COCPIT PROJECT - Biorefinery concept for circular production of microalgae-based fuels for shipping and aviation

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ABSTRACT: COCPIT´s ambition is to enhance the SAF production chain by bringing ground-breaking innovations at each thread of it. It aims also to provide investors with a human centred decision tool in a "test before invest" spirit with a high confidence level to de-risk investments. A lipid-rich microalgae strain is cultivated in an intensified reactor coupled to semi-transparent photovoltaic panels transforming infrared (non-photosynthetic) light spectrum into electrical power. The transformation of algal biomass into SAF is studied using two alternative pathways: The most mature one, HEFA, and a very promising one HTL. The project focuses on the circularity, productivity, sustainability and economic viability of the chain. For HEFA pathway, efficient, low impact and regenerable ionic liquids are used to extract lipids and to catalyse hydrotreatment. For HTL pathway, a continuous reactor, tailored to SAF production from the chosen strain is designed and constructed to reduce clogging issues and to size with higher precision the heat exchangers. Furthermore, the mechanistic models that are developed and used in the design increase the scalability of the HTL. Biocrude upgrading is led to give a high flexibility between SAF and shipping fuel production. The system is designed in a circular way to reduce by-products, feed system with endogenous hydrogen, recirculate nutrients and reduce its water intensiveness. The whole integrated system is simulated with Unism software and all technical, economical, environmental and life cycle indicators are calculated under the COCPIT decision tool and typical scenarios are compiled. The decision tool is delivered within a marketplace that puts at investor's service a range of required technological solutions, equipment and skills.
KEYWORDS: Bioenergy, Energy, fuels and petroleum engineering, Sustainable Aviation Fuels, Hydrothermal liquefaction, Microalgae, decision tool, LCA, Techno-EconomicAssessment, HEFA, System integration, Chemical Engineering.

1 INTRODUCTION

Nowadays, "climate emergency" is becoming more and more urgent. That is why, the necessity of switching from fossil fuels to renewable energy sources to obtain new and sustainable types of fuel is needed. Particularly, transportation sector plays a crucial role, accounting for the 25% of total EU greenhouse emissions. Going more into detail, the sectors that result "hard-to-electrify" are maritime and aviation, and this is due to the high energy density required.
Giving an overview of the target numbers the EU set for:
GHG intensity reduction in shipping sector:

- 2% in 2025;
- Up to 80% in 2050;

SAF (Sustainable Aviation Fuels) integration in aviation fuel mix:

- 2% in 2025;
- Up to 70% in 2050.

2 COCPIT PURPOSE

COCPIT project aims to be part of the process to change the field of development for the bioenergy production of biofuels starting from renewable sources, to develop microalgae-based advanced biofuels. This biofuels production technology emerged in the 2010's, nevertheless this field of research soon slowed down the research application due to general disappointment regarding the process yield or oil compatibility in co-refining.

This brings to one of the main aims of the project: to tackle technical limitations to boost SAF, such as feedstock limitation, production costs and system robustness.

To do it, COCPIT project focuses on:

- HEFA (Hydrotreated Esters and Fatty Acids), that is a mature technology that has proved its viability, but relying on a very limited sustainable feedstock and depending on expensive catalysts presenting regeneration issues;
- HTL (Hydro-thermal Liquefaction) route, that is a promising pathway due to its adaptability to a wide range of feedstocks, and its ability to shift from shipping fuel-oriented to SAF-oriented applications.

Following the above-mentioned pathways, the overall concept is to deliver an innovative circular and complete production chain of microalgae-based SAF through both technologies developing innovations at different steps of the production chain:

- Separation stage, innovative approach to extract lipids for the HEFA pathway through ionic liquids (IL), and covers the extraction of proteins from algae before its use in HTL;
- Transformation stage, IL as catalysts for HEFA pathway, and efforts to solve the problems of clogging and biocrude separation for the HTL pathway;
- The whole process, aims to be circular, optimised and integrable into its immediate environment.

