ITALIAN NATIONAL AGENCY FOR
NEW TECHNOLOGIES, ENERGY AND
SUSTAINABLE ECONOMIC DEVELOPMENT

TOKYO GX WEEK

7th RD20 Conference

Sustainable Aviation Fuels in Italy: opportunities and research challenges faced by ENEA

30th September 2025

TS #1: Synthetic fuels including a wide range of resources, conversion processes and products

Claudia Bassano, Nadia Cerone, Paolo Deiana, Giuseppina Vanga, Rosanna Viscardi

ENEA: Italian National Agency for New Technologies. Energy and Sustainable Economic Development

- 4 Departments: **Energy Technologies and Renewable Energy Sources**. Energy Efficiency. Environment and Sustainability and Fusion and Nuclear Safety
- 9 Research Centers
- 5 Research Laboratories
- a network of territorial offices providing information and consultancy services
- an ENEA-EU Liaison Office in Brussels
- ENEA headquarter in Rome

The 2° Italian R.O.
around 2700 employees

Our mission

Promote the growth and **increase the competitiveness** of the business sector, public administration. and society at large through **technology development**, the **transfer of innovation** and **advanced services**

Our challenge

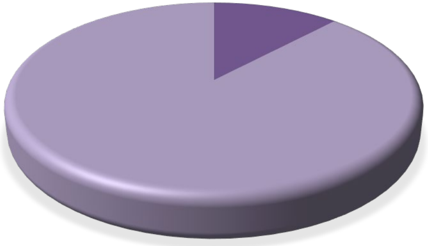
Today ENEA is called to **contribute to the ecological transition** and **provide solutions** in highly critical sectors:

- Energy. from generation to efficient use
- Climate change
- Circular economy
- Eco-friendly technologies to protect the environment. health and ensure safety

ENEA: Areas of activity. expertise and commitment

- Energy Technologies and Renewable Energy Source Department
- Nuclear Fusion Department
- Sustainability Department
- Energy Efficiency Department
- Technology Transfer. Innovation and Development Department
- PNRA, the Italian Research Programme in Antartica
- Radioprotection

What's the current state of aviation sustainability?



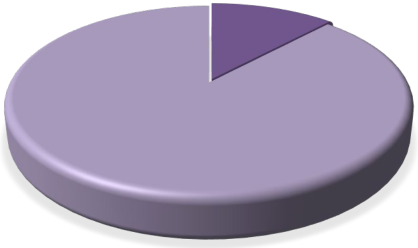
2.05%

The global aviation industry produces around 2.05% of all human-induced CO_2 emissions.

CO_2

50 grams CO_2/ seat kilometer

A typical new generation single aisle aircraft coming off the production line today

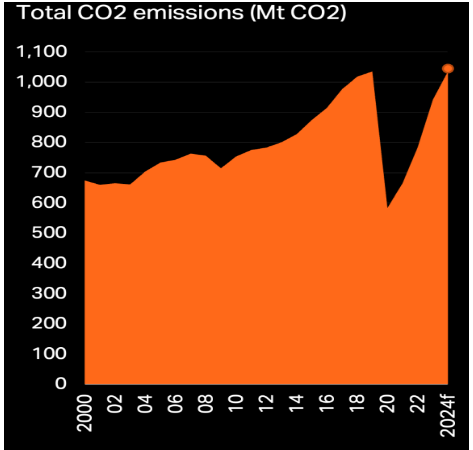


12%

Aviation is responsible for 12% of CO_2 emissions from all transport sources

Source: https://atag.org/facts-figures

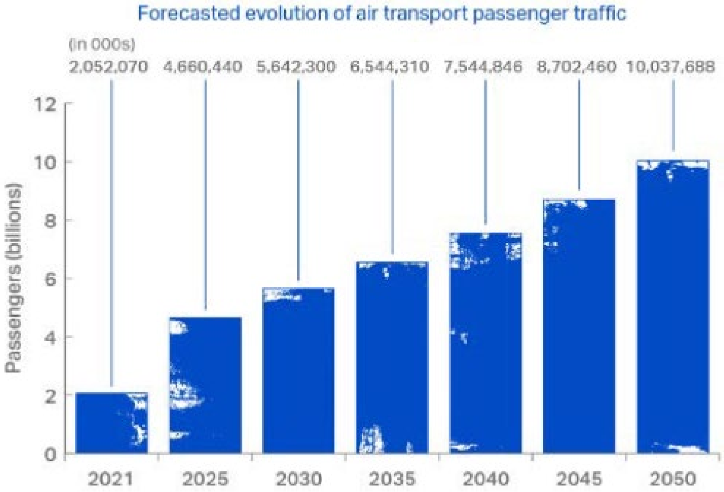
Ensuring aviation's sustainability requires more than just efficiency gains!!!!



Source: «Sintesi catalitica selettiva di e-cherosene: opportunità e sfide» Carlo Giorgio Visconti Workshop"IL RUOLO CHIAVE DI E-FUEL E BIO FUEL NELLA TRANSIZIONE ENERGETICA" Roma, 19.05.2025

Efficiency → reduce emissions per seat

growing travel demand → offsets the progress



www.iata.org/flynetzero Net zero carbon 2050 resolution

2025 set to break all records for air travel volume!!!

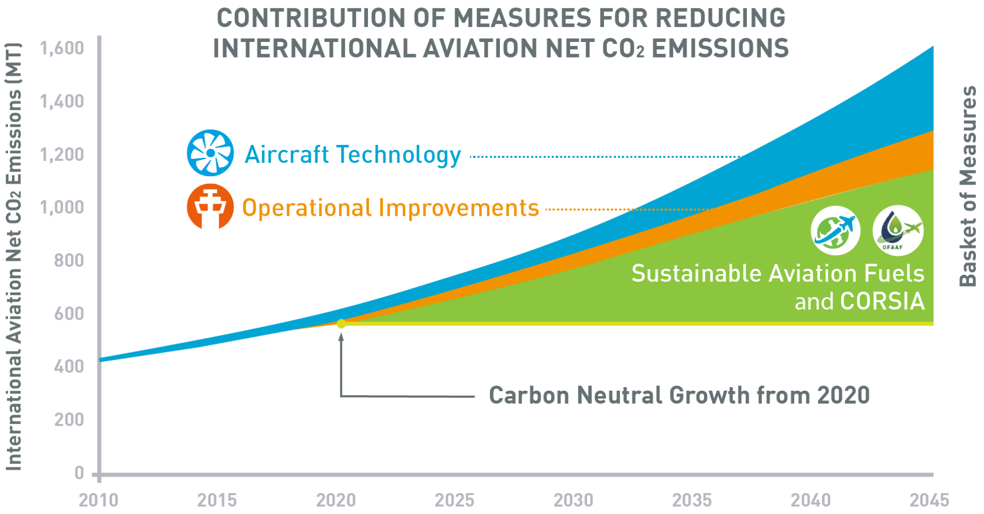
As the effects of the pandemic fade, IATA projects global air travel to reach 5.2 billion passengers in 2025 — an increase of 500 million compared to pre-COVID levels in early 2020.

How can we contribute to making aviation more sustainable?

The ICAO Global Framework for Sustainable Aviation Fuels (SAF) outlines a shared global aspirational vision to cut CO_2 emissions from international aviation by 5% by 2030, relative to a baseline of no cleaner energy use

ICAO

ENVIRONMENT



41st Assembly (2022), Long-Term Aspirational Goal (LTAG)

net-zero carbon emissions from international aviation by 2050

SAF- Sustainable Aviation Fuels

Sustainable Aviation Fuels

renewable or waste-derived aviation fuels that meets the CORSIA sustainability criteria. net CO_2 reduction of at least 10% compared to the baseline fossil kerosene (89 gCO2e/MJ for jet fuel).

ICAO ENVIRONMENT

CORSIA CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION

- ✓ SAF refers to drop-in fuels (whit JET A1) made from renewable sources.
- ✓ SAF meet the same technical and safety standards as conventional jet fuel
- ✓ Blending up to 50% SAF with CAF is allowed: “blended SAF” must meet the requirements set out in ASTM D1655 or Defence Standar d91-091
- ✓ SAF can be used with existing aircraft and infrastructure
- ✓ No modifications or additional investments are needed

SAF ?

