ReFuelEU Aviation: Fuelling Net Zero 2050

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ReFuelEU Aviation: Fuelling Net Zero 2050

Welcome Words

Despite the substantial restrictions resulting from the pandemic, ARC became the hub of knowledge, cross-fertilisation and dissemination on airport, aviation and territory relations. As such, ARC organised hybrid events in different parts of Europe (Vienna, Yerevan, Brussels), dealing with key aviation topics such as recovery, aviation noise management, the role of regions, etc.

But it was not till May 5 that ARC could eventually organise an entire presential conference in their facilities in Brussels to debate one of the most important topics of the aviation & airport sectors which significantly impacts the regions and their citizens: sustainable aviation fuel, SAF and the current discussion of the ReFuel EU Aviation proposal.

This conference was a great success, attracting more than 140 participants and speakers, who I want to thank again for their participation and for sharing their position and knowledge from the point of view of the main political groups of the European Parliament, the airlines, the airports, the regions and the industry.

At the end of the conference, we felt the need to summarise what had been explained, not just as simple minutes but rather as a summary file with state of art on this topic to increase the awareness and knowledge of the audience, perhaps not always familiar but undoubtedly interested in this topic.

Therefore, ARC asked one of the leading EU specialists on the topic and a very good ARC friend, Ms Inma Gomez, to prepare this short but in-depth document to become a lighthouse for all.

I hope you consider it valuable and insightful.

Erich Valentin
ARC President

About the author

Inmaculada Gomez holds an international PhD in Environmental Sciences with over 15 years of experience, works as a sustainability expert at civil aviation consultancy and training firm SENASA since 2007. She has been manager of the EU Biofuels Flightpath Secretariat and coordinator of the ITAKA project, demonstrating and promoting the use of sustainable fuels in aviation (SAF) in Europe and abroad. She is a member of the working group dealing with the strategic research agenda for Energy and Environment for aviation ACARE, of the International Civil Aviation Organisation (ICAO) Fuels Task Group. She co-leads the SAF task group of the European Civil Aviation Conference (ECAC). She supports the implementation and operation of the EU ETS for aviation in Spain. Besides working at SENASA, she has been a professor of Environmental Economics, Environmental Education and Communication, Climate Change Mitigation and Landscape planning, and worked on several research projects focused on designing environmental market measures for sustainable development in Spain and Latin America.

Acknowledgements

I would like to thank you for the kind contributions and lively discussions with the speakers and attendants of the ReFuel Conference, hopefully somewhat reflected in this short book. Thanks to everyone at ARC, from the organisation of the Conference to the review and edition of this book, in particular to Sergi Alegre and Alena Maximova for their amazing support.

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INTRODUCTION

Over the past decades, air transport has played a crucial role in the Union's economy and the everyday lives of Union citizens, as one of the best performing and most dynamic sectors of the Union economy. It has been a strong driver for economic growth, jobs, trade and tourism, as well as for connectivity and mobility for businesses and citizens alike, particularly within the Union aviation internal market. Growth in air transport services has significantly contributed to improving connectivity within the Union and third countries and has been a significant enabler of the Union economy.

From 2020, air transport has been one of the hardest hit sectors by the COVID-19 crisis. With the perspective of an end to the pandemic in sight, air traffic is expected to gradually resume in the coming years and recover to its pre-crisis levels. At the same time, emissions from the sector have been increasing since 1990, and the trend of growing emissions could return as we overcome the pandemic. Therefore, it is necessary to prepare for the future and make the required adjustments ensuring a well-functioning air transport market that contributes to achieving the Union's climate goals with high levels of connectivity, safety and security.[1].

European aviation is highly committed to the achievement of climate neutrality in 2050. Destination 2050 report shows how Europe's aviation cooperates to reduce their climate footprint and make flying more sustainable. However, air transport heavy reliance on liquid hydrocarbons makes its decarbonisation an enormous challenge. For decades, aircraft and engine manufacturers have optimised their designs to the best fuel candidate, jet fuel or kerosene, achieving impressive energy efficiency gains. Breakthrough options such as using electricity or hydrogen to power our flights are promising and starting to take off, especially for the shorter ranges. Unfortunately, due to their readiness level, ability to reach the market and applicability to the entire air transport sector, those new technologies are not helping sufficiently achieve net zero carbon in 2050. So, on top of further improving operations and the available technology, aviation sector must replace fossil jet fuel with alternatives compatible with current and near-future aircraft, engines and fuel infrastructures (drop-in), but with a significantly lower climate impact. Needless to say, the lower impact, the better, even looking for carbon-negative options where possible.

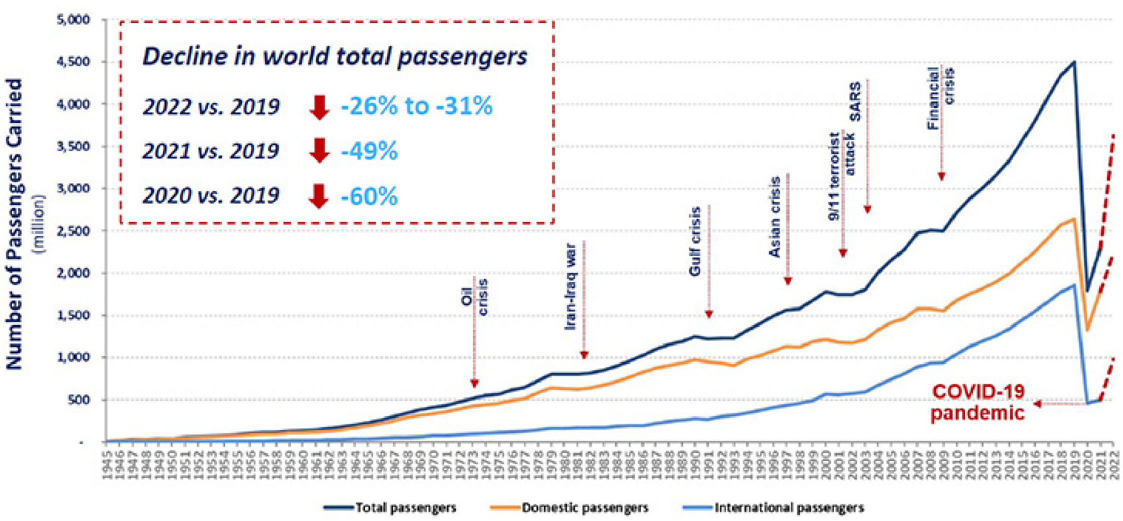
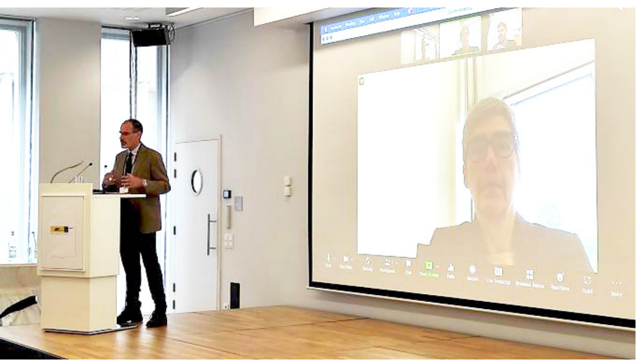


Figure 1. World passenger traffic evolution, 1945–2022. Source: ICAO [2]

1 COM(2021)561 – Ensuring a level playing field for sustainable air transport

2 International Civil Aviation Organisation, https://bit.ly/3ruI5p8 (last accessed on 31/05/2022).



A solution already used in road transport for decades mainly focused on biofuels, but that solution was not made available to the aviation sector until very recently. The very stringent safety requirements for flying have made, and still making today, slower the entry of options for using different feedstocks and technologies to produce aviation fuels. In 2009, with the issue of the ASTM standard D7566, Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons, the possibility of using sources other than crude oil became a reality for commercial air transport. However, it was only after the revision made on 1 July 2011 that bio-jet use started to take off. First called bio-jet or alternative aviation fuels, they are now uniformly named Sustainable Aviation Fuels (SAF), strengthening that any alternative needs to be genuinely sustainable and cover sources other than biomass such as renewable hydrogen or recycled carbon.

Nowadays, and according to the International Civil Aviation Organisation (ICAO),[3] more than 360,000 commercial flights have used SAF, and 47 airports distribute it regularly worldwide, with airlines signing regularly new offtake agreements. Commercial production of SAF increased from an average of 0.29 million litres per year (2013-2015) to 6.45 million litres per year (2016-2018). Additionally, up to 6.5 Mt (8 billion litres) per year of SAF production capacity may be available by 2032.

Despite the impressive SAF(r)evolution and the numbers, it is still far from representing a significant share of the volumes used worldwide due to the substantial price gap compared with the fossil alternative. Today in Europe, sustainable aviation fuels represent only about 0.05% of total jet fuel consumption, according to the ReFuel EU impact assessment. Knowing the multiple benefits of using SAF, policymakers are defining regulations and policy tools to increase the production and uptake of SAF.

In the EU, the renewable energy directive includes the promotion of SAF, even with a specific bonus (multiplier), to the use of SAF not made from food or feed feedstocks. However, today, only the Netherlands has implemented that mechanism. Also, some countries such as Norway, Sweden and recently France have implemented national mandates for SAF, looking forward to enhancing the production and uptake of SAF and reducing the carbon footprint. Many countries have programmes for support (R&D, industry platforms…), but even with those, the uptake of SAF and the production capacity deployment has not followed the desired path.

