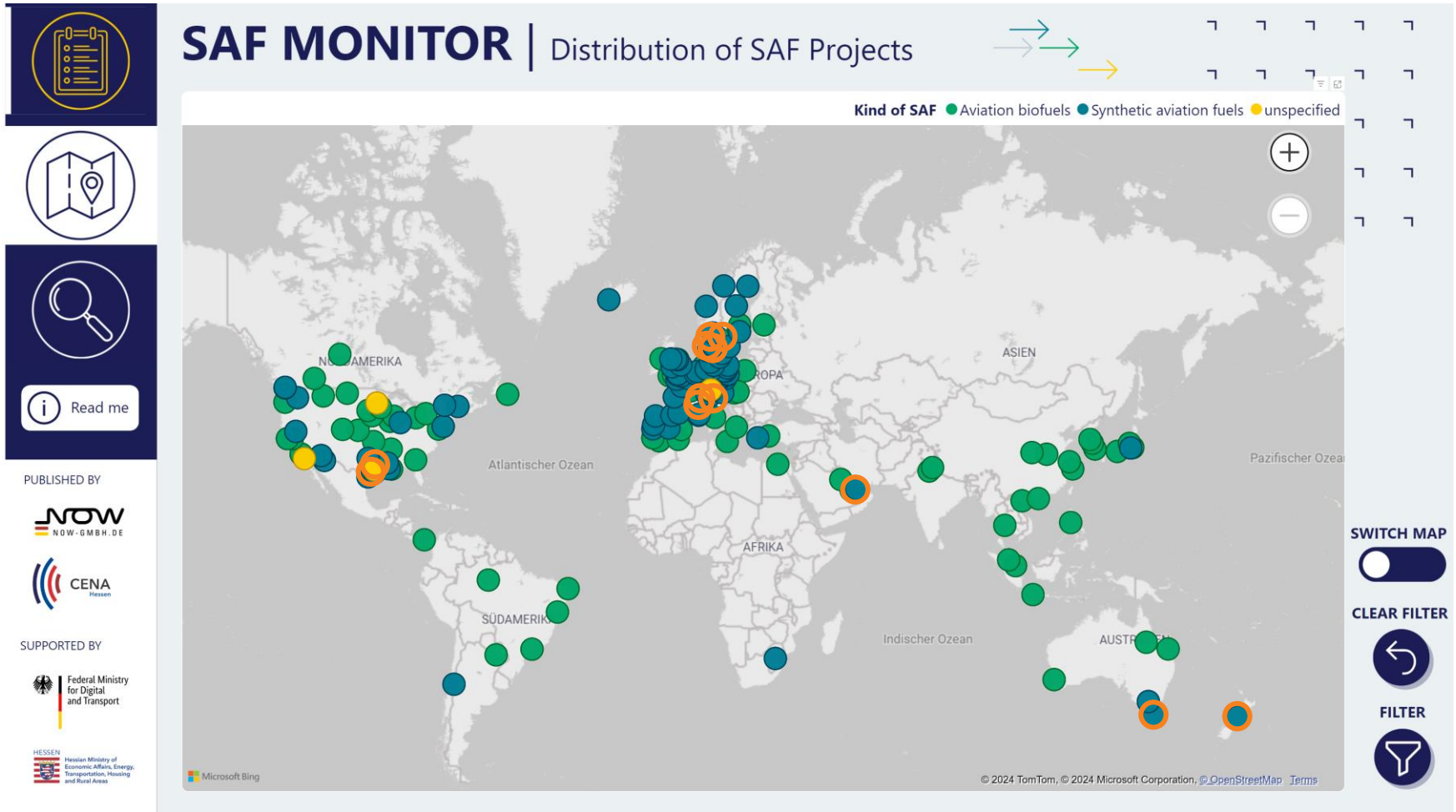
MTJ – Methanol to Jet Fuel

SAF Announcements Overview



- Synthetic aviation fuels (mainly FT)
- Synthetic aviation fuels (MTJ)
- Aviation biofuels (mainly HEFA)
- unspecified

SAF projects by cena Hessen (Status May 2024) [1]

[1] https://www.cena-hessen.de/en/projects/saf-monitor/ [last access, October 2024].

