TAKE-OFF

Production of synthetic renewable aviation fuel from CO_2, water and renewable electricity

Lawien Zubeir

TNO innovation for life

The TAKE-OFF "Production of synthetic renewable aviation fuel from CO_2 and H_2" project, that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°101006799.

PUBLIC

Why Sustainable Aviation Fuels “SAF” ?

And why synthetic SAF?

SAF, sustainable kerosene, is the only short to medium term possibility to make aviation sustainable.

- The kerosene market is huge, multiple technology routes will have to contribute
- Bio-kerosene is important and cheaper on short term, but is limited in feedstock
- Synthetic kerosene – produced from CO_2, H_2O and electricity - is currently still more expensive but has an unlimited feedstock
- Synthetic kerosene has the potential to reach near 100% green house gas reduction
- The importance of synthetic-SAF is underlined by governmental targets, incentives and market analysis
- Technology development is necessary to reduce costs

	HEFA	Alcohol-to-jet[i] / Gasification/FT	Power-to-liquid
Opportunity description	Safe, proven, and scalable technology	Potential in the mid-term, however significant techno-economical uncertainty	Proof of concept 2025+, primarily where cheap high-volume electricity is available
Technology maturity	Mature	Commercial pilot	In development
Feedstock	Waste and residue lipids, purposely grown oil energy plants[ii] Transportable and with existing supply chains Potential to cover 5%–10% of total jet fuel demand	Agricultural and forestry residues, municipal solid waste[iv], purposely grown cellulosic energy crops[v] High availability of cheap feedstock, but fragmented collection	CO_2 and green electricity Unlimited potential via direct air capture Point source capture as bridging technology
% LCA GHG reduction vs. fossil jet	73%–84%[iii]	85%-94%[vi]	99%[vii]

Clean Skies for Tomorrow Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation, November 2020, World Economic Forum in In Collaboration with McKinsey & Company https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/scaling-sustainable-aviation-fuel-today-for-clean-skies-tomorrow

Total shares in the fuel mix (in %)	2025	2030	2035	2040	2045	2050
SAF ramp up out of which:	**2**	**5**	**20**	**32**	**38**	**63**
Biofuels (including Part A and Part B biofuels)	2	4.3	15	24	27	35
Specific sub-mandate on RFNBOs[129]	-	**0.7**	**5**	**8**	**11**	**28**

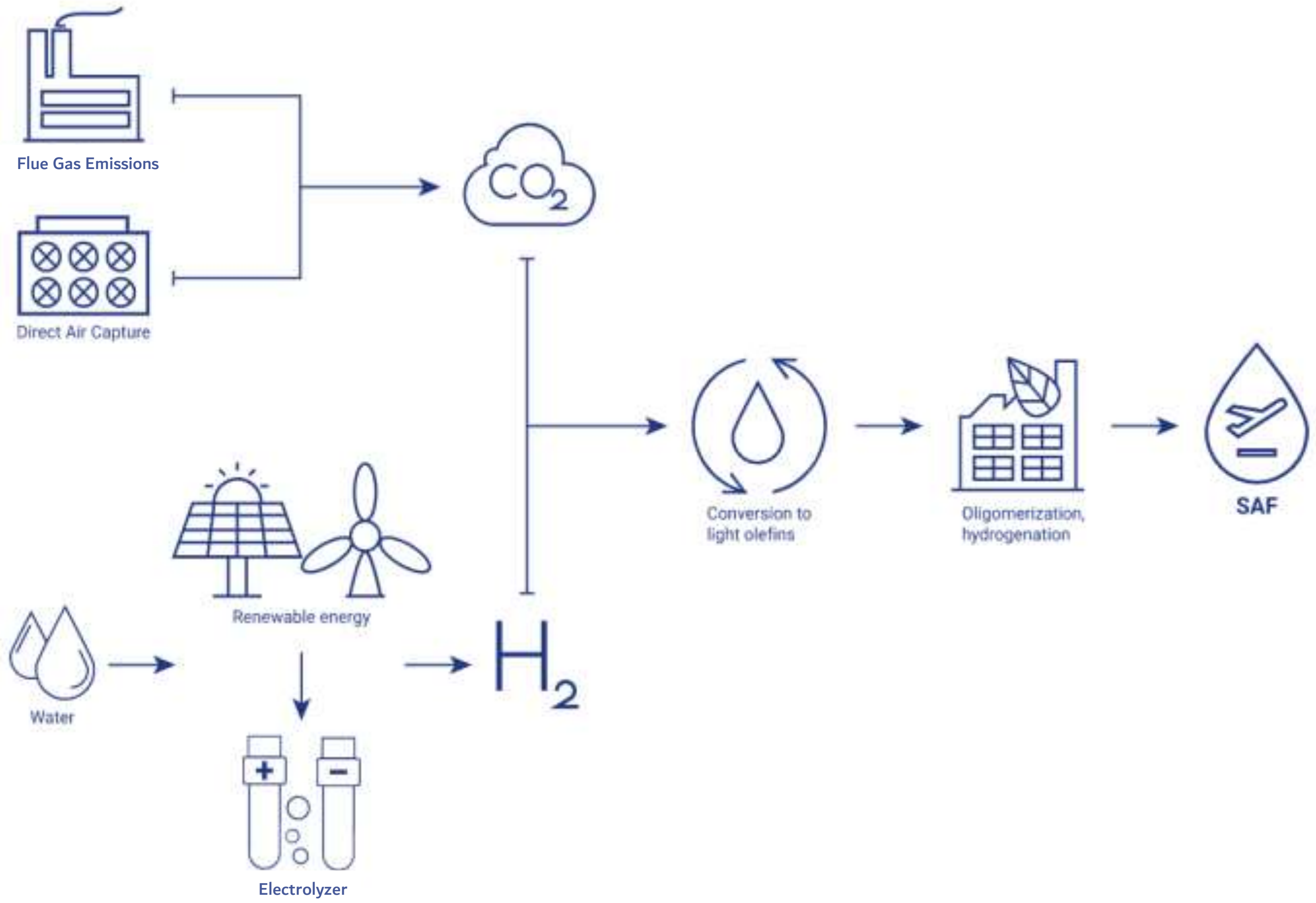
Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ensuring a level playing field for sustainable air transport: https://ec.europa.eu/info/sites/default/files/refueleu_aviation_-_sustainable_aviation_fuels.pdf