3 https://www.icao.int/environmental-protection/pages/SAF.aspx (last accessed on 31/05/2022).

Therefore, on 14 July 2021, framed on the Green Deal, the European Commission published the "Fit for 55" package of legislative proposals. One proposal is the ReFuelEU Aviation Regulation, aiming to lift production and uptake of SAF finally in a path coherent with achieving climate neutrality in 2050. ReFuel sets a SAF blending mandate imposed on aviation fuel suppliers at the covered EU airports. The proposal also includes some provisions to avoid carbon leakage (known as the anti-tankering provision) and data reporting on fuel types and properties. The proposal, officially named "Regulation on ensuring a level playing field for sustainable air transport", strongly focuses on avoiding any competitive distortion in the EU market and, in particular, among airports. Being a Regulation, the proposal, once adopted, will uniformly apply to all EU Member States, without the need for national provisions and reducing the time until effective enforcement, compared with, i.e. a Directive.

This regulation would significantly affect the SAF industry, derive significant benefits for the airport communities in terms of local air quality, and significantly contribute to the decarbonisation targets. With great acceptance from the implicated sectors (fuel suppliers, airports and aircraft operators), ReFuelEU is under the EU Ordinary Legislative Procedure and will therefore be adopted after trilogue[4] (European Commission, European Council and European Parliament common agreement).

In this context, Airport Regions Council organised a pan-European wide conference on Sustainable Aviation Fuel and the ReFuel EU Aviation when the processes for the opinion of the EU Parliament and EU Council was close to completion, almost one year after the publication of the proposal. The conference, named 'ReFuel Europe, Sustainable Aviation Fuel and challenges and opportunities for airlines, airports, industry and regions', brought together the voices of the institutions taking part in the legislative process, but also from the concerned industry key stakeholders. More than 140 attendants, including top experts from the entire aviation industry and representatives from local and regional authorities in airports' vicinity, have discussed this challenge with high-level leaders from the EU Commission and EU Parliament, airports, airlines, and regions. Altogether, the stakeholders gave an overview of the regulatory proposal, the benefits, the doubts and the opportunities.

The introductory words from Mr Erich Valentin, ARC President, and Mr Filip Cornelis, Aviation Director, DG MOVE, started from the cornerstone: ReFuelEU Aviation is a regulation needed and appreciated, even if it comes at an extra cost for the sector.

In the words of Ms Jutta Paulus, European Parliament's opinion rapporteur for the file at The Committee on Industry, Research and Energy (ITRE), Group of the Greens/European Free Alliance: "aviation will only have a future if it is sustainable".

After over a decade, governments, associations, and companies have worked to promote SAF, seeing that the pace of the voluntary measures undertaken by the frontrunners was simply not enough. Then, the RefuelEU aviation proposal came to finalise the job: putting a significant amount of SAF in our flights and boosting the SAF industry in Europe.

During the conference, participants presented and discussed from different angles key topics, such as feedstock, e-fuels, non-CO_2 effects, energy security, responsibility share, the level of ambition or the coherence with other measures of the legislative package Fit for 55, the level playing field and the need of a worldwide SAF target.

Of course, the cost increase and extra EU competition distortion are a threat for airlines and airports, where potential solutions still need to be explored and developed. But always, and as repeated many times at the workshop, without reducing the level of climate ambition. European aviation wants to do its part in complying with the Paris agreement and the net zero by 2050 commitments. Moreover, for doing that, the sector knows SAF are a must, not the only one but the major contributor.

Under a level playing field, but taking advantage of the singularities, SAF production can also contribute to solving regional challenges such as waste management, employment, energy security, local air quality, economic resilience, etc. Therefore, airport regions have many opportunities and a role to play in facilitating SAF production, uptake and benefiting for it.

Therefore, this topic tries to stocktake the magnificent discussion held during the ReFuelEU Aviation workshop held on 5 May in Brussels while providing the readers with a quick 'primer' to deep dive along the SAF world insights.

4 Trilogues are informal tripartite meetings on legislative proposals between representatives of the Parliament, the Council and the Commission. Their purpose is to reach a provisional agreement on a text acceptable to both the Council and the Parliament.

SAF

Despite the breakthrough technology that could soon power with electricity or hydrogen the smaller aircrafts, medium and larger commercial aircraft currently have no alternative to liquid hydrocarbons (conventional or synthetic kerosene) for the near- to mid-term. Therefore, sustainable alternatives to conventional kerosene are required to reduce GHG emissions and thus reach the climate goals. Even when using alternatives to conventional fuels is also helpful to diversify markets, and for energy security reasons, the main driver remains that of the climate impact.

As indicated in the report recently issued by ICAO on the feasibility of a long-term aspirational goal (LTAG) for international civil aviation CO_2 emissions reductions (ICAO, 2022[5]), the aviation sector would heavily depend, even with the deployment of many other measures, on using alternative fuels to reduce CO_2 emissions. In the high ambition scenario IS3, alternative fuels should contribute up to 63% to the total savings expected compared with the other measures (e.g. the second would be new aircraft technologies, contributing up to 24%).

Since alternative fuels have been identified as a key emission mitigation measure for international aviation, significant progress has been made regarding their certification, production and commercial use. This progress is clearly accelerating in this decade, with many commitments from airlines, airports and even corporate passengers, and policy measures for promotion being implemented worldwide.

Once initially called alternative jet fuels or biojet, the international community reached an agreement to denominate those sustainable alternatives sustainable aviation fuels (SAF), including only the alternatives that are genuinely sustainable, and giving space together with biofuels to solar or power to liquid fuels.

Therefore, SAF stands for non-conventional fuel that is suitable for its use in aviation, typically drop-in[6],while produced sustainably from sustainable biological feedstocks (such as biowastes) and/or sustainable but non-biological sources (such as renewable hydrogen from electrolysis). The last ones are known as e-fuels or PtL (power-to-liquid).

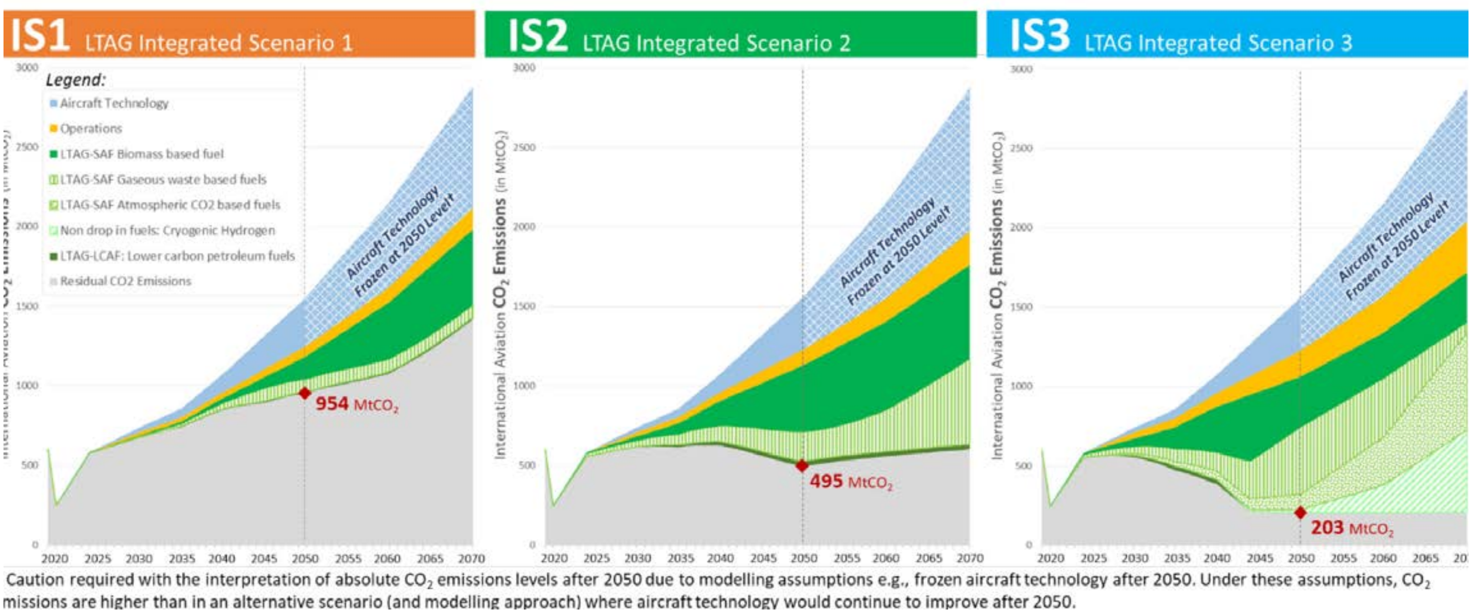


Figure 2. CO_2 emissions from international aviation associated with LTAG Integrated Scenarios, according to the ICAO – CAEP report. SAF (green shadows) have, in all scenarios, a prominent share. Source: ICAO, 2022.

5 ICAO Committee on Aviation Environmental Protection. Report on the feasibility of a long-term aspirational goal (LTAG) for international civil aviation CO2 emission reductions. 2022

6 Drop-in: that is exchangeable with conventional fuel without any adjustment to infrastructure, fuel systems, aircraft or operation.