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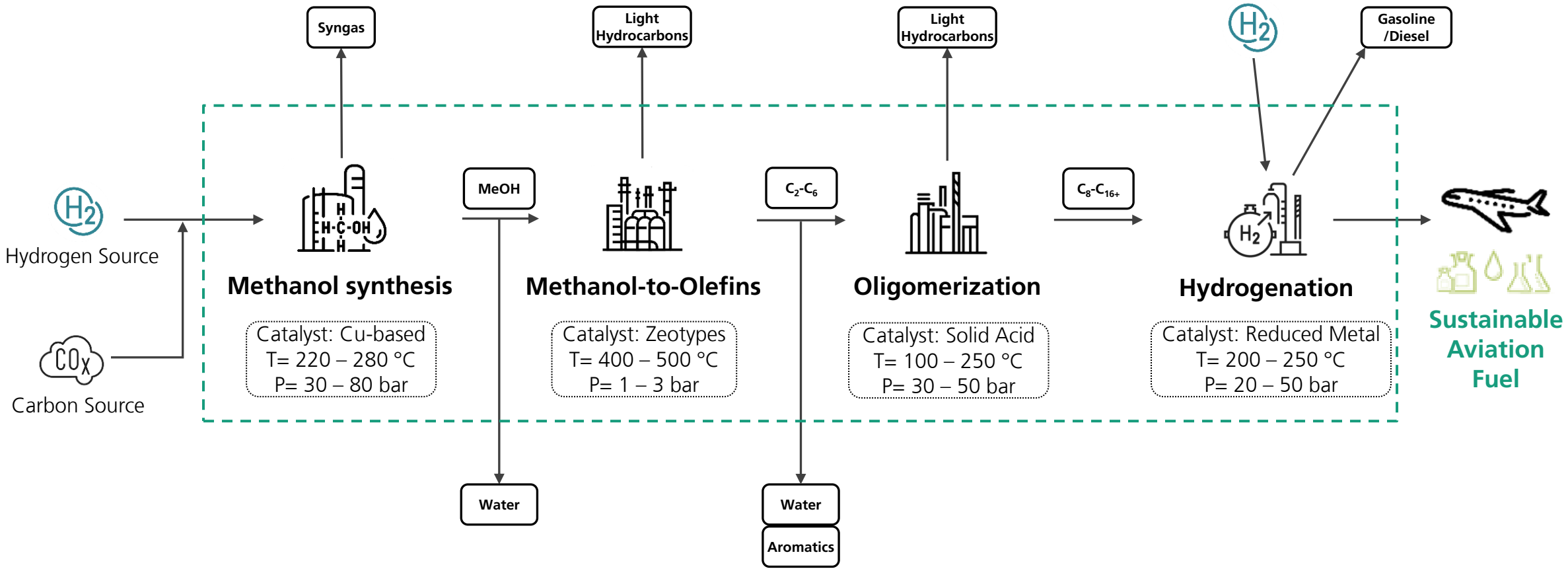
MTJ – Methanol to Jet Fuel

Process Overview: Starting from Hydrogen and Carbon Dioxide



Methanol to jet fuel pathway [1]

[1] A. Elwalily, E. Verkama, F. Mantei, A. Kaliyeva, A. Pounder, J. Sauer, F. Nestler. (2024). Sustainable Aviation Fuel Production via the Methanol Pathway: A Technical Review. [Manuscript accepted for publication].

