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IMPACT ASSESSMENT

Accompanying the

Proposal for a Regulation of the European Parliament and of the Council

on ensuring a level playing field for sustainable air transport

{COM(2021) 561 final} - {SEC(2021) 561 final} - {SWD(2021) 634 final}

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Glossary

Term or acronym	*Meaning or definition*
ICAO	International Civil Aviation Organisation
SAF	Sustainable Aviation Fuels
RFNBO	Renewable fuels of non-biological origin, in the meaning of Article 2(63) of the Renewable Energy Directive, known as well as "synthetic fuels"
HEFA	Hydro-Processed Esters & Fatty Acids, a SAF conversion pathway
Gas+FT	Gasification + Fischer Tropsch, a conversion pathway used to produce SAF
ATJ	Alcohol-to-Jet, a pathway to produce SAF
TRL	Technology Readiness Level
RED	Renewable Energy Directive
RED II	2018 Recast Renewable Energy Directive
GHG emissions	Greenhouse gas emissions
Jet A and Jet A-1 (incl. certified SAF)	Kerosene fuels types
HVO	Road transport biofuel
Mtoe	Millions of tonnes of oil equivalent
ATAG	Air Transport Action Group
ASTM International	American Society for Testing of Materials
ILUC	Non-negligible indirect land use change emissions
CAPEX	Capital expenditure
OPEX	Operating expense
LCA	Life-Cycle Assessment
FQD	Fuel's Quality Directive
EU ETS	EU Emission Trading System
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CAAF/2	Conference on Aviation and Alternative Fuels
LTAG	Long-term global aspirational goal for CO2 emissions reductions for international aviation
PO	Policy Option
WTW Jet Emissions	Well-to wing emissions
WTT Emissions	Well-to-tank (upstream or indirect emissions)
NvPM	Non-volatile particulate matter
ECAC	European Civil Aviation Conference
CO_{2eq}	Equivalent Carbon dioxide, a measure to compare the emissions
UCO	Used Cooking Oil
SCS	Sustainability Certification Scheme
LCA	Life-Cycle Assessment

1. INTRODUCTION

1.1. Political and legal context

This Impact Assessment accompanies a legislative proposal – hereby 'ReFuelEU Aviation' – aimed at maintaining a competitive level playing field in the air transport market while boosting the production and uptake of sustainable aviation fuels. An external support study[1] has been carried out in 2020 and will be published alongside this report.

The EU aviation internal market is essential for the mobility of European citizens and for the European economy as a whole. In 2018, the aviation and aeronautical industries employed an estimated 0.4 million people directly in the EU[2], and contributed to the EU's GDP by an estimated 2.1%[3] in 2017. Aviation is a strong driver for social and regional cohesion that boosts tourism, stimulates business and connects people. In 2018[4], over 1.2 billion passengers flew to and from more than 500 airports in Europe. The EU aviation sector contributes to European integration and reinforces the EU's position as a geopolitical leader.

Air connectivity and the air transport sector as a whole bring significant socio-economic benefits to EU citizens and businesses. It is **essential to ensure a well-functioning EU aviation market** where economic actors can operate on a competitive level playing field. Nevertheless, air transport has a **significant and growing impact on the environment**, notably in terms of greenhouse gas emissions but also aircraft noise and local air pollution. In 2018, aviation accounted for 3.6% of the EU's greenhouse gas emissions (2% at global level) and for 13.2% of the emissions from EU transport[5]. Aviation has been one of the fastest growing sectors in terms of CO_2 emissions over the past decades[6]. Looking into the future, EU CO_2 emissions from the sector could further grow by 17% up to 2030, relative to 2015[7]. This has caused **public and political pressure to increase** in the past years, asking for the sector to intensify its efforts to decarbonise.

In December 2019, the Commission adopted the **European Green Deal Communication**[8], which emphasised the need to accelerate the transition to a climate-neutral economy, including through the shift to sustainable mobility. To achieve climate neutrality, a 90% reduction in transport emissions is needed by 2050. All transport modes, including aviation, will have to contribute to the reduction.