QUALIFICATION

Aviation has adopted strict, rigorous safety standards and procedures for all its operations, harmonised at the international level, including stringent quality standards for the fuel used in the aircraft. The suitability for being used by commercial aircraft is assessed against the international standards that regulate the quality and fit for purpose of jet fuel. As mentioned before, ASTM issued as soon as 2009, the first standard regulating the qualification of SAFs. There are currently up to nine production pathways able to produce SAF ready for immediate application. Also, other technologies are queuing to be approved by ASTM[7].

The standard most widely used to define jet fuel's key characteristics and properties for commercial aircraft is ASTM D1655 Standard specification for aviation turbine fuels (Jet A-1). The ASTM D1655 is complemented by the ASTM D7566, the Standard specification for aviation turbine fuel containing synthesised hydrocarbons, issued in 2009, addressing the specifications for alternative drop-in aviation fuels. Every new SAF production pathway needs to follow a complex and stringent three phases and four-tiers testing process according to the ASTM D4505, Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives. Once the new pathway successfully completes all the tests and balloting, ASTM D7566 is adequately amended to include it.

Completing the process set by ASTM D4054 can take around 3-5 years and costs several million euros (on testing costs and fuel required for testing) for candidate fuel producers. To reduce this burden, ASTM approved a Fast Track Annex to D4054 that would allow some new candidates to be approved quicker but with a lower blending cap of a maximum of 10%. In addition, the US Federal Aviation Administration has established a Clearing House, run by the University of Dayton Research Institute, helping to prioritise the new SAF candidates to avoid bottlenecks due to the limited testing resources. At the EU, EASA (European Aviation Safety Agency), with contributions from the green-smart airports project TULIPs, is also studying the development of an EU Clearing House and testing resources to speed up the process and help new promising technology to reach earlier the market.

Moreover, the ASTM D1655 has also admitted some changes to include the possibility of co-processing certain biomaterial (vegetable oils and FT bio-crude) up to 5%, following the conventional jet fuel production process, with a potential increase of the bio-share being currently studied.

Any blended fuel batch certified against the ASTM D7566 is a drop in fuel. It should be considered compliant with the ASTM D1655 and, therefore, be treated as conventional fuel and compatible with the fuel systems and commercial aircraft. The drop-in characteristic is essential for the aviation industry as a drop-in SAF can be handled and blended with any other aviation fuel. Any non-drop-in fuel would imply higher costs and safety risks associated with potential mishandling and would require duplicate infrastructures and potentially create risks of lack of availability.

By May 2022, nine[8] conversion processes to produce SAF had been certified, and over 360,000 commercial flights had been completed using these fuels, supplied from more than 47 airports worldwide (ICAO, 2022), without duplication of logistic infrastructures or changes to the aircraft or operations. Share of SAF in the final fuel goes from 5% to 50%, but as expected by OEMs[9], they are now looking to make compatible the new aircraft with 100% SAF use; those limits could be increased in the near future along with the fleet renewal.

7 Other jet fuel standards are applicable in other countries/regions, but in terms of SAF, those usually refer to the ASTM.

8 Two co-processing routes at D1655, seven pathways at D7655.

9 OEM stands for Original Equipment Manufacturers, related to aircraft and its components, such as engines and fuel systems, manufacturers.

PATHWAYS

While ASTM has been able to qualify nine conversion processes, from a feedstock-technology perspective, we can group them into four main pathways:

1. HEFA: produced from lipids such as vegetable oils or used cooking oil. It would include coprocessing.
2. G-FT: gasification of solid biomass (or gases) to Fischer-Tropsch.
3. ATJ (Alcohol(s) to Jet): from fermentation of biomass or waste gases via methanol or isobutanol.
4. PTL (Power to Liquid) can also include sun to liquid routes. Using a waste carbon gaseous source (CO or CO2) or DAC (direct air capture), combined with renewable hydrogen (or directly in the case of the sun to liquid).

As for today's costs (CAPEX & OPEX), the most mature and cheapest fuel is being produced as HEFA. The use of lipids, which are already close to the characteristics of the final product, makes the process easier and cheaper if the feedstock costs 'were' also cheap. For G-FT and ATJ, the feedstock is very cheap (even cost negative such as the municipal solid wastes (MSW)), but its collection and treatment are challenging compared with the lipids. Such "cheap" feedstock is broadly available but disseminated in such a way that collection could become, in many cases, no-cost effective. When using waste gases for G-FT, ATJ and also PTL, the main challenge is the sustainability of such point sources in the long term, provided that we want to head to emission-free industries.

With the challenges affecting the other pathways, the alternative fuels sector and policymakers are envisaging a future based mainly on the high potential of the Power to Liquid route. Such high potential is due to the, in theory, unlimited availability of renewable energy and atmospheric CO_2. Due to its singularity, it is worth describing it more in detail.

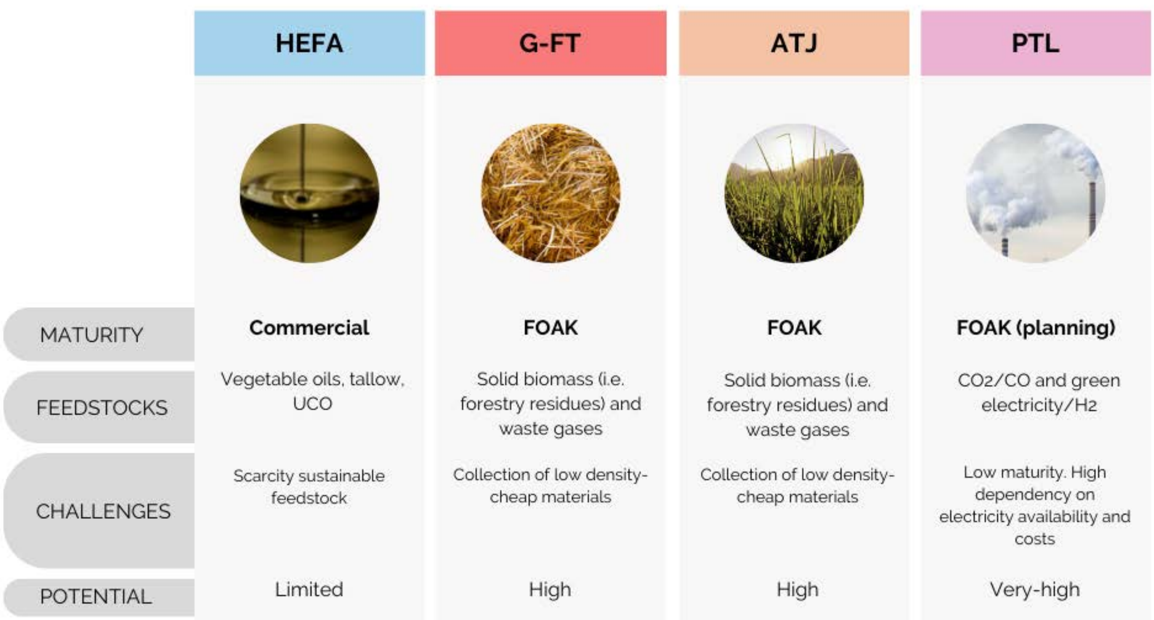


Figure 3. Main SAF pathways. FOAK: First of a Kind. DAC: Direct Air Capture.
Source: own elaboration.

POWER TO LIQUID

The PTL pathway includes the technologies and routes where the main energy content of the final fuel is supplied by renewable electricity. For the sake of simplicity, it usually also consists of the pathways that are not using electricity but directly use sunlight energy, also known as 'sun to liquid'. Their relevance is their limited dependence on the use of land. Land occupation is only required for electricity production and the facilities themselves, in comparison with, i.e. cropping. It also requires less water than crops[10]. Therefore, the route barely competes with food production or biodiversity, helping with their sustainability and making possible the production of potential (volume) theoretically unlimited.

In general terms, the process uses reverse water gas swift (RWGS) technology for combining CO and green hydrogen, usually from electrolysis, originating a syngas that can be later processed to kerosene using the Fischer-Tropsch technology. In some cases, the production of alcohol as an intermediate step is also being considered. The CO or the CO_2 can be obtained from various sources, including biomass combustion, industrial processes (e.g. flue gases from fossil fuels combustion, waste CO_2 from fermentation processes...), and CO_2 captured directly from the atmosphere (DAC).

One of the main complexities of this pathway is the different names that are associated with it. PTL is the most common one, but it is also frequent to refer to them as e-fuels and synthetic[11]The Renewable Energy Directive names them as Renewable Fuels of Non-Biological Origin (RFNBO) when the energy sources are fully renewable and Recycled Carbon Fuels (RCFs) in the case of at least part of the energy (e.g. CO, H_2) are considered not renewable. This terminology is aligned with ReFuel definitions, but it is a topic of increasing complexity, as the boundaries are often not very clear and/or regulated yet.

At the ICAO level, technical groups are working on better defining these extents. However, the European denominations (RFNBO, RCF) are not used in the international context, with PTL being preferred.

While the PTL fuels are currently the most expensive ones, multiplying from 7 to 10 times the price of the fossil alternative, it is also the pathway with the highest potential to decrease their costs based on the expected improvement of the electrolysis technology and the renewable energy production ramp-up.