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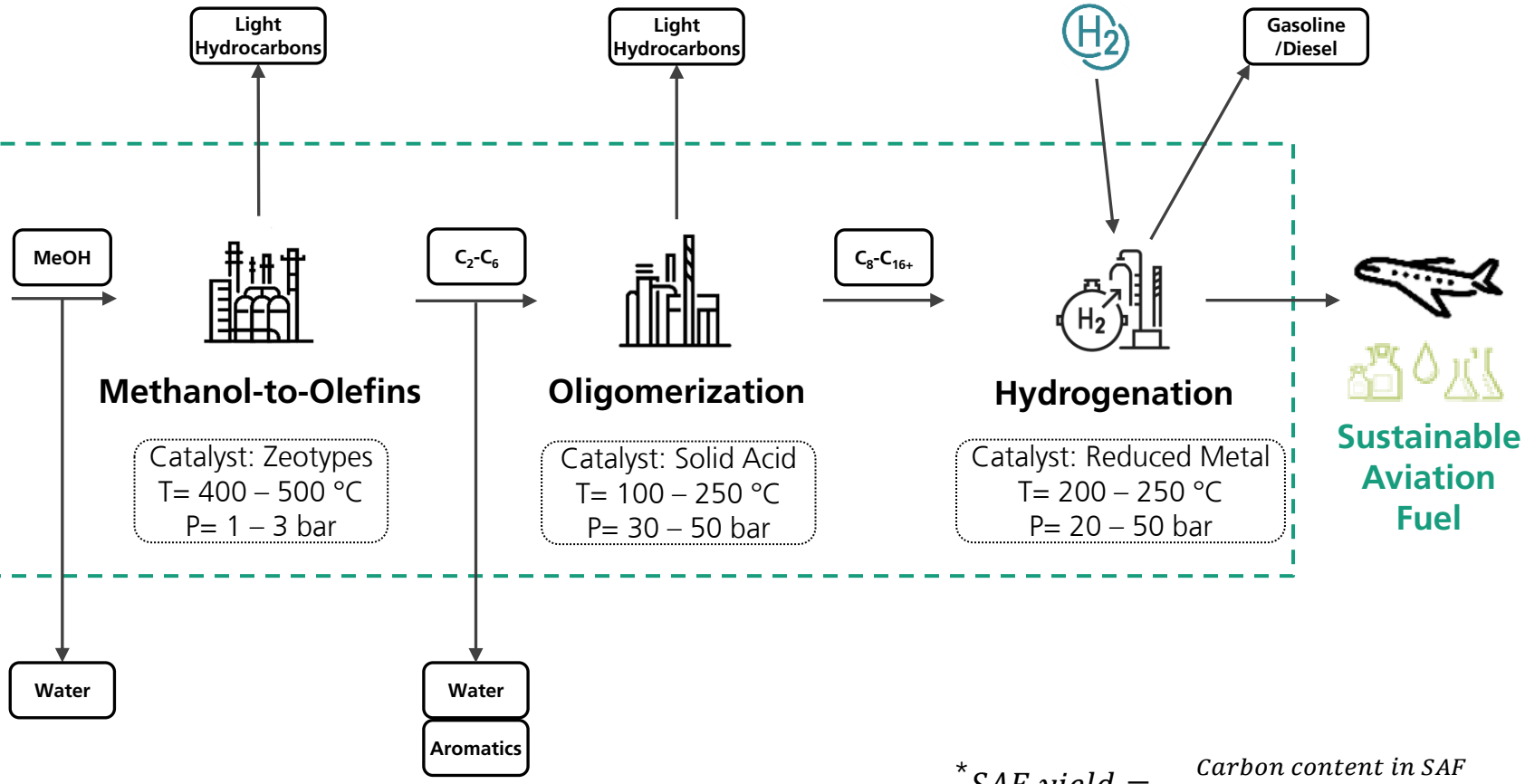
MTJ – Methanol to Jet Fuel

Process Overview

Advantageous of MtJ

- **Flexible MeOH production** (various raw materials, dynamic operation, etc.)
- High **SAF yield > 70%***
- High overall process **energy efficiency**
- **Flexible product distribution** (light olefins, gasoline, SAF, diesel, etc.)
- **High TRL** of individual subprocesses

➢ **Process integration** (recycle streams, etc.) and **optimization** for target product distributions (e.g. high SAF yield)



Methanol to jet fuel pathway [1]

$$^{*}SAF\ yield = \frac{Carbon\ content\ in\ SAF}{Carbon\ content\ in\ Methanol}$$

[1] A. Elwalily, E. Verkama, F. Mantei, A. Kaliyeva, A. Pounder, J. Sauer, F. Nestler. (2024). Sustainable Aviation Fuel Production via the Methanol Pathway: A Technical Review. [Manuscript accepted for publication].

