Centre for Research & Technology Hellas
Chemical Process & Energy Resources Institute

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Techno-economic and Environmental Considerations for Aviation and Marine Fuels Production from Biomass Derived Microbial Oil

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ETIP Bioenergy
European Technology and Innovation Platform

12th Stakeholder Plenary Meeting

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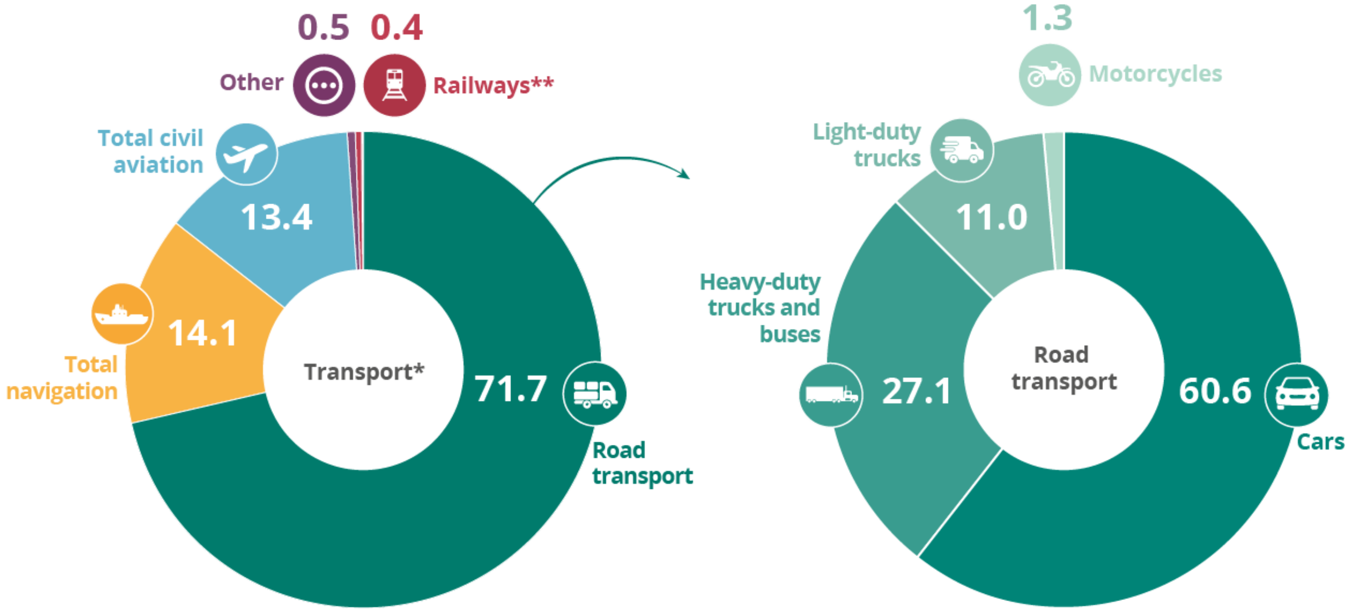
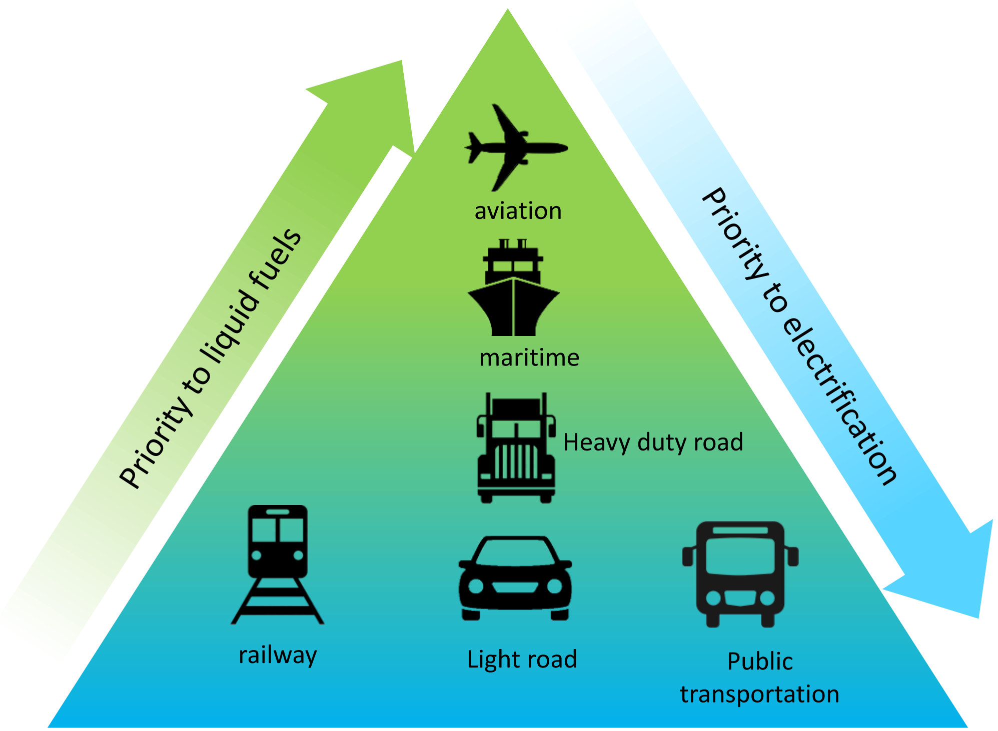
Biomass and sustainable transport

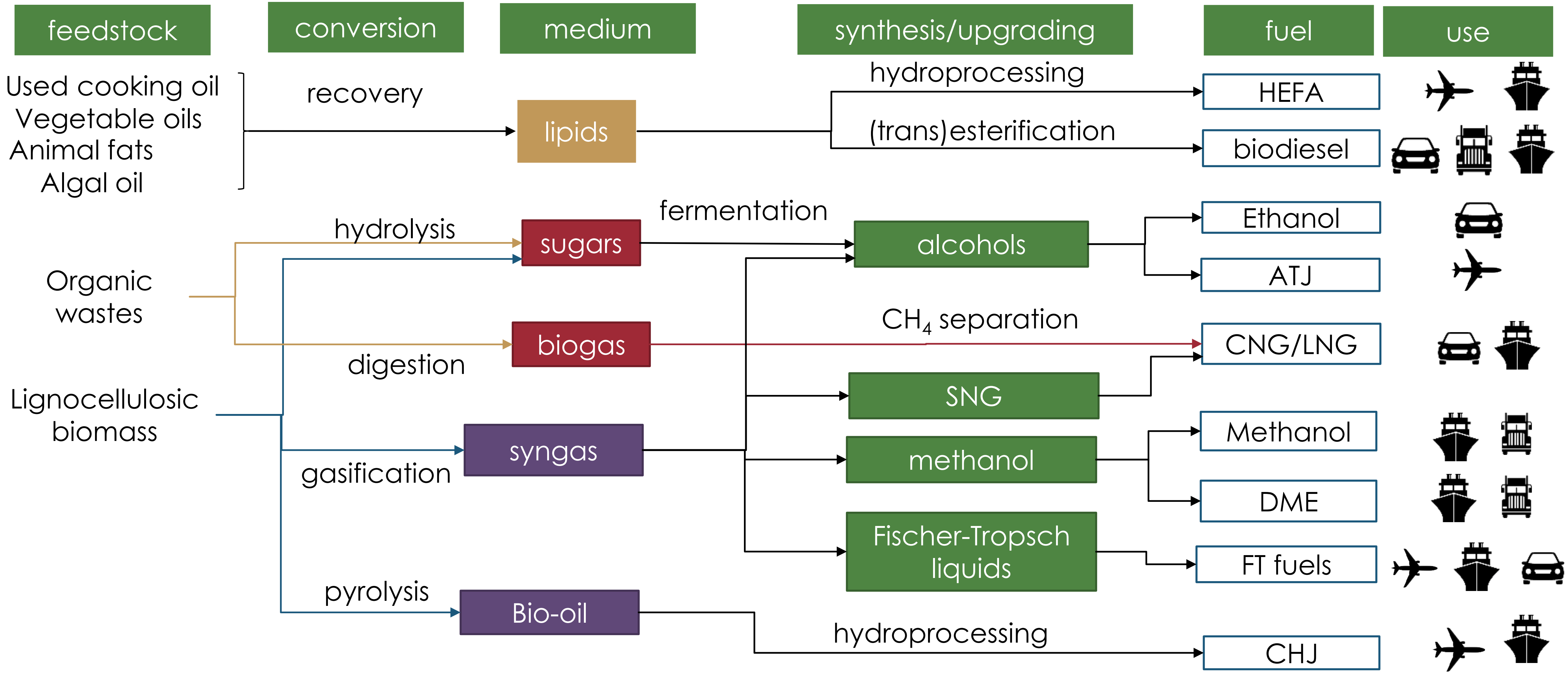
- Transport is responsible for about 25% of the EU's total CO_2 emissions
- The EU aims to reduce by 90% the greenhouse gas emissions from transport by 2050, compared with 1990
- Biofuels are crucial for reducing emissions in the transport sector
- Major role on the so-called "hard-to-abate sectors" aviation and maritime decarbonization