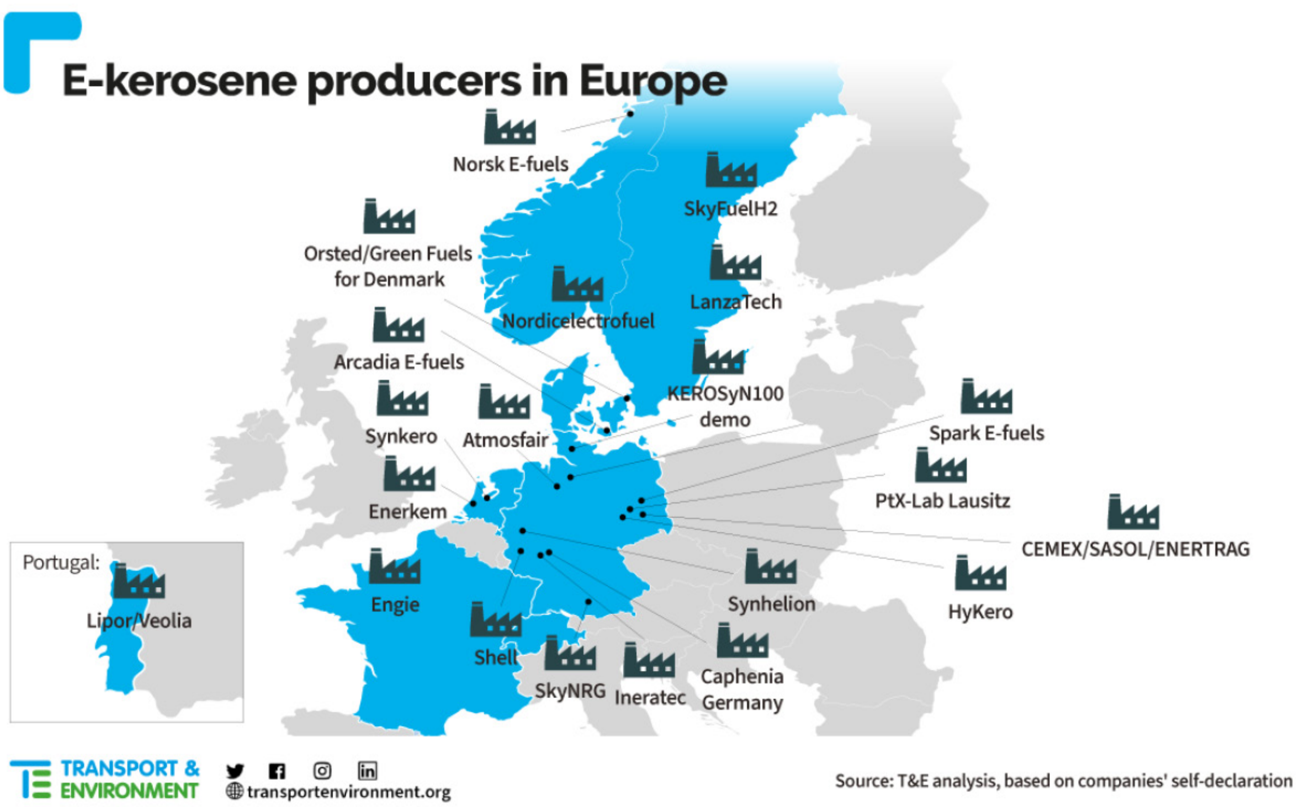


Figure 4. Map of planned plants for PTL production in Europe, according to public sources and companies' self-declaration. Source: Transport & Environment, June 2022.

10 According to CONCAWE, the mass balance to produce 1 litre of liquid e-fuel is 3.7–4.5 litres of water, 82–99 MJ of renewable electricity and 2.9–3.6 kg of CO2 (Concawe Review Volume 28 (1) October 2019).

11 As for ASTM terminology, all non-conventional fuels are synthetic; therefore, naming PTLs fuels as the only synthetic can create confusion.

However, their potential has attracted the policy and investors' attention, and many production plants are under planning, as seen in figure 4.

Another exciting advantage of the PTL route is that it can, at least in theory, be produced anywhere on the planet as it does not depend on biofuels where the biomass can be produced (such as climate constraints). Nevertheless, the best places to produce PTL are where the cheapest hydrogen can be produced. This should be seen as an opportunity for airport regions to gain energy security (geopolitical strategy).

Despite those deployment plans and the policy efforts, figure 5 shows how the PTL contribution could be pretty limited until 2035. On a broader view, all pathways would necessarily contribute to the set targets for using SAF, in the case of ReFuel Aviation but also for national mandates such as in the UK and others globally, such as in the USA.

Hydrogen (H_2) and electricity

Even if the ReFuel proposal was not initially focused on promoting hydrogen or electric aircraft, renewable electricity and hydrogen production have many synergies with SAF production. Available, affordable renewable electricity is a primary building block for the decarbonisation of aviation even if, as said before, its direct contribution to power aircraft would be limited. Renewable electricity is the main source of producing green hydrogen via electrolysis. Such green hydrogen is also a long-term alternative for powering aircraft (directly or as fuel cells) with enormous climate and environmental benefits but also a foreseen small contribution to 2050. However, hydrogen is a crucial input for SAF production, so using green hydrogen would help enhance the carbon performance of the HEFA, G-FT and ATJ routes while being essential to the deployment of the PTL.

Beyond the synergies with SAF deployment, to increase the pace for the penetration of direct use of electric and hydrogen aircraft, the opinion from the European Parliament on ReFuel EU Aviation is also considering its promotion, including it in the targets.

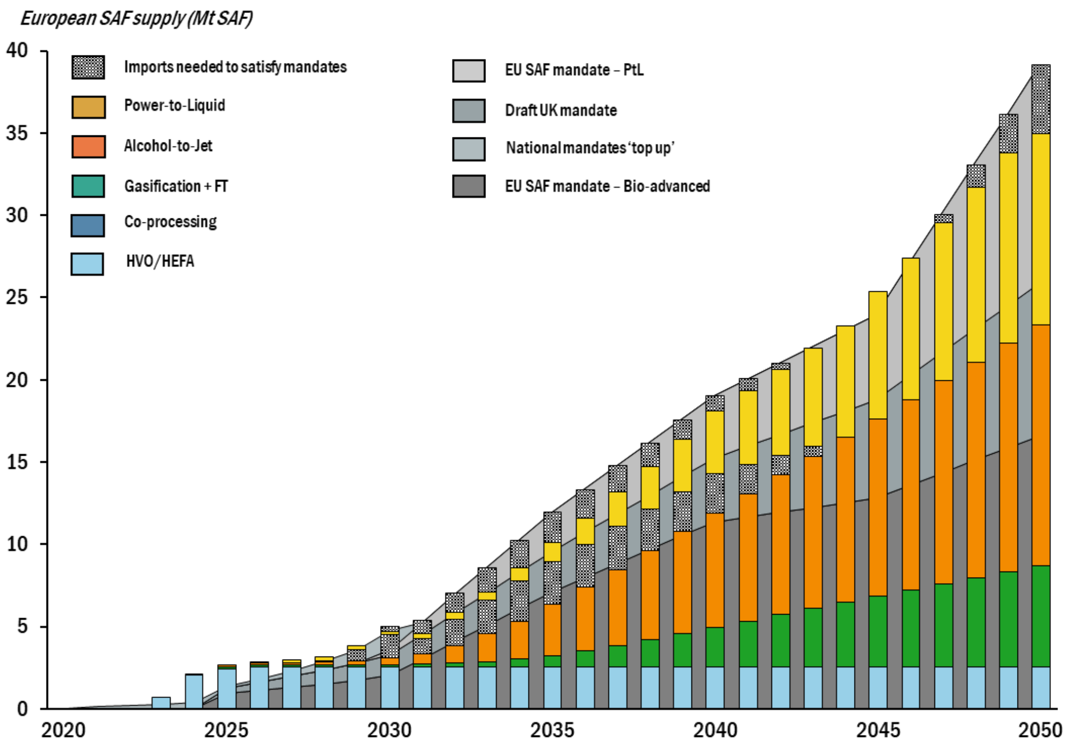


Figure 5. SAF pathways penetration forecasts to comply with the EU and UK mandates (provisional figures). Analysis from SkyNRG shown at the Conference.

SUSTAINABILITY

The use of SAF provides climate benefits through improvement in energy efficiency (from 1-3%) and the reduction of some emissions (particulate matter, unburnt hydrocarbons) due to more complete and efficient combustion of the novel fuels. However, as the combustion of SAF emits similar quantities of CO_2 and other greenhouse gases (such as NOx) to those from the combustion of conventional fuels, the GHG savings need to be assessed on a life cycle basis (LCA).

In the case of biofuels, during growth, the biomass used as feedstock captures the carbon from the atmosphere, so its combustion at the engine produces no additional increase in the atmospheric CO_2. However, on a life cycle basis, all the emissions produced during extraction, processing and transport, and other GHG and climate impacts during combustion need to be accounted for, so the savings usually do not reach 100% with the fossil comparator (94 gCO_{2eq}/MJ fuel[12]. These emissions savings will vary according to the feedstock production and extraction, conversion technologies, inputs and logistics.

When feedstock is fossil residues, such as plastic at Municipal Solid Wastes, the emissions reductions come from the multiple uses of fossil carbon, so those are called recycled carbon fuels (RCFs), as mentioned before.

In the case of the PtL or e-fuels, the emissions reduction benefit is associated with the use of zero emissions, renewable electricity to produce hydrogen that is combined with carbon captured directly from the atmosphere (DAC) or a waste gas source, ideally renewable and unavoidable (e.g. CO from industrial biomass fermentation). Depending on the process details, pathways can achieve GHG savings even beyond the 100% when part of biogenic or atmospheric carbon (DAC) is captured and stored (CCS) permanently during the production process.

