Bundles | 29 November 2022

Sustainable aviation fuels play a critical role in future air travel

Battery-powered flights may be the future for short-haul trips and hydrogen could be promising for longer distances, but both options are still a long way off, and the climate can't wait. In the meantime, people continue to fly. We look at the role of sustainable aviation fuels in reducing net emissions, and the potential challenges

In this bundle

Transport & Logistics | Sustainability

Climate targets expedite the take-off of sustainable aviation fuels

Sustainable aviation fuels are at the forefront of climate change commitments in the airline industry

By Rico Luman and Coco Zhang

Transport & Logistics | Sustainability

Stronger supply of sustainable aviation fuels crucial to securing uptake

Blending sustainable aviation fuels needs to grow massively to meet ambitions for 2030 and beyond

By Rico Luman and Coco Zhang

Article | 11 May 2023

Transport & Logistics | Sustainability

Climate targets expedite the take-off of sustainable aviation fuels

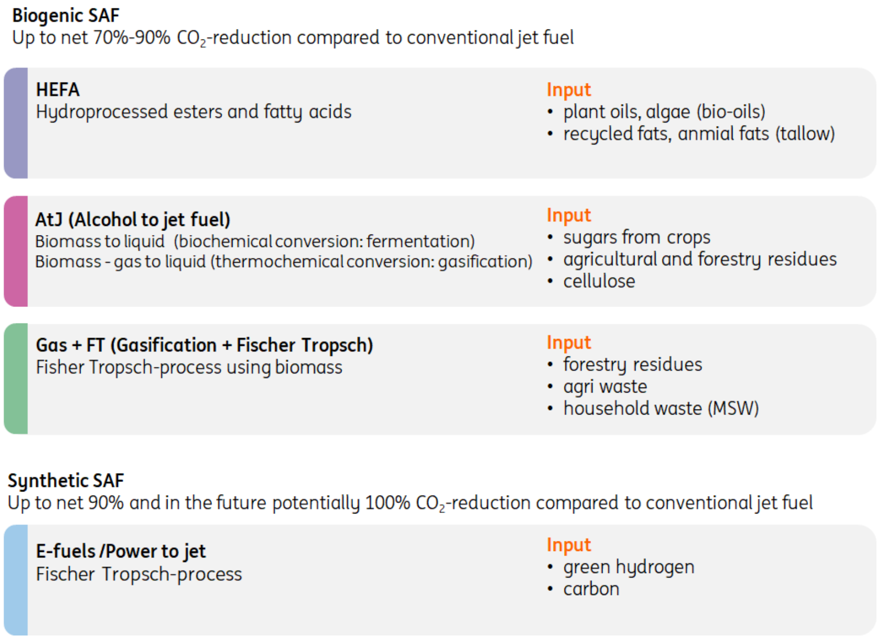
It's a pivotal time for sustainable aviation fuels (SAFs). Demand depends heavily on regulation and airline commitments, and blending is just starting off. But on the back of progressive target-setting for 2030, demand is about to accelerate. And this is necessary to curb and reduce net emissions, with airline traffic rebounding post-Covid

This article has been updated following the EU parliamentary adoption of amended blend fuel mandates last month.

SAFs may only seem a bridge solution for reducing net carbon emissions in aviation, but aviation is one of the hardest to abate sectors and new technologies won't be mature anytime soon. SAFs offer the opportunity to reduce net emissions significantly and can ultimately be produced synthetically and almost free of emissions. Public authorities, airlines, and corporate customers increasingly push for SAFs, and they are approved as fuel under the global carbon offset and reduction scheme CORSIA. Global blending is still fractional at less than 0.1%, but acceleration is in progress and ambitions push for upscaling in the coming years, with the first target in Europe for 2025.

SAFs are still significantly more expensive. The US now provides incentives to drive production higher as part of the inflation reduction act. Incentives in other regions, as well as commitments to set in stone SAF targets from the global authority, the International Civil Aviation Organization (ICAO), could help support uptake.

Four main production routes of SAFs with net CO2 reductions from 70% to nearly 100%



Source: ING Research based on multiple sources

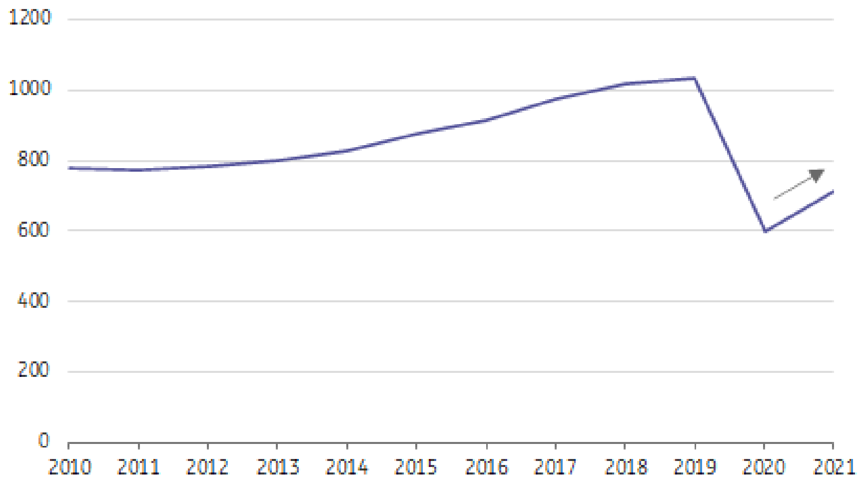
Drop-in fuels with four main production routes and multiple feed stocks

