GREENFLEXJET TO PRODUCE ADVANCED SUSTAINABLE AVIATION BIOFUEL

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ABSTRACT: GreenFlexJET is an EU funded project that is developing a pre-commercial demonstration plant to produce sustainable aviation fuel from waste vegetable oil and organic solid waste biomass. The plant will demonstrate the integration of the SABR-TCR technology i.e., transesterification (TRANS), hydrodeoxygenation (HDO) and hydrocracking/isomerisation (HC) and Thermo-Catalytic Reforming (TCR®) combined with hydrogen separation through pressure swing adsorption (PSA) to produce a fully equivalent jet fuel (compliant with ASTM D7566 Standards). The project plant installed close to waste sources and product off-takers at Gloucestershire Park of Science and Technology, Berkeley (UK) will produce 1,200 tonnes of jet fuel from around 3,600 tonnes of waste vegetable oil and 3,500 tonnes of dried organic waste per year. The demonstration plant will provide a real example of how sustainable aviation biofuels can be produced economically on a large scale, whilst simultaneously addressing social and environmental sustainability.
Keywords: bio-jet fuel, organic wastes, waste vegetable oil, green hydrogen, Thermo-Catalytic Reforming, transesterification, hydrodeoxygenation, pressure swing adsorption.

1 INTRODUCTION

Emissions of CO_2 from aviation currently amount to almost 3% of total global emissions with around 1 Gt of CO_2 per annum, under a business-as-usual operation [1]. Fleet replacement with low-carbon technologies due to the significant capital cost and long lifetime is predicted to take several decades. Therefore, “drop-in” alternatives that can be used in the existing engines are required during transition. However, the current high cost resulted in a low uptake of sustainable aviation fuels. But the introduction of the EU Green Deal and the EU commitment to reduce the block’s carbon emissions by 55% during the next decade and reach net-zero by 2050, stimulated activities in the development of bio-jet fuels. The RED II [2] provides an opening for aviation inclusion, through “opt-in” for aviation, including a 1.2 multiplier for the use of sustainable fuels in aviation. The need for bio-jet fuel will be even higher after the introduction of the considered EU aviation fuel taxation rules. This will effectively establish renewable fuel blending requirements for the global aviation industry. Therefore, it is important to focus on the production of high yields of sustainable liquid jet fuels.

Renewable fuel blending for jet fuel is regulated under ASTM D7566 [3] containing detailed requirements regarding the production of jet fuel blends along with several annexes specifying certain types of renewable/synthetic jet fuel components which are permitted for use. There are different pathways to produce sustainable aviation fuel (SAF). Currently (May 2022), eight different technology platforms have been certified to produce SAF for use in commercial aviation: Fischer-Tropsch synthesised hydro-processed paraffinic kerosene with and without aromatics (FT), paraffinic kerosene from hydroprocessed esters & fatty acids (HEFA), iso-paraffins from hydro-processed fermented sugars (SIP), synthesised kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources (FT-SKA), synthesised jet fuel from alcohols (AtJ), catalytic hydrothermolysis (CHJ), hydroprocessed hydrocarbons, esters and fatty acids (HC-HEFA) and co-processing, as defined in ASTM D1655 [4]. Through the new provisions included in ASTM D7566, up to 50% bio-derived synthetic blending components can be added to conventional jet fuel [3].

2 GREENFLEXJET PROJECT FEATURES

GreenFlexJET is a six-year project part funded by the European Commission through the Horizon 2020 research initiative. The project is diversifying the feedstock for SAF beyond vegetable oils and fats to bio-crude oil produced from a wide range of organic waste. The GreenFlexJET process is highly scalable and less capital-intensive than current technologies and can be integrated into existing infrastructure. It provides for a sustainable, cost-competitive aviation fuel by combining regional and local supply and demand strategies in a circular economy. As a key factor to the decarbonisation of the aviation transport sector, it contributes to the Renewable Energy Directive Targets in Europe and to the fulfilment of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) goals.