Unlike biofuels or RCFs, e-fuels neither rely on biomass nor are necessarily[13] dependant on other products or processes. This means that sustainability concerns that can be linked with the large-scale production of biomass, such as land scarcity or competence, would be significantly avoided. In addition, regarding costs, if the renewable energy costs are lowered as expected, e-fuels can be a highly attractive choice for SAF. However, as already mentioned, the e-fuels readiness level is still low, and production costs are significantly higher than the other alternatives. For that reason, both the Renewable Energy Directive and the ReFuelEU Aviation include specific sub-targets for promoting its development.

12 94 gCO_{2eq}/MJ is the fossil comparator according to the EU RED II. The fossil comparator agreed at ICAO for CORSIA is 89gCO2e/MJ. Those differences are due to the different scopes of the calculation methodologies applied on both sides (LCA and comparator).

13 In the case of DAC PTLs

SAF sustainability is determined against specific sustainability criteria. Sustainability principles and standards vary along with the national and international legislation. At the EEA level, the reference is the methodology for LCA GHG emissions savings and sustainability criteria set by the renewable energy directive (RED) that applies to both the ReFuelEU Aviation and the EU Emissions Trading System (ETS)[14]. At the international level, ICAO has set principles and criteria for CORSIA Eligible Fuels, which include SAF and Low Carbon Alternative Fuels (LCAF).

Every sustainability framework counts with its recognised Sustainability Certification Scheme(s) (SCS). The most internationally known ones for aviation are ISCC and RSB, both having versions for EU RED and CORSIA. Under those SCSs, fuel producers apply specific procedures and provide the requested information, which an independent third party verifies to get a certificate that allows them to produce and sell/use the SAF accompanied by a codified and traceable Proof of Sustainability.

As airlines operate flights to many different jurisdictions, the differences in criteria and scope can challenge airlines to deal with several standards. Still, it would also be challenging for the governments and SCS to deal with avoiding double counting and claiming practices.

Besides, thanks to the reduction of other non-CO_2 emissions that improves local air quality, emerging scientific evidence shows that the use of SAF can also decrease the non-CO_2 climate effects of aviation by reducing radiative forcing of contrails and associated cirrus. Even when non-CO_2 effects are a research topic still subject to many uncertainties and challenges, scientific evidence indicates that the unwanted climate effects of contrails can be at least as significant as that of CO_2. Therefore the use of SAF would allow addressing both CO_2 and non-CO_2 climate effects of aviation, at least partially.

Beyond this, SAF provides social and economic opportunities and supports energy security diversification. Energy security diversification has a strategic value for airlines (reducing their dependency on providers), and for the governments, given the crisis we are facing in 2022 due to the Russian invasion of Ukraine, but in any case, supporting geopolitical stability.

14 Compliance with GHG savings thresholds and sustainability criteria is mandatory for any financial support for biofuels, as for the RED. This includes the zero rating for bio SAF set in the EU ETS Directive and its implementing regulations.

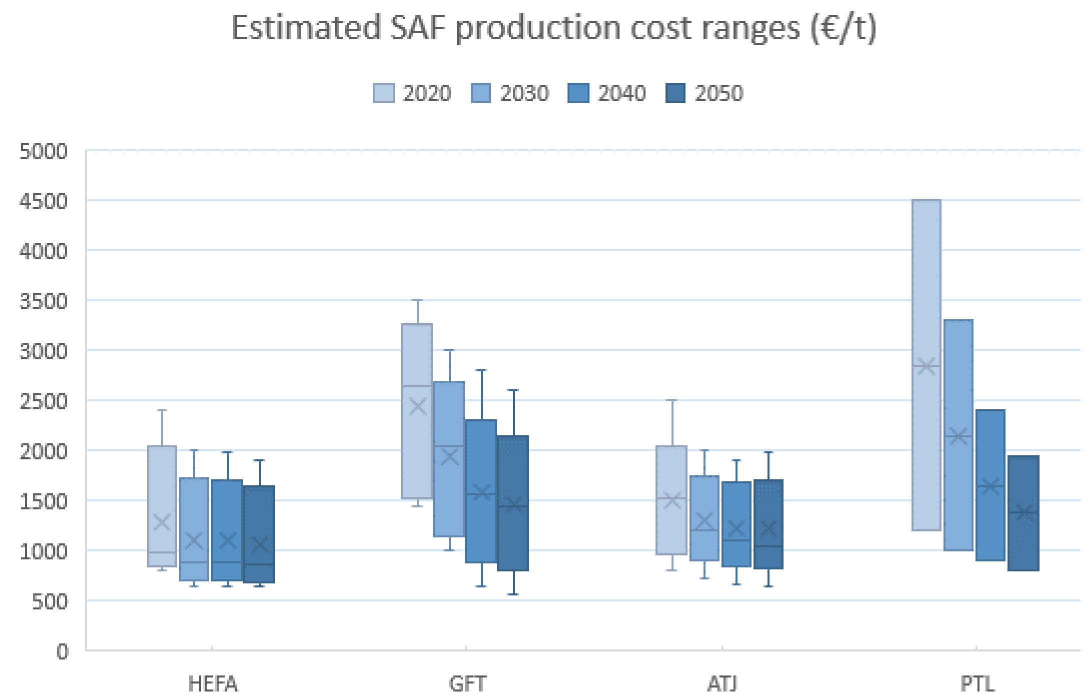
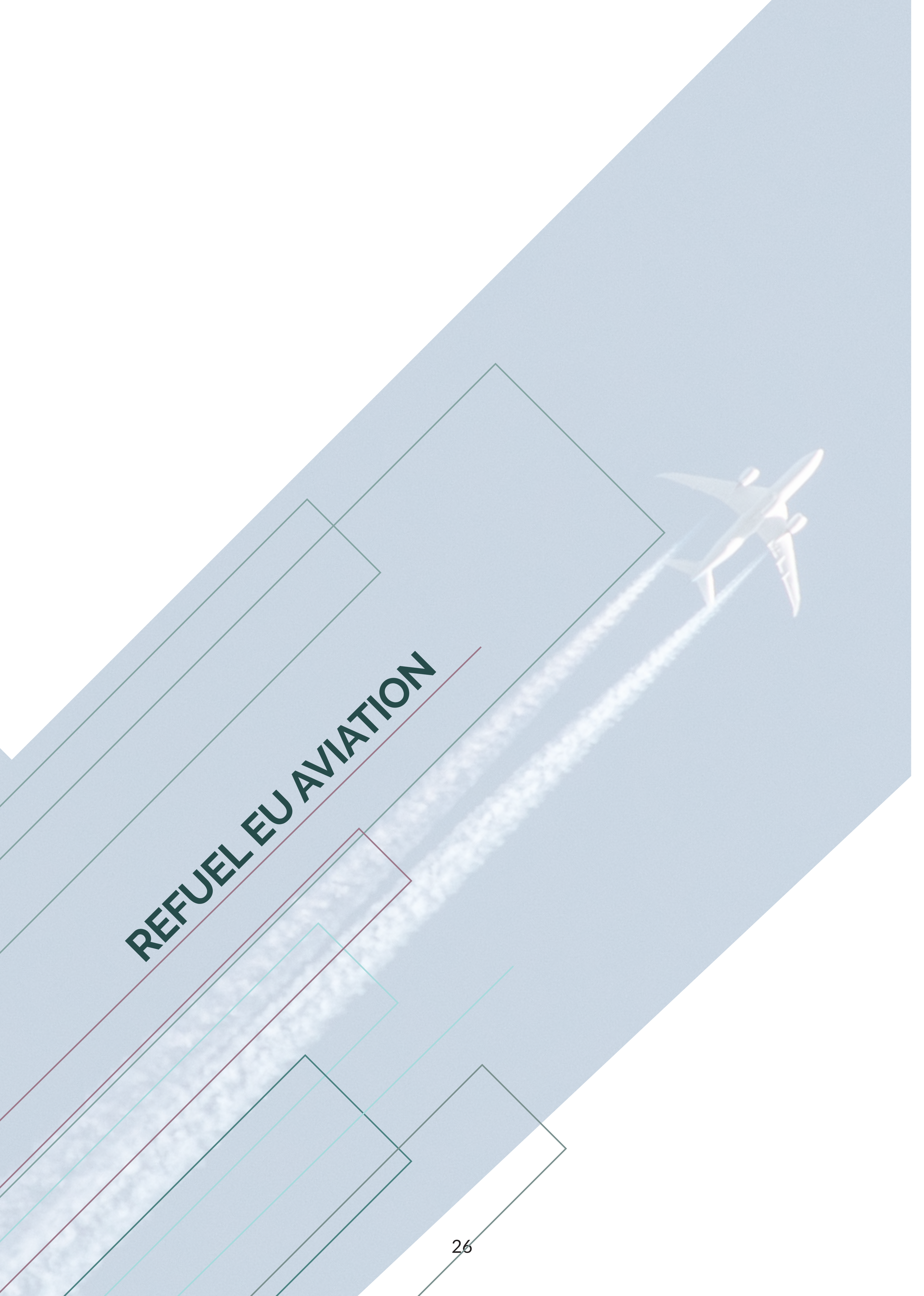


Figure 4. Estimated SAF production cost ranges (EUR/t). HEFA: hydro processed esters and fatty acids, G-FT biomass gasification and Fischer Tropsch synthesis, ATJ: Alcohol to Jet, PTL: Power to Liquid, synthetic fuels from renewable electricity or solar energy, also known as RFNBOs in the EU regulation. Sources: ICAO SAF Rules of Thumb[15], EPRS[16].

