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Sustainable Aviation Fuels: the challenge of decarbonization

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Abstract

Aviation is steadily growing worldwide as well as in the European Union (EU). Overall, EU transports increased their GreenHouse Gas (GHG) Emissions since 1990, while the other energy sectors succeeded in achieving a constant reduction over the same period. In this context, air transport is the most critical area to decarbonize, given the limited number of options that can be implemented, such as optimization of flight routes, increase of jet engine energy efficiency, and few others. Switching to renewable or low carbon fuels is thus the main opportunity for aviation. Large scale deployment of Sustainable Aviation Fuels (SAF) is however a real challenge, as it requires large investments in new production facilities, strong reduction in production costs (over the entire value chain, i.e. including feedstock production, collection and delivery), and considerable investments in ASTM certification. The present work shortly reviews the perspectives of aviation fuel in terms of demand and GHG emission trends, possible routes to jet fuel production, and the status of ASTM certified routes to jet fuel as of today.

Keywords: Sustainable Aviation Fuels; Advanced Biofuels, Aviation;

1. Introduction

Nomenclature

ASTM	American Section of the International Association for Testing Materials

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CAF	Conventional Aviation Fuels
FOAK	First Of A Kind Plant
GHG	Greenhouse Gas emissions
ICAO	International Civil Aviation Organisation
MTOE	Million tons of Oil Equivalent
SAF	Sustainable Aviation Fuels
UN	United Nations

The effort carried out during the last decades by the European Union to decarbonize the energy sector achieved significant results in all areas except transport, that still represents 32% of the EU final energy consumption. In fact, the analysis of the evolution of EU GHG emissions shows a constant and decreasing trend for both the industrial and the civil sectors, while transports continued to grow or remained almost stable, representing ~22% of total emissions in 2015 and remaining well above 1990 levels [1]. Moreover, EU relies on oil by 94% of its energy needs.

Data from Fuels Europe [2] indicates that the EU demand for fossil fuels in 2016 accounted for 256.7 MTOE of diesel fuel (fig.1), 40.4 MTOE of jet/kerosene, and 117.8 MTOE of gasoline. The analysis also clearly show that the consumption of diesel and gasoline is still largely unbalanced (fig.2), which cause a still increasing trend for gasoline export (highly uneconomic for the EU refineries) and lack of diesel. This caused a significant reduction in EU refining, and therefore the closure of some EU refineries.

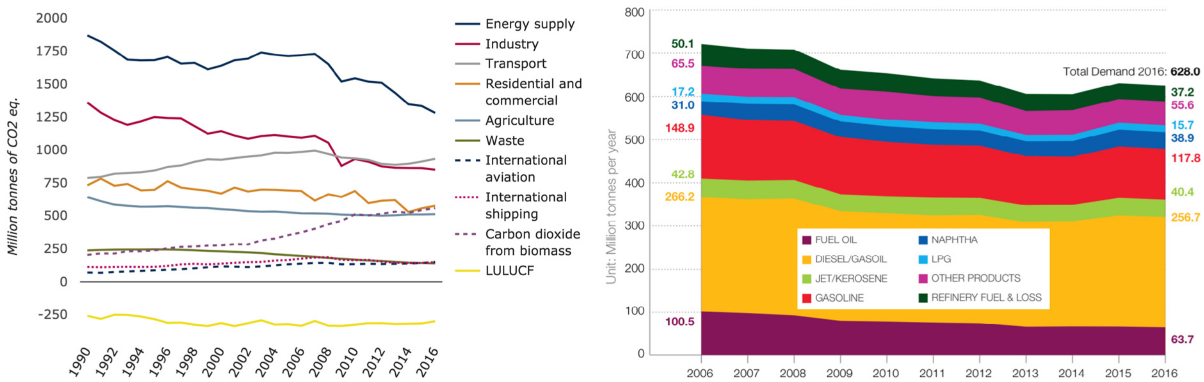

Fig. 1. Evolution of GHG emission 1990-2016 (left) [1] and demand of fossil products in the EU (right) [2]

As regards the 40.4 MTOE of jet/kerosene consumed in the EU, the amount of imported aviation fuel is more than 40% (16.32 MTOE), largely coming (60%) from Middle East Countries (fig.2).