Sustainable aviation fuel is jet fuel from a qualified renewable source which can be used by blending it into conventional jet fuel. SAFs require certification to be blended. The current maximum certified blend is 50%, but trials have been executed with a 100% usage of SAF, which is expected to be authorised in due course.

Of the four main production routes we distinguish, three are bioSAFS and one is synthetic (in this report we exclude direct combustion of liquid hydrogen). The extent to which a SAF reduces emissions depends on the lifecycle emissions profile of feedstock, considering production, transportation, and combustion.

CO2 emissions of global aviation have continued to grow over the last decade

CO2 emissions of global aviation in MT



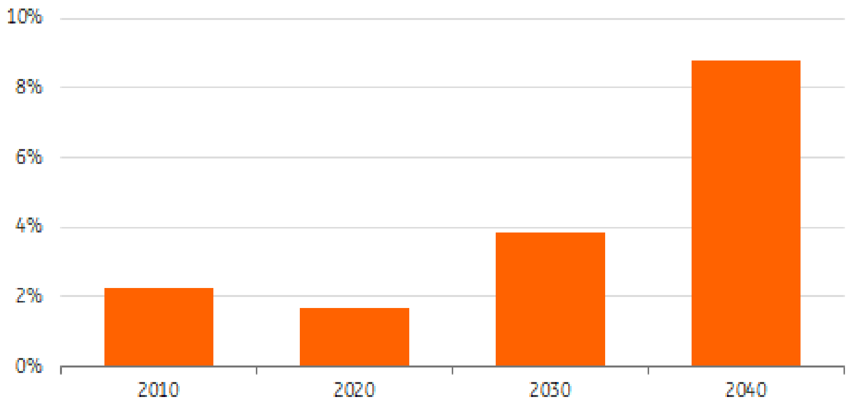
Source: IEA, ING Research

The aviation sector is responsible for 2% of global greenhouse gas (GHG) emissions, but emissions have grown rapidly, and aviation is one of the hardest to abate sectors because of the required propulsion power and the importance of weight. The real climate impact (based on effective radiative forcing) could be larger due to emissions high in the atmosphere. The pandemic led to a temporary drop in emissions, but global airline demand is expected to recover from the pandemic before 2025 and will continue to grow at an annual pace of around 3-3.5% over the next few decades[1]. Consequently, emissions will barely come down. Despite efforts by the sector, the share of aviation's CO2 emissions in the International Energy Agency's (IEA's) net-zero emission scenario is expected to exceed 8% by 2040. This emphasises that change is required, in the short and long run.

[1] Based on multiple sources including: IEA, IATA, ICCT

Aviation's share of global emissions will rise significantly, even when including SAF blending

CO2 emissions of global aviation as % of (expected) global total emissions in the IEA's net-zero emission scenario (including an increasing blend of SAF)



Source: IEA, ING Research

Zero-emission aircraft not yet on the horizon in commercial aviation

Many articles and reports have been published about the future of flying, often suggesting that electric propulsion is already within reach. On the other hand, Airbus has explored direct hydrogen propulsion and announced plans to bring this aircraft concept for commercial purposes to the market in 2035. But technical ability doesn't automatically mean the concept will be scalable and feasible to replace current commercial aircraft operations in the short run.

The energy density of batteries and hydrogen, possible lower expected speed, required spare capacity and not least extremely high specific safety standards pose a real challenge. "Zero-emission" flights powered by batteries or pure hydrogen might eventually be able to execute short-haul (regional) flights over the course of the next decade, but an efficient and commercially-viable zero-carbon alternative for current long-haul flights is not yet on the horizon. This builds the case for using SAFs and there are more reasons.