The primary ambition of this project is to demonstrate and validate the technical and economic viability of the integrated SABR-TCR® technology approaches, together with their environmental and social sustainability, as well as the cost-competitiveness at commercial scale through the construction of a demonstration plant that will serve as an exemplar to facilitate rapid uptake and significantly de-risk subsequent commercial exploitation.

The process offers better economics and improves overall sustainability by processing waste feedstocks near the source and at a scale that matches the waste availability.

This project provides technical and economic validation by building a demonstration plant at a pre-commercial scale to deliver SAF. The GreenFlexJET project is delivering a blueprint for the production and distribution of this novel SAF technology. This will be a showcase of the medium to long-term impact on the aviation industry in Europe and beyond.

3 GREENFLEXJET CONCEPT

The GreenFlexJET project plant is based on a Sustainable Aviation Through Biofuel Refining (SABR) process developed by Green Fuels Research for decentralised transesterification of waste vegetable oils and animal fats, followed by hydro-deoxygenation (HDO) and hydrocracking (HC), targeting HEFA-based jet fuel already certified under existing ASTM D7566 standard [3]. The combination of decentralised transesterification and HDO treatment results in reduced conversion costs while providing access to a wider feedstock base. The GreenFlexJET is also one of the first technologies to use green hydrogen from the processed waste feedstock for the downstream refining process that is maximising greenhouse gas savings. Green hydrogen required for the SABR process will be produced from bio-waste using Thermo-Catalytic Reforming (TCR®), with hydrogen separation through pressure swing adsorption (PSA).

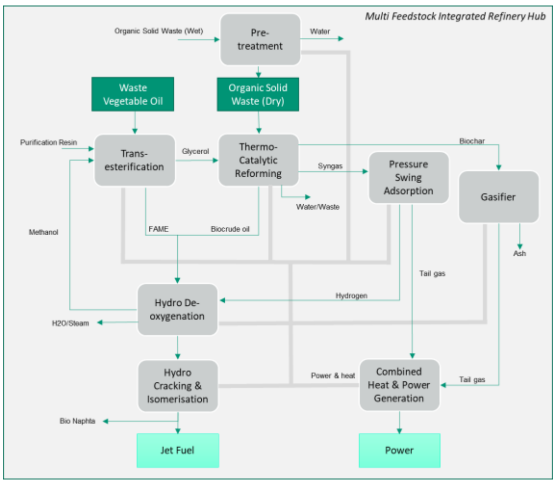

Figure 1: Flowsheet of the SABR-TCR process – demonstration plant.

TCR® reactor will produce also high-quality bio-crude oil suitable for hydro-deoxygenation and fractionation for sustainable aviation fuel. However, due to the lack of ASTM certification for blending, the intention for hydrotreated TCR® oils or their blends within GreenFlexJET is to demonstrate reasonable scale production and "fit for purpose" testing which will be used to inform the ASTM working group on quality assurance and performance standards of the new fuel and its blends with HEFA.

The GreenFlexJET plant will provide a sustainable, cost-competitive aviation fuel by combining regional and local supply and demand strategies in a circular economy. The GreenFlexJET project consortium brings together twelve industrial and academic partners from five European countries. The consortium has brought together partners from across the whole value chain and ranges. The University of Birmingham is the project coordinator. Green Fuels Research, HyGear Technology and Services BV, Fraunhofer-UMSICHT, Sterling Power and SORMEC are the main plant technology providers who designed and are building the conversion devices. SkyNRG is responsible for the final supply chain logistics of the biofuel products and validates the viability of integrating the biofuels produced into the existing aviation fuel refinery infrastructure. The University of Sheffield will analyse the fuels produced according to ASTM D4054 [5] (standard practice for qualification and approval of new aviation turbine fuels and fuel additives) to meet ASTM D7566 [3] (standard specification for aviation turbine fuel containing synthesised hydrocarbons). In addition, the entire value chain is mapped based on environmental performance, social and economic impact factors as well as potential risk elements by Università di Bologna and Leitat Technological Center. Finally, results are disseminated and promoted through dissemination partners, WRG and ETA-Florence Renewable Energies.

