REFOLUTION - UNLOCKING THE POTENTIAL OF BIOFUELS FOR AVIATION AND MARINE SECTOR

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ABSTRACT: Among solutions to reach an EU net zero emissions economy by 2050, advanced biofuels have the potential to reduce emissions in the transport sector by saving several gigatons of CO_2 emission per year. Ambitious targets by 2050 were set for the green transition of air and marine transports, respectively with a blending mandate of 70% for sustainable aviation fuels, and 80% reduction in emissions from ships. However, the development of advanced biofuels is hampered by a conjunction of several factors: the complex conversion of biomass feedstock, the massive investments needed for each new refinery unit, the lack of certification for market adoption and social acceptance concerning the biofuel production itself. REFOLUTION is a 4-years project started in 2023. The project will tackle these limitations by delivering a cost-effective production (reduction of CAPEX by 50% and OPEX by 45%) of advanced biofuels for the aviation and marine sectors via a process that can be implemented in existing European refineries.
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1 AIMS OF THE PROJECT

REFOLUTION builds the basis of an increased incorporation of advanced biofuels production in existing plants, enhancing the potential of Europe's 93 operating refineries in accelerating the transition to a greener economy and delivering up to 30% reduction in CO_2 emission from their core FCC units.

The project will develop and demonstrate an innovative process to convert biomass derived from fast pyrolysis oil (FP) into advanced biofuels by combining different co-processing technologies. It will apply Fluid Catalytic Cracking (FCC) co-processing of bio-oils for aviation and marine applications at TRL7, and hydrotreating bio-oil for marine at TRL6 targeting the integration with refining for large-scale biofuel production.

It will contribute also to increase digitalization in refinery and will develop innovative tools for green carbon tracking along the whole process, allowing the optimization of carbon content and the validation of new standards.

2 FCC TECHNOLOGY

Fluid Catalytic Cracking (FCC) is a refining technology that converts heavy hydrocarbon feedstock, typically Vacuum Gasoil (VGO) to lighter products such as LPG, gasoline, kerosene, diesel and gasoil.

With the transition towards green transportation refiners will have to adapt to a significantly different product demand by 2050. While gasoline demand will be reduced due to the uptake of light duty electric vehicles and phase out of ICEs (internal combustion engine) for cars and vans, demand for advanced biofuels in the aviation and marine sector will increase due to obligatory blending mandates or obligatory reduction of GHG intensity. Refinery operators must reconfigure their plants to process significantly more sustainable feedstock, maximize yields of kerosene and marine fuels while assuring compliance with fuel specifications.

REFOLUTION will optimize FCC process parameters, catalyst, and plant design starting at lab-scale (~0.1 kg/h), through small-scale piloting (~1 kg/h) and finally at large-scale pilot (~20 kg/h) to maximize co-processing rates and the FCC kerosene yield to meet the expected significant increased demand for sustainable aviation fuel.

REFOLUTION will configure a large-scale FCC pilot-plant with ~20 kg/h which will be openly accessible to the European refining industry, equipped with dedicated bio-feed injectors.

REFOLUTION will evaluate hydroprocessed kerosene samples derived from FCC co-processing for suitability as aviation fuel. In the early stages of the project, low fidelity assessment (pre-screening) will be conducted for the samples produced at lab-scale and small-scale to provide rapid feedback on the fuel quality and support process development. With larger sample volume from the small-scale and mainly from the pilot plant, high fidelity assessment, selected from Tier 1 and Tier 2 of ASTM D4054 will be carried out and the results will be used to developed a concerted fuel approval strategy for future inclusion of the REFOLUTION production process in ASTM D1655.

3 HYDROTREATING TECHNOLOGY

Hydrotreatment is historically related to the petroleum processing industry, mainly used to remove sulphur from petroleum feeds (HDS of SRGO), at temperatures between 300 and 500 °C, and hydrogen pressures of 35 to 170 bar.

Several technical challenges motivated the search for hydrotreating processes and catalysts that better suit the highly oxygenated and heterogeneous nature of the pyrolysis liquids, where process characteristics, reaction mechanism and eventually new innovative catalysts for the pyrolysis treatment were developed. Precious metals-based catalysts such as Ru, Pd and Pt have generally shown serious deterioration even after repeated use. This main challenge has been overcome by a two-step processing: reducing the 'carbohydrate' content by selective hydrogenation ('stabilization') at low temperatures before processing at high temperatures to remove the oxygen.

For the first step of stabilization, the Nickel-based catalyst (Picula^{TM}) shows a very high selectivity at low temperatures towards the hydrogenation of the reactive aldehydes.

Compared to other catalysts (e.g. noble metals), the stability is below a reasonable commercial target (of > 1000 L/kgfeed). It is understood that the main contaminants in the oils affecting the catalyst's activity are not (only) sulphur and (alkali and heavy) metals, but more likely some other reactive oxygen (or nitrogen) containing components present.