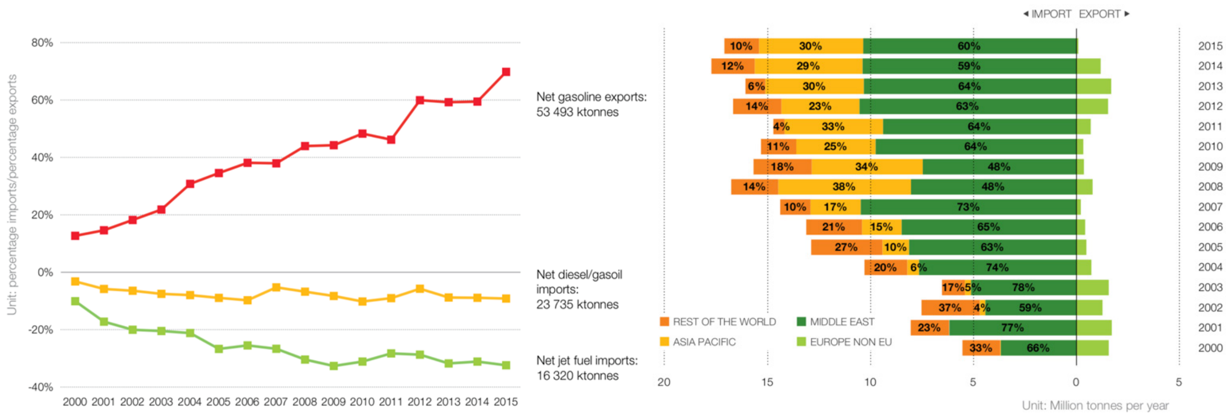

Fig. 2. Evolution of Gasoline, Diesel and Jet fuel import and export (left), and details of jet import/export per area (right) [2]

UN-ICAO [3] reported that the consumption of Conventional Aviation Fuels (CAF) in 2010 was 142 Mt/y: it is estimated that CAF demand will grow to 860 Mt/y by 2050, if only air fleet renewal and the demand for air travel is considered. This amount corresponds to 71% of the expected global, i.e. international plus domestic. If instead some consumption-reduction improvement measures are implemented, CAF fuel demand at 2050 should be limited to 570 Mt/y. In any case, it is more than 4 times the demand in 2010. It has to be mentioned that ICAO analysis refers to International Aviation only, which represents approximately 2/3 of global jet demand. Today, global jet-fuel demand accounts for ≈ 300 M t/y, with ≈ 200 for International Aviation.

Based on the figures reported above, ICAO developed CO_2 emission scenarios. Sustainable Aviation Fuels (SAF) could theoretically substitute 100% CAFs (MAX scenario): this would require some 170 new biorefineries to be built per year from 2020 to 2050, at a cost of 15-60 $B/y, and result in 63% CO2 emission reduction. The LOW scenario would instead replace 4% CAF, with 20 Mt/y SAF produced in 2050. All scenarios converge on a short-term (2025) production of 5 Mt/y SAF (against the 0.9 Mt/y off-take agreements of today).

