The Bioeconomy Consultants

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Market Perspective

Aviation Biofuel

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NNFCC is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels and biobased products.

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1 Executive Summary

The aviation sector is one of the principal sources of man-made greenhouse gas emissions, contributing over 2% of global emissions – more than 90% of the world's countries. As air traffic levels continue to rise, the required longevity of airline fleets rules out engineering solutions for emission mitigation. Thus, at present, the only significant available solution to the aviation emissions is biofuels. The sector has been held back in the past by stringent performance requirements and a lack of market presence, but is now picking up steam.

As far as aviation biofuel technology goes, five options are currently sanctioned by ASTM standards:

- Hydro-processed esters and fatty acids (HEFA)
- Fischer-Tropsch Fuels
    - From Syngas
    - From Biogas
- Synthesised Iso-Paraffinic Fuels (SIP)
- Alcohol-to-Jet (ATJ)

Of these technologies, HEFA is the only one to have been used commercially, but all of them remain at various stages of development. The most significant barrier to any one of them taking-off is the need to make the fuels themselves affordable. Fuel costs make up one third of airline running costs, and so for widespread adoption to become a reality, significant market development is required. There are issues with economies of scale, as well as individual problems attached to each technology, such as competing end-markets, and complex supply chains. In order for any one (or more) of the above technologies to establish themselves, significant support will be required from legislation to help stimulate the markets, and to economically justify development of the fuels.

The sector is still a young one, and needs to be given time to develop, with different measures needed in different places – more diverse recognition of technologies in the USA, and greater faith placed in the sector's economic potential in the UK – but in the absence of alternative technologies (with hydrogen- and/or electric-powered flight still being decades away from viability), aviation biofuels have a very high market potential, once development hurdles can be successfully navigated.

2 Context

2.1 Aviation Sector Emissions

Each year, the aviation sector is responsible for over 150 megatonnes of carbon emissions, accounting for over 2% of global emissions. This may not seem like a large proportion, but at this level, the aviation sector has greater emissions than 90% of the world's countries. Aviation has been acknowledged as a significant problem that needs to be overcome for the decarbonisation of human activities.

Aviation sector emissions have continued to rise since 1990, but have actually risen at a slower rate than airline traffic has. This has resulted in an effect where emissions per passenger kilometre have actually decreased over this period. This has, in a large part, been down to the upgrading of jet engine technology and the retiring of older planes, resulting in increased fuel efficiency. However, this effect is not expected to last. Forecasts from the IMPACT emissions model suggest that over the next few decades, as air traffic continues to rise, the technology will not be able to keep up, and emission efficiency will no longer be a significant mitigating factor of aviation sector emissions.

At the current state of play, future emissions from the aviation sector will be determined by what degree traffic increases. The worst-case-scenario predicted by the IMPACT emissions model, wherein traffic increase is "high", will see aviation sector emissions reach almost double their current levels by 2035. The more conservative baseline forecast estimates an increase of around 50%, which is still not acceptable in a world where decarbonisation is becoming a priority.

Pexels

2.2 Aviation Fuel Standards

Obviously, due to the nature of aviation, aviation fuels need to have more stringent properties: in order to not lose performance at high altitudes, jet fuel must have a low freezing point and low volatility, in order to cope with the low temperatures and pressures involved. Aviation fuels in general also usually require a higher octane number (the required pressure level for the fuel to spontaneously combust) than other transport fuels. The reason for this is that jet engines frequently utilise their fuel for more than just power – it is used as a lubricant and as a hydraulic fluid also. This exposure to greater mechanical stress demands a higher octane number to reduce risk of explosion, as well as suitable physical properties to serve in these additional mechanical applications.

To this end, aviation fuels are governed by strict standards, that are kept harmonised by the various standards authorities, due to the international nature of the aviation sector. Standards differ slightly for different types of aviation, but since the greatest source of air traffic is commercial passenger flights, this is the most important standard in this context.

2.3 Decarbonisation

Beyond the aforementioned increases in fuel efficiency of jet engines, there are few feasible options for the decarbonisation of the aviation sector. Some of the options available to terrestrial transport, such as electric power, are not powerful enough for the demands of commercial flights. This leaves the available options as very limited, with biofuels being the most viable option for decarbonisation of the sector.

3 Technology

By necessity, all aviation biofuels must be "drop-in" technologies. Due to the long intended lifespan of commercial planes, it is not desirable for biofuels to require modification to engines to run successfully, and so all aviation biofuels must be functionally identical to their petroleum-based counterparts. Use of 100% biofuels in aviation is currently forbidden, and so the biofuels must be blended with their petroleum counterparts to produce the final fuel, with 50% biofuel being the current maximum legal blend level.

Currently, five different kinds of biofuel are legal for use in jet fuel according to ASTM standards.