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MTJ – Methanol to Jet Fuel

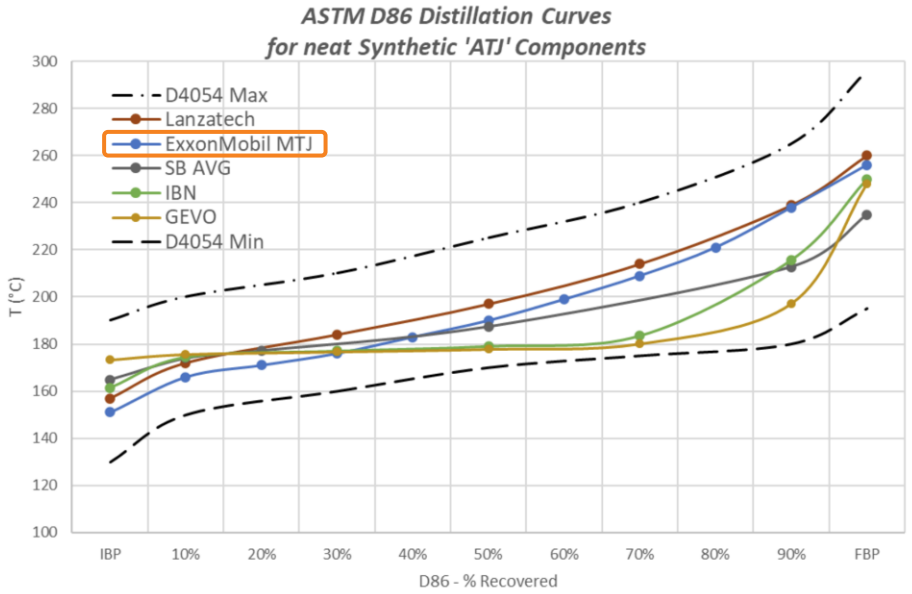
ASTM Approval

ASTM INTERNATIONAL
Helping our world work better

ASTM D02.0J AC724 Task Force [1]

- Start: Dec 2022
- Objective: 50 vol.% blending of MTJ SAF
- Participants: ExxonMobil (lead), Topsoe, UOP, Fraunhofer ISE, DLR, Clariant, BP and further
- Status: Delivery of samples to Clearinghouse
  - ExxonMobil
  - UOP
  - Topsoe
  - Further samples expected
- Iteration of the first report
- Tier 1 and 2 properties analysis and evaluation on samples

- New SAF processes must be approved by the **ASTM D7566**
- **ASTM D4054** outlines the data the industry requires
- SAF and fossil jet fuel blends must be approved by the **ASTM D1655**



ASTM 86 distillation curves of various ATJ samples and ExxonMobil MTJ sample show similar shapes. [1]

[1] D. Kadlecek (2023). Methanol to Jet (MTJ) – ASTM D02.0J AC724 Task Force, https://www.caafi.org/resources/pdf/Methanol-to-Jet_CAAFI_Kadlecek_07_25_2023.pdf (last access: October 2024).

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BMDV Public Funding

- The main objective of the SAFari project is the **production** and testing of Sustainable Aviation Fuel (**SAF**) from **methanol** in a **pilot plant** for the purpose of **full ASTM approval** and the achievement of a blend rate also of perspective **> 50%** SAF.

Scan the **QR code** for more information on the **SAFari project**

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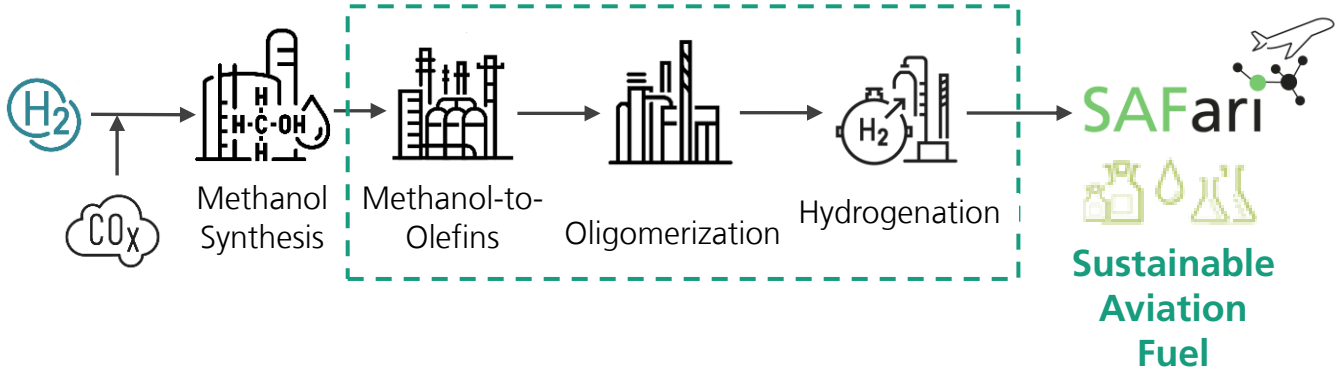
SAFari Project – Sustainable Aviation Fuels based on Advanced Reactions and Process Intensification

SAFari
- Project duration: 6 years, **2022-2028**
- Funding budget: **15 Mio. €**
- **BMDV** public funding
- Coordination: FhG **ISE**
- **Partners**
  - **ASG** Analytik-Service AG
  - **BP** Europa SE
  - **Clariant** Produkte (Deutschland) GmbH
  - **DLR** Institut für Verbrennungstechnik
- **Associated partners**



Partner	Tasks	Partner	Tasks
Fraunhofer ISE	Project management / process development and simulation / pilot plant / TEA / LCA	ASG Analytik-Service	Process development separation / analytics / gaseous feedstock preparation
CLARIANT	Catalyst preparation / qualification / oligomerization / process optimization	bp	ASTM support / refinery integration logistics / market introduction
DLR	Analytics / ASTM pre-screening and approval procedure / combustion tests		

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Time line

Phase 1
2022-2025
Optimization / Pre-Screening /
Pilot Plant Engineering

SAFari Pilot plant
TRL > 5

Phase 2
2026-2028
Demonstration / TEA / LCA / Scale-up /
Conceptual Engineering > 100 kt/a

Modular pilot plant for demonstration & testing

Business Case Development, ASTM Approval Procedure, Patents, etc.