In September 2020, the Commission adopted its **proposal to cut greenhouse gas emissions by at least 55% by 2030**[9] and put Europe on a responsible path to becoming climate neutral by 2050. The Communication on the 2030 Climate Target Plan[10] clearly mentions: *"Both the aviation and maritime sectors will need to scale up efforts to improve the efficiency of aircraft, ships and their operations and to increase the use of sustainably produced renewable and low-carbon fuels. This will be assessed in greater detail in the context of the ReFuelEU Aviation and FuelEU Maritime initiatives that aim to increase the production and the uptake of sustainable alternative fuels for these sectors. The necessary technology development and deployment has to happen already by 2030 to prepare for much more rapid change thereafter."* On 11 December 2020, the

[1] Ricardo (2021), Study supporting the ReFuelEU Aviation Impact assessment.
[2] Eurostat (lfsa_egan22d).
[3] Source: SWD(2017) 207 final.
[4] Source: Eurostat; Indirect job generated from air transport can be as high as three times the direct ones (European Commission, 2015).
[5] Source: EEA.
[6] Total CO2 emissions from flights departing from the EU27 and domestic flights within the territory of a Member State of the EU27 grew from around 112 million tonnes (Mt) in 2005 to 120 Mt in 2015, equal to a 7.6% increase.
[7] The Baseline scenario projections, reflecting the COVID-19 pandemics, are explained in Annex 4.
[8] COM(2019) 640 final.
[9] COM/2020/563 final.
[10] COM/2020/562 final.

European Council endorsed the binding EU target of a net domestic reduction of at least 55% in greenhouse gas emissions by 2030 compared to 1990[11].

The Commission adopted in December 2020 the **Sustainable and Smart Mobility Strategy**[12]. This strategy sets the course of action for each mode of transport to decrease its carbon footprint in line with the objective of cutting greenhouse gas emissions by at least 55% by 2030 and reaching EU climate neutrality by 2050. It also sets a number of milestones for the transport sector, drawing on the common analytical work underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy, while considering deploying a broad mix of policy instruments including carbon pricing and moderate increase in the energy and transport sectoral regulatory policy ambition. Overall, **the EU Emission Trading System (EU ETS) and the Effort Sharing Regulation (ESR)** combined, provide the general framework and mechanisms to ensure that emission reductions are achieved in line with the 55% increased ambition by 2030 and an EU climate neutral economy by 2050. The flexibility of EU ETS ensures a central role in delivering the required level of ambition. The Commission will propose in 2021, as part of the 'Fit for 55' package, a revision of the EU Emissions Trading System Directive and of the Effort Sharing Regulation, along an amendment to the Renewable Energy Directive, the revision of the Energy Taxation Directive, the revision of the Alternative Fuels Infrastructure Directive, etc.

Importantly, attainment of the EU's climate targets is a joint effort between the EU and the Member States. As such, the basic legislative framework provide by the ETS and ESR needs to be supported by a set of Union level regulatory measures that complement action at national level. These measures will enable the various sectors of the economy, such as aviation to step up their efforts to decarbonise. The Commission will propose two initiatives specifically aimed at accelerating the decarbonisation of aviation and maritime transport - two sectors which have shown specific difficulties to increase the use renewable sources of energy and decrease their emissions until now - with the use of sustainable fuels, i.e. 'ReFuelEU Aviation' and 'FuelEU Maritime'.

The ReFuelEU Aviation is overall welcomed by the air transport and fuels industries, as well as climate non-governmental organisations, as a key initiative to make aviation more sustainable, while reinforcing the level playing field in the aviation internal market and the competitiveness of the sector. There is also a strong impulse given by a leading group of Member States, for the ReFuelEU Aviation initiative, and more generally for a swift delivery of an EU-level regulatory framework for sustainable aviation fuels. During the *High Level Conference on Synthetic SAF* of 8 February 2021, the Ministers of Transport of eight EU Member States (Denmark, Finland, France, Germany, Luxemburg, the Netherlands, Spain and Sweden) issued a joint statement to *"support the aim of the European Commission to boost the supply and demand for SAF in the EU so as to create favourable conditions in order to ramp up the production and deployment of SAF (...). The challenge is to make use of the current momentum by providing for a clear long-term perspective so as to contribute to a scalable SAF marketplace. A European blending mandate for SAF can achieve this."*