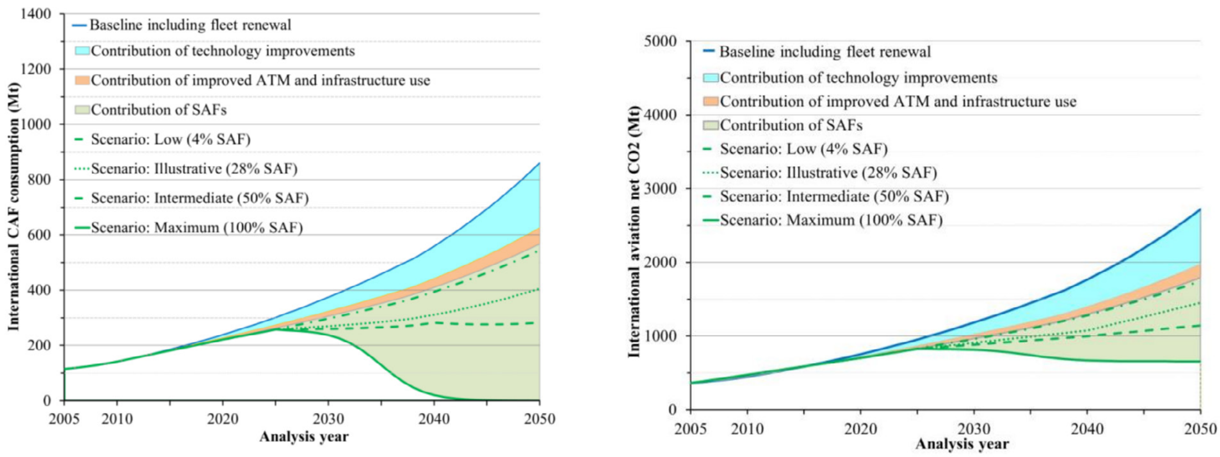

Fig. 3. Expected fuel consumption and aircraft CO2 emissions from International aviation, reflecting aircraft, ATM and infrastructure use improvements, and possible substitution with SAFs from 2005 to 2050 (Source: ICAO [3])

Decarbonizing Aviation, a complex but unavoidable action necessary to fight Climate Change, will heavily rely on shifting to cleaner aviation fuels (SAF). However, it is well known that SAF production cost is today still considerably higher than CAF (i.e. fossil), and the price-distance bio-to-fossil in aviation is larger than the price difference that characterize conventional vs low-carbon/renewable road transport fuels, thus making the introduction of renewable and low carbon jet fuels very difficult. To further complicate the situation, Aviation fuels are normally tax-exempted, differently from road fuels, thus the competition CAF vs SAF becomes even more sever and challenging.

In this context, the policy framework plays the key role to reduce the gap and create a market.

Following the latest updates on the new Renewable Energy Directive [4] (REDII, status as of May 2018) it seems likely that the policy structure that will drive the EU renewable and low carbon transport fuel markets will assign a special focus to Aviation and Maritime sectors, thus encompassing a multiple counting mechanism for the fuel replacement in these sectors. These multipliers could likely be ≈ 1.2 for Aviation and Maritime: this will be the result of the Trialogue debate among the EU Institutions, i.e. the European Commission, the EU Council, and the EU Parliament. Depending on these figures, the production of SAF at industrial scale could be closer (or not) to achieve economic sustainability.

In addition, it is necessary to remark that Aviation is a global industry and a global field of work. Harmonization between the forthcoming new EU policy framework (REDII) and the UN ICAO CORSIA programme will have to be ensured and implemented to allow the deployment of SAF. Sustainability, in particular the minimum sustainability criteria and how these are guaranteed/certified, will be key components that will deserve a specific attention.

2. Pathways to innovation: Sustainable Aviation Fuels

The pathway needed to bring innovation to industrial scale in bioenergy and, in particular, in the Advanced Biofuel field is long and complex. There is today a large amount of literature dealing with how new processes and technical solution requires adequate time to become full industrial products. Among various possible cases that could be mentioned, the technological development of pyrolysis technology in The Netherlands at BTG is an exemplary case: more than 30 years passed from the initial lab work at Twente University to the industrial scale at BTG-BTL.

