Sustainable Aviation Fuels II – Technological Landscape

Introduction

In the previous instalment of the Sustainable Aviation Fuels (SAF) article series, we had a look at the current SAF policy landscape on the global scale, as well as in the EU and in the United Kingdom. We saw that legislative support for SAF incorporation remains very recent, and that Europe and North America are currently leading the way in this aspect. In this second article, we shed some more light on the current technological tools available for the production of SAF, as well as the main technologies being explored for future use. We show that although Asia and Africa lag behind other regions in terms of policy support, they are both aiming to place themselves at the forefront of feedstocks supply for the production of aviation fuels.

Several technologies have been developed for the production of SAF, all with varying degrees of GHG emission reductions. These technologies are often patented by producers and key players within the SAF supply sector. However, there remain similarities between them all. Most approved SAF fuels are drop-in fuels which can be blended with conventional petroleum-derived fuels at high inclusion rates, and used in conventional engines. Contrary to sustainable fuel types commonly used for road transport where inclusion rates are limited by conventional fuels standards, Many SAF fuels can be blended to high concentrations of up to 50%[i]. In addition, SAF can make a significant impact in the fight to reduce GHG emissions by reducing life-cycle emissions by as much as 80%[ii]. In addition to established fuels such as HVO and ethanol-derived SAF, e-fuels and zero emissions hydrogen-based fuels are being actively researched. Although these are yet to make it to the market, the ambition is to have the world's first zero fuel emission commercial aircraft by 2035[iii].

In this article, we start by providing an overview of the main feedstocks used for the production of sustainable aviation fuels. Then, we cover the main technologies being used to produce SAF in more detail. In addition, we look at two promising innovations which are likely to bring the sector even further in its ambition to reduce GHG emissions and to provide zero-emissions commercial flights in the near future.

Hydrotreated Esters and Fatty Acids Technology (HEFA)

HEFA technology is fully commercially deployed, and currently is the main pathway for the production of SAF globally. This process predominantly uses oils and fats as feedstocks[iv].

Here, fatty acids undergo hydrotreatment to produce alkanes during which nitrogen and sulphur are removed[v]. Then, the next step of the process involves the hydrodeoxygenation of the feedstocks, which removes oxygen from the substrates in the presence of hydrogen. Then, the saturated hydrocarbon chains are broken down – or cracked[iv,vi]. The extent of the cracking defines the length of the chains, which in turn defines the use that the refined product will have: typical outputs include gasoline, diesel or naphtha. To produce SAF, the diesel fraction is further refined by distillation to separate out lighter fractions suitable for jet engines[iv].

HEFA was approved for use as a jet fuel in blends of up to a maximum of 50% HEFA in 2011[vii].

Alcohol-to-Jet Technology (ATJ)

Alcohol-to-Jet technology, or ATJ relies on the fermentation of substrates to produce alcohol, which is then transformed into jet fuel through refining steps conventionally used for the petroleum industry[viii].

In this case, biomass feedstocks – such as sugar or starch rich feedstocks or lignocellulosic biomass – are hydrolysed to extract sugar monomers. These sugars are then fermented by yeasts, to produce ethanol, or less commonly n-butanol or iso-butanol, all being suitable for the subsequent production of SAF. The subsequent steps involve the dehydration, oligomerisation, hydrogenation and fractionation of the alcohol resulting from the fermentation stage, which ultimately leads to the production of the finished ATJ fuel[ix]. CO- and CO_2-rich industrial waste gases can also be fermented into ethanol and then be converted into SAF[ix].

ATJ technology is a very flexible tool for the production of SAF and chemicals. A wide range of feedstocks can be used as the fermentation process can be tailored to deal with different materials[x]. The cost of this technology is linked to the nature of the feedstocks themselves, as well as the alcohol production stage. For instance, lignocellulose is cheaper than wheat, however, as lignocellulose is harder to treat (due to its lignin component), lignocellulosic ethanol is more expensive than wheat ethanol.

Commercial volume production of ATJ fuels is expected to enter the market this year.

Currently, ATJ is certified up to a maximum of 50% in blends with conventional jet fuel[vii].