1 million tonnes SAF in 2024

In 2024, 1 million tonnes (1.3 billion litres) of SAF was used for commercial flights

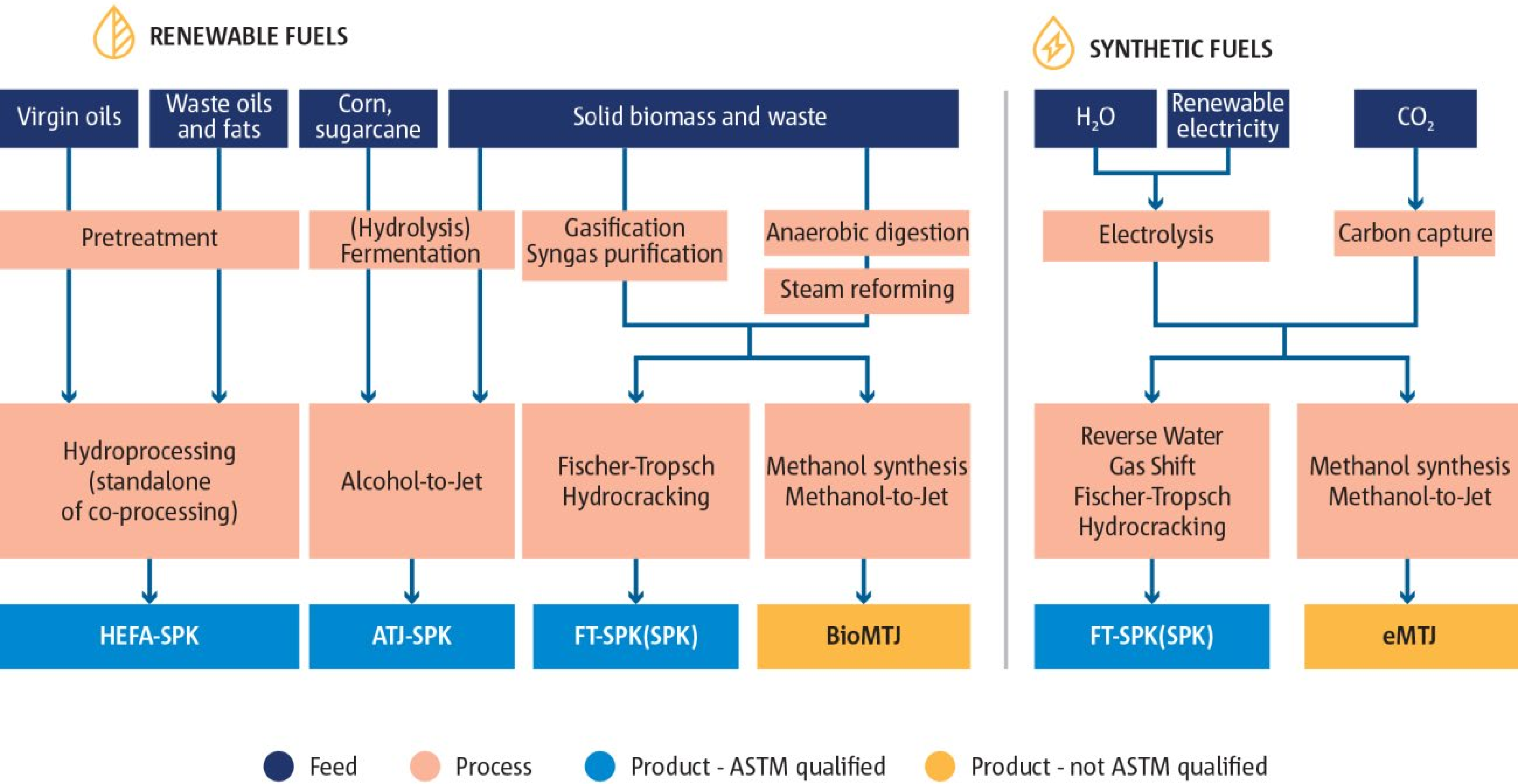
2x 2023 production

In 2024, SAF production was more than double the 240,000 tonnes produced in 2023.

0.7%

In 2025 SAF accounting for 0.7% of airlines’ total fuel consumption

Source: https://atag.org/facts-figures



https://www.easa.europa.eu/

Production Pathways and Technologies

ASTM

11 synthesis processes approved for the production of drop-in SAF.

11 more are under evaluation.

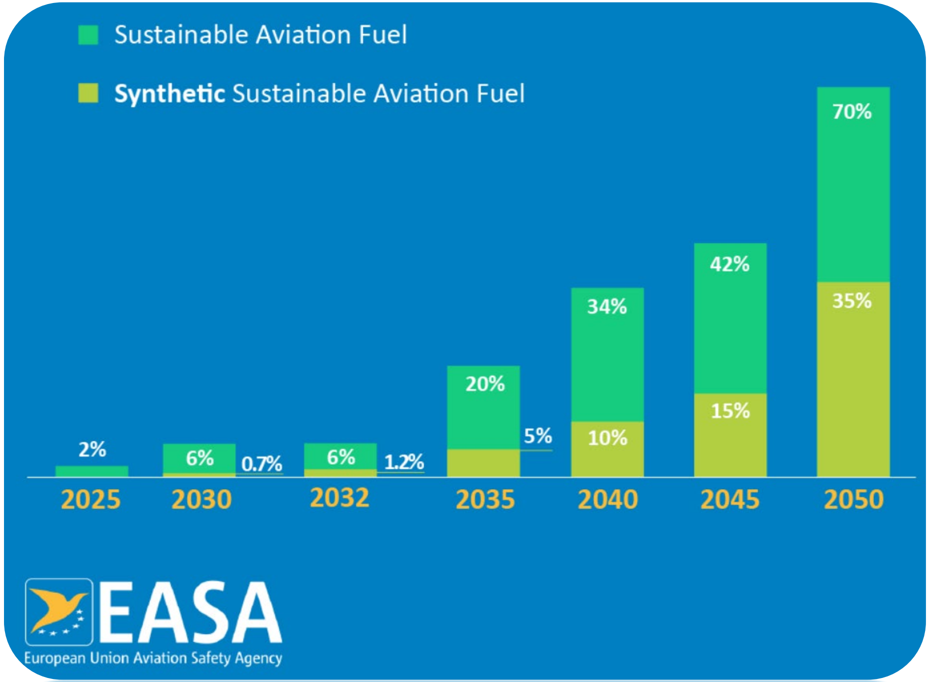
	HEFA (HYDROPROCESSED ESTERS AND FATTY ACIDS)	ATJ (ALCOHOL-TO-JET)	FT (FISCHER-TROPSCH)	PTL (POWER-TO-LIQUID)
ASTM reference	ASTM D7566 Annex A2 (50% max blend ratio)	ASTM D7566 Annex A5 (50% max blend ratio)	ASTM D7566 Annex A1 (50% max blend ratio)	N.A.
Feedstock	Vegetable oils + H_2 Animal fats + H_2 Used Cooking Oils + H_2	Ethanol and isobutanol from biomass fermentation + H_2	Syngas (CO + H_2) from biomass gasification	CO_2+ (green) H_2
Process	Hydrodeoxygenation + hydroprocessing	dehydration + oligomeriz. + hydroprocessing	FT + hydroprocessing	Different routes available
Advantage	Maturity Existing supply chains	Amount of feedstock Cheap feedstock	Unlimited potential via DAC or DOC	
Disadvantage	Amount of feedstock	Collection of feedstock; cost of 2nd gen. ethanol	Collection of feedstock; high CAPEX	REN consumption / cost
TRL	Commercial (available now!)	Commercial pilot (mid-term solution)	in development (long-term solution)	
GHG reduction	70-85%	82-94%	85-100%	

Dedicated regulations are in place or proposed ReFuelEU Aviation

European Commission

Main European Union policies currently related to the development and adoption of SAF

- **REDIII**
- **ReFuelEU Aviation**
- **EU-ETS**



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ReFuel EU SAF definition

European Commission

Article 3(7) of the ReFuelEU Aviation Regulation.
drop-in aviation fuels compliant with the sustainability criteria of the Renewable Energy Directive (RED).

- ✓ Synthetic aviation fuels from renewable hydrogen and captured carbon and limited to liquid drop-in fuels only
- ✓ Advanced biofuels from waste and residues notably (produced from feedstock listed in Part A of Annex IX. Article 2(34) of RED);
- ✓ Biofuels produced from oils and fats notably (feedstock listed in Part B of Annex IX. Article 2(33) of RED);
- ✓ Recycled carbon aviation fuels Article 2(33) of RED.