TAKE-OFF Technology Concept

Sustainable aviation fuel from CO_2, water and renewable electricity

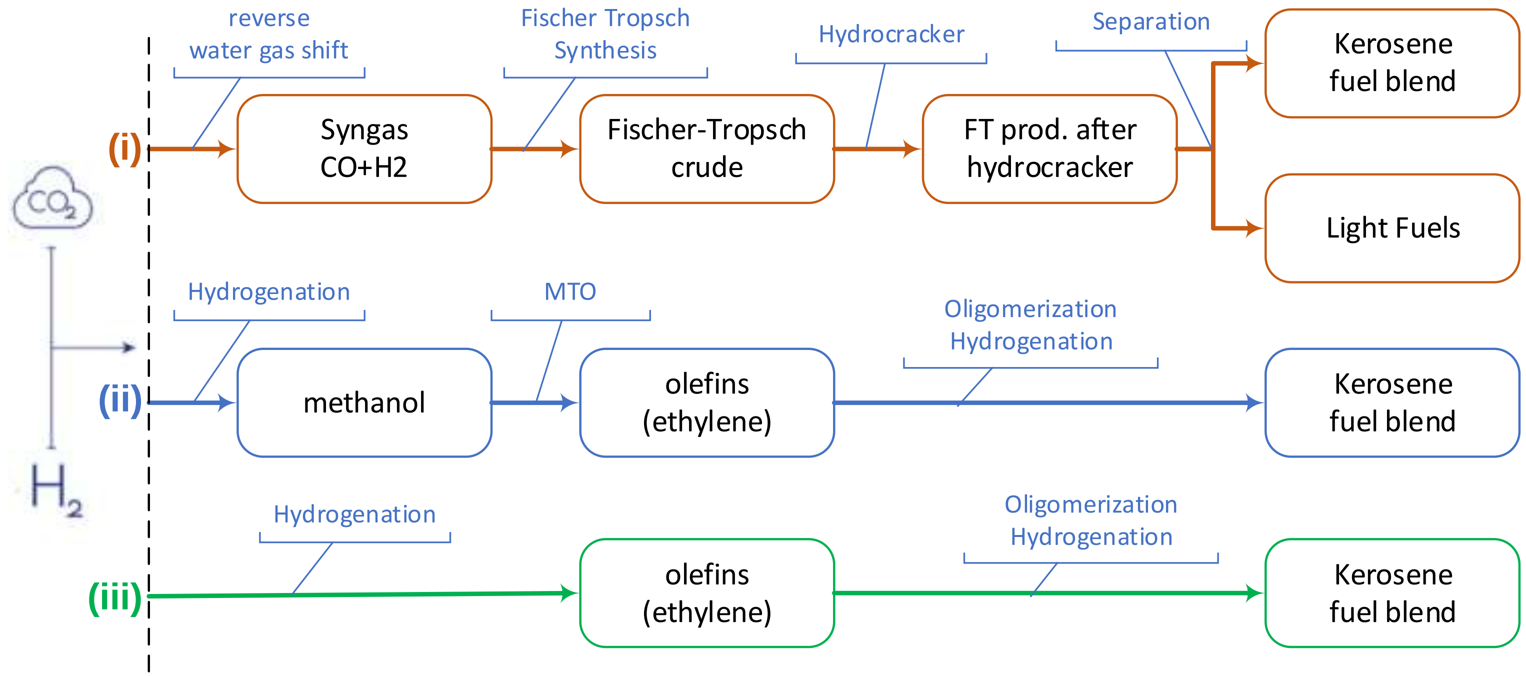
The TAKE-OFF project explores the development of a unique technology based on the conversion of CO_2, H_2O and renewable electricity to SAF via olefins as an intermediate.

