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Sustainable bio kerosene: Process routes and industrial demonstration activities in aviation biofuels

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HIGHLIGHTS

- Routes to aviation biofuels are examined, focusing on drop-in biofuels, capable of high blend levels with fossil kerosene.
- Industrial demonstration activities are reported.
- Used cooking oil is considered as alternative sustainable biomass feedstock for paraffinic fuel production.

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ABSTRACT

Alternative fuels are expected to play a major role in EU in the coming years due European Directives on the promotion of renewable energies and reduction of greenhouse gas emissions in transports. However, while in road transports a variety of possible renewable fuels (mainly biofuels, but also electricity) can be considered, in aviation only high quality paraffinic biofuels can be adopted. This means that biomass must be converted through advanced processes into pure hydrocarbon fuels, fully compatible with the existing systems. The aviation sector is responsible for the 2% of the world anthropogenic CO_2 emissions and the 10% of the fuel consumption: airlines' costs for fuel reach 30% of operating costs. In addition, the aviation traffic is expected to double within 15 years from 2012, while fuel consumption and CO_2 emissions should double in 25 years. Thus, more than 2 billion people and 40 Mt of good/cargo will have to be moved every year. In this context, the EU Flightpath set a target of 2 Mt per year for aviation alternative fuel by 2020 (i.e. 4% of annual fuel consumption). New processes towards bio-hydrocarbons are being developed, demonstrated and soon industrialized.

The present work explores the possible routes from biomass feedstock to sustainable paraffinic fuels, either through bio or thermo-chemical processes, as well as discusses those more mature, focusing on industrial demonstration initiatives. In fact, while the number of possible options towards paraffinic biofuel production is very large, and covers both thermochemical and biochemical routes, as well as hybrid one, only two pathways are today ready for testing a significant large scale: these are FT and Hydrotreating. Major industrial activities and testing experiences are thus reported in the present work.

In this context, the ITAKA group is developing a full value-chain in Europe to produce sustainable drop-in Synthetic Paraffinic Kerosene (SPK) – called HEFA – in an economically, socially and environmentally sound manner, at large scale enough to allow testing its use in existing logistic systems and in normal flight operations in Europe. The generated knowledge will aim to identify and address barriers to innovation. Within ITAKA, possible pre-processing of used (waste) cooking oil (UCO) to make it compatible with current downstream hydroprocessing techniques are being investigated: this can includes esterification of waste oils, as well as catalytic thermal processing, which will be carried out in a pilot unit available at RE-CORD/CREAR. First samples of feedstock oils were collected and characterized, for further investigation towards their conversion into biokerosene through hydrotreatment.

1. Introduction

The aviation sector is expected to become a considerable market for advanced biofuel in the coming years [1]. There are several reasons for that [1,2]:

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Nomenclature

APU	Auxiliary Power Unit
BTL	Biomass to Liquid
CTL	Coal to Liquid
EC	European Commission
EU	European Union
FAME	Fatty Acid Methyl Ester (biodiesel)
FP7	7th Framework Programme
FT	Fischer–Tropsch fuels
GHG	Greenhouse gas emissions
GTL	Gas to Liquid
HEFA	Hydrotreated Ester and Fatty Acids
HRJ	Hydrotreated Renewable Jetfuel
HVO	Hydrotreated Vegetable Oil
IEA	International Energy Agency
MGTs	Micro Gas Turbines
PO	Pyrolysis Oil
RED	Renewable Energy Directive (EC/28/2009)
RME	Rape Methyl Ester
SPK	Synthetic Paraffinic Kerosene
UCO	Used Cooking Oil
VO	Vegetable Oil

- Aviation generates approximately 2% of the world CO_2 emissions, and covers 10% of total fuel consumption.
- More than 2 billion people and 40 Mt of good/cargo will have to be moved every year.
- Airlines operational costs are significantly dependent on fuel costs, which corresponds to roughly 30% of the total.
- Aviation traffic should double within 15 years from 2012, while fuel consumption and CO_2 emissions should double in 25 years.
- While some road transports could be shifted to other alternative fuels than biofuels, as green electricity, this will not be the case for airplanes where kerosene will always be required, either of fossil or renewable origin.
- Airlines will also have to implement concrete actions in view of GHG emission reduction. A target has been set in the EU: 2 Mt aviation alternative fuel by 2020 (corresponding to 4% of annual fuel consumption).
- Sustainability will be a key factor to gain public acceptance of any alternative fuels: thus, advanced biofuels, i.e. those biofuels produced with innovative GHG-efficient technologies from sustainably cultivated crops or agricultural residues/wastes, will represent the preferred option.