Multiple reasons why the aviation sector can't wait for new zero-emission aircraft technology and need SAFs

- The largest part of total GHG emissions in aviation comes from long-haul flights, with hardly any alternatives.
- Safety always comes first in aviation. Together with technological complexity, this means future generation "zero-emission" aircraft will require billions in research and development and a long and time-consuming certification process with many years of preparatory testing.
- Airbus and Boeing have introduced a range of new-generation aircraft over the last decade and research and development cycles easily exceed a 10-year timeframe. Moreover,

manufacturers still have extensive order books, with production backlogs running up to seven to eight years.
- The aircraft market is an oligopoly with Boeing and Airbus as dominant manufacturers. Challengers may disrupt the market, but given their power it's likely that the incumbents will retain a dominant influence. An important point in this regard is that the development and ultimately successful introduction of a new commercial aircraft requires massive capital investments.
- Fleet replacement is slow and manufacturers currently face production constraints. Most of the current installed fleet will still be in operation in the 2030s.
- The aviation sector needs a solution that enables the current fleet to operate with lower net emissions and SAFs used as a drop-in fuel. Extra storage facilities at airports may be required, but regular infrastructure and current aircraft can be used, which is a major advantage that avoids massive capital loss.

Emissions from long haul flights and short term progression make SAFs crucial for decarbonisation

In practice, around 80% of global CO2 emissions emerge from flights travelling more than 1,500km, and in Europe around 50% of CO2 emissions are represented by long-haul flights of more than 4,000km (EASA). In several parts of the world including the US and Australia, these long-haul flights are even more important. For physical, security and economic reasons, a technology switch in commercial aviation is not within reach and this bolsters the case for sustainable aviation fuel. The three main short-term directions to decarbonise aviation are:

1. Fleet renewal/replacement by new generation aircraft.

2. More efficient operations.

3. Blending SAFs.

Fleet renewal and efficiency gains can contribute significantly to emission reductions, but SAFs are supposed to make the most difference in the medium term.

Global and government targets drive the uptake of SAFs

The production of SAFs is still 1.75-4.5 times as expensive as conventional jet fuel, depending on the type of SAF (REfuel aviation, EC). In most cases, customers are not willing to pay the (full) green premium on a voluntary basis. Research by ACM in The Netherlands showed that just over a third of customers are willing to pay for lower net CO2 emissions and just 10% have done so previously. Early-moving airlines take on responsibility, but a level playing field is required to push up consumption of SAFs and create economies of scale in production to bring down prices. Therefore, regulation is a critical support factor. This can either be done by taxing conventional kerosene (and redistributing the gains for decarbonisation) or subsidising SAFs.

Drivers of blending sustainable aviation fuel (SAF) – ambition framework

1. Global regulation (ICAO)
2. Government targets
3. Sector targets – IATA, collectives and individual airlines
4. Corporate clients ambitions included in travel policies (scope 1,3 emissions)

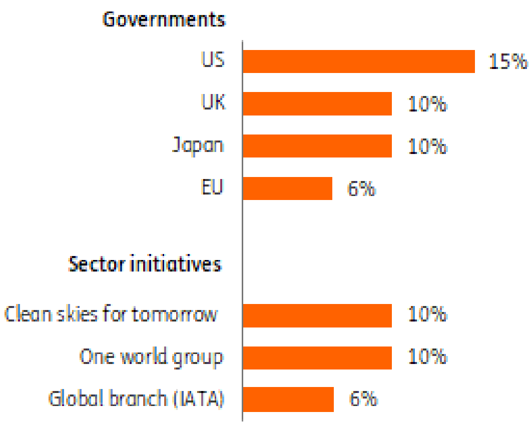
1 ICAO net-zero aspiration promising for pushing decarbonisation and SAF

Aviation is a sector with a global level playing field, therefore compelling policies ideally have a global scope. Due to regional differences and varying interests, ICAO struggled for a long time to agree upon climate targets aligning with the Paris agreement. After years of deliberation, in October of this year, ICAO finally succeed in adopting a net-zero emission target by 2050. This was a milestone achievement which shows support for increased production and blending of SAFs.

The general ICAO goal is aspirational, and the decarbonisation pathways and solutions are still to be developed, but it's a signal and call to action. ICAO backs SAF and it seems reasonable to align with the ambitions of the airline association IATA. Implementation of ambitious global targets by ICAO would be most effective to push up SAF consumption.

Governments and sector representatives posed ambitious SAF blend targets for 2030

SAF blend mandates and targets for 2030 in % of total jet fuel consumption



Source: Multiple sources, ING Research

2

Governments pursue a green recovery with setting blend targets for 2030

Government policies are the most direct regulatory drivers of SAFs. The past two years have been pivotal for increased urgency and ambitions, which led to pledges. Although the aviation sector went through an unprecedented crisis with steeply dropping passenger volumes over the pandemic, it has also been a catalyst for attempts to "build back greener" as the UK government called it. The EU already wants the blend to reach a level of 2% in 2025, which means consumption volumes will have to increase considerably in the years to come. Governments of larger advanced economies set targets to blend 6-15% of SAFs by 2030.