3.1 Hydro-processed esters and fatty acids (HEFA)

By far the most common sources of aviation biofuel are vegetable oils and other waste oils. These oils are directly pressed from their source feedstocks (such as oilseeds) or are waste products from food manufacturing. There are also some manufacturers who collect waste cooking oil from households and businesses, and use this oil for the production of biofuel. The oils are hydrogenated and refined - in a process not dissimilar from the refining of fossil fuels – to produce the eventual biofuel.

Biofuels from this source have been legal for use in jet fuel since 2011, and also offer the opportunity for the highest blend level of 50% - all other biofuel types have lower limits. In terms of development, this is also the kind of aviation biofuel furthest along the development pipeline, with several plants already capable of producing the biofuel at a commercial scale, and several airlines having already conducted test flights using this fuel.

However, the market currently does not favour HEFA production and uptake, as it is both cheaper and more profitable for companies to produce road fuel by this process instead of aviation fuel. This has the advantage of being both cheaper to produce, and already being a widespread technology, creating a market situation that greatly favours road biofuel production. For this technology to really take off, measures need to be taken to stimulate a better market situation.

3.2 Fischer-Tropsch Fuels

3.2.1 From Syngas

This was one of the first aviation biofuel technologies to be certified by ASTM, back in 2009. In this process, biomass is thermochemically "gasified", wherein it is converted into syngas – a mixture of hydrogen and carbon monoxide – which can be converted into hydrocarbons using Fischer-Tropsch synthesis. This process can utilise a wide range of feedstocks, from agricultural waste to coal, and has been demonstrated to function as a way of processing the organic fraction of municipal solid waste, as well as woody biomass.

However, the technology has been slow to develop, with high costs and technical demands meaning very few plants have been commissioned worldwide. Currently, several commercial plants are planned, but for now the technology remains at the pilot scale, albeit seemingly ready for commercialisation, markets willing.

Pixabay

3.2.2 From Biogas

Gasification is not the only method of producing gas that can be converted to fuels via the Fischer-Tropsch method. Another is to have the biomass undergo anaerobic digestion, which produces biogas – a mixture of biomethane and carbon dioxide. The biomethane component of this can be converted into a similar gas mixture to syngas, enabling it to then be converted into liquid fuels via the Fischer-Tropsch process.

Anaerobic Digestion is a much more established technology than gasification, with hundreds of plants around the UK alone. However, this makes it a competitive market, as biogas also sees use in the heat and power sector, which is much more heavily subsidised for biogas than transport fuel.

Given the ready availability of biogas, and the fact that Fischer-Tropsch fuels have a blend limit of 50% in aviation fuel, there is great potential in this technology that has yet to be realised due to market barriers, and the fact that more attractive markets lie elsewhere.

Realising this potential, however, may be more of a task than first envisioned. There is a significant issue of scale. Anaerobic Digestion takes place almost exclusively at a small scale, with annual feedstock tonnages in the tens of thousands, whereas Fischer-Tropsch plants tend to operate at much greater scales. This disparity in scale would create a highly complex supply network, with biogas having to be supplied from many different plants – a significant logistical challenge.

3.3 Synthesised Iso-Paraffinic Fuels (SIP)

In this method of producing aviation biofuel, microorganisms ferment sugars into farnesene, a chemical which is then hydrogenated into farnesane, which can be blended with conventional jet fuels. This form of fuel has the lowest blend limit, with only a 10% maximum blend, and lags behind HEFA and Fischer-Tropsch fuels in Technology Readiness Level: this fuel has reached the pilot plant stage, but not further, despite being accepted in international aviation fuel standards.

SIP also suffers from the fact that its intermediate chemical, farnesene, is a valuable chemical in its own right, often making the process of conversion to farnesane less economically viable for those who produce it.

3.4 Alcohol-to-Jet (ATJ)

This technology is a relatively recent development, only becoming ASTM-certified in 2016, and still has very few commercial-level production plants. In this technology, alcohols, usually obtained through fermentation of biomass, are converted into jet fuel. Traditionally, the alcohol used has been butanol or isobutanol, although the process has been demonstrated with ethanol also. Until recently, however, ethanol-derived ATJ was not certified for commercial use by ASTM, meaning that the commercial process tended to rely on isobutanol, which in itself is a valuable chemical, potentially resulting in ATJ falling into the same trap as SIP in having one of its intermediates be more viable to produce than its end-product. This, however, changed in April 2018 when ethanol for the first time became a certified feedstock for ATJ, potentially opening up another supply chain for this technology, and a new value chain for ethanol. This dovetailed with an increase in ATJ's blend limit to 50%, putting it on a par with the other most viable aviation biofuel options.