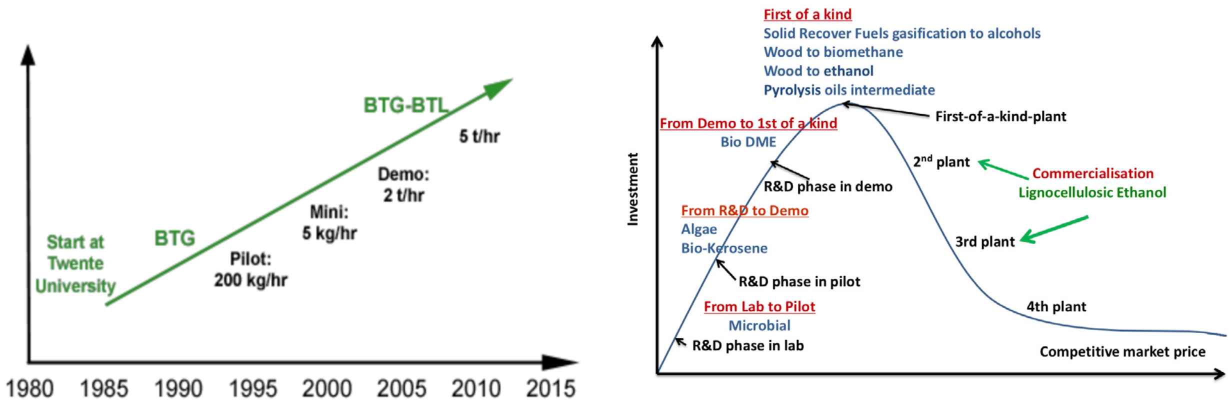

Fig. 4. Development path of University of Twente-BTG for biomass Fast Pyrolysis technology (left) and the "Mountain of Death" for innovative biomass technologies (Source: K.Maniatis, DG Energy [5])

The curve describing the route from lab/pilot to demo and First Of A Kind (FOAK) plants in the Advanced Biofuels and Low Carbon Fuels sectors has been well depicted by dr Maniatis, DG Energy [5]: the development of industrial scale demonstration plants for biofuels requires significant investments, most often measurable in the order of several tens or more than a hundred million €. These industrial initiatives are normally difficult to finance, as risks associated to innovation are relevant and projects are therefore not bankable. For these reasons the curve describing the innovation pathways is called Mountain of Death, as many projects collapse at this stage, mostly for financial reasons.

As regard air transports, the possible pathways to develop new biomass-based aviation biofuel chains are numerous and positioned at different stages of the above reported Mountain of Death figure.

A summary of most relevant process chains to biofuels is shown in the following figure [6], which includes Aviation Biofuel production.

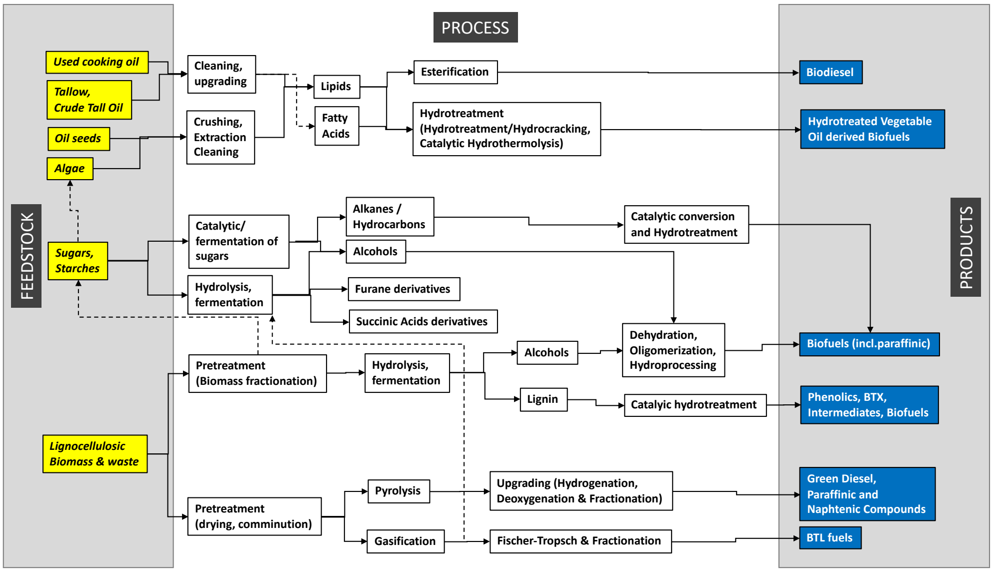

Fig. 5. Major Biofuels process routes [5]

3. Main challenges

While it is evident that the need for decarbonizing aviation represents a significant opportunity for Sustainable Aviation Fuel producers, it is also true that it represents a significant challenge. In fact, bringing new fuels in commercial flights with passengers requires to go through a long and expensive route towards ASTM certification, which is governed by the following main norms:

- ASTM D1655 Standard Specification for Aviation Turbine Fuels
- ASTM D7566 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons;
- ASTM D4054 Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives;

To carry out the entire path necessary to certify a new aviation fuel requires several years of work and some Million of euros expenditures, as summarized in the ASTM D4054 guideline. Moreover, moving from Tier 1-2 to Tier 3-4 of the certification route will also need a significant amount (order of tens of cubic meters) of jet fuel. In general, this requires the construction of a Demo plant, which is a further investment for the developers of the new biofuel production pathways. There are therefore several obstacles and barriers, both technical and financial, to the goal of introducing a new fuel on the market. The status of certified ASTM fuels is summarized in the following table.