National ambitions of several European countries exceed the EU's goals

The European Union still takes a relatively conservative approach in setting its SAF targets. Several other European countries had already established goals that are more ambitious than the EU's 6% mandate for 2030, adopted as part of the RefuelEU aviation act. Member states including The Netherlands, Sweden and Finland earlier adopted SAF-targets of 14-30% for this decade, although the question raises if these still hold. The UK aims for a 10% blend of SAFs by 2030 and Norway aims for 30%.

US might take-over the lead from Europe in pushing SAFs

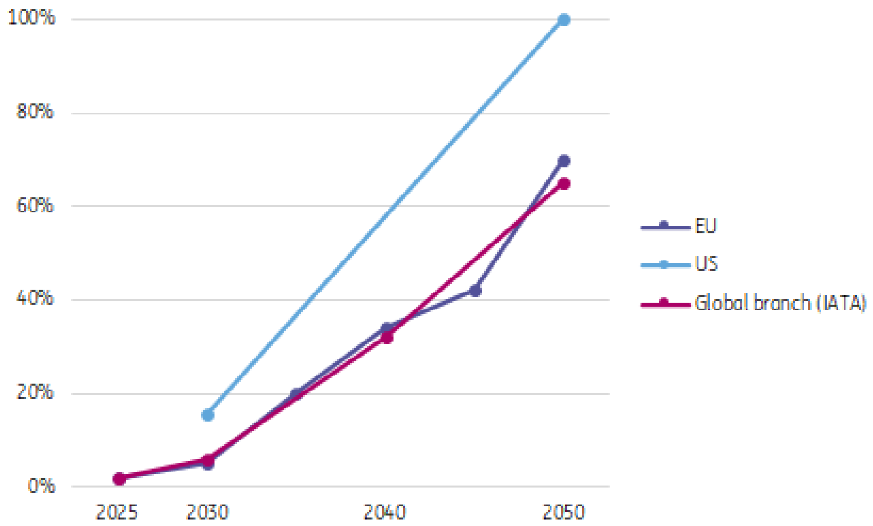
The US has also introduced its SAF strategy as part of its inflation-busting act, with an absolute production target of three billion gallons of SAF in 2030. Based on expected jet fuel consumption, this comes down to some 15% of total usage, and the ultimate goal is to replace the full 100% of future jet fuel consumption with SAFs. The US targets surpass the European ambitions in the medium term, as the EU forecasts a 2% blend in 2025 based on its REfuel Aviation plan, but a less aggressive path afterwards. However, the European ambitions also included a sub-target for synthetic fuels[2].

In addition, the US is offering a tax incentive of $1.25-1.75 per gallon of SAFs to push up production, which is critical for the fuels' uptake. While Europe is generally leading in climate regulation, and may still choose to impose accompanying support or taxation measures and raise its targets later on, SAF production could grow at a faster pace in the US, at least this decade.

[2] As part of the general targets, Europe seeks to stimulate the development of synthetic SAF by setting sub-targets for the fuel mix from 2030 (1.2%, increasing to 5% in 2035 and 35% by 2050).

Decarbonisation ambitions also rely on massive future growth of SAFs

SAF blend target development per stakeholder in % of total jet fuel consumption



Source: EP, US Gov, IATA, ING Research

3 Sector initiatives set a voluntary standard, but show strategic commitment

Sustainability targets from airlines are an additional driving force from the private side. Global branch IATA adopted its net-zero 2050 target in 2021 and published its SAF strategy which aims for a 6% blend by 2030 and a 65% blend by 2050. Within the World Economic Forum, a significant number of airlines, airports, producers, original equipment manufacturers (OEMs) and corporate buyers teamed up in the "Clean skies for tomorrow" initiative in 2021, which focuses on accelerating SAF development in order to reach a 10% blend by 2030. In 2020, a group of airlines joined forces in the One World group to develop a SAF supply network. The largest European airline in passenger numbers – Ryanair – didn't sign up for the collective initiative, but nevertheless aims for a 12.5% SAF blend by 2030.

Altogether, the number of airlines to adopt SAF targets has grown from just one (KLM) in early 2020 to more than 30 airlines in 2022, which shows a major acceleration in commitment.

4 Corporate clients' climate commitments increasingly makes sense as the green premium needs to be paid

Airlines also have corporate clients that are increasingly aware of their responsibility in corporate travelling. Companies seek to reduce direct scope 1 or even scope 3 emissions of (long-haul) business travelling. This is regularly not a big share of emissions for manufacturing companies, but it does make sense for larger services companies active in, for example, consultancy, IT, or financial services.

On the air cargo side, it's about decarbonising shipments for cargo owners. Global forwarder Kühne

+ Nagel, for instance, offers a 50% blend option for clients with ambitious climate reduction goals. And large logistics companies Fedex and DHL both set SAF targets of 30% by 2030.

Corporate clients can clearly support airlines on their journey, as SAFs are significantly more expensive than conventional jet fuel and the green premium needs to be paid.