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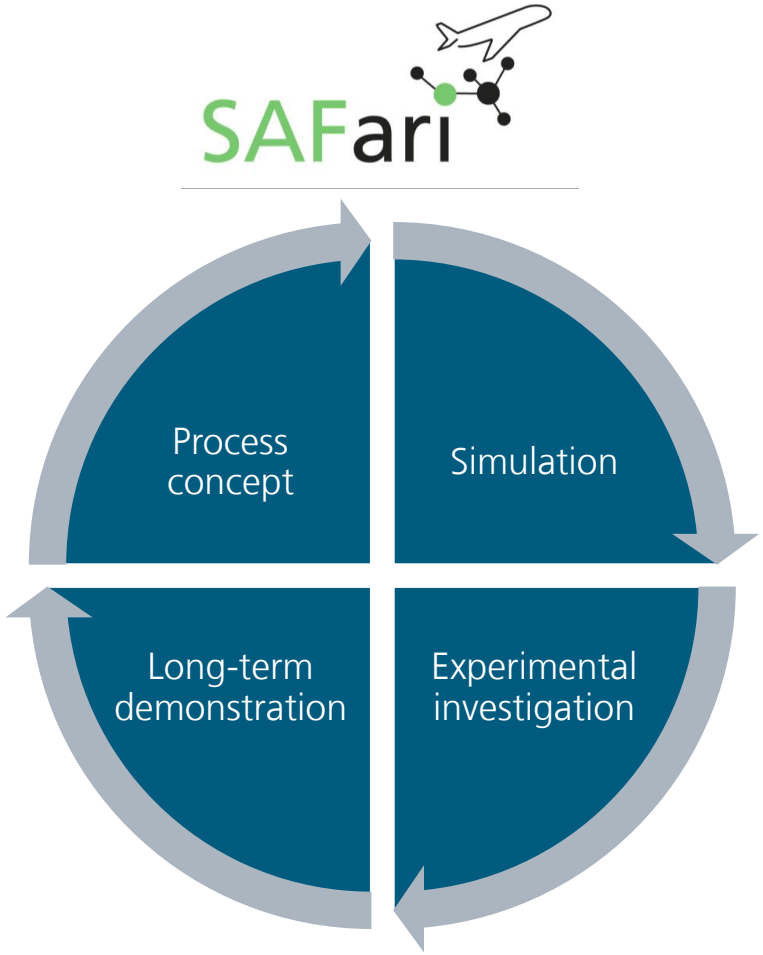
Process Development and Simulation

Process development objectives

- High **SAF yield > 70%** (carbon basis)
- High overall process **energy efficiency**
- ➢ Process integration (recycle streams, heat integration, etc.) and optimization
- In addition: Concept development for the **integration** of MtJ process into **refinery infrastructure**
  - Range of products
  - Feedstock supply
  - Heat integration
  - etc.



Process simulation in Aspen Plus

- Detailed modelling of the individual **synthesis steps**
- Detailed modelling of the **product separation**
- **Process integration** and **optimization**
- **Heat integration** strategies
- Process equipment sizing for **Conceptual engineering** for **> 100 kt/a SAF plant**
- Techno-economic, ecologic and risk assessment
- Comparison of alternative process concepts