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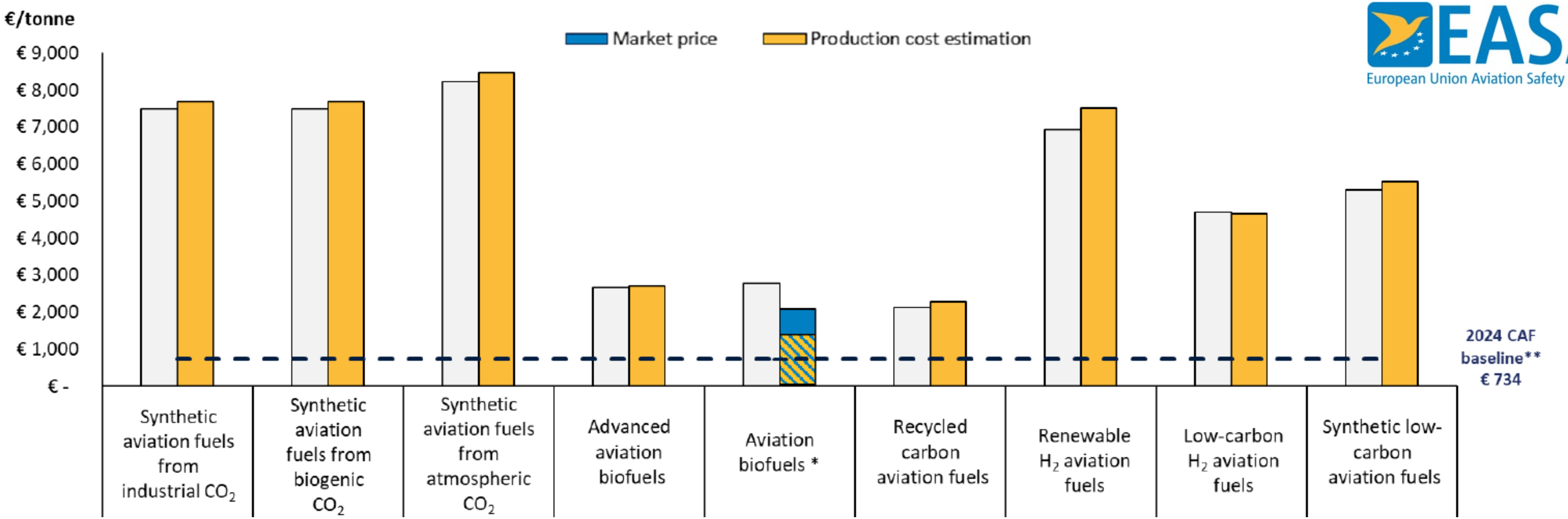
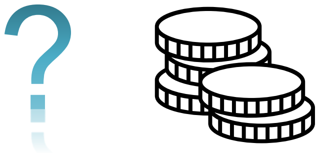
SAF production costs



Costs are still high!!!!!



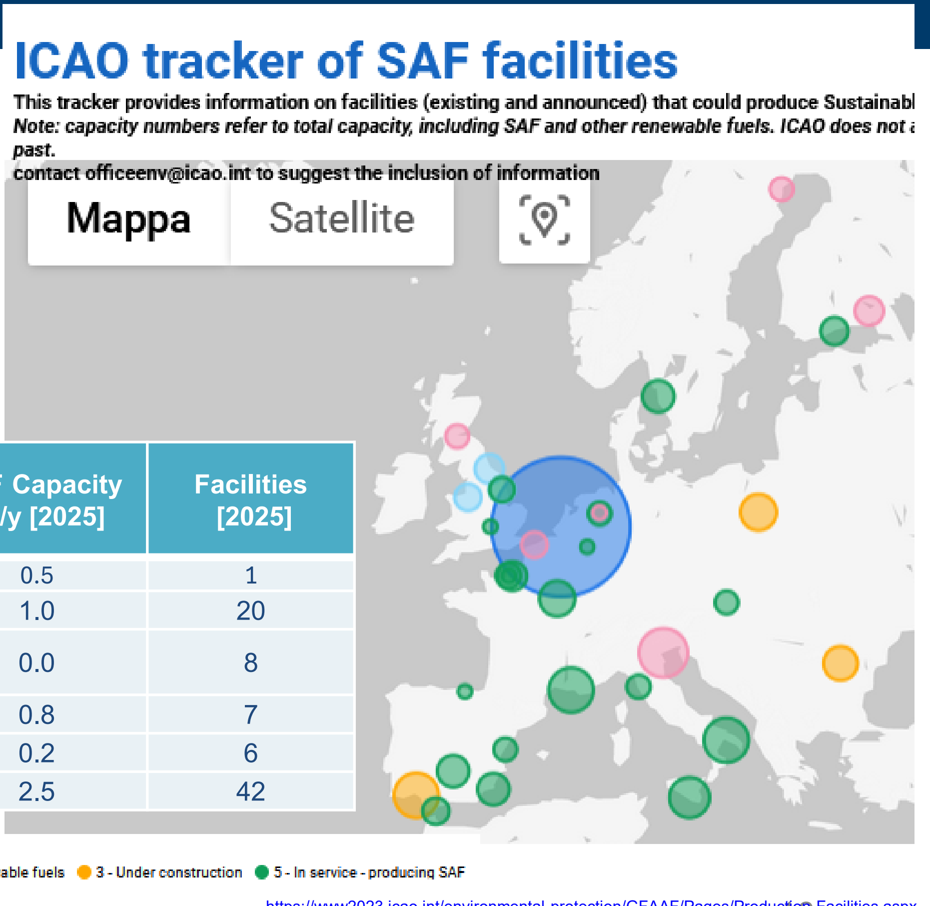
EASA 2025 Briefing Note – 2024 Aviation Fuels Reference Prices for ReFuelEU Aviation

SAF Facilities EU Estimates

- ICAO Tracker of SAF Facilities reports the total production site capacity existing and announced (SAF + other renewable fuels)

- 42 facilities identified in the EU
- 2.5 Mt/a (SAF + other renewable fuels) estimated capacity

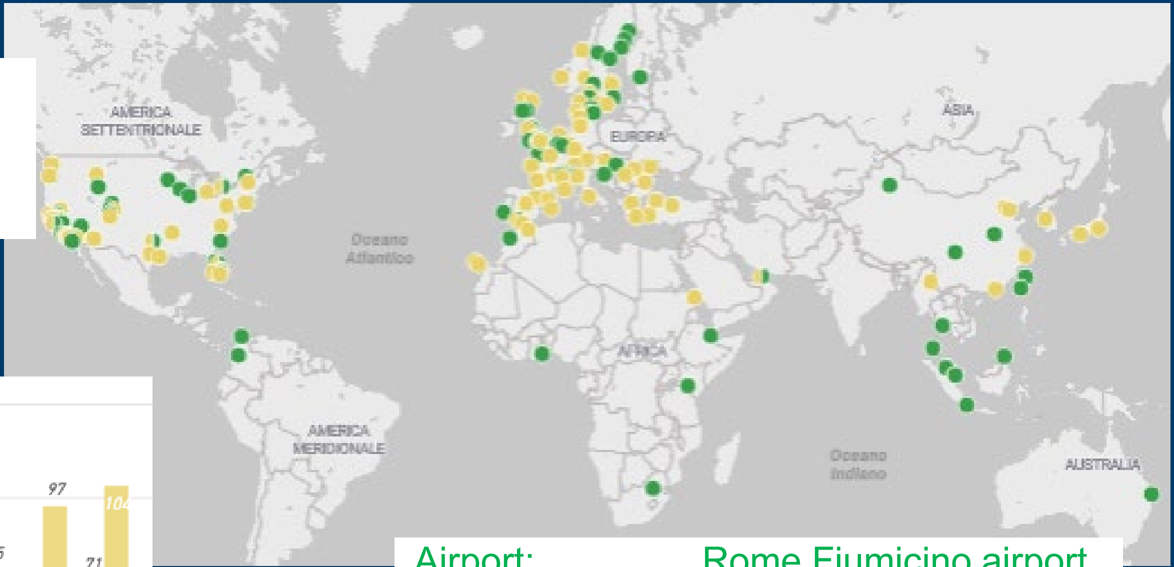
	Total capacity Mt/y [2025]	SAF Capacity Mt/y [2025]	Facilities [2025]
Producing CORSIA SAF	0.5	0.5	1
In service - producing SAF	2.7	1.0	20
In service - producing other renewable fuels	0.8	0.0	8
Under construction	1.5	0.8	7
Front End Engineering Design	0.5	0.2	6
Total EU	6.0	2.5	42



https://www2023.icao.int/environmental-protection/GFAAF/Pages/Production-Facilities.aspx

Where is SAF available today?

Airport:	Milano Linate airport
Status:	ongoing deliveries
Member State:	Italy
Fuel producer:	Eni