- Innovative catalyst and reactor technologies are developed and demonstrated under industrially relevant conditions
- Objective is to significantly increase efficiency and reduce cost compared to the existing Power-to-Liquids benchmark

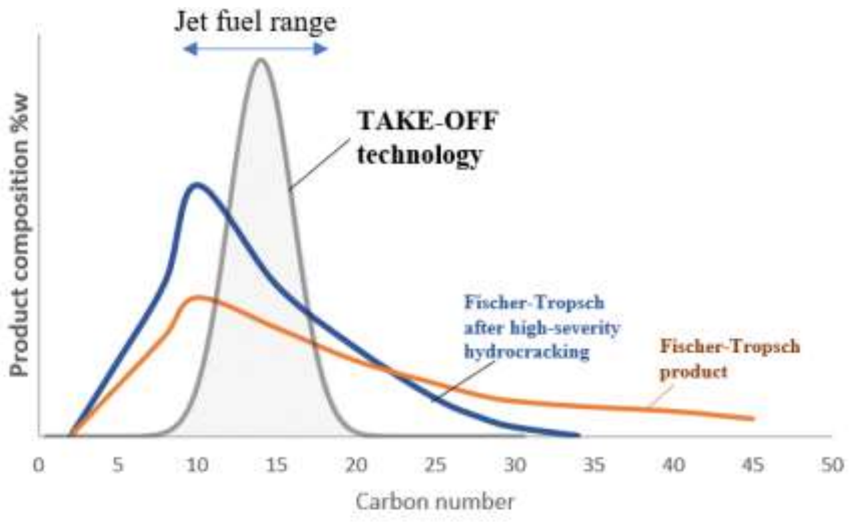


Take-Off route vs. the Fischer-Tropsch benchmark

The Fischer Tropsch route to kerosene is industrially proven at large scale and certified for use as aviation fuel. This route is therefore the industrial benchmark.



Main steps in (i) Fischer Tropsch (ii) TAKE-OFF via MeOH and (iii) TAKE-OFF



The main feature of the TAKE-OFF route is that it is selective to the desired kerosene blend. Side products are avoided leading to a more selective use of H_2 towards the final kerosene end product

TAKE-OFF consortium and advisory board

Partners shown at their main work package

Work package	Partners
Catalyst Development	CNRS
Reactor Technology	TNO innovation for life
Demonstration	RWE, Mitsubishi Power, Asahi Kasei Europe
Compliance & emissions	FEV, RWTH Aachen University, SkyNRG
Techno-economic and environmental assessment	SDU University of Southern Denmark
Dissemination, Communication, Exploitation	CO2 Value Europe

Advisory Board

- TotalEnergies
- Global Alliance Powerfuels
- NISA Nordic Initiative for Sustainable Aviation
- ExxonMobil
- Port of Amsterdam – Port of partnerships
- KLM
- dmt Environmental Technology
- alcoenergy sustainable pioneers | Rotterdam

TAKE-OFF Result in 2022

Experiments are executed in multiple setups to achieve TAKE-OFF Objectives

DME Pilot Unit

HGD Rapid Compression Machine (RCM) for NOx emissions

CO$_2$ hydrogenation catalytic tests
High throughput test – 16 parallel reactors

Oligomerization tests

Testing SIENNA
(in situ water separation reactor – fo
MeOH/DME)

Expected impact of the TAKE-OFF project

- Advance the development of processes for the conversion of CO_2 to methanol, dimethyl ether (DME) and light olefins (ethylene) from TRL-3 to TRL-5. These intermediate products to the SAF end product have their own markets
- Advance an innovative olefins to jet fuel process from TRL-3 to TRL-4 and investigate compliance and emissions of the produced SAF
- Demonstrate the entire technology chain for TAKE-OFF's next generation jet fuel technology
- Techno-economic and environmental assessments to support TAKE-OFF's claims on efficiency, sustainability and costs reduction

+25%
Carbon and hydrogen efficiency
compared to other PtL alternatives

SO_2
-100%
Sulphur
compared to fossil aviation fuel

-20%
Total emissions compared to
other PtL alternatives

-36%
SAF production costs
compared to other PtL alternatives

Stay in Touch with TAKE-OFF

www.takeoff-project.eu

TAKE-OFF-project

The TAKE-OFF Advisory Board is open for relevant industry participants

Lawien Zubeir
Lawien.Zubeir@tno.nl

The TAKE-OFF "Production of synthetic renewable aviation fuel from CO_2 and H_2" project, that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°101006799.