The primary ambition of this project is to demonstrate and validate the technical and economic viability of the integrated SABR-TCR® technology approaches, together with their environmental and social sustainability, as well as the cost-competitiveness, at a commercial scale through the construction of a demonstrator that will also serve as an exemplar to facilitate rapid uptake and significantly de-risk subsequent commercial exploitation. This project will mark the first pre-commercial scale deployment of the technology processing up to 3,482 tonnes per year of biomass waste and 3,600 tonnes per year of waste vegetable oil into 1,200 tonnes of SAF.

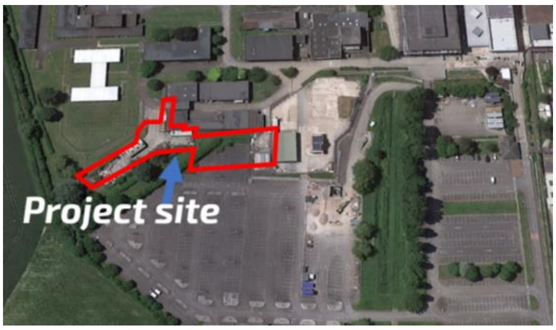

Figure 2: GreenFlexJET site plot plan at Berkeley, UK.

Jet fuel will be produced from the dried and pre-conditioned organic waste as well as waste vegetable oil, reducing the dependence on fossil fuels, increasing the variety of organic feedstocks which can be used and triggering the decarbonisation of the aviation transport sector.

4 SABR PROCESS

In the HEFA process, vegetable oil feedstock (from oil crops or waste oils) is first converted into FAMEs through transesterification with subsequent hydrotreatment, such as HDO and HC. HEFA bio-refineries operate in highly capital-intensive facilities, specifically designed, and implemented to process vegetable oil to renewable jet fuel (to be blended 50% with kerosene) and renewable diesel. Currently, most of the fuel produced in HEFA plants is sold as renewable diesel, since most of the fuel produced after hydro treatment and fractionation can be fed into diesel engines but not the other way around. In fact, HEFA plants usually produce 77% diesel and 10% jet fuel. These figures could be changed by additional process steps, entailing extra costs and lowering the production yield, which is a disincentive for producers to make renewable jet fuel. For this reason, although HEFA has the most competitive production cost for renewable jet fuel compared to other existing routes, there are not many HEFA bio-refineries globally.

SABR technology was developed and patented by Green Fuels (US8715374 B2), a global leading and longest established manufacturer of biodiesel production equipment, with over 30 major bio-refineries already commissioned around the world, producing over 100,000 litres of biodiesel every day. The transesterification module (the first part of the SABR process) constructed for the GreenFlexJET demonstration plant is presented in Figure 1. The hydrotreatment of FAMEs will be performed in the second part of the SABR process, the SABR Hydrotreatment module.

Figure 3: GreenFlexJET SABR transesterification module, FuelMatic ®, Green Fuels Ltd.

In the SABR process renewable aviation fuel can be obtained from waste cooking oil, animal fat residues or other waste bio-oils, which is ideal to meet the market request of the aviation industry (end users) and biodiesel manufacturers (clients) for the following key purchasing factors:

- scalable and low capital intensity plant,
- integration to existing biodiesel plants,
- flexible production,
- flexible feedstock.

5 TCR® PROCESS

TCR® produces renewable fuels from waste organic feedstocks such as sewage sludge, paper industry residues, the organic fraction of municipal solid waste, anaerobic digestate, etc.