15 https://www.icao.int/environmental-protection/Pages/SAF_RULESOFTHUMB.aspx (last accessed 30 May 2022)

16 Soone J., Sustainable Aviation Fuels, infographic, EPRS, European Parliament, March 2022.

REFUEL EU AVIATION



ReFuel EU aviation is a Regulation proposed in July 2021 by the European Commission as part of the legislative package "Fit for 55" that ambitions to adapt the regulatory framework to the commitment of reducing greenhouse gas (GHG) emissions a 55% by 2030 in the context of the European Green Deal. The ReFuelEU proposal aims to boost the production and uptake of SAF by introducing a set of mandatory quotas and complementary measures. The proposal includes a blending mandate imposed on aviation fuel suppliers for most European airports. The mandate would start in 2025 with a minimum volume of SAF at 2%, significantly increasing the growth ratio after 2030 up to finally reach a minimum volume of 63% in 2050, of which 28% would be synthetic aviation fuels (understood as PTL). As already mentioned, synthetic aviation fuels are considered a green promise to the potential environmental problems related to biomass production or the scarcity of biogenic residues, and sub-quotas are established for synthetic aviation fuels as early as 2030, with a 0,7%.

As the mandate would raise aviation fuel costs due to the current higher cost of SAF (even higher for synthetic aviation fuels), the proposal includes measures to avoid carbon leakage in the form of fuel tankering[17]. According to the proposal, all airlines departing from the EU concerned airports will be obliged to uplift jet fuel prior to departure, being the yearly quantity of aviation fuel uplifted by a given aircraft operator at an included EU airport at least 90% of the annual aviation fuel required for the operated flights, no matter the destination.

The proposal also includes reporting obligations from aircraft operators, including data about the SAF they have purchased (tonnes, types, emissions) and the claiming of the use of such quantities in GHG schemes such as the EU ETS or CORSIA. Independent third parties (verifiers) should verify such data provisions from the aircraft operators.

The proposal also includes features to control and prevent double claiming and double counting for fuel suppliers and aircraft operators. Fuel suppliers also acquire reporting obligations about SAF and aviation fuel supplied to the Union Database. The Union Database is planned as a central registry for renewable energy, as foreseen in article 28 of the Renewable Energy Directive (Directive 2018/2001).

In principle, the mandate for fuel suppliers would be compatible with any other renewable energy scheme, such as the Renewable Energy Directive (RED II)[18], or the EU Emissions Trading System (EU ETS), what would not be therefore considered double claiming or accounting.

The sustainability framework of the mentioned Renewable Energy Directive guarantees the sustainability of the aviation fuels promoted. Moreover, the proposal from the European Commission limited the types of SAFs to those considered 'advanced' and certain types of residues, leaving out the mandated food and feed crops and some controversial types of residues (such as PFAD[19], molasses…). In more detail, according to the initial proposal, eligible SAFs should be made only from feedstocks listed in Annex IX (either part A or B) in the RED. This Annex is the Annex IX.A, listing of the feedstocks for 'advanced' biofuels can be enlarged (but never reduced), and it is currently under revision. Nowadays, Annex IX.A includes lignocellulosic wastes and some very scarce oils (algae, POME, tall oil), while Part B includes tallow and used cooking oil (UCO). While Annex IX.B feedstocks in the RED are limited to a contribution of 1.7% to the transport objectives, due to its scarcity and several competing uses, no similar limit has been incorporated into the ReFuelEU aviation proposal.

17 Tankering occurs when the airline operator uplifts more fuel than required for the trip at a given airport to avoid total or partially refuelling at the destination for the subsequent leg. It can be done due to fuel price difference or operational reasons (shorter turnover at airports), but it costs as the extra weight of the extra fuel replaces payload and/or imply a higher fuel consumption for the trip.

18 The Directive 2018/2011 (RED II) enables the member states to consider the supply of SAF for their renewable energy targets for transport, and with an incentive in the form of a multiplier (1.2x) for SAF made from feedstocks other than food and feed crops.

19 PFAD – Palm Fatty Acid Distillate, the residue of palm oil refining.

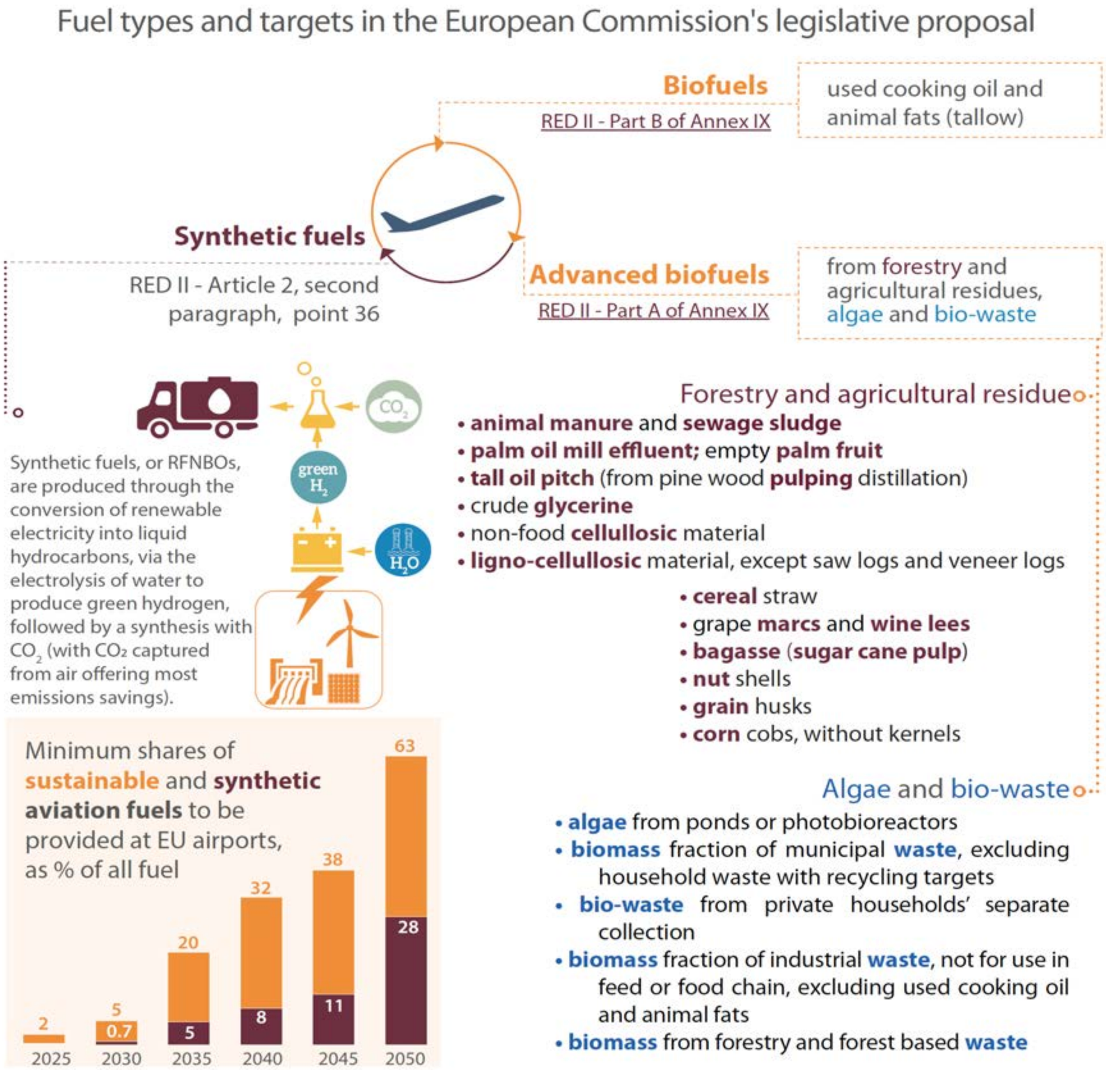


Figure 4. Fuel types and targets set in the ReFuelEU Aviation proposal. Soone J., Sustainable Aviation Fuels, infographic, EPRS, European Parliament, March 2022.

Particular attention has been brought to the use of synthetic fuels. Named in the RED as 'renewable fuels of non-biological origin' (RFNBOs), ReFuelEU definitions broaden the concept by using a softer denomination: synthetic fuels. The spirit seems to refer to the power-to-liquid drop-in fuels, which can be generated using a source of carbon and renewable hydrogen. However, this is a controversial point, as regulations about how to define renewability[20] or carbon origin is still unclear even at the RED, with several Delegated Acts[21] pending.

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The ReFuel EU proposal appears to have in mind the potential, but future, the inclusion of the regulation of the supply of what are called non-drop-in fuels, that is, fuels such as renewable hydrogen for direct burnt at new aircraft or for its use in hydrogen cells, or renewable electricity to electric or hybrid aircraft. When there are mentions of alternative fuels infrastructure that could only be required in case of those non-drop-in, provided that drop-in fuel do not require any additional infrastructure, both 'pure' renewable hydrogen or electricity are not covered in the initial proposal by the EC (but they are in the EP one).

20 Using blue hydrogen or hydrogen produced with low carbon but not renewable power (e.g. from nuclear sources) or the potential point of capture for carbon is controversial.