Gasification of waste and Fischer-Tropsch Upgrade

SAF can also be produced from the gasification of solid waste products, often municipal solid waste (MSW) which would otherwise be landfilled or incinerated. Through gasification, organic or petroleum-based solid waste is exposed to high temperatures (<700°C). The oxygenation of the process is monitored to prevent combustion and to lead to the production of CO, CO_2 and H_2-rich synthesis gas (or syngas)[xi]. This is also how syngas used in the ATJ process is obtained.

The syngas produced as a result of gasification can then be upgraded through the Fischer-Tropsch (FT) process. Developed in the 1920s, the FT process has been used by the coal and gas-to-fuel refinery sector for decades and has proven to be highly flexible. It is a well-known and well-understood process that transforms CO, CO_2 and H_2 into liquid hydrocarbons of varying molecular weights which can subsequently be used as fuels[xii], including SAF.

The infrastructure needed for both gasification and FT upgrade are high cost, offset to some extent by the low cost of feedstock (most often municipal solid waste)[iv]. However, the cost of SAF produced from the gasification/FT pathway remains a hurdle for high-scale commercial production, therefore, for the aviation sector to reach its 2050 decarbonisation goal, significant improvements and/or new technologies will have to be developed[xiii].

Electrofuels (e-Fuels)

Although the SAF produced from the processes described above offer a high reduction in GHG emissions, some argue that the benefits are not significant enough. Arguments mainly focus on feedstocks and their carbon footprint, particularly for fossil-derived waste feedstocks. Therefore, there is now a push to support the development of e-fuels (including e-SAF)[xiv].

E-fuels, sometimes also referred to as Power-to-Liquids (PtL) fuels, are made by transforming CO_2 and H_2 into liquid fuels (such as gasoline and diesel) using renewable electricity as a power source to derive the renewable hydrogen (from electrolysis) [xv].

E-fuels remain far from commercialisation, but large investments are being made in what is considered to be a very promising technology, and even, the future of aviation and shipping[xvi].

Hydrogen propulsion

Hydrogen propulsion is another technology being heavily researched as it has the potential to provide a “zero emissions” solution for aviation. Multiple routes are being considered, including: liquid hydrogen combustion in the presence of oxygen; hydrogen-powered fuel cells; and a combination of hydrogen combustion and fuel cells[xvii].

This technology requires the design of dedicated hydrogen propulsion engines. This is an option that is likely to take years to develop, and which should therefore be regarded as a long-term solution. However, the technology gained momentum in 2020 when Airbus launched its ZEROe project which aims to see the first hydrogen-fuelled commercial flights by 2035[iii].

SAF Feedstocks

Sustainable aviation fuels can technically be made from biological materials such as plant biomass, to municipal solid waste including used clothes and non-recyclable plastic[ii]. However, as with most sustainable technology, the issue resides in taking into account the entire life-cycle of a product to assess its “true” sustainable potential. Therefore, although SAF can be made from a wide spectrum of materials and compounds, they are currently mainly made from a relatively short list of feedstocks, which mainly include waste products: used cooking oil, animal fats, plant oils and agricultural residues. These trends are being pushed further by environmental policies in the EU which promote the use of waste-based feedstocks as opposed to fresh vegetable oils made for the purpose of producing biofuels and bioenergy[xviii]. Furthermore, the EU Waste Framework Directive advises that waste-derived feedstocks for biofuel production be limited to waste products that cannot be valourised otherwise, and for which the only other alternative would be landfill or incineration[xix]. Even in such cases, such fuels need to demonstrate that they can deliver a meaningful impacts in reducing GHG emissions.

Used cooking oil (UCO) is fast becoming a very sought-after commodity for the production of biofuels, and biodiesel in particular. The global UCO market was registered at $6 billion in 2019, and is expected to reach as much as $8.88 billion by 2026[xx]. China and South-East Asia, where vegetable oils are a prime ingredient in traditional cuisine, are the fastest growing producers of UCO globally, with a forecast market increase of 5.9% between 2019 and 2026[xx,xxi]. Just like UCO, animal fats are a by-product of the food industry. China and the US currently are the main producers of lard and tallow. In the Asia-Pacific region as a whole, the demand for animal fats is on the increase, while demand for butter is on the decline[xxii]. In 2020, the global animal fat market was estimated to reach as much as 27.1 MMT, and is expected to reach about 31.8 MMT by 2026[xxii].