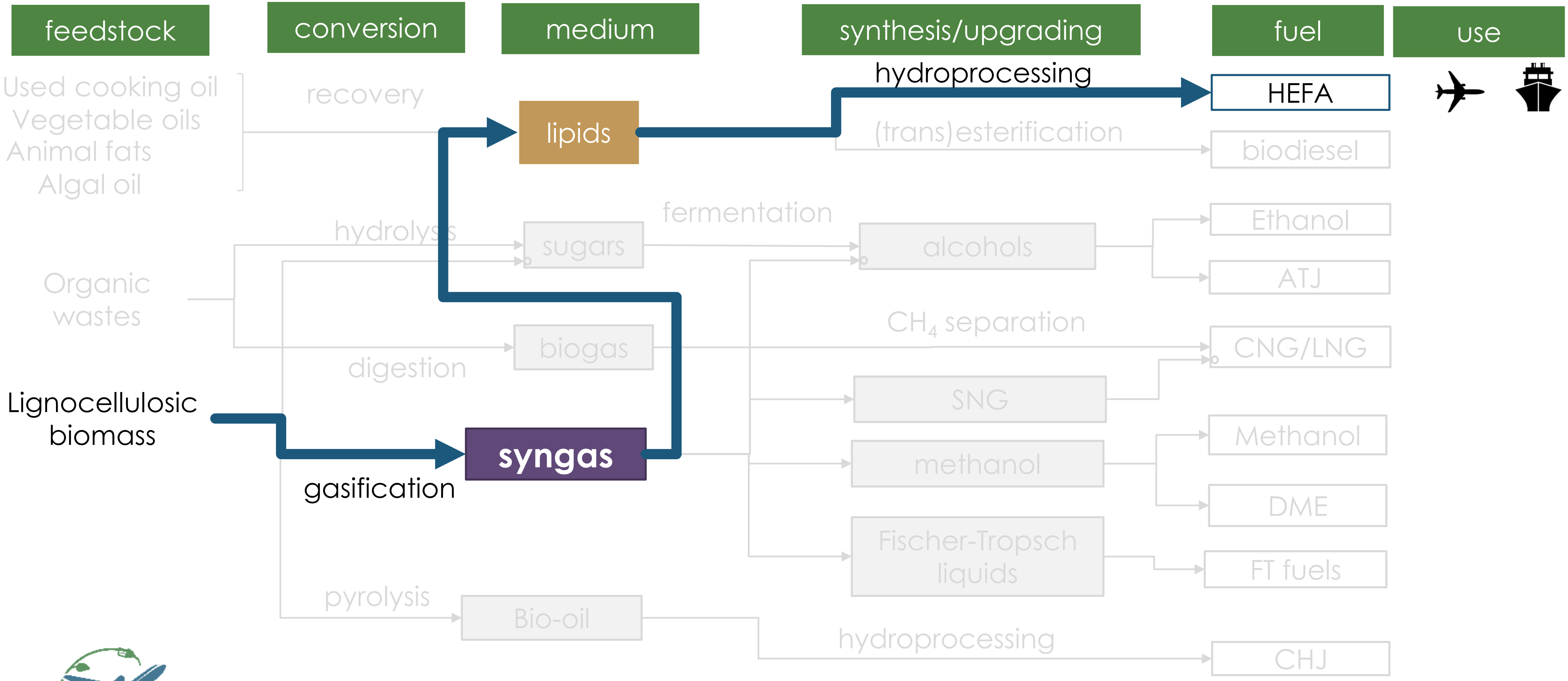


Source: European Environment Agency 2022

Advanced biofuels production pathways



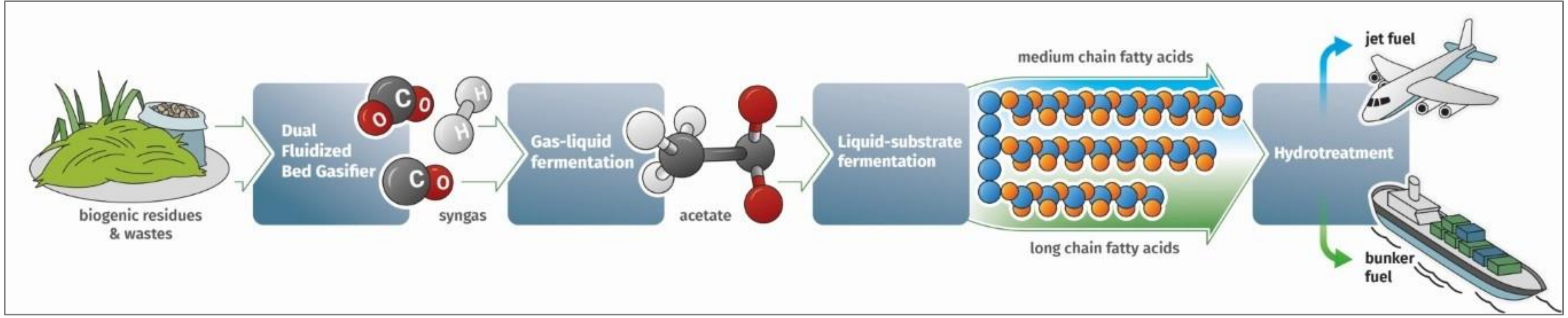
Advanced biofuels production pathways



BioSFerA
Biofuel for biotravels

Drop-in aviation and marine biofuels through a combined thermochemical – biochemical pathway: the **BioSFerA** project

Development and validation of a novel biorefinery concept based on 2-step biological gas-to-liquid process using syngas from Dual Fluidised Bed Gasifier for the production of hydrotreated triacylglycerides (HTAGs)



CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS — Project coordinator

VTT, CARTIF, CSIC, Bio Base Europe Pilot Plant, ENVIRONMENT PARK, RINA, Sumitomo SHI FW, Q8 Research, GoodFuels

April 2020 – March 2024

€ 4,998,654

www.biosfera-project.eu

Horizon 2020 (884208)

Fuel flexibility, minimal the gas cleaning requirements, low opex, enhanced yields of the target biofuels