Full deoxygenation of bio-liquids following the first stabilization step is also demonstrated, typically applying commercial CoMo or NiMo catalysts. It yields a marine diesel-like fuel, but apparently the type of catalysts as well as the operating conditions significantly dictate the overall process performances (yield, H_2 Consumption...) and quality. This step requires hydrogen as well (overall typically 600 NL/kgfeed), while both NiMo and CoMo catalysts are applied.

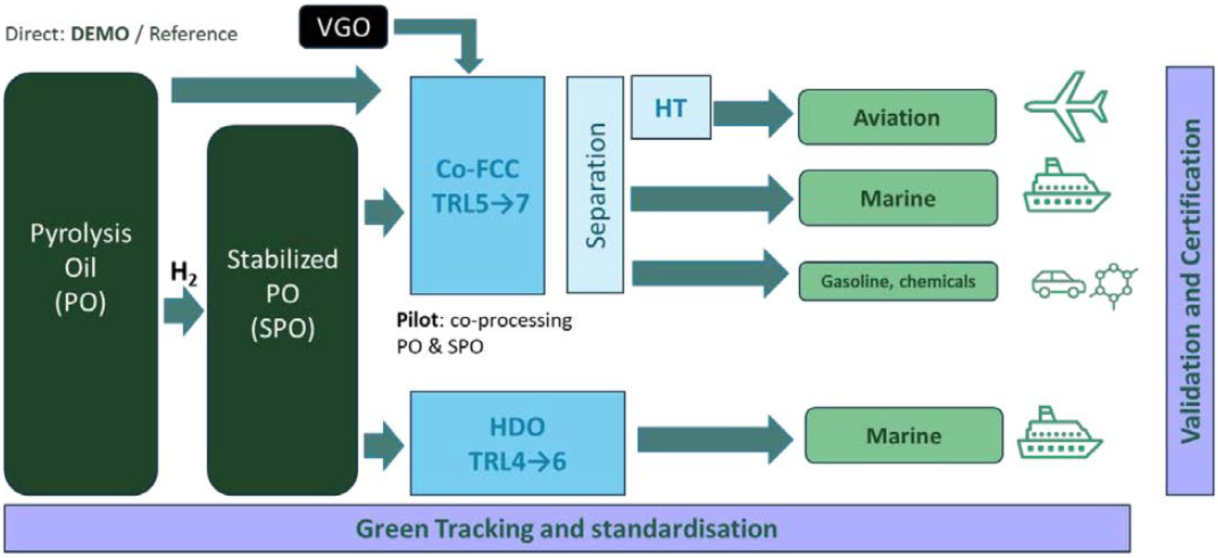

Figure 1: REFOLUTION Technical pathway

4 METHODOLOGY

At a scientific level, the methodology of the project includes three steps:

1. In the first stage, benchmark renewable and fossil liquids provided by the partners will serve as a reference to allow focus on refinery integration.
2. In the second step, the partners will develop innovative and appropriate understanding of the process parameters' influence on the targeted transport fuels quality by comparing the initial reference materials with the optimized fuels produced during the project. This strategy will allow appropriate improvement of the conversion processes to take place in the initial stage of the project. The knowledge and feedback gained through a series of iterations will be further applied to produce biofuels with higher co-refining rates, thus gaining development time and reducing failure risks.
3. At the end, the processes developed for the conversion of biomass into fuels will allow fuel properties, quality, and performance to be tuned in terms of green carbon rate, carbon efficiency and process parameters (temperature, pressure, duration…) to be compatible with the diverse industrial requirements.

REFOLUTION is designed to respond to the challenge of cost-effective biofuels in existing plants to facilitate their market uptake. The implementation of this technology is expected to reduce the CAPEX by 50% and OPEX by 45%.

Advanced biofuels markets are seen as a part of society and as a part of a system for achieving green transition.

REFOLUTION combines technological breakthroughs with public acceptance through the Responsible Research and Innovation approach that is the way to create a dialogue between researchers, stakeholders and citizens.

The project includes also interviews, webinars and workshops to feed the connection between all of them.

5 RESPONSIBLE RESEARCH AND INNOVATION APPROACH

REFOLUTION will use the Responsible Research and Innovation approach which is a key in organizing such dialogue creation processes between researchers, stakeholders and citizens. For this reason, the project will involve many stakeholders to make sure that a large public is reached.

The Responsible Research and Innovation process has the goal of understanding the social implications of the research and ensuring the social acceptance of the outcomes, such as biofuel and its production processes.

The social acceptance requires social awareness which means that all the stakeholders of biofuel markets understand how biofuels are produced and distributed. Awareness includes also understanding of the raw material system, emissions and influence on climate change mitigation. Sustainability includes social and economic impacts, which should be made clear to the stakeholders including citizens in the roles of consumers and customers.

Furthermore, REFOLUTION strives for the goal of equal opportunities, without any types of discrimination.