21 Delegated acts are, by definition, non-legislative acts adopted by the European Commission to amend or supplement the non-essential elements of the legislation. However, in many cases like this one, their effects can be very relevant for the implementation and enforcement of the legislation.

As indicated before, the current development is very limited even for the coming decades, and somehow the development is supported by other regulations, the Alternative Fuels Infrastructure Regulation (AFIR), also part of the 'fit for 55' package (in this case repealing a previous Directive).

Whereas commonly named ReFuel EU Aviation, the Regulation's official title is *Regulation on ensuring a level playing field for sustainable air transport*. This emphasises the aim of the regulation to avoid any competitive distortion at the EU level, including some provisions to block the potential higher national mandates that, however, had been implemented or announced in several European states before.

While the proposal by the EC was issued in July 2021, this needs to follow the EU Ordinary Legislative Procedure (COD). The proposal was sent to the EU Council and the EU Parliament to gather their respective opinions. Once issued, the resulting opinions will need to be confronted in trilogues[22]. To find a compromise position before adopting the final legislation.

At the European Parliament, and for the application of the rules of procedure, being the Committee of Transport and Tourism (TRAN) responsible for the document, the Committees of Industry, Research and Energy (ITRE) and of Environment, Public Health and Food Safety (ENVI) would also give an opinion. Numerous amendments have been proposed at the different committees (more than 1000 in total), going in many cases in several directions.

During the conference organised by ARC, the designated rapporteurs from TRAN, ITRE, and ENVI participated, showing their major remarks on the Regulation proposal.

ITRE and ENVI voted and approved their respective opinions right after the conference. The main changes proposed refer to increasing the level of ambition. Target a mandate of 100% SAF in 2050, increasing all ramp-up numbers while significantly reducing the thresholds for aircraft operators and airports. In the last case looking for the inclusion of 100% of the airports excluded by the CE in its proposal for reducing the administrative burden. Both Committees ask for the specific inclusion of pleasure flights and a particular focus on short-haul flights.

22 Trilogues are informal tripartite meetings on legislative proposals between representatives of the Parliament, the Council and the Commission. Their purpose is to reach a provisional agreement on a text acceptable to both the Council and the Parliament.

Also, regarding the types of fuels, ITRE and ENVI ask for particular eligibility for renewable hydrogen and electricity directly supplied into the plane (non-drop-in energy vectors) on top of the proposed SAF and synthetic fuels. Regarding the Annex IX part B feedstocks, ENVI asks for a cap, as in the RED, of 1.7%.

One common point that is worth mentioning and is highlighted in both ENVI and ITRE opinions is the non-CO_2 effects. While TRAN highlights that the scientific knowledge regarding the non-CO_2 effects of air transport and its link with the fuel supplied (particularly the content in certain aromatic compounds and sulphur) is still nascent, the Committees ask the EC to assess further the issue (report) and, if appropriate, to propose a regulation for curtailing aromatics and sulphur for addressing these issues. Initially, draft proposals asked for a cap on aromatics and sulphur content on aviation fuels. However, the agreement reached is still insufficient to establish such a limit today. Therefore, the EC would then be tasked with improving that knowledge regarding the baseline to be considered.

To prevent carbon leakage and market distortion outside the EU market, the TRAN committee draft report tasked the European Aviation Safety Agency (EASA) with developing an environmental labelling scheme in order to drive consumers' choices and further encourage the use of SAF and other sustainability measures. The parliamentarians also suggested that part of the overall amount of ETS allowances should be allocated free of charge to aeroplane operators for uplifting SAF. This last measure should be understood as additional to the possibility for the airlines to benefit from a zero rate at EU ETS for the use of SAF, planned and as an additional economic incentive in a context where the EU ETS is being reviewed and the so far free allowances distributed to airlines are expected to phase out.

Once the relative Opinions were approved at the ENVI e ITRE Committees, the TRAN draft Report was voted in the TRAN committee on 27 June[23], and endorsed[24] in Plenary as the Parliament's negotiating mandate 7 July. As the Council had already reached a position agreement[25] (2 June), the trilogues can start. It seems that the debate could be solved quickly, as there is alignment between the different proposals, except maybe on ambition in Annex I (see table 1).

23 https://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/TRAN/VL/2022/06-27/Finalvotinglist_RefuelEUaviation_Gade_EN.pdf

24 https://www.europarl.europa.eu/doceo/document/TA-9-2022-0297_EN.html (last accessed 10 July).

25 https://www.consilium.europa.eu/media/56725/st09805-xx22.pdf (last accessed 27 June).

	EC proposal (July 2021)	EU Council (2 June 2022)	EU Parliament (TRAN, 27 June 2022)
Scope	EU Airports > 1M pax/y or 100,000 t freight/y Exempt OMRs AOs >= 729 flights/y	EU Airports > 1M pax/y or 100,000 t freight/y Exempt OMRs Opt-in any airport AOs >= 500 flights/y	EU Airports (all) Exempt OMRs (opt-in) AOs >= 52 flights/y
SAF definition	Drop-in Annex IX A Annex IX. B RFNBOs	Drop-in Annex IX A Annex IX. B (cap 3%) RCFs Non-food and feed feed-stocks RFNBOs + synthetic low carbon fuels	Drop-in and no drop-in Annex IX A Annex IX. B RCFs Non-food and feed feed-stocks (until 31/12/2034) excl. intermediate crops, PFAD and other palm/soy derivatives, soap stock RFNBOs + H2 + renewable electrici-ty (direct supply)
Synthetic fuels definition	RFNBOs	RFNBOs + synthetic low carbon fuels	RFNBOs + H2 + renewable electricity (direct supply)
Transitional period	5 years	10 years	Book and claim flexibility mechanism (10 years)
Mass balance	No	Yes	Yes
Refuelling obligation		Trip fuel Possible exemptions	Considering safety
Airports infrastructure	Generic	Adjusted to managing body	Adjusted to managing body Includes H2 + electricity
Non-CO_2 provisions	No	reporting (aromatics, naphthalene and sulphur) + EC report	reporting (aromatics, naphthalene and sulphur) + EC report
Fines	To InvestEU	To support R&I in SAF	To Sustainable Aviation Fund
Others		Study carbon leakage	ETS bonus Environmental labelling Reporting in toe Sustainable Aviation Fund
Mandate: SAF volume	2025 – 2 % 2030 – 5 % 2035 – 20 % 2040 – 32 % 2045 – 38 % 2050 – 63 %	2 % 6 % 20 % 32 % 38 % 63 %	2 % 6 % 20 % 37 % 54 % 85 %
Mandate: synthetic fuels volume	2025 – 0 % 2030 – 0.7 % 2035 – 5 % 2040 – 8 % 2045 – 11 % 2050 – 28 %	0 % 0.7 % 5 % 8 % 11 % 28 %	0.04 % 2 % 5 % 13 % 27 % 50 %

Table 1. Comparison of the European Commission (EC) positions of the EU Council and the EU Parliament in advance to the trilogues.

In general, the ReFuel EU aviation initiative has been welcomed at all levels of the industry. Aware of the challenges of reducing the climate impact and the alternative policy tools (such as taxation), the mandate on SAF is undoubtedly the preferred choice for airlines and fuel suppliers.

Nevertheless, there is foreseen economic and financial impact and potential competitive distortion in the extra EU market, not only from ReFuel EU but from the whole application of the 'fit for 55' package (includes a more stringent EU ETS and a possible tax on kerosene) which worry the EU airlines and the main EU hubs airports.

Considering that there have been several attempts to analyse the potential impact, the baseline conditions after the COVID pandemic and the associated extra uncertainties on costs and future traffic have made it a complex exercise. Nevertheless, the industry has managed to make valid its request for additional ETS benefits (i.e. reflected in the Parliament position on ReFuel, but also negotiated in the recast of the EU ETS Directive) and pursued a worldwide SAF goal, at least aspirational and the request of an analysis of the impacts once implemented. Also, it is common the request to derive the costs of this green transition to more R&I funds for greening aviation (reinvesting in the sector).

THE INDUSTRY

Airlines

Airlines have been worried about potential issues arising from lack of SAF supply at small airports, motivation to ask for a book and claim system that would allow the airlines to buy SAF where they want, not necessarily at every airport, substituting the need for a transitional period.

OEMs

Ask for more ambition while enlarging the types of SAF (and feedstocks) to, for example, low ILUC crops. Also supported the creation of an industrial alliance, Renewable and Low-Carbon Fuels Value Chain Alliance (RLCF), to ensure more SAF availability while encouraging other public and private investments specific to SAF.

Fuel providers

Most critics of the ReFuel EU proposals from fuel providers address its differences with the Renewable Energy Directive framework in terms of the scope of biofuels and caps. Associations such as ePure, APPA, Fuels Europe ask for ReFuel the same RED II biofuels scope, phase-outs and caps, and ILUC risk provisions without banning food and feed crops feedstocks.

Airports

One essential masterpiece in the energy transition of aviation and the fight against climate change is the airports. Airports are neither SAF consumers nor SAF producers; therefore, during the past decades, they were aside in deploying the SAF market, pushed onwards mostly by civil society, some politicians and some airlines. However, airports will play a significant role in transitioning to climate-neutral aviation. It is not casual that ReFuel aviation has been framed airport centred. While airports do not consume SAF and do not traditionally produce it, the situation could change.