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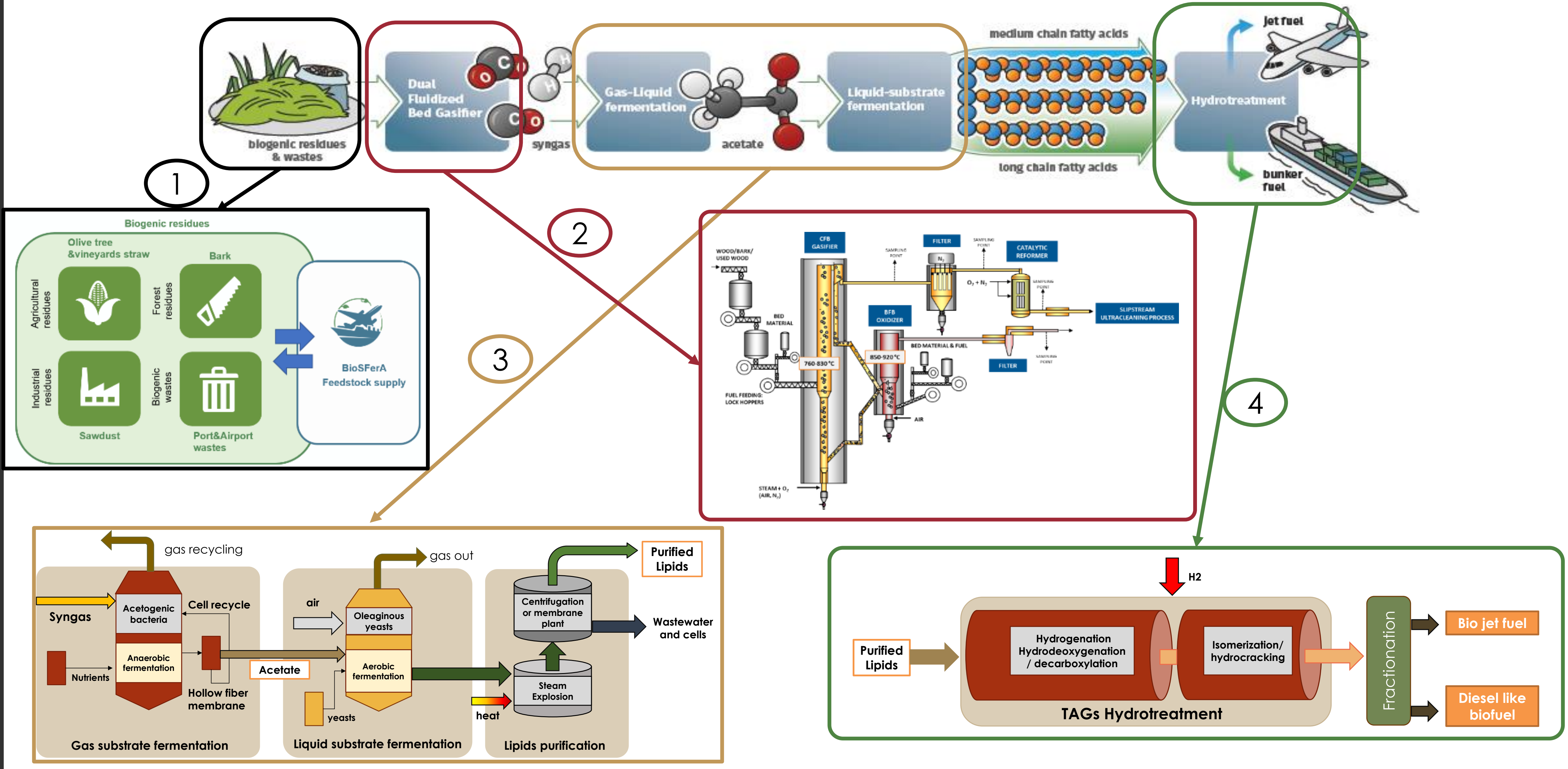
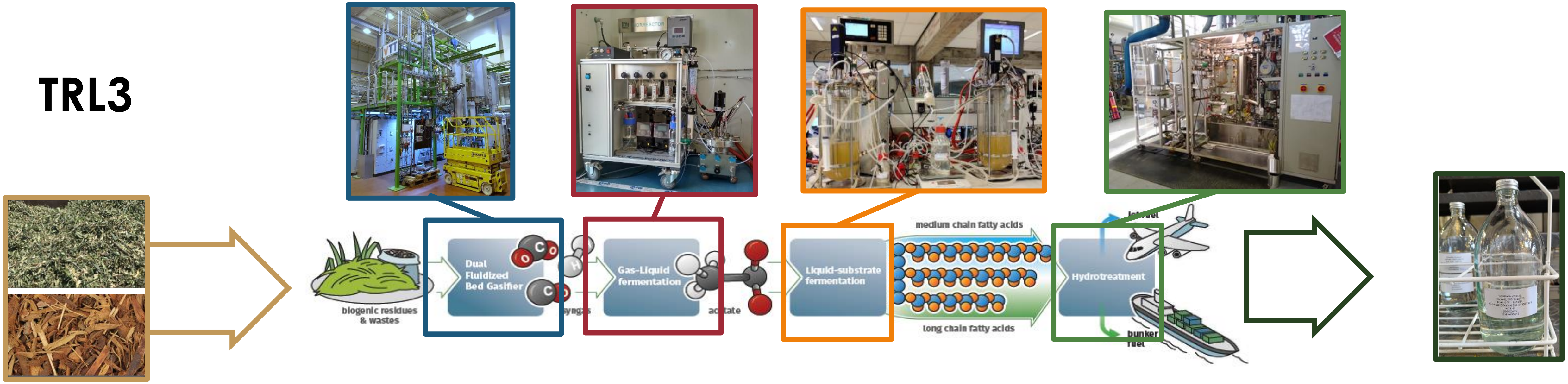
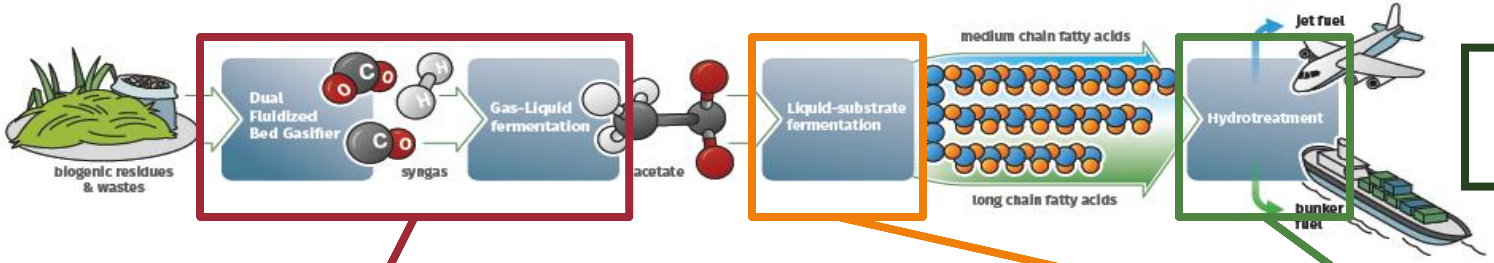


Drop-in aviation and marine biofuels through a combined thermochemical – biochemical pathway: the **BioSFerA** project

TRL3



Drop-in aviation and marine biofuels through a combined thermochemical – biochemical pathway: the **BioSFerA** project



TRL5

BioSFerA scale up and impact assessment

Methodology

TRL 3 → *BioSFerA experimental/pilot activities* → TRL 5 → Upscaling design considerations & models validated at pilot scale