For this purpose, an interdisciplinary team has been assembled, and a cooperative work process is strived for, as the basis for achieving a successful project work.

6 REFOLUTION CONTRIBUTION FOR CO_2 REDUCTION

This project will evaluate the environmental impact of the developed biofuels and the potential impacts related to the co-processing of biobased and fossil raw materials.

The assessment will be mainly based on life cycle assessment (LCA). LCA will be conducted following the principles defined in ISO14040 and 14044 standards, and taking into account the requirements set out within the European Product Environmental Footprint method (PEF, EC 2021) and the Renewable Energy Directive where relevant. The assessment includes also the environmental impact categories (such as acidification, eutrophication and land use) included within the PEF method.

LCA will cover the whole life cycle of the developed biofuels, starting from raw material acquisition (including production of biomass) until the main processing steps (e.g. the pyrolysis process and following up-grading or processing steps) until the use phase. The assessment will consider the foreseen/proposed/latest requirements of the European Climate and Energy Package related to maritime and aviation fuels, and the on-going standardization activities related to co-processing, as part of transition to fully biobased fuels. The GHG emission reduction achieved by REFOLUTION will be derived from the reduction of CO_2 fingerprint in the final fuel products and fossil-carbon CO_2 emissions from the flue gas of the FCC unit since a significant part of the burnt coke will be bio-based carbon, obtained from the PO/SPO.

With regards to the aviation fuel production the partners of REFOLUTION aim at producing around 100-120 kty of biomass-derived aviation fuel in 2030. Considering the fossil aviation fuel emissions account for 3.16 mt CO_2/mt aviation fuel; thus, the switch from fossil to REFOLUTION aviation fuel is estimated to save 316-380 kt CO_2 per year.

Regarding the operation of the FCC units fed with PO / SPO, the emission factor for a typical FCC unit has been estimated as 62.9 t CO_2/h for a typical unit of 60.000 barrels per day. The total amount of CO_2 emissions for such FCC unit would reach 500 kt CO_2/year. If only 33% of the total coke production comes from the PO / SPO, such unit would diminish its net CO_2 fingerprint down to 333 ktCO_2 per year.

FCC units may account for 20-25% of the total CO_2 emission of the refining operations.

7 REFOLUTION RESULTS

The results of this project are:

- Development of innovative processes for the conversion of bio-oil made from lignocellulosic biomass into biofuels for aviation and marine applications, that can be implemented in existing facilities
- Increased digitalisation, FCC through add-ons to existing flow sheeting programs /unit model, with the objectives to provide scenarios for implementation of bio-liquid into existing archetype refineries
- Development of innovative tools for green carbon tracking
- Pathway towards fuel certification for aviation application, and standardisation for both aviation and marine applications
- Social Sciences and Humanities (SSH) analysis to ensure the social acceptance of the technologies and products obtained

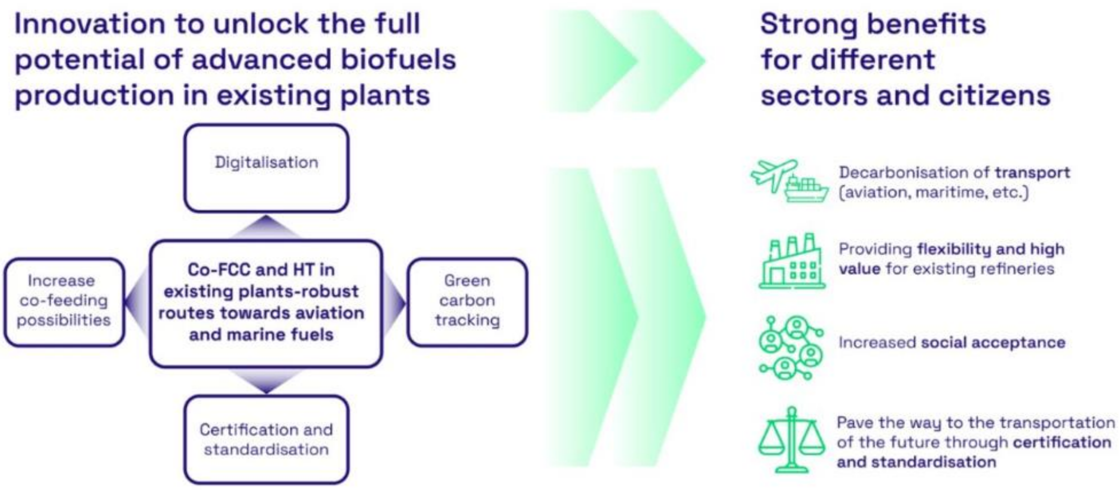

Figure 2: REFOLUTION overview – answering the challenge of cost-effective biofuels in existing plants to facilitate market uptake.

8 REFERENCES

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REFOLUTION
Unlocking the potential of biofuels

10 PARTNERS LOGOS