Though not at the commercial stage of development yet, one perceived advantage of ATJ is that it is produced solely with aviation in mind: it does not have the same problems of HEFA and Fischer-Tropsch fuels in that these processes' products are also of use in other sectors. However, this is an oversimplification, as ATJ is in itself derived from another fuel: ethanol, meaning the same market competition occurs, just further along the value chain, with jet fuel not providing a significant increase in value from ethanol.

4 Market Factors

4.1 Competition

Without doubt, the biggest barrier to aviation biofuel establishing itself as a viable decarbonisation option for the aviation sector is an unfavourable market. As the crude oil price remains low, so too does the petroleum-based jet fuel price. With the relative infancy of the technologies used to produce aviation biofuel (except for HEFA), these processes remain an expensive route to aviation biofuel. There are also issues with economy of scale, where production is not yet high enough to see a reduction in costs.

One of the most significant issues is the cost of running an airline itself. Approximately 30% of an airline's expenses come solely from fuel, and so understandably airlines wish to keep these costs down. As aviation biofuel remains expensive to produce, prices remain high, and airlines are unwilling to adopt biofuels.

This is not to mention the fact that, as discussed above, many of the aviation biofuel technologies produce intermediates that are valuable in themselves, such as butanol or farnesene, or products that are already useful in other sectors, such as diesel or biogas. These products already have established markets and value chains, meaning it is easier for producers to simply tap into these markets than to pursue aviation fuel. It is a double-edged sword: producers favour other markets, driving up aviation biofuel prices, thus discouraging the airlines from making the switch.

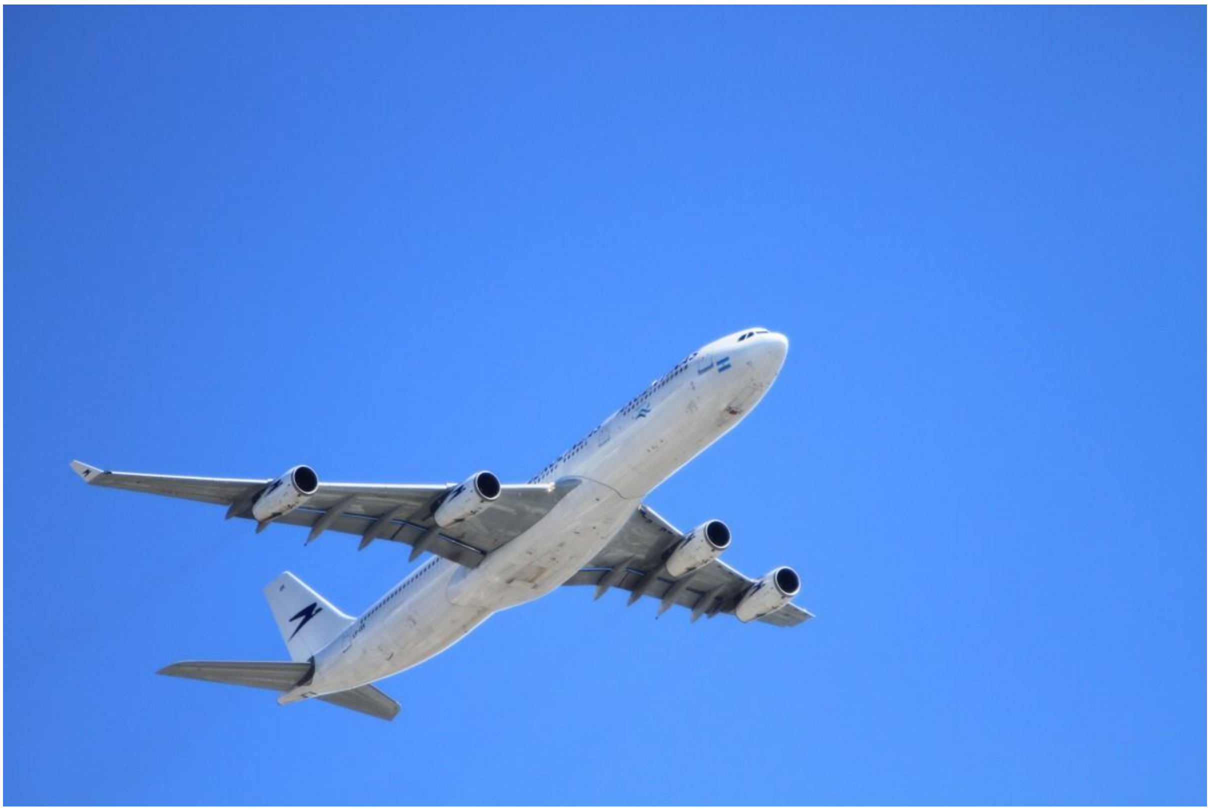
4.2 Available Support

It is nothing new that an emerging renewables technology is unable to compete in established markets. Particularly in the energy sectors, petroleum-based technology has developed to a degree that the bioeconomy cannot match in its current form. It is for this reason that governments need to step in and provide legislatory support for renewable sectors, in order for them to become viable, and hopefully establish themselves in future.