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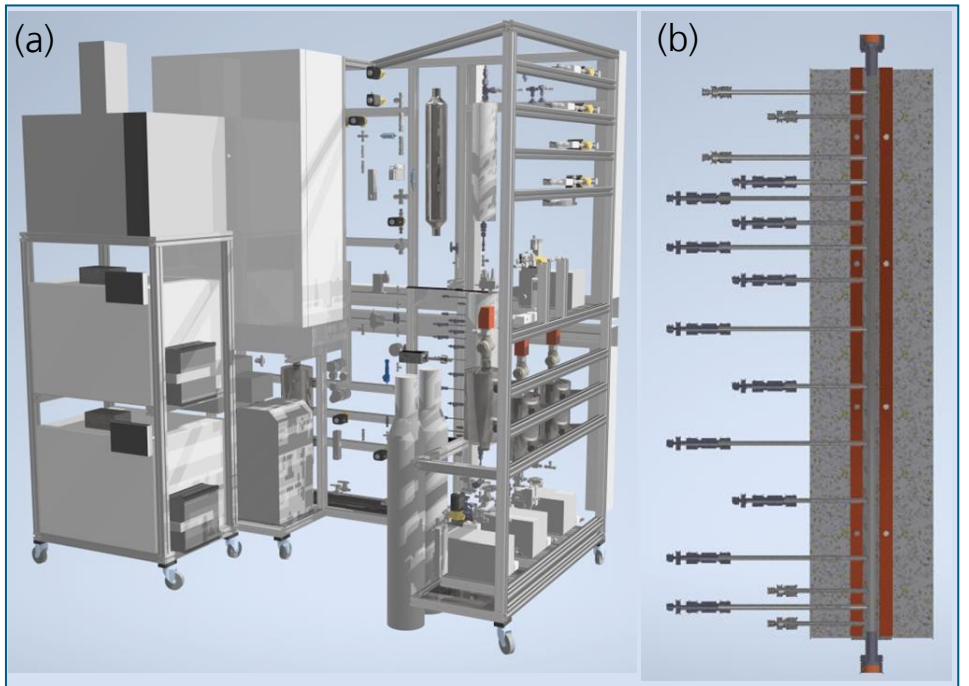
Experimental Investigation of Synthesis Steps Using Tailor-Made Test Rigs

Syntheses investigation

- **Flexible feedstock dosing** (gases, liquid gases, liquid)
- **Temperature profile** (16 sensors)
- **Concentration profile** (11 sampling lines)
- **Online analytic** (GC-FID/TCD)
- **Automated 24/7 operation** (data recording, adjusting operation conditions, etc.)



(a) **Kinetic investigation** and screening setup
(b) Reactor unit for experimental optimization of the **MTO synthesis**.
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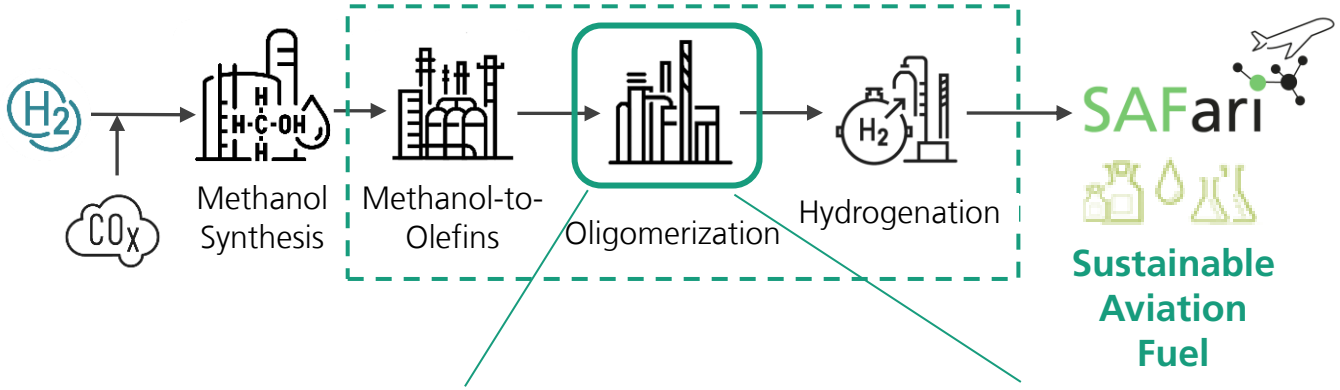
SAFari Project – Sustainable Aviation Fuels based on Advanced Reactions and Process Intensification



Olefinic MtJ SPK samples for analytics and property evaluation which might be used for ASTM after hydrogenation.