It has been a while, but after two years of accelerated progress we believe that the regulatory and strategic landscape is ready for the take-off of SAFs, although the current goals aren't legally binding and backed by sanctions. Demand is there and has to be matched by supply, which is challenging.

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Article | 11 May 2023 Transport & Logistics | Sustainability

Stronger supply of sustainable aviation fuels crucial to securing uptake

Blending sustainable aviation fuels (SAFs) needs to grow massively to meet ambitions for 2030 and beyond. Demand is there, but supply is limiting uptake. Ramping up capacity investments is critical to meet the aspired goals. Airlines (purchase grants) and suppliers (production, delivery) have a joint role here, but more policy support will help

This article has been updated following the EU parliamentary adoption of amended blend fuel mandates last month.

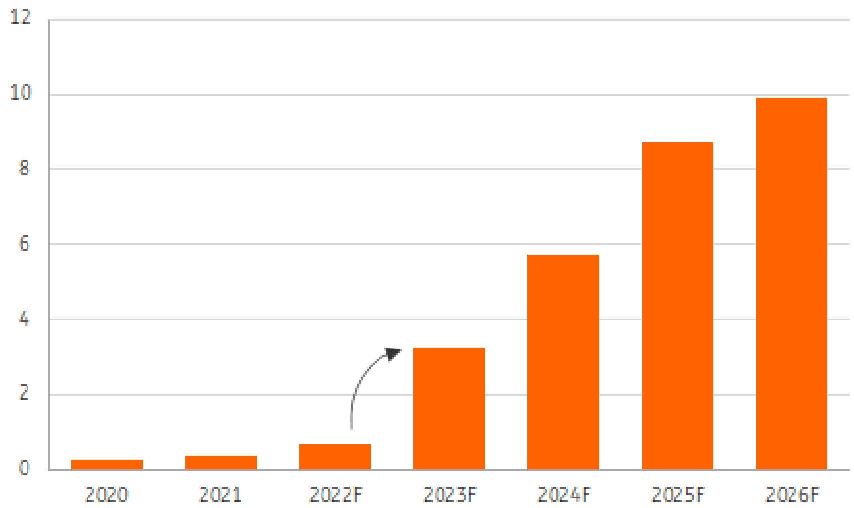
Ambitions and goal-setting for using sustainable aviation fuel (SAF) by authorities and governments, as well as airlines and corporates, have gained traction over the last two years. This created the conditions for the take-off of SAFs from the demand side. But what is the current state of play in supply? What are the critical factors and what is expected in terms of growth?

Global jet fuel demand expected to recover and continue to increase

The global consumption of conventional jet fuel by commercial airlines totalled 360 billion litres in 2019, according to the trade association IATA. Consumption dropped following the Covid-19 pandemic, but airline activity is expected to recover and fuel burn is bound to exceed pre-pandemic consumption levels again by 2025. Over the following decades, an average annual global growth of passenger aviation (RPK) of around 3-3.5% is estimated. Operational efficiency measures (such as in taxiing, flight and arrival optimalisation) and aircraft replacements are likely to offset a significant part of the additional fuel consumption, but not all. So annual jet fuel consumption is expected to continue increasing. Given the lack of mature and commercially viable low-carbon technologies, this means aviation will rely heavily on SAFs to pave the way for decarbonisation over the next two decades.

SAF production and delivery on the brink of acceleration

SAF production capacity per year in billion litres based on publicly-announced intentions



Source: BNEF, ING Research

SAF production to reach 1% of jet fuel consumption in 2023 and almost 3% in 2026

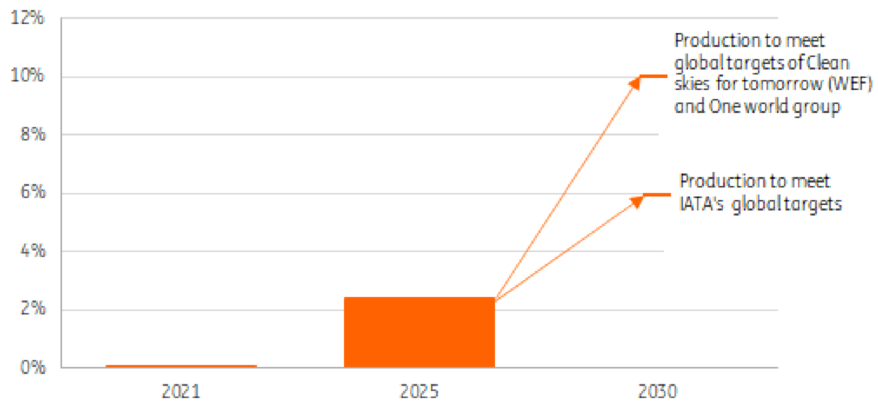
The usage of SAFs has been under discussion for quite a while, but on a global scale production hasn't made a large difference yet. That's about to change, though. If all publicly-announced initiatives to start and expand production by the summer of 2022 come to fruition, available global SAF capacity will increase fivefold in 2023 and continue to rise in the years after. Production capacity could reach a 1% share of global consumption in 2023, more than 2% in 2025 and nearly 3% by 2026.