↓

Full-scale (200 MWth) process simulations of the integrated BioSFerA concept

↓

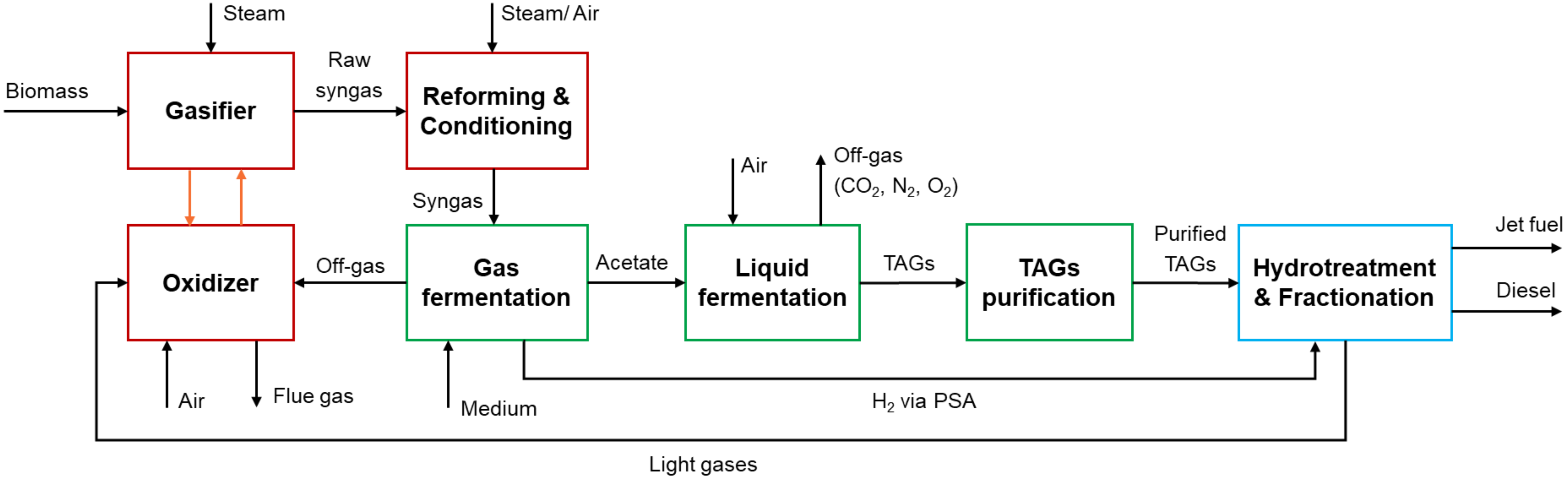
Full-scale Heat & Mass balance calculations

↓

Techno-economic assessment

Environmental assessment

BioSFerA integrated concept

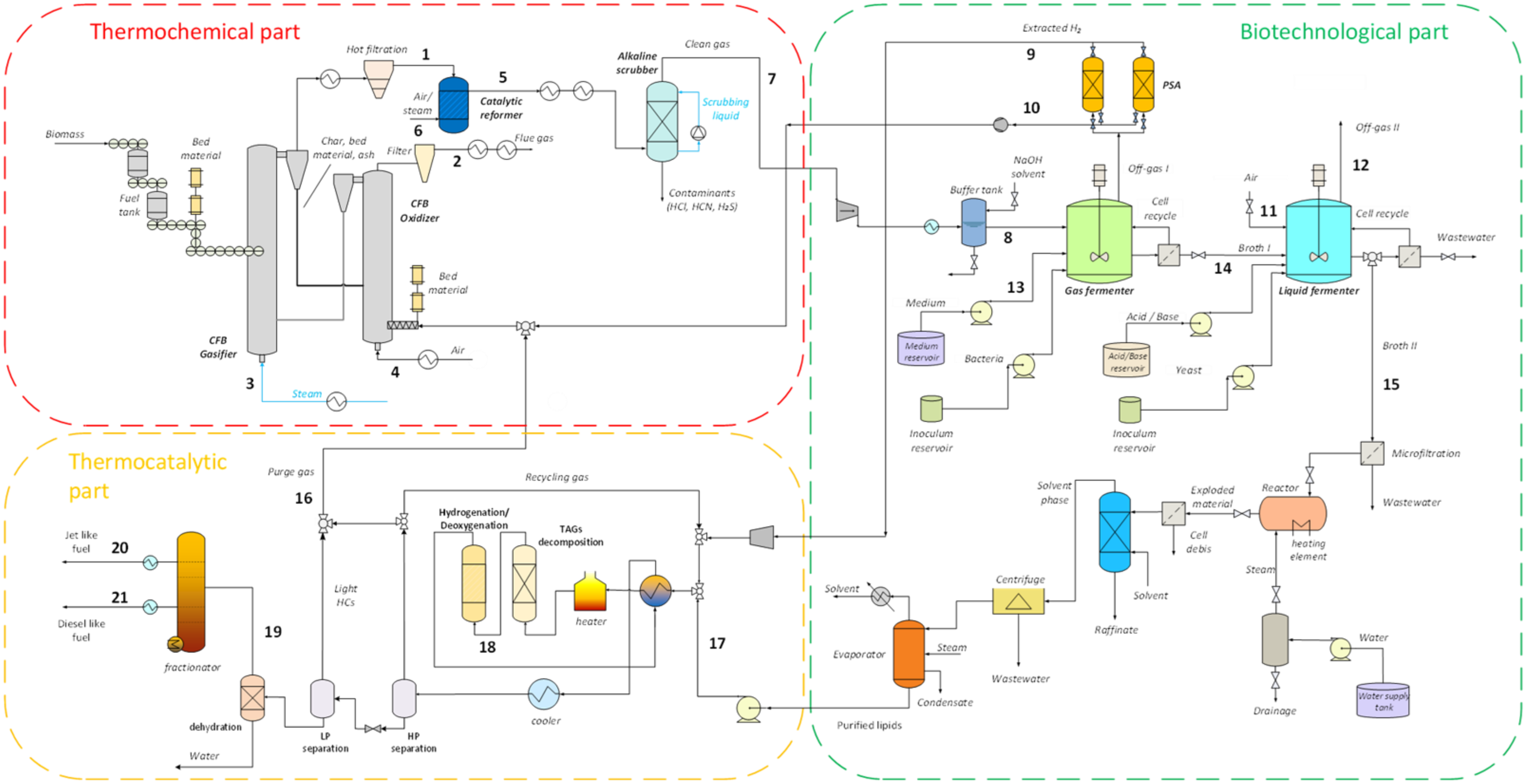


- Utilization of the off-gas (unreacted gas) of the gas fermentation in the oxidizer of the DFBG unit → **higher gasification efficiency, avoidance of technical barriers related to internal gas recycle in the bioreactor (i.e. inerts/contaminants accumulation)**

- Internal hydrogen extraction (and supply to the hydrotreatment unit) from the off-gas of the anaerobic fermentation via PSA (Pressure Swing Adsorption) → **avoidance of such an energy/cost-consuming unit like an electrolyzer**

- Air-driven autothermal reforming of syngas hydrocarbons instead of oxygen-driven, since in the absence of gas recycle in the bioreactor, some nitrogen content in the reformed gas would not be a critical problem → **avoidance of operational costs related to external purchase of industrial oxygen**

BioSFerA process flow diagram at industrial scale



Full-scale (200 MW_{th}) process simulations

- **Energetic Fuel Efficiency (EFE)** is the fraction of the chemical energy in the initial feedstock that is transferred to the final fuels
- **Carbon Utilization (CU)** is the fraction of carbon in initial feedstock that is converted to the final fuels
- **Liquid Fuel mass yield** is the mass flow ratio of liquid fuels (products) to biomass feedstock (feed)

Parameter	Unit	Value (simulation output)
Feed (crushed bark)	t/h	40.46
Liquid product (jet fuel)	t/h	2.56
Liquid product (diesel)	t/h	2.88
Cellular biomass (by-product)	t/h	1.21
Electric power demand	MWel	8.20
Energetic Fuel Efficiency (EFE)	**%**	**35.60**
Carbon Utilization (CU)	**%**	**25.40**
Liquid Fuel mass yield ($kg_{product}/kg_{feed}$)	**%**	**13.44**

Energy Balance

Waste heat	*37.4%*
Useful excess heat	*17.5%*
Cellular biomass formation	*9.5%*
Liquid fuels (EFE)	***35.6%***