Table 1. Status of ASTM certified Sustainable Aviation Fuels

Annex	Conversion Process	Abbrev.	Possible Feedstocks	Max Blending Ratio by Vol.
1	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene	FT-SPK	Coal, natural gas, biomass	50%
2	Synthesized paraffinic kerosene produced from hydroprocessed esters and fatty acids	HEFA-SPK	Lipids	50%
3	Synthesized iso-paraffins produced from hydroprocessed fermented sugars	SIP-HFS	Biomass used for sugar production	10%

4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	SPK/A	Coal+, natural gas+, biomass	50%
5	Alcohol-to-jet synthetic paraffinic kerosene	ATJ-SPK	Biomass used for starch & sugar production and cellulosic biomass for isobutanol production	30%

Thus, increasing the global SAF production capacity is a challenge, as it requires large industrial investments in a moment when SAF are not yet economically competitive with CAF. In the EU, two new H2020 projects have been recently launched, with the support of the European Commission: BIO4A [7] and FlexJetFuels [8]. These projects aim at increasing the biojet production capacity in the EU, favoring the market uptake of SAF, addressing also the logistics and distribution, the social, economic and environmental assessment, and the supply of residual lipids. In addition, BIO4A will also investigate sourcing of sustainable lipids from drought resistant oil crops cultivate in EU MED marginal lands.

4. Conclusions

The development of Sustainable Aviation Fuels is expected to represent a major action in the coming years in the EU, in particular when the new policy framework - that will be defined (among others) by the new Renewable Energy Directive (REDII) - will be in place. The need for scaling up the production capacity will require large investments in new pilot and demo plants, significant costs for certification, and a huge mass of investments in new industrial plants, if the GHG emission reduction targets are to be met.

While SAF certainly represent not only a need for the environment but also an opportunity for the industry and researchers, it has to be acknowledged that bringing these pathways to full commercial scale and wide deployment will demand time and resources. This will only be possible if a suitable and stable policy framework is in place in the EU and abroad, otherwise investments could shift to road transport.

References

[1] European Environment Agency. GHG emissions by sector in the EU-28. Available at https://www.eea.europa.eu/highlights/small-cut-in-eus-total (last accessed on 31.05.2018)

[2] Fuels Europe. Statistical Report 2017. Available at https://www.fuelseurope.eu/publication/statistical-report-2017/ (last accessed on 31.05.2018)

[3] UN-ICAO. Trends and scenario on alternative fuels – Working Paper. Conference on Aviation and Alternative Fuels, Mexico City, 11-13 October 2017, Mexico. Available at https://www.icao.int/Meetings/CAAF2/Documents/CAAF.2.WP.006.4.en.pdf (last accessed on 31.05.2018)

[4] European Commission. Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources (recast). COM(2016) 767 final 2016/0382 (COD). Brussels, 30.11.2016.

[5] Maniatis, K. EU Transport & Renewable Energy policies: The role of Advanced Biofuels in Decarbonising Transport. EU-India Conference on Advanced Biofuels, 6-8 March 2018, New Delhi. Available at https://ec.europa.eu/energy/en/content/conference-presentations-7-8-march-2018-eu-india-conference-advanced-biofuels

[6] Chiaramonti D, Prussi M, Buffi M, Tacconi D. Sustainable bio kerosene: Process routes and industrial demonstration activities in aviation biofuels. Applied Energy, 12/2014; 136:767-774. http://dx.doi.org/10.1016/j.apenergy.2014.08.065

[7] http://www.bio4a.eu/

[8] http://www.besustainablemagazine.com/cms2/flexjet-project-converts-organic-waste-into-sustainable-aviation-fuel/