SAF supply is the critical factor to reach the targets

Despite the higher costs of SAF, supply is currently still the most critical factor to secure further uptake. The investment case requires long-term cooperation and commitment between airlines, manufacturers (like Neste, Gevo and World Energy) and distributors (like SKY-NRG – which also develops production partnerships – and World fuel services). Planning and development of production facilities can easily take several years before delivery starts off. This means 2030 targets are already around the corner.

Much more production is required to reach ambitious targets for 2030

Development global SAF capacity based on publicly-announced intentions and future blend ambitions



Not on track yet – blending goals require much more SAF-production locations

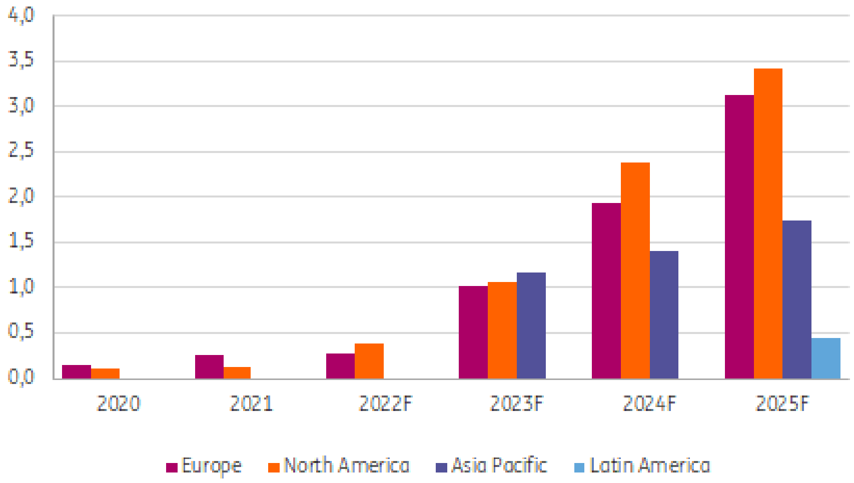
Although SAF production is about to accelerate, 2030 targets from IATA (6%) and the corporate initiatives Clean skies for tomorrow and One world group (10%) require more progress, especially when taking into account the expansion risks, such as project delays. The industry targets require strong growth, but they still fall short of what IEA deems necessary for a global net-zero scenario pathway. This implies we're just at the start of the required surge and we face a long haul to push growth. Market analysts estimate that ultimately 5,000-7,000 SAF facilities may be required to achieve the global SAF blending goals of the aviation industry by 2050 (ATAG/ICF).

Global challenge is also a regional challenge – locations availability at airports is key

There's also a regional puzzle of supply and demand as airlines are dependent on available SAFs at local airports. This means supply networks will need to be unrolled and developed. Currently, SAF supply in the US is concentrated in San Francisco and Los Angeles, and in Europe it is mostly at Amsterdam-Schiphol, London Heathrow, as well as Scandinavian airports, whereas supply at the Asian hubs Singapore and Hong Kong is expected shortly. Local production and diversification are obviously crucial to fueling airline aircraft with more SAF and avoiding long lead times.

Europe and US take the lead in SAF production capacity, Asia follows

SAF capacity per year in billion litres per region based on publicly-announced intentions



Source: BNEF, ING Research

The US is taking the lead in developing SAF production capacity

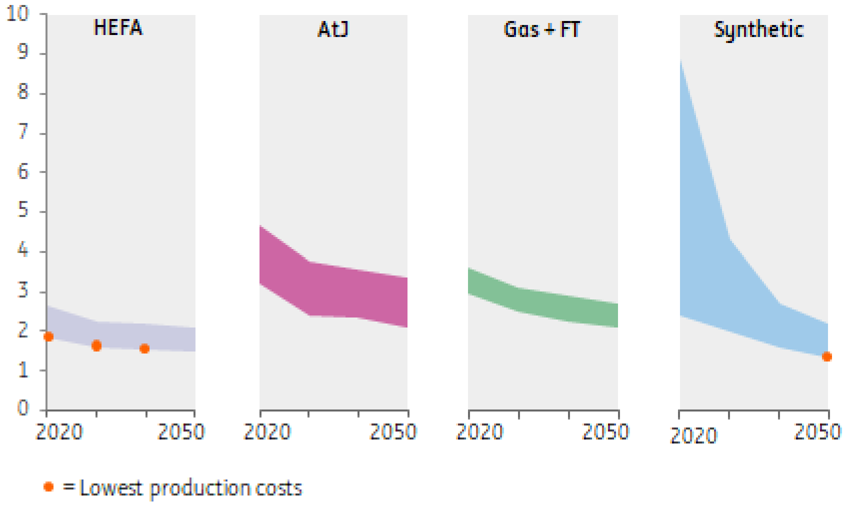
European market players seemed to be most ambitious in developing SAFs, but the US now leads the way thanks to efforts made by the Biden administration in the US. America has adopted a different approach to Europe's demand targeting by subsidising $1.25-1.75 per gallon of bioSAF ($0.33-0.46 per litre) and stimulating supply. Production capacity in the US is expected to surpass Europe's potential in 2023 or 2024. Examples of recent agreements include Aemetis's delivery to eight members of the One World group at San Francisco Airport. The Asian-Pacific region falls behind despite air travel in Asia expanding at the highest pace over the last decade, and it will continue to do so post-pandemic.