Carbon Balance

Biogenic CO_2	*67.9%*
Wastewater	*1.1%*
Cellular biomass formation	*5.6%*
Liquid fuels (CU)	***25.4%***

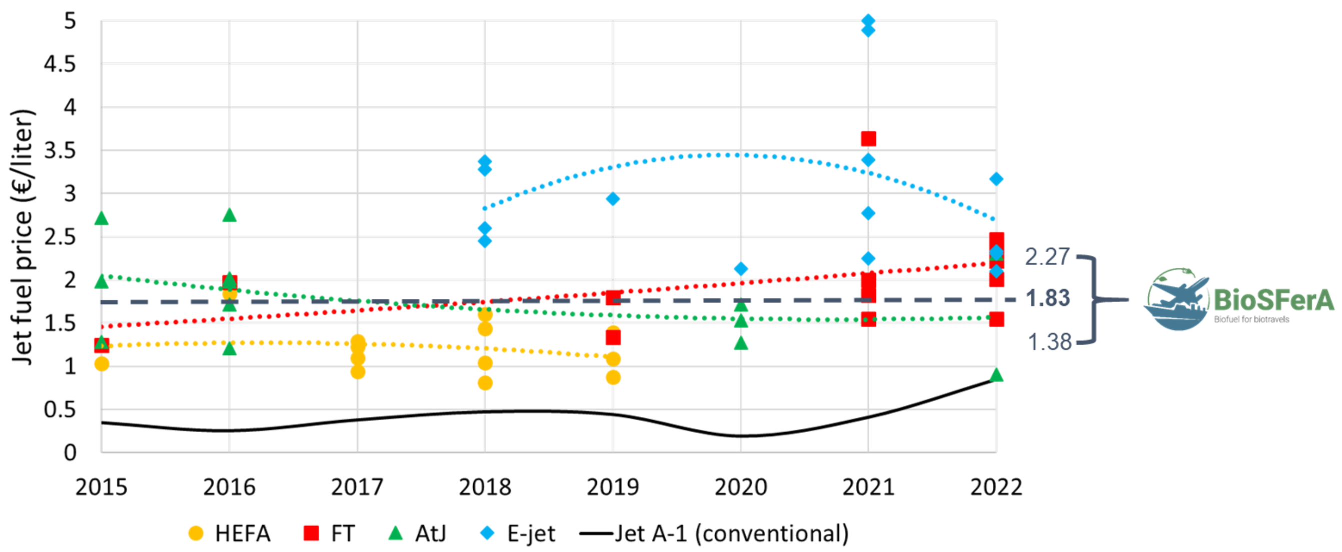
Techno-economic assessment

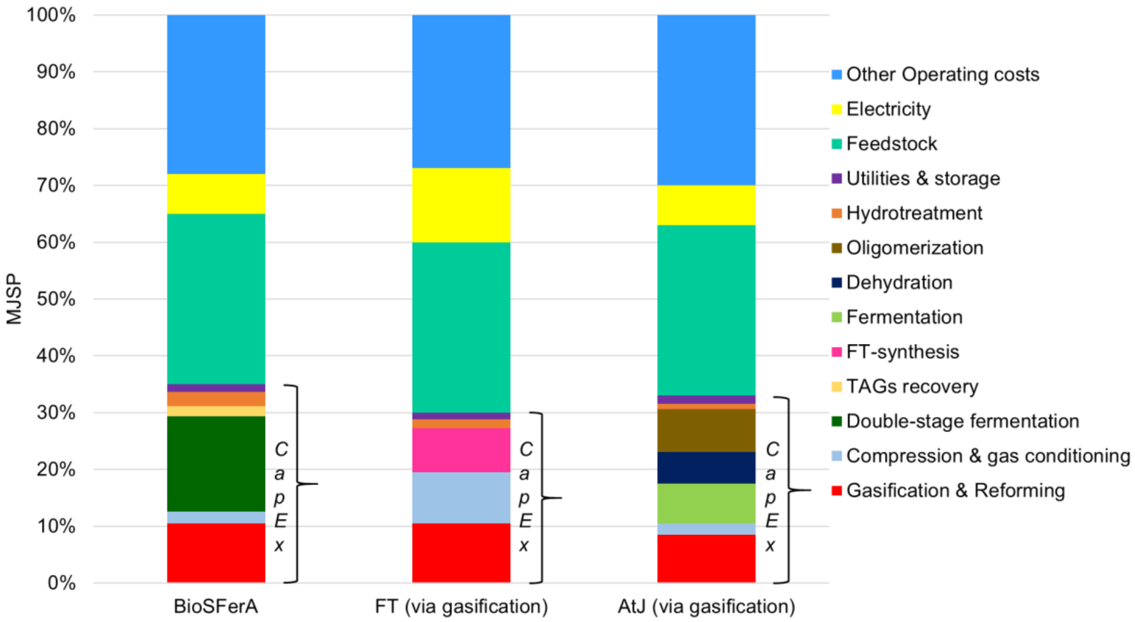
Business cases – Main results

Business case	Jet Fuel scenario	Marine fuel scenario	Microbial oil scenario
Total Capital Investment (€)	*576,928,000*	*557,568,000*	*526,592,000*
Annual operating costs (€/year)	*49,984,760*	*49,509,560*	*48,749,240*
Income from diesel (€/year)	*14,475,024*	-	-
Income from cellular biomass (€/year)	*6,288,716*	*6,288,716*	*6,288,716*
Biomass feed (t/year)	*301,295*	*301,295*	*301,295*
Produced jet fuel (t/year)	*32,435*	-	-
Produced diesel (t/year)	*8,042*	*40,744*	-
Produced microbial oil (t/year)	-	-	*50,395*
Minimum Jet Selling Price - MJSP (€/L)	*1.83*	-	-
Minimum Diesel Selling Price - MDSP (€/L)	-	*1.71*	-
Minimum Oil Selling Price - MOSP (€/L)	-	-	*1.32*