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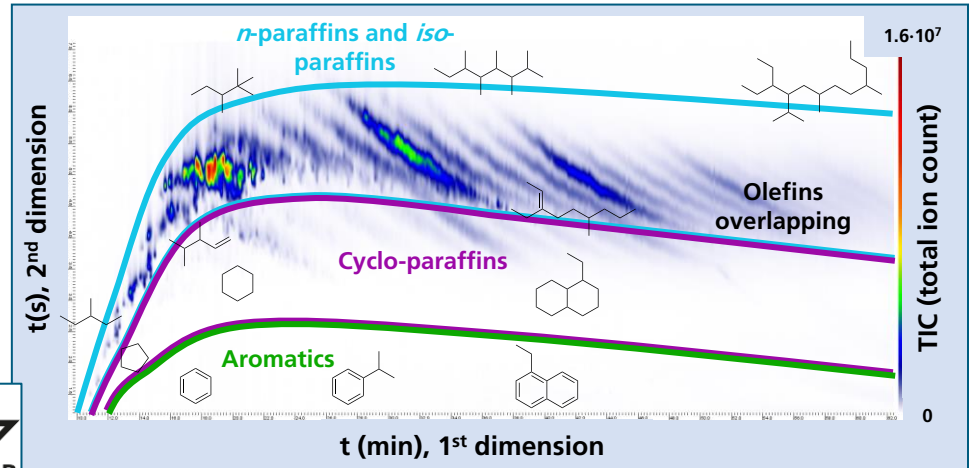
Accurate Analysis of Samples



Detailed **analysis** of the intermediate products by two-dimensional gas chromatography and mass spectrometry.

Analytics

- **Online analytic** (GC-FID/TCD) on the setups
- **2 dimensional GCxGC-MS** and **FID** for detailed product distribution for longer chain hydrocarbons (e.g. different isomer identification)
- Various analytic devices to measure **fuel properties for ASTM**
- model and data based **jet fuel prescreening** to predict relevant properties based on low volumes (ml) via analytic evaluation

→ **Iterative optimization of process conditions based on fast analytic response**

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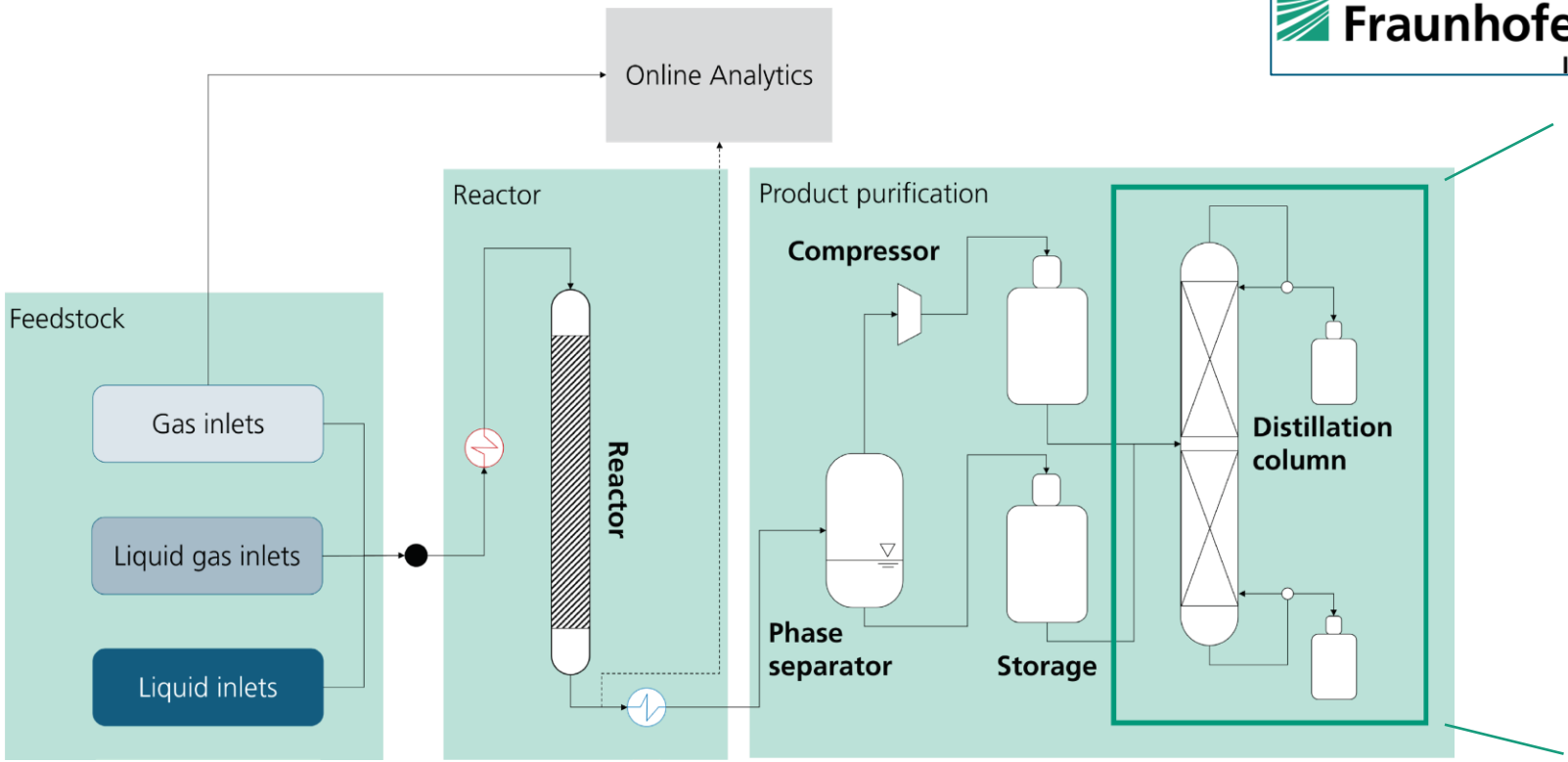
Pilot Plant