New processes towards bio-hydrocarbons must therefore be developed, demonstrated and industrialized in a very short period to meet these ambitious goals. It is estimated that by 2020 nine refineries able to deliver these 2 Mt will have to be developed, with an estimated total investment cost of approximately 3 billion €.

So far, innovation and industrialization of advanced biofuel production technologies has been driven by road transports: today a great attention is given to aviation applications, were large amount of hydrocarbon biofuels fully compatible with existing fuel infrastructure, distribution and utilization systems will be requested.

A common definition of drop-in fuel used in the aviation sector is a fuel [3] "*which [...] meet the specifications of crude oil derived jet fuel and result in the same overall performance. As such the use of an alternative fuel would represent no change or challenge in the ground and supply infrastructure, airframe or engines.*"

The main technical approaches to 2nd generation biofuel production are represented by the biochemical route and the thermochemical pathway, even if hybrid (bio/thermochemical) and/or purely chemical solutions were also developed. Typical examples of new generation fuels are lignocellulosic ethanol (and higher alcohols), Fischer–Tropsch (FT) fuels, green diesel/fuels from pyrolysis oil, synthetic natural gas, etc., as described later in the present work. These biofuels have in common the use of lignocellulosic (either dedicated or residual) or unconventional (e.g. algae) feedstocks, rather than conventional food-competing sugar or oily crops.

A special case is represented by hydrotreated vegetable oils, which have been commercially developed by various companies for the production of biomass-derived diesel-like fuels of higher quality (compared to FAME/biodiesel). This type of biofuels are currently dominating the scene, with almost 2.2 Million tonnes per year of production. However, even if a truly advanced process is applied, the feedstock still remains conventional (lipids), and it is therefore essential to ensure that sustainably grown crops (as Camelina) or waste oils (as used cooking oils, or other oily residues) are used as feedstocks. More in general, HVOs requires that sustainable means/solutions are in place in order to be considered as a real sustainable alternative biomass-based fuel.

The target set by the EU Flightpath for the aviation sector focuses on all production routes, but in particular considers synthetic or biologically-derived paraffinic fuels from biomasses. The biofuels for aviation must be fully compatible and blendable with standard fossil fuels (as Jet-A fuel). These fuels must also be tested and certified before commercial use, and emissions verified. In addition, not only production and use must be developed and checked, but also the entire transportation and distribution chain.

The FP7 EU project ITAKA project is focused on the analysis and the test of solutions towards biofuels in aviation. This paper introduces the issue of aviation biofuels, the production routes currently under investigation or already industrialized, and those still at research level, the expected costs, and the efforts currently being carried out by the ITAKA European Consortium – composed by research centers and large companies – in the field of production and testing of sustainable aviation biofuel.

2. Defining the European regulatory framework

Aviation, as well as the other means of transport, needs to face various challenges posed both by climate change as well as key financial factors. The increasing cost of conventional jet fuel and the likely cost of meeting emission reduction targets, as well as an increasingly societal expectation, are driving the sector investigation on different pathways of fuel production [4]. The public and political pressure on the sector to decrease GHG emission was continuously rising during last years, particularly in Europe after the extension of the European Union Emission Trading Scheme (ETS) to the air transport sector since January 2013 [5] that will add another component to the overall cost of jet fuel [6]. Also for this reason the aviation industry has committed itself to reduce net CO_2 emissions of 50% by 2050 compared with 2005 levels, and to achieve carbon–neutral growth by 2020 [7], a really ambitious goal.

Nevertheless, the large scale deployment of sustainable biofuels in air transport has been slow down by inadequate policies and regulations. The Renewable Energy Directive (Directive 2009/28/EC on the promotion of the use of energy from renewable sources) set up the objective of 10% of renewable energy consumption in transport in 2020, promoting the use of biofuels (through the

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