Techno-economic assessment

Benchmarking with the dominant biofuel (jet) technologies

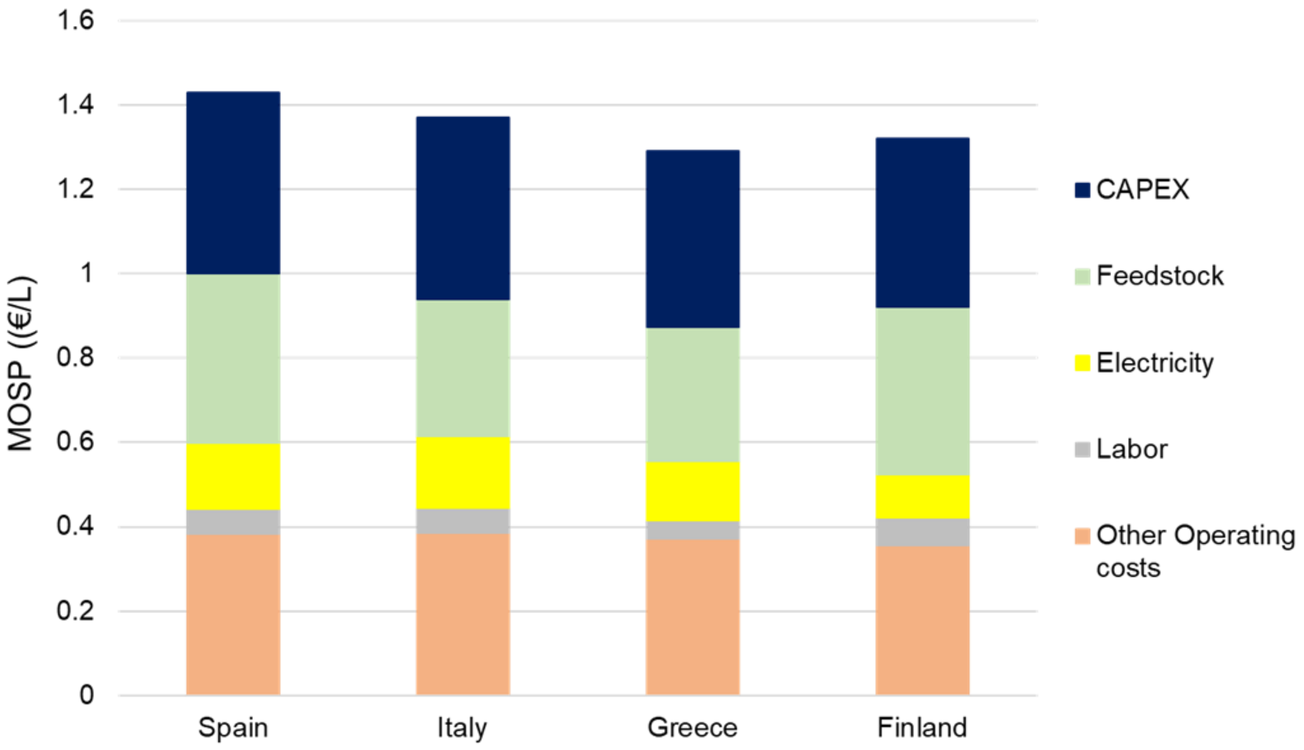




- **HEFA-produced** SAF is the most cost-competitive option and the only route so far that can consistently compete with conventional jet fuel prices. The respective trend lines for the semi-commercialized **Fischer-Tropsch (FT)** and **Alcohol-to-Jet (AtJ)** routes lie well within the range of **1.50-2.00 €/L**.
- The obtained **baseline MJSP of 1.83 €/L** reveals the preliminary ability of the BioSFerA concept **to be financially competitive since it is within the range (1.50-2.00 €/L) of the dominant BtL technologies (FT & AtJ)**.
- The capital investment of the **BioSFerA** concept seems as demanding as for the other technologies, mainly due to the large required number of bioreactors. **Higher obtained productivities and concentrations for acetic acid/TAGs production can drastically reduce the capital costs of the double-stage fermentation and upgrade the financial competitiveness of the concept**.

Techno-economic assessment

Replication pre-feasibility studies in 4 EU countries



Environmental assessment

Life Cycle Assessment (LCA) framework

Scope
Evaluation of the environmental impact of 5 different scenarios throughout their entire life cycle - different types of biomass feedstock and biorefinery locations are considered.

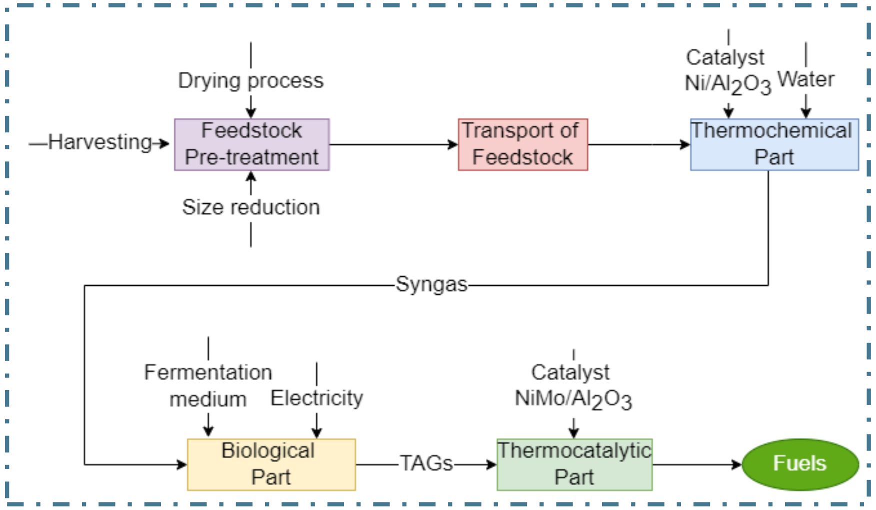
Methodology
Guidelines & modelling framework in accordance with the European Renewable Energy Directive 2018/2001/EU (RED II) & the ISO 14040/44 Standards.

System boundaries
All stages of BioSFerA project are considered in the analysis;

- Feedstock pre-treatment stage (harvesting, drying, chopping)
- Thermochemical part / biomass-to-syngas
- Compression stage / prior to fermentation process
- Biological part / syngas-into-TAGs
- Purification of TAGs & Thermocatalytic part / TAGs-into-liquid fuels

Several KPIs are calculated – specific focus on GHG emissions

Simplified definition of system boundaries



Investigated Scenarios

Country	Feedstock
Finland	Crushed bark
Greece – Case 1*	Olive tree pruning & organic waste (80/20 w/w DM)
Greece – Case 2	Olive tree pruning
Italy	Cereal straw
Spain	Vineyard pruning

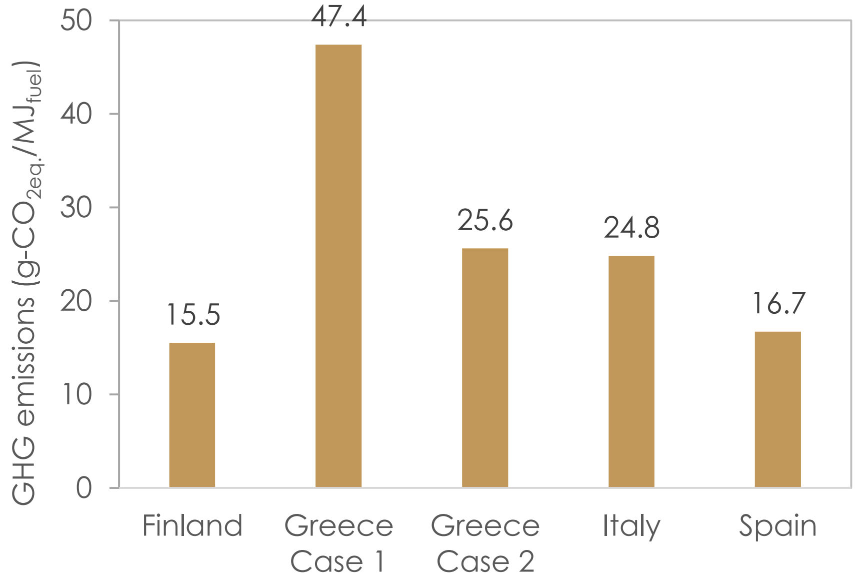
**Drying process is only included in Case 1 of Greek scenario (high moisture content of organic waste 70-75%)*

Environmental assessment

LCA Results

Achievement

50-86 % GHG emission savings are achieved compared to the fossil fuel comparator (as defined in RED II Directive).



Major findings

Results are strongly affected by the (a) electricity consumption for the compression stage, (b) natural gas for the drying process (organic waste scenario) & (c) nutrients utilization for the fermentation.

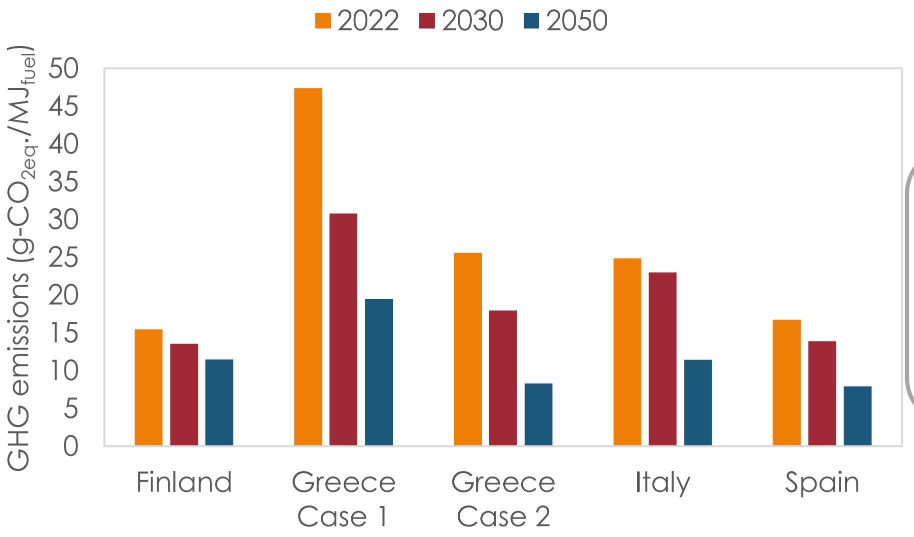
BioSFerA LCA results are **consistent** & **competitive** with the ones reported in similar cases in the relevant literature.