Demonstration in a pilot plant



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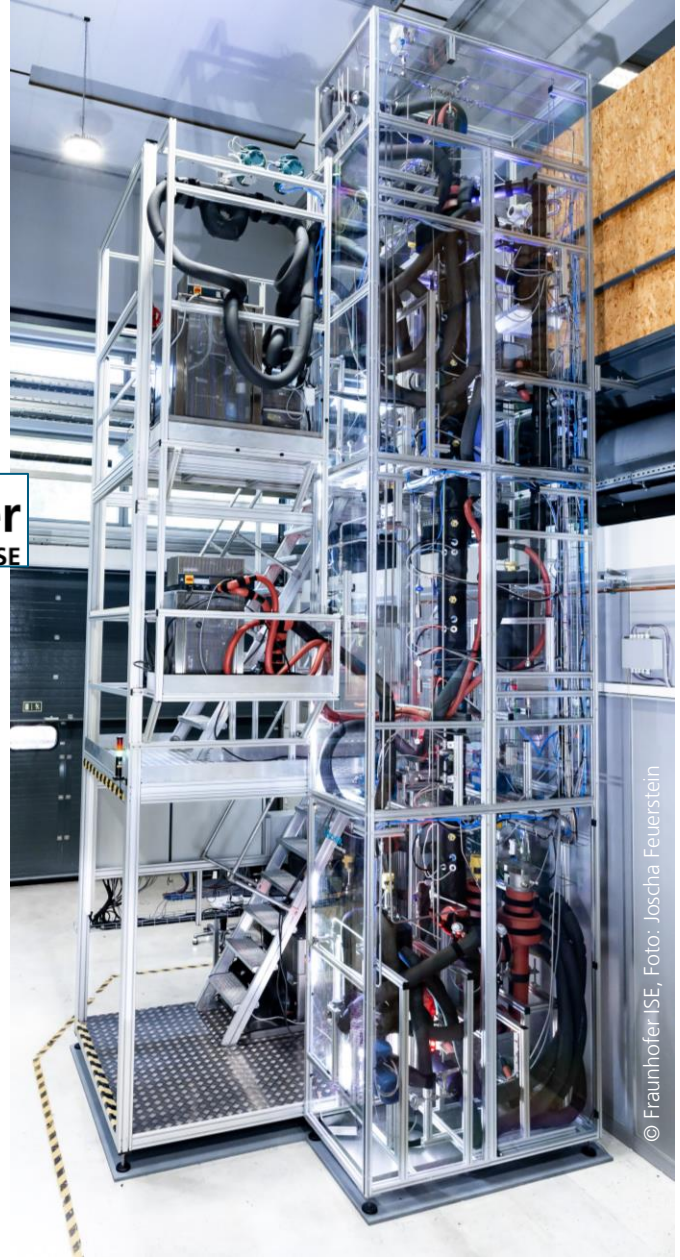

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Conclusion

MTJ processes are promising options for the production of SAF at a large scale.

The SAFari project contributes to the development of the MtJ technology by:

- **detailed process simulations and modelling**
- **experimental investigations: Optimisation and integration of individual subprocesses for a high SAF yield**
- **demonstration in a pilot plant**
- **supporting ASTM MTJ task force activities**

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Scan the **QR code** for more information on the **SAFari project**

Many thanks to the SAFari Team

SAFari

FUNDING PROGRAMME RENEWABLE FUELS

Funded by: Federal Ministry for Digital and Transport

on the basis of a decision by the German Bundestag

Coordinated by: NOW GMBH.DE

Project management agency: VDI|VDE|IT, FNR

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