Airport:	Rome Fiumicino airport
Status:	ongoing deliveries
Member State:	Italy
Fuel producer:	Eni

https://www.icao.int/environmental-protection/SAF-airports

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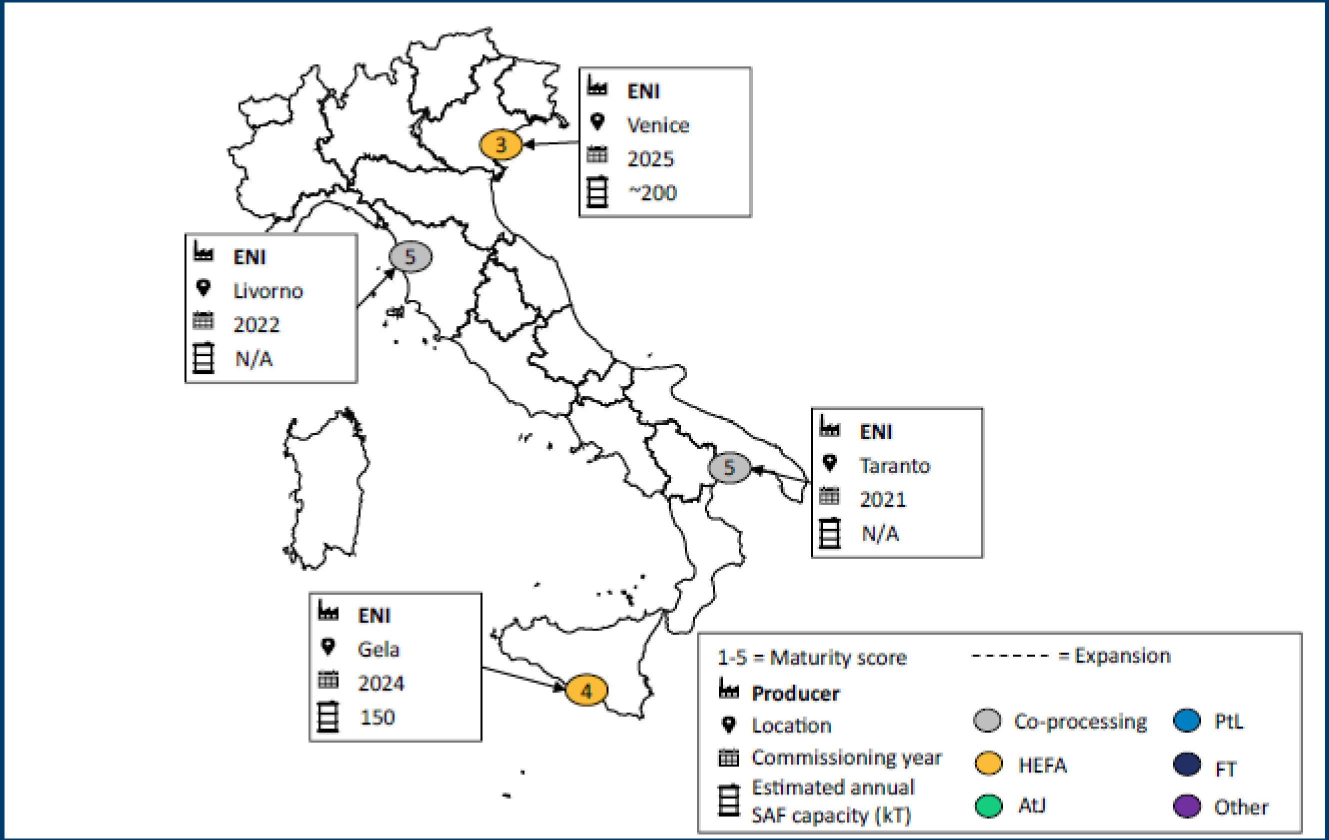
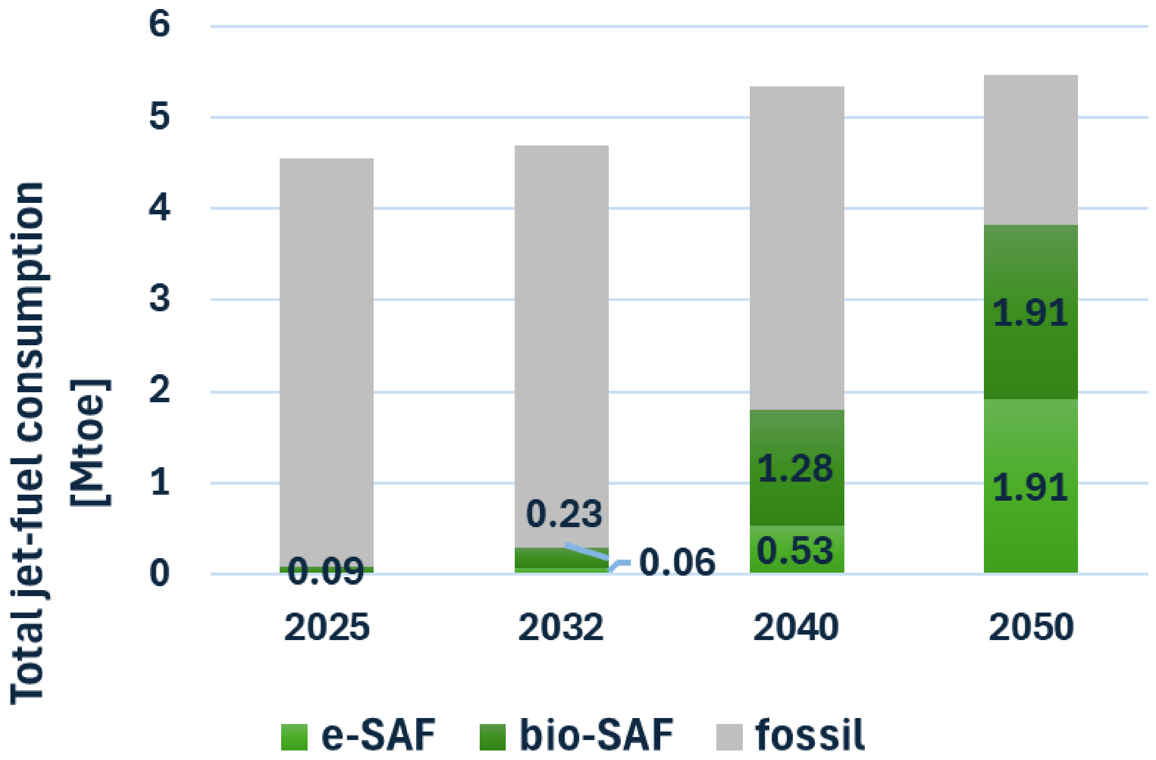
Operating and announced SAF facilities in Italy



EASA Report – State of the EU SAF Market in 2023

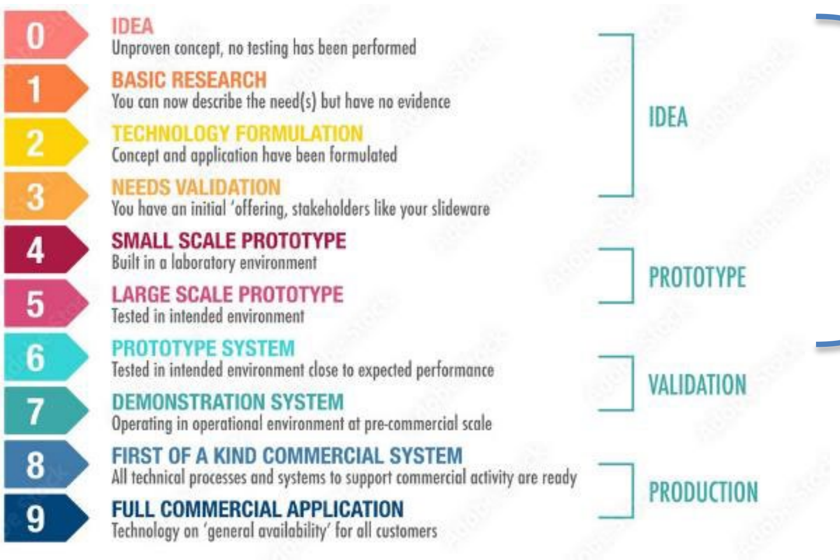
Expected volumes of SAF jet-fuel (Italy)



Source: Adapted from Matteo Prussi «L'Italia e la sfida della ReFuel EU Aviation: domanda e produzione attesa di SAF» 2025

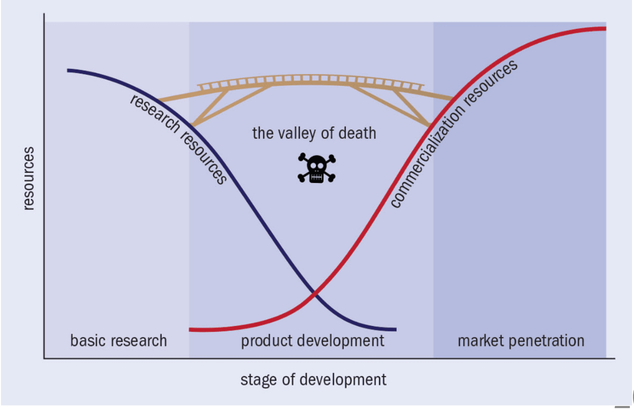
ENEA's SAF R&D focus on TRL

Technology Readiness Level (TRL)



ENEA main focus in R&D projects

From lab to pilot scale to support the development of integrated demonstration projects, from FOAK to FEED.