Future perspective

Effect of potential increase of RES share on GHG emissions;

- ✓ By 2030, around 70% of RES in each country's electricity generation mix is expected and
- ✓ by 2050, around 100% of RES is expected.

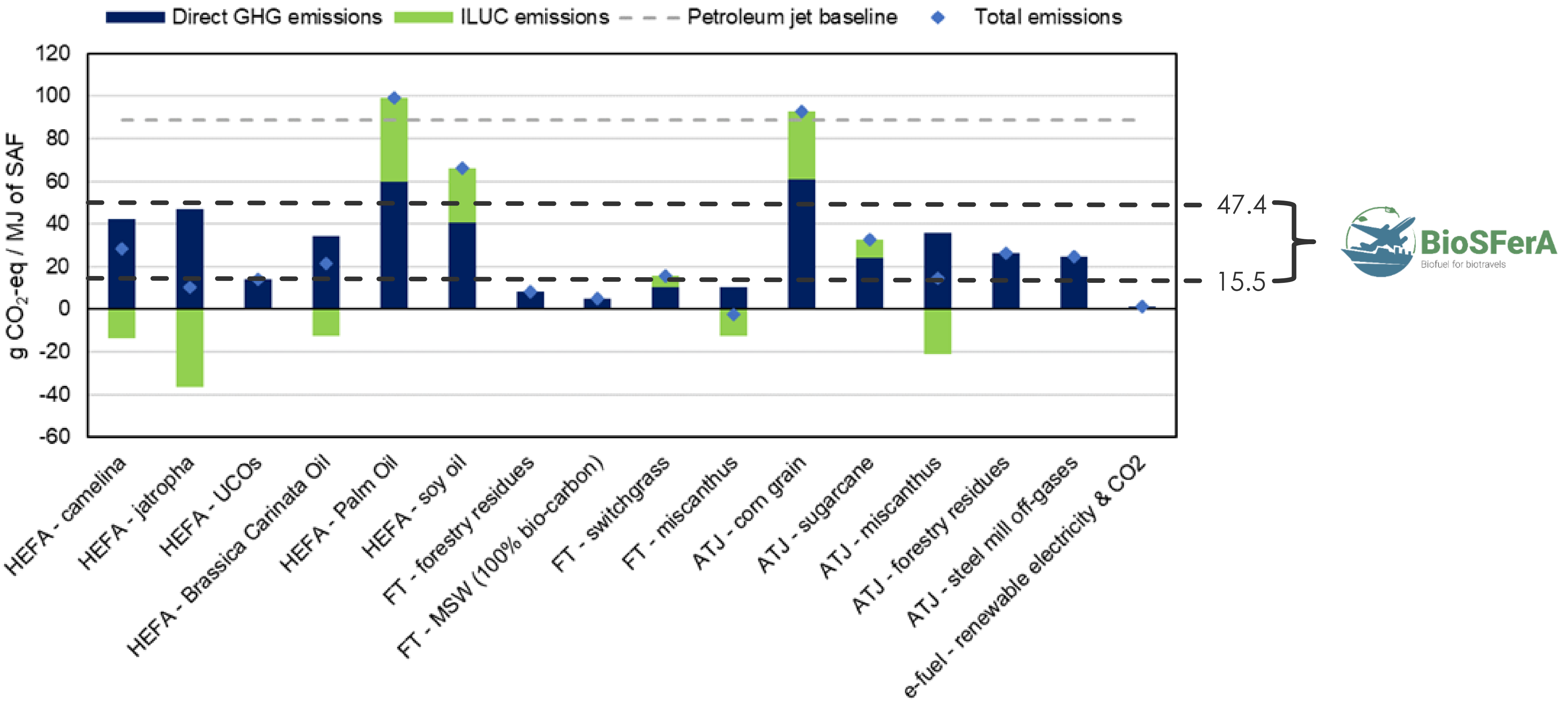
Results are calculated considering each country's *National Energy And Climate Plan*.



Results indicate that, in 2050, GHG emissions will experience a **great decrease (26% – 68%)**, compared to 2022 levels.

Environmental assessment

Benchmarking with the dominant biofuel (jet) technologies

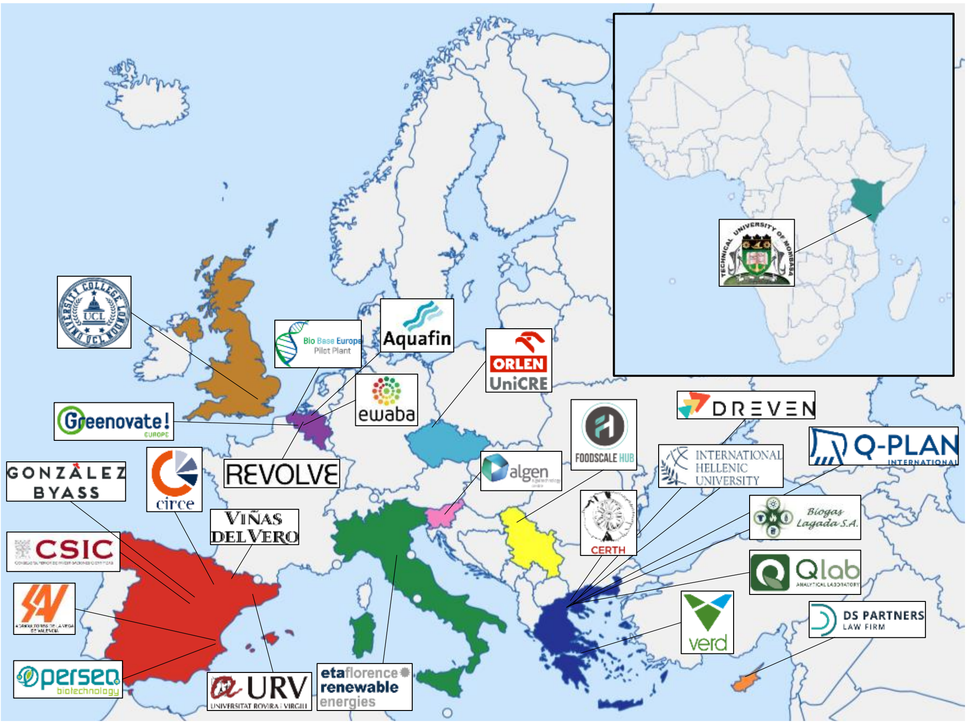


- Conventional jet fuel produced from petroleum resources, has a carbon intensity within the range of **85-95 g CO2eq/MJ**. BioSFerA's measured carbon footprint lies in the range of **15.5 – 47.4 g CO2eq/MJ**, achieving **50-86% GHG emission savings** compared to conventional jet fuel.

What is next?