Airports can play a significant role in helping the smaller airlines on getting better offtake agreements with SAF producers, thanks to joining tendering[26] or helping to cover the price gap with different incentive systems. In return, airports with more SAF use would enjoy cleaner air, reducing potential air quality constraints or liabilities, and help them to position themselves in the starting competition for more sustainable travelling, demanded more and more by the potential or actual passengers. This can apply to the airport itself or the region surrounding it. Traditionally both work closely when talking about SAF, as the production and supply of this new fuel can create more than a few economic and social opportunities while improving the environmental situation.

With this role in mind, the European Commission, through their R&D program H2020 and with the later Horizon Europe has awarded several projects led by airports to gain a green transition for aviation, where SAF are always present. Representatives of those projects participated in the conference presenting their work plan and progress related to SAF. ALIGHT[27],the pioneer started in November 2020, led by the Copenhagen Airport, targeting net zero carbon emissions airport by 2050 and with ambitious targets for the use of SAF at the airport. OLGA[28] Project started in October 2021, will count with a magnificent occasion for showcasing at the 2024 Paris Olympic Games, counting on Paris CDG, Milan MXP, Zagreb ZAG and Cluj CLJ airports. OLGA is also progressing towards a better SAF supply. STARGATE[29], started in November 2021, exploring how to optimise the supply of SAF to Brussels airport. Last but not least, TULIPS[30], counting on Amsterdam Schiphol, Oslo, Turin and Larnaca airports, starting in January 2022. The consortium plans to enable a large-scale supply of SAF and, in particular, includes the design and preparation of an EU clearing house, helping to optimise the path from the technological design of the SAF production pathways to the market. All four projects, working together and in the framework of the ReFuel EU initiative, counting on the cooperation of key partners of the regions, will be defining the roadmap for the EU airport of the coming decades, where SAF will play, without any doubt, a crucial role on decarbonisation but also in competitiveness.

26 https://www.swedavia.com/arlanda/press/swedavia-continues-to-support-aviations-climate-transition-annual-joint-tender-for-sustainable-aviation-fuel-includes-total-of-six-partners-with-refuelling-carried-out-at-stockholm-arlanda/
27 https://alight-aviation.eu/
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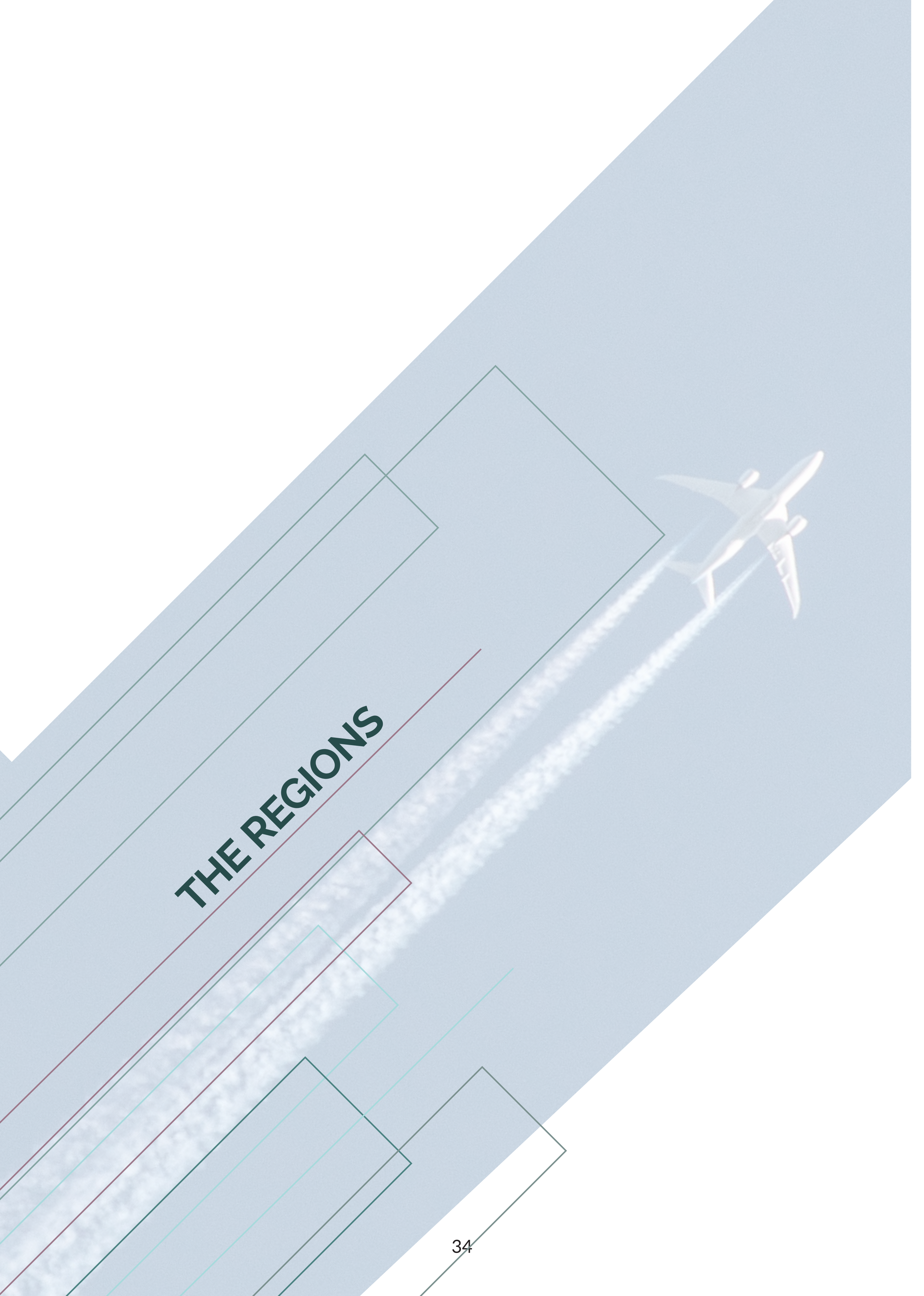

THE REGIONS

While SAF is a "drop-in fuel", and theoretically, there is sufficient feedstock globally to power all aviation by 2030, SAF volumes remain low. They account for less than 1% of global jet fuel consumption due to the lack of production capacity with a competitive price. Cost differential (price gap) is currently the most significant barrier to broader SAF production and use. SAF production costs result in market prices 2-6 times greater or even more than traditional fossil jet fuel, depending on the production pathway used, limiting the potential for market-driven scale-up. The rise in oil price does not help that much, as the prices of the related commodities (fertilisers, feedstock and other inputs, transport, hydrogen, heat…) also often[31] increase.

One singularity of the SAF supply chain is the need for direct involvement of diverse stakeholders usually distant from the aeronautical industry, such as those from the agriculture or waste sectors. Because of that, SAF supply also requires particular involvement from different governmental institutions (e.g. financial, environmental, civil aviation, energy authorities and agencies). That can be a challenge, but it is also a tremendous opportunity for cooperation and synergies.

Even considering that is sufficient feedstock globally to power all of aviation by 2030, its deployment would require improvements in feedstock production and collection and technology, allowing for the affordable use of such a broad range of feedstock types, being the main challenge the collection, transport and transformation of low value, low energy dense biomass, usually abundant but disperse.

Public policies are crucial for promoting the deployment of SAF value chains, helping bridge the cost differential, drive demand, and generate greater certainty for investors and financers. Those policies should be as broad as possible in a geopolitical context to avoid creating competitive distortion. Nonetheless, regional or local guidelines should be directed to foster comparative advantages or release underutilised resources. Governments can act by implementing regulations and legislation, financial measures (such as taxation) and/or subsidies, cooperating with project promoters to detect and remove implementation barriers, or even through cooperative funds.

Local governments and stakeholders can also promote the study of the local conditions such as fuel demand, infrastructures, feedstock or production capacity, etc. Feasibility studies are powerful tools to help new value chains to be implemented. Moreover, significant investments in research, development and demonstration (RD&D) are needed to mature the existing technologies and production pathways.

There are many options to create regional or local pathways, but two attracted particular interest and were presented during the Conference.

One is the production of green hydrogen, either for enhancing the production of conventional fuel or biofuels, improving the life cycle impact of fuels, directly enabling the production of power to liquid fuels or e-fuels or being considered for hydrogen-powered aircraft.

The other route would be using non-recyclable municipal solid wastes (MSW), as their increasing production is a growing concern in many big cities worldwide regarding management, economic, social and environmental impacts. The production of SAF through gasification (G-FT)[32], or the fermentation routes (ATJ) can be a strong ally to solve the MSW trouble while generating SAF for supporting a more sustainable aviation in regions around big cities. The geographical association between MSW production in large cities and a greater demand from the usually bigger airports is a significant opportunity and synergy[33].

Local governments and stakeholders, such as airlines, airports, and fuel producers, can join forces to create value chains that reinforce the economic benefits of airports within their locations while improving local and global environmental sustainability.

There is a long and challenging path to fly through net zero 2050, but regions, airports, airlines, OEMs, fuel producers, policymakers, passengers, and other relevant stakeholders working together will make the change, and the potential benefit is, definitively, huge.

31 The sensitivity to those changes depends on the type of pathway, being higher for HEFA than for the other routes.

32 The waste to fuel route through G-FT was presented at the Conference by Luis Alarcó from the investment firm Aurea Capital Partners.

33 As an example, ERA is supporting studies for the deployment of this route in the Canary Islands, as its DG Montserrat Barriga commented at the Conference.

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