SAFs gain from scaling, but will continue to trade at a premium

SAFs production entails significantly higher costs than conventional jet fuel. Based on WEF figures and a fixed production cost of $600 per MT (which is relatively low but still provides a relevant comparison), we have detailed the relative cost ranges for the four distinguished eligible SAF production pathways over time. As a result of economies of scale, production costs are expected to come down significantly in the following decades. But they are unlikely to drop below conventional jet fuel before 2050. This means SAFs will keep trading at a premium, leading to higher fuel costs for flights fueled by SAF blends, as well as higher ticket prices.

HEFA is the cheapest production option, but ultimately synthetic SAF is expected to be most competitive

Development of production costs per SAF route (upper and lower boundary) as multiple of jet fuel



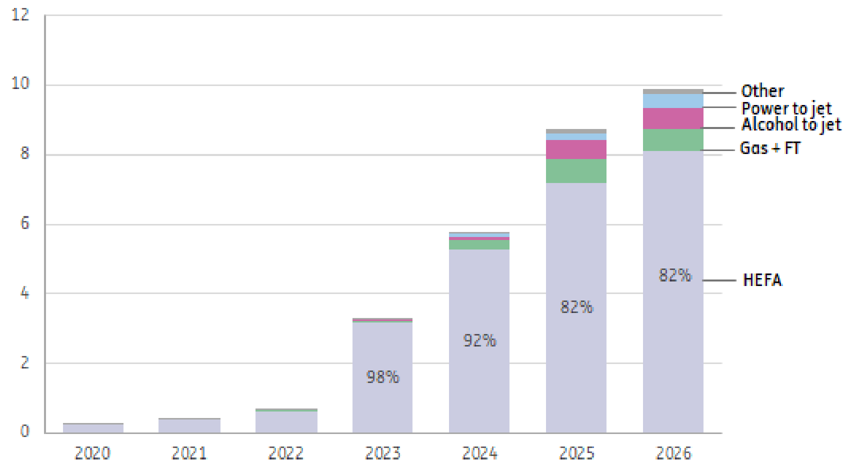
Source: WEF, ING Research

HEFA is most competitive, but ultimately synthetic SAF is expected to be the most cost-efficient

The HEFA production route which has bio-oils and recycled fats as feedstocks (bioSAF) is the most mature and most competitive, with an estimated price range of 1.8-2.7 the cost of conventional jet fuel. The other biogenetic pathways are still significantly more costly at this point. Synthetic SAF currently has the largest cost range, depending on the production costs of hydrogen and the origin of carbon (waste sources, direct carbon capture). With the expected global surge in green energy supply, the costs are expected to drop below the bioSAF in the long run.

Most cost efficient HEFA is dominant, but other SAFs are increasingly needed as well to supply sufficient SAF

Forecasted SAF capacity per year in billion litres per technology based on publicly-announced intentions



Source: BNEF, ING Research

HEFA dominates, while the development of other SAF pathways is also needed to meet future demand

HEFA is the cheapest pathway for SAF and is also expected to represent the vast majority of global production this decade. Availability of feedstocks enables HEFA production to expand towards 2030, but expanding bioSAF will increasingly need to be accommodated by alternative feedstocks like cellulosic (paper) and municipal waste (MSW). For the US, feedstock from fats and oils (HEFA) won't be enough to meet SAF demand. Other production methods are technically feasible but more expensive. Nevertheless, feedstock availability, increasingly stringent requirements, as well as regional differences leave little choice. Development and upscaling of Alcohol to Jet (AtJ), Gassification+FT as well as synthetic SAF are also required to meet future demand.