Accelerating the sustainable production of advanced biofuels and RFNBOs - from feedstock to end-use: the **FUELPHORIA** project

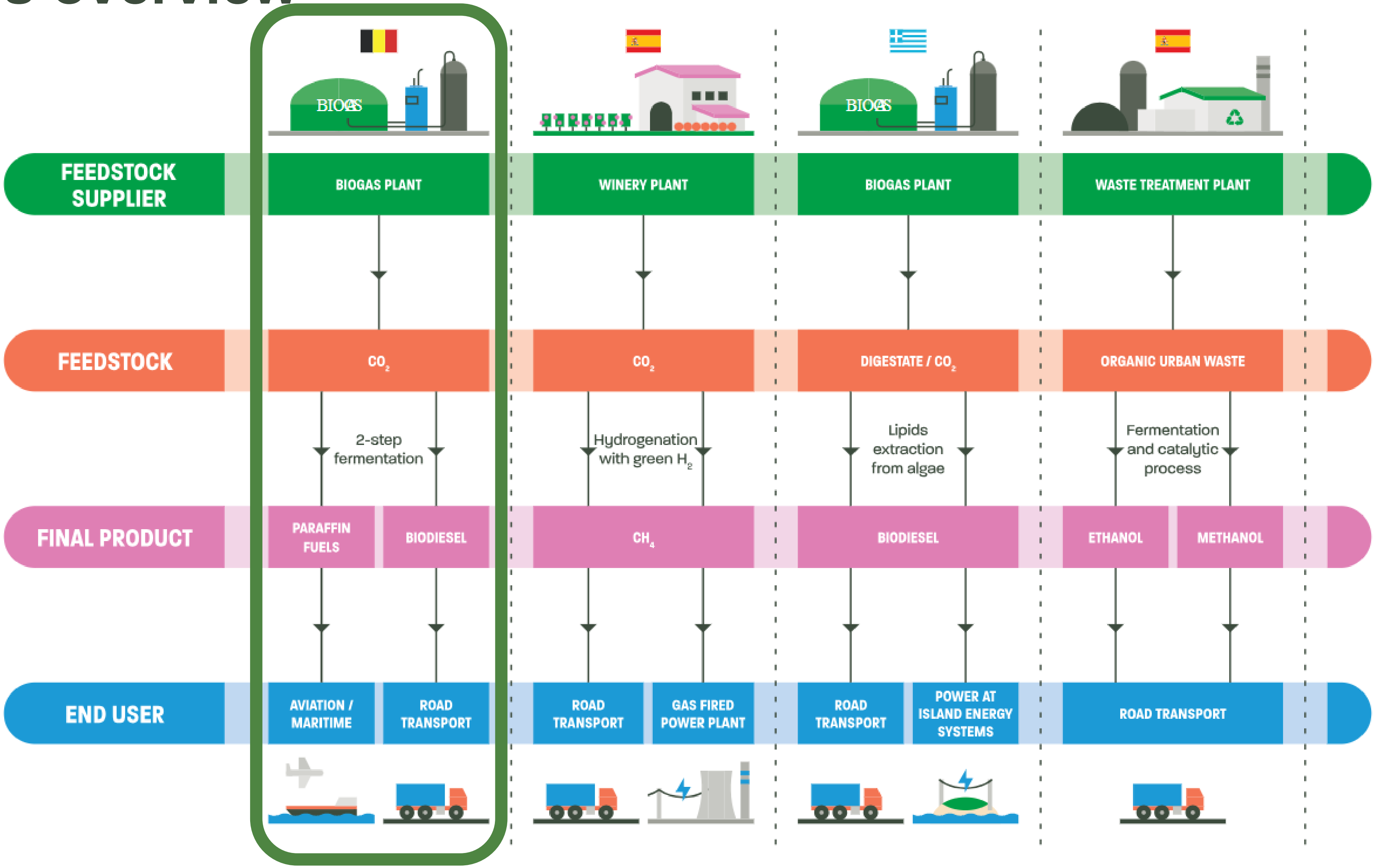
- Duration: 1/10/2023 – 30/09/2027 (48 Months)
- Budget/ EU contribution: €11,144,321.30/ €9,678,598.55
- Coordinator: CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS
- Beneficiaries: 22, Affiliated Entities: 3, Associated Partners: 1
- https://fuelphoria.eu/



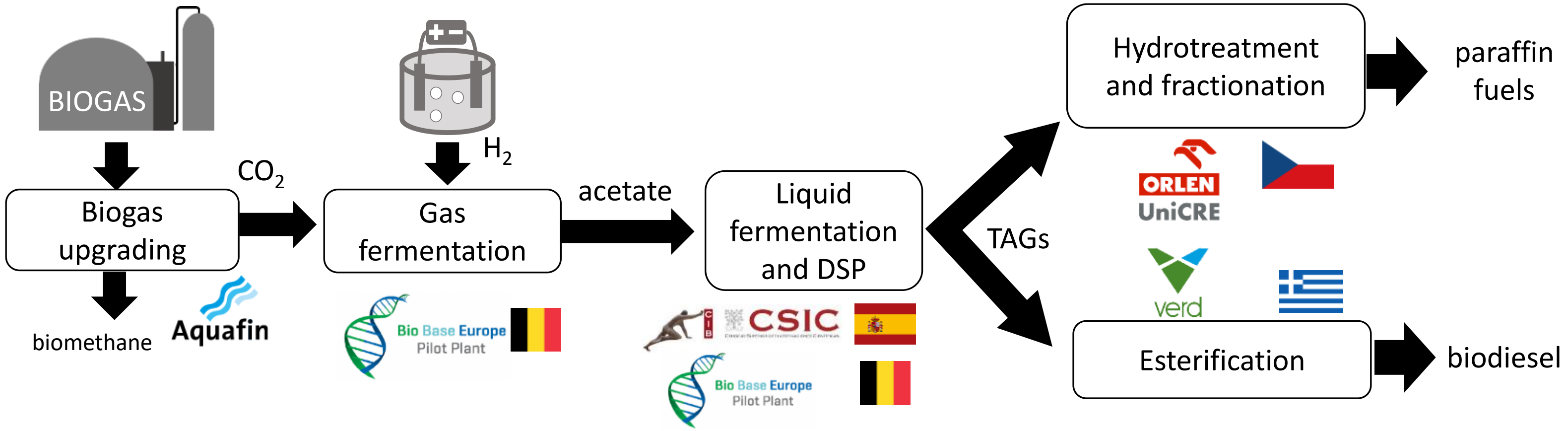
OBJECTIVES

- Demonstrate robust and cost-effective technological solutions for the production of advanced biofuels & RFNBOs
- Build a portfolio of sustainable, secure & complete Value Chains for advanced biofuels and RFNBOs from feedstock to end use
- Promote the exploitation of advanced biofuels and RFNBOs
  - by identifying barriers in value chains at EU level and in Africa
  - through policy recommendations at EU level
  - through new business and marketing concepts in Europe and Africa

Demos overview



DEMO 1 description



Location:
Aquafin's WWTP (Antwerp, Belgium)

Key technology:
Mobile gas fermentation unit

Expected results

- 75 kg biogenic CO2 will be converted into advanced liquid renewable fuel
- 30-day gas fermentation run with the mobile unit: 75 kg CO_2 in total
- Up to 90% of CO_2 conversion at the fermenter
- Hundreds of kilos of TAGs produced at the second fermenter
- Acetate concentration 25-30 g/L after the first fermentation step
- Lipids concentration 50-100 g/L after the second fermentation step
- 150L of liquid paraffinic fuel from microbial oil hydroprocessing
- 100L of biodiesel produced from microbial oil esterification

Key results & conclusions

- Introduction of a new sustainable feedstock for HEFA plants, expanding the portfolio of advanced feedstocks for marine and SAF
- 35.6% energy efficiency, 25.4% total C utilization
- Baseline MJSP: 1.83 €/L
- GHG emission savings: 48% to 86% compared to conventional fossil fuels
- Most environmental case: GHG emissions at 15.5 g $CO2_{eq}/MJ_{fuel}$
- New endeavor at demo scale for turning biogenic CO_2 into microbial oil for marine fuels and SAF

Thank you!

BioSFerA
Biofuel for biotravels

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 884208

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