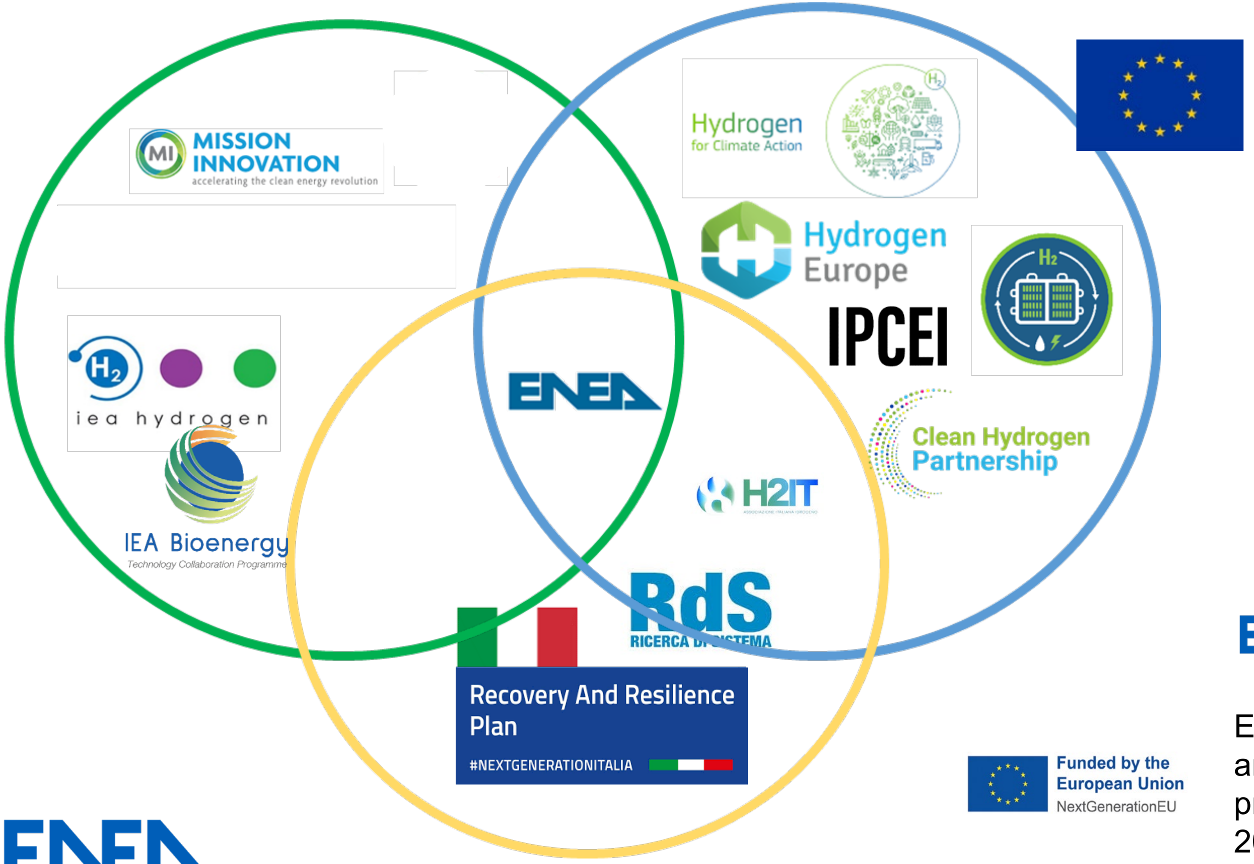


ENEA’s SAF R&D focus

Research is focused **on innovative applications for advanced production processes covering all the value SAF value chain**

- technical and economic assessments, LCA and social impact;
- development of prototypes and demonstrators integrated in experimental platforms for the validation of innovative SAF technologies in view of market introduction;
- development and synthesis of innovative catalytic materials; study of advanced reactor solutions, process engineering and novel plant configurations;
- experimental work on bench-scale and demonstration-scale;
- students, researchers and young professionals training
- technology transfer to public administrations and private companies.

ENEA – R&D Activities on Liquid E-Fuels Collaborations National, EU, International



ENEA Consiglio Nazional delle Ricerche RSE we move research

Funded by the European Union NextGenerationEU

ENEA is the main beneficiary in Recovery and Resilience Plan, coordinating R&D project on H2 Value chain with 110 M€ 2022-2026

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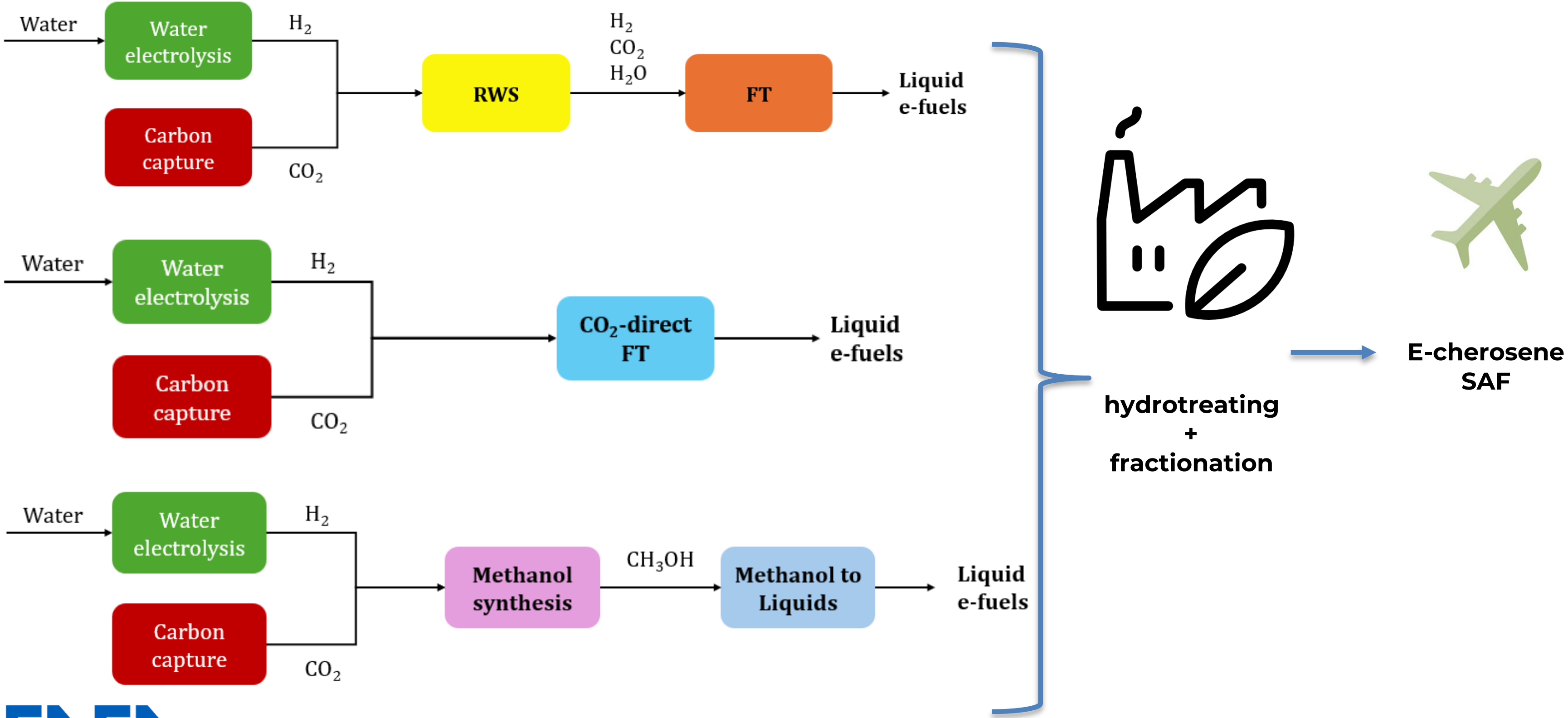
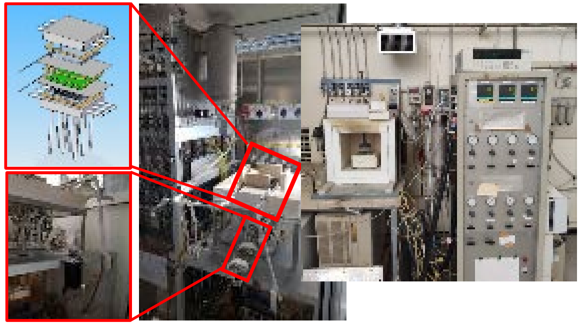
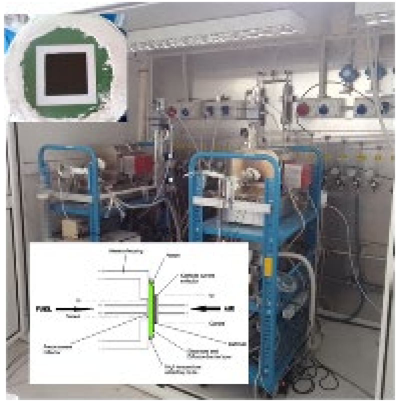
SAF production via PTL (PTL-SAF e-cherosene)