As mentioned above, using food crops as feedstocks for the production of bioenergy and biofuels is an emotive topic in relation to question around food security and sustainability. Using crops for the production of biofuels, remains common practice and a lucrative market in a large part of the world. Asia produces as much as 90% of the world's palm and palm oil stocks which has allowed it to place itself as a leading supplier of palm oil for the production of biofuels[xxiii]. Although trade with the EU has slowed down, and use in biofuels will be phased out, the rising biofuel demand in Asia itself is maintaining the demand for plant oils at a high level. Africa is also beginning its journey within the SAF feedstocks sector. Studies show that land availability in sub-Saharan Africa could become an invaluable asset for the production of biofuel feedstocks such as tobacco, palm oil, soybean, sugar cane and maize[xxiv]. Data reveals that biofuel feedstocks production could lead to significant economic growth for African countries and lead to an annual 5% GDP growth until 2050. However, this case scenario exemplifies the complexity of using crop feedstocks for the production of bioenergy and biofuels. In a continent which often struggles with food and water security, establishing an international industrial-scale agricultural industry for the sole purpose of producing biofuels is understandably a controversial project. On the other hand, should this dilemma be solved, this may present an unprecedent opportunity for a large part of the developing world.

Feedstock availability is at the centre of the SAF industry and questions remain as to whether there is enough sustainably-sourced feedstock available to allow for the planned decarbonisation of the aviation sector. Markets are still taking shape and supply chains are still being designed and developed, therefore, the next few years are likely to see a lot of changes and opportunities which will shed more light on the future of the SAF industry as a whole.

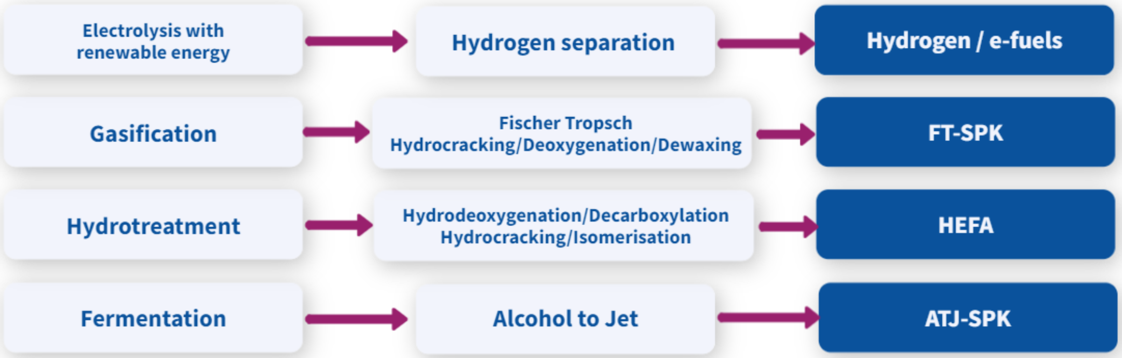

Table 1. Summary of the main current and future pathways for the production of SAF and net-zero hydrogen.

Conclusion

A variety of technologies are currently available for the production of SAF, some of which are already well established on the global market. It is true that these options do not eliminate GHG emissions completely, and that a tight control is required to limit the negative environmental impacts that feedstocks may have. However, SAF significantly reduce GHG emissions compared to conventional petroleum-derived aviation fuels, and therefore, provide a short- to medium-term way of slowing down atmospheric and climate change.

Hydrogen is regarded as one of the main means of reaching global net zero. Policymakers are putting a lot of investment in the development of hydrogen technologies in a variety of sectors, including transport. However, it is important to keep in mind that hydrogen-derived power is still in its infancy and cannot provide any short-term mitigation. Research will take time – a decade at the very least – and solutions need to be implemented in the meantime. Therefore, it is important to continue supporting technologies which, even though are not perfect, do provide GHG emissions relief.

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Biocentre, York Science Park, Innovation Way, Heslington, York, YO10 5NY

Phone: +44 (0)1940 435182 **Fax**: +44 (0)1940 435345 **Email**: enquiries@nnfcc.co.uk

www.nnfcc.co.uk

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