In the EU, aviation biofuels are covered by a target: for Europe to produce 2 million tonnes of aviation biofuel by 2020, but a 2016 report by the European Environment Agency found that this target is unlikely to be met. There has also been support from the European Commission for the building of aviation biofuel plants, but this support does not translate into market competitiveness once the plants have been commissioned.

In the US, there is a general biofuels target under the Renewable Fuels Standard, wherein the oil industry must blend increasing volumes of biofuel into the country's fuel mix. Currently, only HEFA jet fuel is accepted under the Standard. This system relies on the industry itself to force the market, rather than providing support, meaning the industry will prioritise what is most economically viable, which, as far as HEFA is concerned, is road fuel, having a more developed value chain, and established market. It can also end up with situations, as has happened recently in America, where the industry lobbies for lower targets, claiming the existing ones aren't feasible, which stifles progress in the development of the sector.

Under the Renewable Transport Fuel Obligation, the UK government mandates that fuel suppliers with an annual output of over 450,000 litres must supply a certain percentage of biofuel or face financial penalty. Through the award of Renewable Transport Fuel Certificates, this scheme allows smaller producers to profit from producing biofuel by selling their RTFCs. Historically, this scheme only rewarded renewable road fuels and non-road mobile machinery, but from April this year the scheme now also rewards the supply of aviation fuel. Unlike other fuel types, however, jet fuel producers are not subject to the obligation, creating a situation where the aviation sector can benefit from this scheme without fearing penalties for non-compliance. The new RTFO guidance also places extra emphasis on aviation biofuels, under the new sub-cap for "Development Fuels". This is an additional target set to come into force next year, looking to develop renewable hydrogen, drop-in fuels, and, significantly, aviation biofuels. This potentially sets the UK up to elevate its status in the aviation biofuel sector.



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5 The Future

It is no secret that the eventual target for all transportation is for it to be electric or hydrogen powered, in order to eliminate carbon emissions from the sector entirely. Aviation is no exception, but we are still decades away from zero-emissions technology being able to provide the necessary power for this sector. In the meantime, biofuels are the solution, however, greater market penetration is required for the sector to develop. This will, in all likelihood, have to be facilitated by legislation, as the current market environment is not a good one for aviation biofuel, having to compete with road fuel as an end-market, and facing the daunting costs of bringing relatively new technologies into commercialisation.

In the US, the sector would benefit from a diversification of the acceptable technologies under the Renewable Fuel Standard. Alcohol-to-Jet would be the most significant beneficiary of such a change, as American companies are forming the vanguard of the technology's development, but also as US ethanol production continues to grow year on year, the certification of ATJ fuel from ethanol could be a significant milestone, providing a new end-market for that value chain. US-based airlines have also shown a willingness to adopt biofuel technology, but as costs remain high, outside investment is still required to solve the economies of scale and to bring down costs for the airlines themselves.

In the EU, the issue is more complex, as the Renewable Energy Directive merely provides targets for biofuel production: it is left up to member states to determine how they achieve the targets. The EU has shown a commitment to building plants, but could do more to help stimulate the market, by establishing value chains and providing investment into development and scale-up of the technology.

For the UK, however, aviation biofuel is a sector that the country really could grow into. With the changes to the RTFO to incentivise aviation biofuel, the UK could see a new market emerge. The UK's existing industry does not favour any one of the aviation biofuel technologies, which would allow for widespread development of the technology. An increasing number of both waste gasification plants and biorefineries could result in a strong base for production of biofuel via Fischer-Tropsch technologies. This has previously not been viable in the UK due to lack of support, but may now become an option as, particularly in the north-east of England, the bioeconomy is looking to establish itself.

Another potential avenue for the UK to develop aviation biofuels is to take the Alcohol-to-Jet route. In Vivergo fuels, the UK has a major producer of bioethanol who recently resumed operations after a brief shutdown due to unfavourable market conditions. The new certification of ethanol-based ATJ could, as it also would in the US, provide a new possible ethanol value chain. This would, of course, necessitate the establishment of an ATJ plant in the UK, which may take some years, but this is another possible avenue to consider.

Overall, the aviation biofuel sector remains relatively young – few markets have established themselves – but there are plenty of possible routes for the development of the technology and its eventual commercialisation, provided the right legislatory support is put in place. The market situation is currently a tight knot, but over time this will begin to unpick, hopefully leading to eventual decarbonisation of one of the most significant emitting sectors in the world.

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