ENEA - Current activities and expertise
Green hydrogen production low TRL

- Electrochemical (water-splitting) :
    - Materials for polymer electrolyte (PEM & AEM) electrolysis
    - Testing and characterization of PEM & AEM cells and short stacks
    - High-T and high-p polymer electrolyte (PEM & AEM) electrolysis
    - Testing and characterization of Molten Carbonate electrolysis (MCEC)
    - Testing and characterization of Solid Oxide Electrolysis (SOEC)
    - Integration of electrolysers with renewable heat & power sources
- Photo-Electrochemical (water-splitting):
    - Preliminary investigations on the use of active peroskite materials in progress
- Biotechnologies:
    - Microbic electrolysis
    - Fermentation of biowastes and CO_2
- Thermochemical Water-Splitting Cycles (TWSC):
    - A new TWSC based on a modification of the well-known Sulfur-Iodine cycle patented
    - Capability to study two-steps complex metal oxide TWSCs up to 1500° C
- Thermochemical conversion of (bio)wastes:
    - Innovative reforming of (bio)methane in electrified reactors
    - Cracking of (bio)methane (planned)
    - Pyrolysis of solid (bio)wastes with valorization of the solid by-product (biochar)
    - Plasma pyrolysis of bio(methane) or CO_2

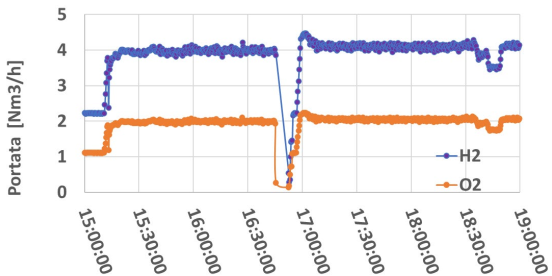


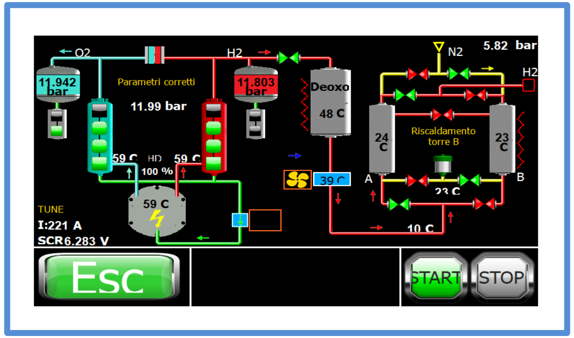


ENEA - Current activities and expertise Green hydrogen production medium TRL

Alkaline type electrolyser

H_2 production 4 Nm^3/h
Size 25 kWe
working pressures 12 bar
Deoxo unit H_2 purity 99.9999%
Control panel and remote monitoring
Battery energy storage unit ($LiFePO_4$ type)

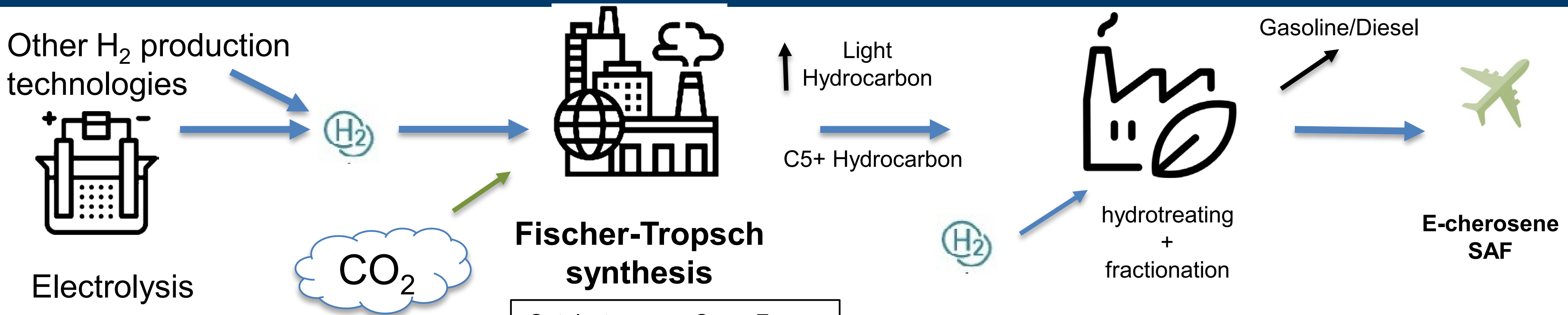




Study Power To Gas process evaluating the dynamic environment start up. shut-down. stand-by e idle condition

Electrical characterization of the power supply/conversion system

ENEA SAF production via PtL
e-cherosene via Fischer Tropsch synthesis



Catalyst	Co or Fe
Temperature	200–350°C
Pressure	20–30 bar

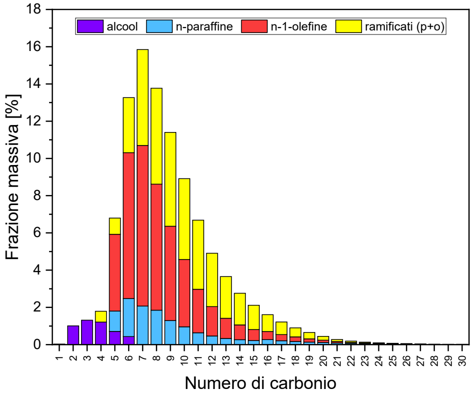
Experimental test: Fischer-Tropsch synthesis

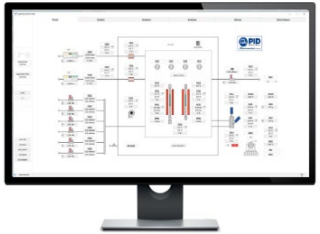
e-cherosene production **Direct CO_2 hydrogenation**

$nCO_2 + 3nH_2 \rightarrow -(CH_2)_n- + 2n\ H_2O$

e-cherosene via Fischer Tropsch synthesis laboratory plant- low TRL

Funded by the European Union
NextGenerationEU

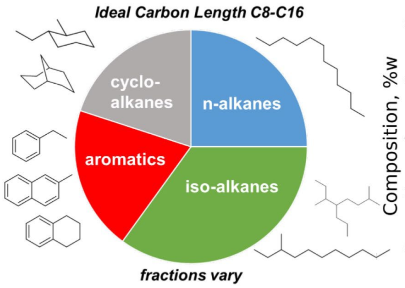


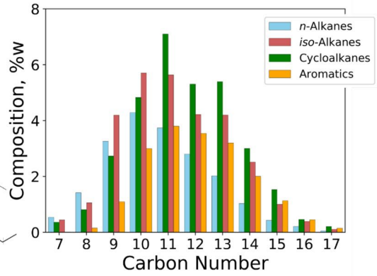


POLITECNICO MILANO 1863
DIPARTIMENTO DI ENERGIA

Flow reactor bench scale evaluation of innovative bifunctional catalysts performance (Fe based)

Test results using Fe based catalyst → higher C8-C16 content typical of kerosene

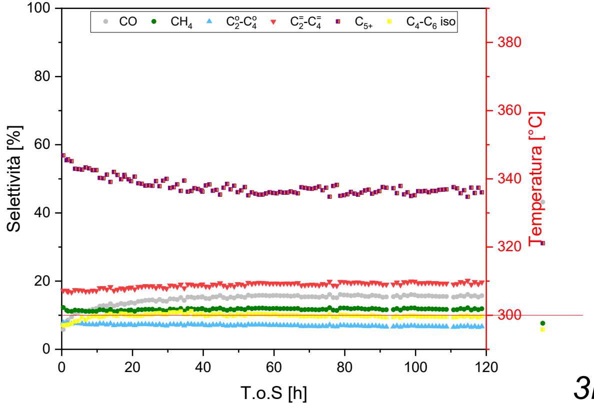




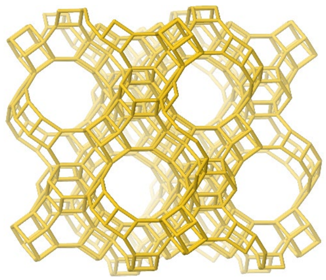
e-cherosene via Fischer Tropsch synthesis laboratory plant- low TRL

DOUBLE CATALYTIC BED:

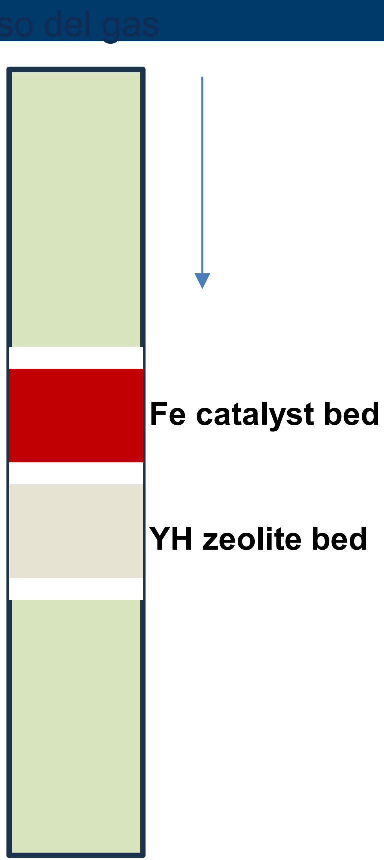
1. **Fe catalyst bed for CO_2 hydrogenation**
2. **YH zeolite bed (at the end of the Fe bed) for wax cracking**