3 COCPIT's Key Specific Objectives (KSO)

1. Increasing microalgal feedstock for SAF production by developing an innovative semi-transparent photovoltaic bioreactor which enhances sunlight conversion efficiency while reducing energy requirements;

2. Provide a novel HTL reactor fully tailored for SAF production by elaborating mechanistic models for upscaling and producing a numerical testbench;

3. Achieving reliable hydrodenitrogenation with minimum H_2 for maximum drop-in SAF production;

4. Developing an IL-based separation method to enhance lipid extraction from *Parachlorella kessleri*;

5. Producing aromatics to improve SAF properties;

6. Developing IL-based catalysts for HEFA pathway;

7. Quality and lifecycle-driven optimization of SAF production from HTL followed by upgrading pathway;

8. Provide a fully circular, cost-effective and sustainable jet fuel production chain by recirculating CO_2 and nutrients and by recovering H_2 from the organic by-products of both pathways;

9. Delivering a decision tool based on Sustainability (TEA, LCA and s-LCA) indicators to facilitate the selection of the most relevant conversion pathway for SAF production;

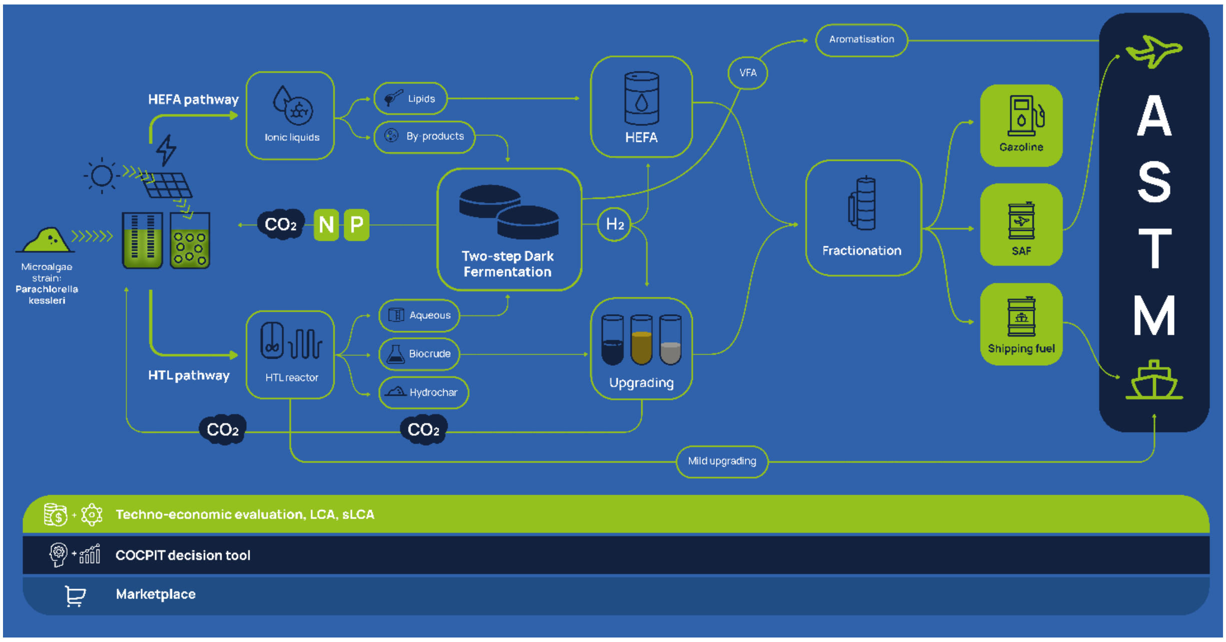

Figure 1. Overall workflow of the process

4 PROJECT IMPACTS

The European roadmap for aviation fuels set the objective of satisfying the 70% of aviation sector's demand using SAF by 2050 (92% should be produced in the EU).
COCPIT wants to promote a strategic autonomy by leading the development of key digital, enabling and emerging technologies, sectors and value chains with a fully circular, optimised and predictable microalgae-based SAF production chain in which *Parachlorella kessleri* is seen as a promising strain for its lipids and carbohydrates density when associated with the conversion processes aiming beyond the state-of-the-art performances.
Furthermore, this project contributes in making Europe the first digitally enabled circular, climate-neutral and sustainable economy by supporting the carbon abatement of the aviation sector.
COCPIT intends to make a real contribution to the sustainable growth by developing low emission biofuels to reduce our exposure and optimising the entire process to reduce production costs while the circularity of the systems also provides benefits for a cleaner production. In conclusion, this project aims to create a decision tool, which provides a fuel through an overall chained, environment-friendly methodology, reducing GHG emissions in use.

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