The TCR® technology converts a broad range of residual biomass into three main products: H_2-rich synthesis gas, biochar, and liquid bio-oil. By integrating hydrotreatment and conventional refining processes, the bio-oil can be upgraded to SAF.

The TCR® process generates significant quantities of green hydrogen as a product (approximately 160 m^3 per tonne of biomass), which can be separated, purified and used as a stand-alone fuel: it can also be used for HDO and HC of the TCR®-oil, to give liquid fuel which can be subsequently fractionated and refined to produce sustainable aviation fuel.

To demonstrate and validate the technical and commercial viability of this integrated approach, the project will combine the TCR® plant with PSA technology to separate from the synthesis gas the produced H_2, that will be used in the HDO and HC, creating a new value chain.

The main objective is to create value products from the upgraded TCR® bio-oil. The bio-oil feedstock from the TCR® will be fed with hydrogen from the PSA unit into the SABR reactors. There, catalytic reactions will occur, resulting in the removal of heteroatoms of the bio-oil such as sulphur, nitrogen and oxygen, increasing the quality of the oil. To maximise economic efficiencies, unused hydrogen recovered from hydro treatment will be recycled through the PSA unit.

6 EVALUATIONS RELATED TO THE WHOLE LIFE CYCLE

To evaluate the environmental sustainability of the integrated SABR-TCR® technology, the project uses sustainability metrics including Life Cycle Assessment (LCA), GHG calculations, mass and energy balance and will compare the results with conventional fossil-based jet fuel technologies and feedstock alternative valorisation routes in support of subsequent commercialisation. The project maps the full carbon footprint of the demonstration facility and determine the process sustainability with respect to greenhouse gas emissions and net carbon savings. In addition, all aspects related to the overall environmental impact of the process will be considered by means of the comprehensive LCA methodology.

The social sustainability is addressed by developing a set of socio-economic indicators to evaluate the socio-economic impacts of the project and based on the methodology of the Guidelines for Social Life Cycle Assessment developed by the Society of Environmental Toxicology and Chemistry (SETAC). Social acceptance of the project has a high priority within the consortium with a dedicated partner analysing social reception of the project activities and aspects related to SAFs.

The project economic analysis combines scenario analysis, business-case model development, business potential analysis, and business planning.

7 CONCLUSIONS AND NEXT STEPS

The SABR-TCR® project integrates the SABR process, producing HEFA fuels with the TCR® process that is able to provide the hydrogen (from PSA) for the hydrotreating component. It uses waste vegetable oil and organic waste biomass as feedstock, and it is not competitive with food crops. Maximum carbon capture and sequestration is achieved by confining valuable carbon into by-products from the process such as biochar, which itself can be useful in generating additional fuels. By using organic solid wastes as a feedstock, the process also benefits from reduced production costs of SAF. Also, SABR is a flexible, scalable, and low capital-intensive alternative to the traditional HEFA process that could be integrated with the downstream of existing biodiesel facilities and municipal waste treatment plants.

GreenFlexJET process advantages can be summarised as follows:

- high feedstock flexibility,
- green hydrogen: hydrogen separated from TCR® syngas by PSA to be used in HDO/HC,
- side and end products flexibility,
- highly scalable (modular small scale decentralised facilities can be built),
- it can be integrated into existing infrastructure.

The plant construction phase is implemented, while the commissioning step will be fulfilled in 2022. The demonstration phase will be running from 2023 up until 2024.

GreenFlexJET will set the basis for long-term opportunities to convert organic waste into renewable fuels and to directly implement these fuels into existing petroleum infrastructure.

Stakeholders' engagement is a key aspect of GreenFlexJET approach. Thus, single or grouped stakeholders from any sector being linked to industry, research and innovation in the field of the clean energy, and who are interested in sharing and receiving information about GreenFlexJET, best practices regarding market implementation, commercialisation and deployment of new technologies and processes, are invited to register themselves to the dedicated platform (project website: www.greenflexjetproject.eu).

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10 LOGO SPACE