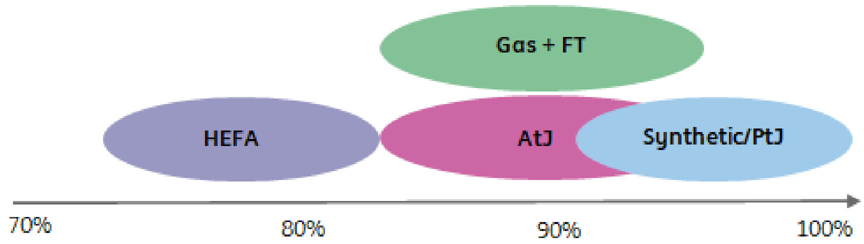
Using SAF will eventually push up airline ticket prices

The fuel cost for airlines usually varies between 15-30% of operating costs. Assuming a 25% fuel cost share, an average SAF blend of 10% in 2030 would push total operational costs up by 2.5-5%. For a ticket from London to New York, this initially means an increase of some €15-25. After 2030, the step up in blending rates will push fuel costs up further, despite the expected price decrease. In the low margins airline industry, this will quickly be reflected in higher ticket prices.

Increased climate awareness leads to scrutiny of SAF feedstocks

With respect to decarbonisation efforts, corporate sustainability actions are increasingly under scrutiny. The Science Based Target Initiative (SBTI) approach is also increasingly used as a reference. This may not only lead to a shift away from carbon offsets but also encourage the shift to more advanced SAF feedstocks. Sustainability-linked loans with SAF targets have also been introduced. Palm oil blends are already controversial because of deforestation, but the use of (by)products of food crops like corn for SAF (alcohol to jet fuel) will have adverse effects on food or feed supply chains and this might also push up food prices. In the EU, there's a push for the use of advanced feedstocks and the European Commission also considers a cap on waste oil feedstocks and focuses on more advanced waste and residual sources. But limited availability also leads to tensions. In the US, corn is still seen as an important source for bioSAF going forward.

CO2 reduction potential ranges of the SAF pathways



Source: ING Research

Large contribution from synthetic SAF needed to maximise decarbonisation

The aviation sector is expected to require hundreds of billions of litres of SAF in 2050. At the same time, demand for biofuels and bio feedstocks from sectors including road transport, shipping and the chemical industry is also increasing. On a global level, an estimated 41-55% of SAF could potentially be provided from biogenic origin. In Europe, bio feedstock supply for SAF is expected to lack ambitions from 2035 onward. This means the remainder should eventually be provided by synthetic fuels. Synthetic SAFs also have the highest potential for decarbonisation when using (almost) 100% green electricity. However, producing synthetic SAFs is energy-intensive and requires more electricity than it contains. It requires large areas of land or sea to produce and intensified competition with other sectors is expected. Consequently, synthetic SAF will depend on the availability of sufficient green energy to convert into the required green hydrogen.

Synthetic SAF is expected to be the accelerator from 2030 onward

In Europe, several low-volume production facilities for synthetic SAFs (including in the Netherlands and Sweden) are planned to come online between 2025 and 2030. The EU already includes a sub-mandate for synthetic SAFs as part of general targets, which starts at 0.7% of total fuel consumption in 2030, increasing to 28% in 2050. In the US, the introduced production subsidies currently only apply to bioSAFs.

Generally, the rise of synthetic SAF requires a significant reduction in the three cost drivers: green energy, electrolyser technology and direct air capture – and this takes time. Once the global availability of green energy has expanded significantly and the production of synthetic SAF can be scaled, the production costs of synthetic SAF are expected to come down. Eventually (in 2050) synthetic SAF is also expected to be the cheapest option.

Some regions have a competitive edge in producing synthetic SAFs

The success of SAFs also has a regional element to it, as previously explained. Countries with an abundance of solar energy and space such as Australia, and Saharan countries, as well as European countries like Spain, could benefit from a competitive advantage as locations for the future production of synthetic SAF as low renewable energy costs are a critical pillar of the business case.

Corporate cooperation required to accelerate SAF supply, more policy support would help

SAFs have higher production costs and trade at a premium. Imposing mandatory global blending rates enforced by ICAO would probably be most effective to ramp up supply, although that's not easy to achieve. From a market perspective, subsidies for scaling up production, such as in the US, could improve the business case and push up investments in global supply in the short run. Pricing emissions on a global scale can generally be an efficient measure to structurally improve the market position of SAFs, especially if revenues are (partially) redistributed for decarbonisation. ICAO's CORSIA programme takes a start by increasing obligations for carbon offsets, but only from 2027 and it's not yet clear how this will eventually play out for the SAF market. In Europe, continental flights are already subject to the European emission trading scheme (ETS), but due to free allowances the impact is currently still limited. Thus, policy changes to support and speed up SAF supply are possible.

Demand for SAFs is already there, but supply needs to catch up with the blend ambitions in the coming years. Viable alternative technologies in commercial aviation are still a long way off and SAFs, therefore, have a critical role in emission reductions. Manufacturers, distributors, airlines and corporate users are challenged to team up to develop and secure even more SAF supplies and more policy support can be helpful.

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