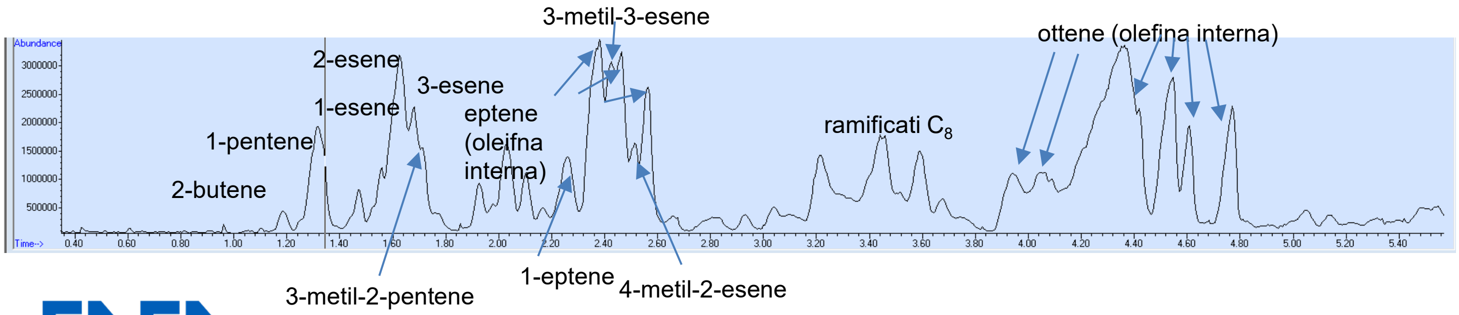


GAS PHASE - Marked presence of isomers - zeolite activity



3D structure of faujasite





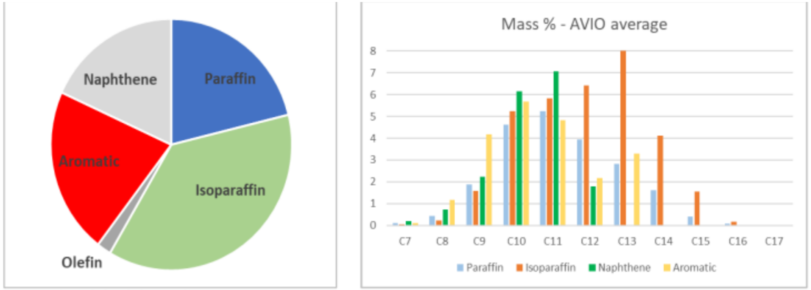
CONDENSED PHASE - C6-C12 compounds have a greater contribution of branched products

e-cherosene via Fischer Tropsch synthesis
Fraction characterization and AST compliance

Objective: To develop a method capable of separating and characterizing small quantities of e-kerosene fraction of a synthetic crude oil obtained in a FT process and verifying compliance with international standards.

Activities: Characterization of fossil jet fuel using ASTM standards and GC-VUV (Gas Chromatography–Vacuum Ultraviolet Spectroscopy) / GCxGC techniques to identify the hydrocarbon families present (it is important to differentiate between isomers) based on the number of carbon atoms then comparing the results with the literature.

10 fossil jet fuel samples analyzed by GC-VUV

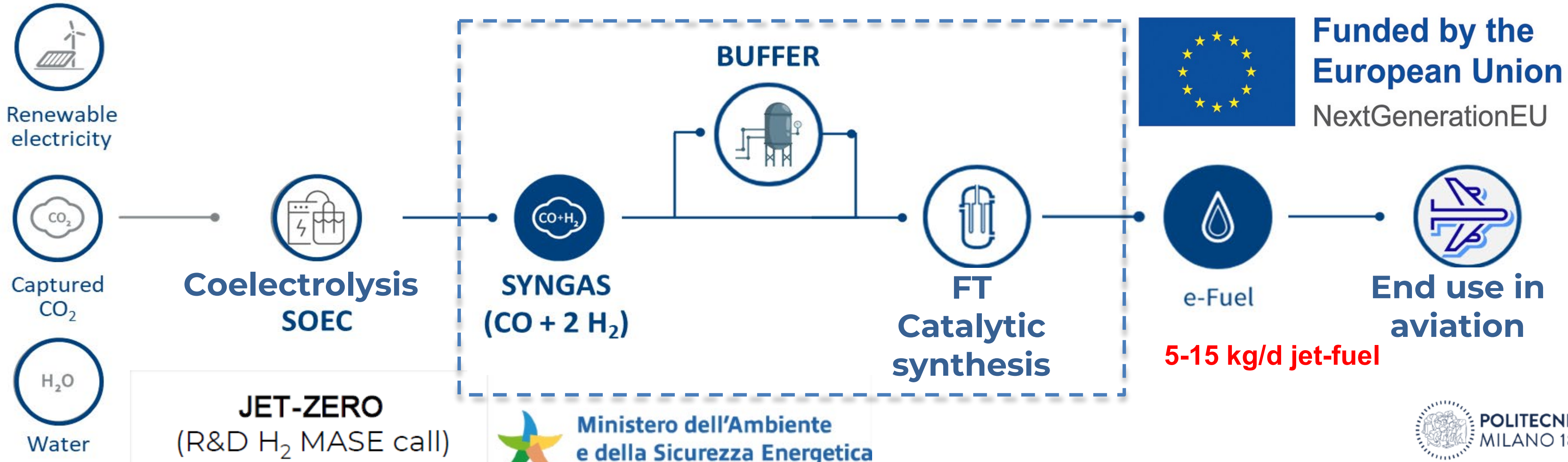


INNOVHUB STAZIONI SPERIMENTALI PER L'INDUSTRIA

innovazione e ricerca

ENEA

e-cherosene via Fischer Tropsch synthesis pilot plant - medium TRL (kg/d)



Funded by the European Union
NextGenerationEU

5-15 kg/d jet-fuel

JET-ZERO
(R&D H_2 MASE call)

Ministero dell'Ambiente e della Sicurezza Energetica

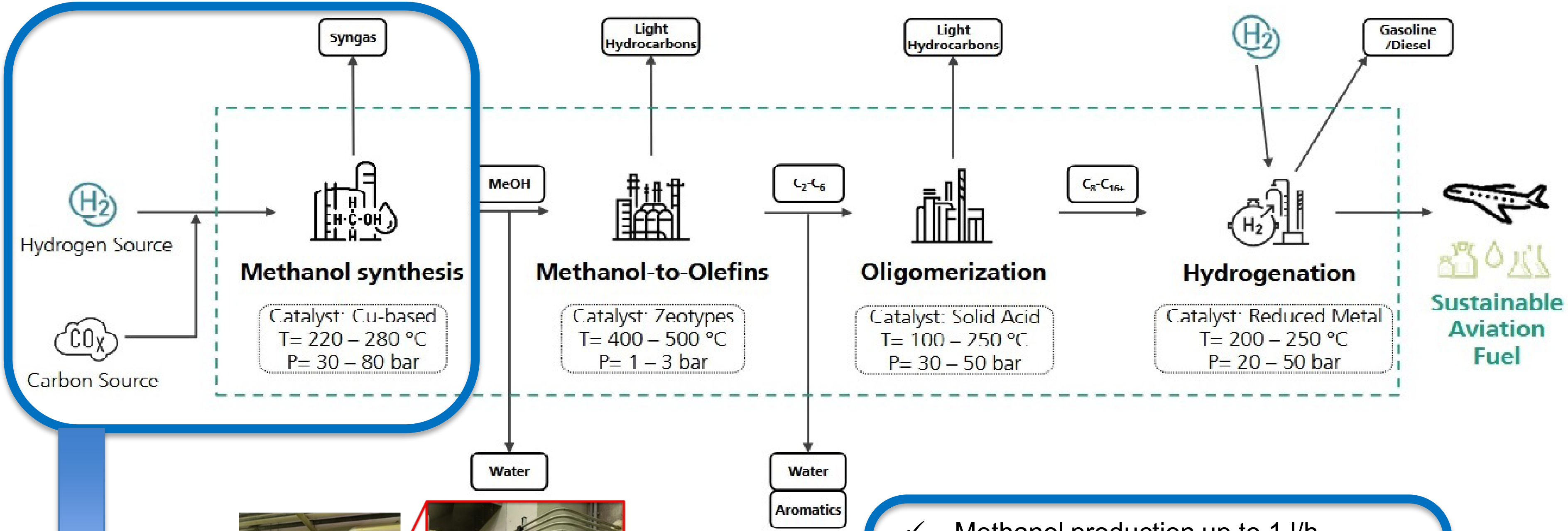
POLITECNICO MILANO 1863

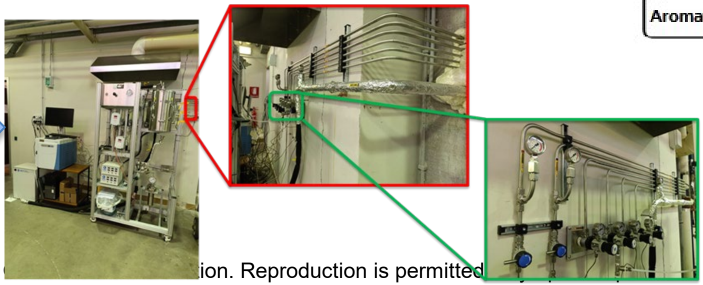
UNIVERSITÀ DELLA CALABRIA

INNOVHUB STAZIONI SPERIMENTALI PER L'INDUSTRIA
innovazione e ricerca

techfem
Human & Sustainable Engineering

SAF production via PtL
methanol synthesis low TRL



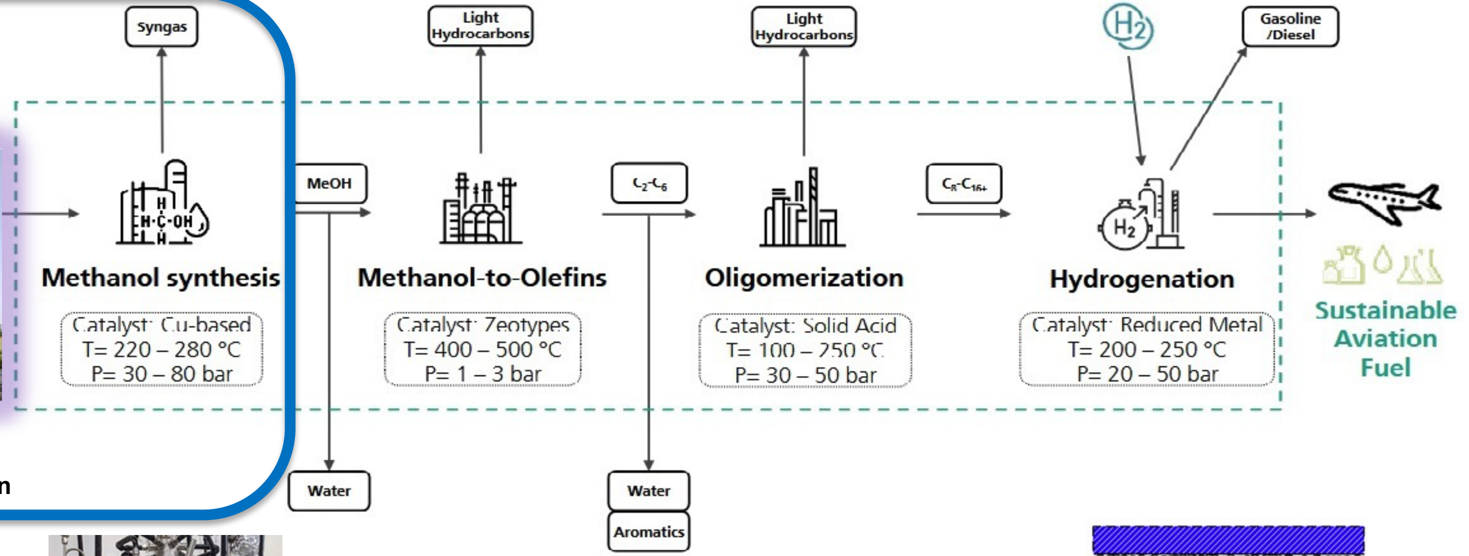


- ✓ Methanol production up to 1 l/h
- ✓ Working pressures 1-100 bar
- ✓ Working temperatures 20-550 °C
- ✓ Control panel and remote monitoring
- ✓ Catalyst development and screening
- ✓ Process modelling

SAF production via PtL
methanol synthesis medium TRL

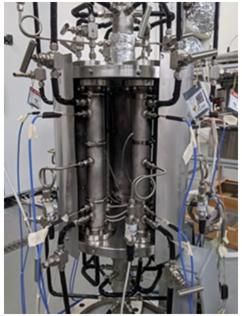
Biomass and waste

Syngas production from biomass gasification



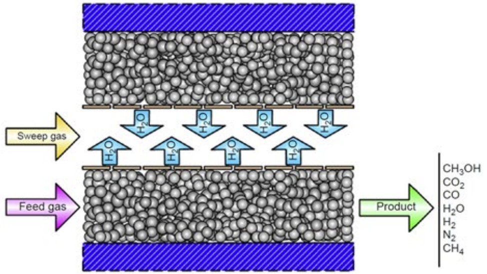
CO, CO2, H2

Syngas
($CO+2H_2$)
(CO_2+3H_2)

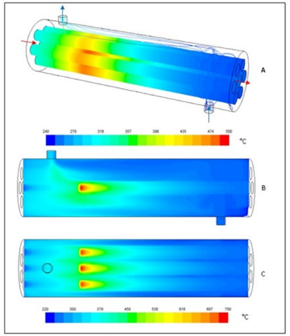


Catalytic membrane reactor for the methanol synthesys composed by:

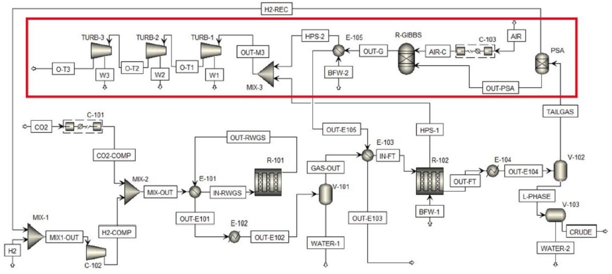
- Six zeolite membranes stable under reaction conditions (180–220 °C, 30–40 bar) and selective for water permeation
- Multitubolar reactor feed by 0.2 Nm³/h of syngas with a core composed of six alumina tubes coated with zeolite synthesized and deposited on their surface.



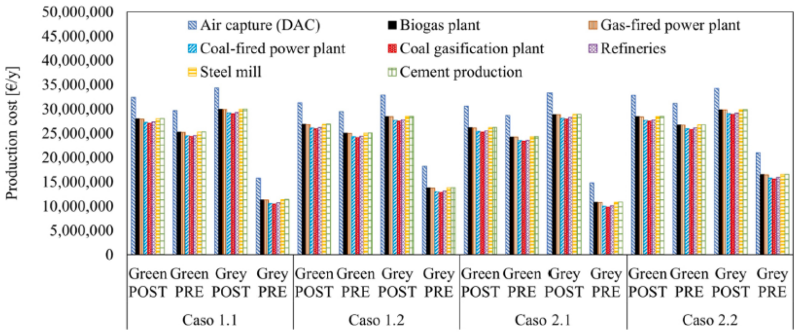
SAF-technical and economic assessments

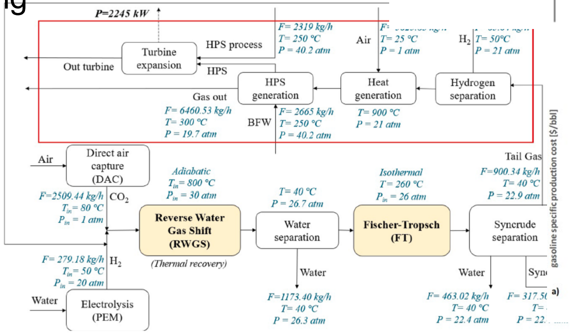


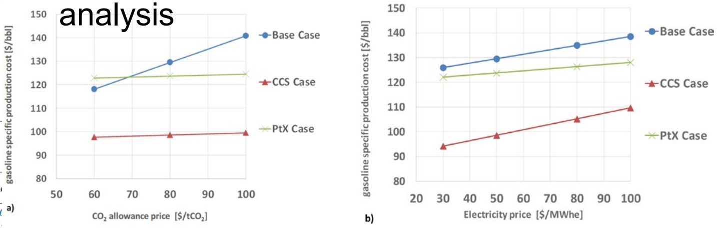
Component and reactor model



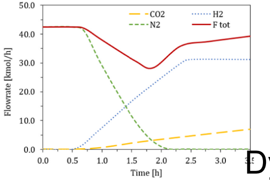
Process modelling

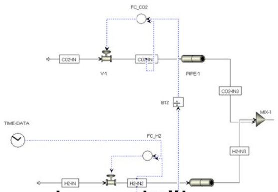






Levelized cost of production and economic analysis





Dynamic modelling

Training and workshop

Take-home messages

- Sustainable Aviation Fuel are essential to reducing the aviation sector's carbon footprint.
- Several challenges are limiting large-scale adoption:

  - High production costs
  - Limited availability of feedstock
  - Competition with other sectors for resources
  - Regulatory and certification hurdles
  - Need for dedicated infrastructure development

- HEFA-SAF are available now: it is the only near-term large-scale decarbonization option for the aviation.

Take-home messages

- Expanding the feedstock base and diversifying conversion technologies requires sustained investment in research and development.
- A streamlined and harmonized regulatory environment is essential to reduce complexity and provide certainty for investors.
- Public funding continues to play a crucial role in enabling the large-scale deployment and rapid scale-up of SAF technologies.
- More SAF will come, with larger market potential !!!!!

We are working making SAFs ready for takeoff.

Thank you for
your kind attention

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