1.2. Role of sustainable aviation fuels in the sector's decarbonisation

The aviation sector is particularly difficult to decarbonise due to its exclusive reliance on fossil energy, the limited technological options available for reducing its emissions, and the long lifespan of aircraft. This is why the EU has adopted a **comprehensive approach to addressing aviation emissions**. The decarbonisation of the air transport sector will rely partly on intensifying the efforts and measures already in place**.** These include market-based measures (the EU Emissions Trading Scheme and the Carbon Offsetting and Reduction Scheme for International Aviation of the International Civil Aviation Organisation - ICAO[13]), improved air traffic

[11] Source: https://www.consilium.europa.eu/media/47296/1011-12-20-euco-conclusions-en.pdf
[12] Source: https://ec.europa.eu/transport/themes/mobilitystrategy_en
[13] ICAO is the UN specialised agency in the field of air transport; all Member States are ICAO members.

management operations, and research on more efficient aircraft design and technology. Some of the policy instruments particularly relevant for aviation, notably the EU Emissions Trading System, the Renewable Energy Directive and the Energy Taxation Directive will be reviewed as part of the forthcoming 'Fit for 55' package. The coherence of 'ReFuelEU Aviation' initiative with those other 'Fit for 55' initiatives is discussed in section 1.4.

In order to decrease significantly its emissions, the aviation sector will need to reduce its current exclusive reliance on fossil jet fuel[14] and accelerate its transition to innovative and sustainable types of fuels and technologies. However, the aviation sector lacks immediate alternatives to liquid fuels for commercial aircraft propulsion. New zero-emission aircraft technologies such as electric- or hydrogen-powered aircraft are promising but not expected to be mature soon enough to play a significant role in commercial aviation in the next decades. **Because aviation needs to address its carbon footprint already by 2030, the role of sustainable aviation liquid fuels will be essential**. For this reason, as part of the comprehensive approach, measures are also needed to increase the use of sustainable aviation fuels (biofuels, advanced biofuels or renewable fuels of non-biological origin as defined in the recast Renewable Energy Directive (EU) 2018/2001).

Figure 2 in section 2.1.3 gives information about the **aviation industry's expectations of the role to be played by SAF** and other CO2-reducing measures (improvements in aircraft design and technology, more efficient operations and better infrastructure, including ATM, offsetting) in the decarbonisation of the aviation sector by 2050. Under this scenario focusing on SAF deployment, SAF and offsets would account for 75% of achieved emissions savings, improved technology would account for 15% and better operations and infrastructure would account for 10%.

For the purpose of this impact assessment, **the term "sustainable aviation fuel (SAF)" refers to the following three categories of drop-in[15] liquid fuels**: Annex IX Part B biofuels[16], advanced biofuels (Annex IX Part A biofuels) and renewable fuels of non-biological origin (RFNBOs) – mainly synthetic fuels, within the meaning of the Renewable Energy Directive (RED II)[17], which are certified to be used to power commercial aircraft. Section 5.4.1 of this impact assessment brings forward clear policy choices about the precise types of SAF that are eligible under the policy options considered. It explains notably why this initiative focuses on the three categories of above-mentioned drop-in SAF, and explain why it does not cover hydrogen and electricity as primary fuels for aviation.

1.3. Ramp-up trajectories for sustainable aviation fuels (SAF)

The common economic assessment[18,19] underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy, looked at the feasibility of achieving a higher climate target and provided insights into the efforts that individual sectors would have to contribute. The assessment looked at a range of possible pathways/scenarios to explore the delivery of the increased ambition of cutting the economy-wide greenhouse gas emissions by at least 55% by 2030 and achieving climate neutrality by 2050. These pathways/scenarios were constructed around a set of indicative policies for all sectors of the economy that either focus on carbon pricing or focus on regulatory measures, or combine the two types of instruments. For air transport, the same policy instruments including the 'ReFuelEU Aviation' initiative were included in all scenario configurations.

[14] More than 99% of jet fuel used in the EU in 2018 was fossil kerosene. Source: Eurostat.
[15] Liquid fuels that can be blended with conventional kerosene and are compatible with aircraft engines that are currently in operation.
[16] Biofuels produced from feedstock listed in Part B of Annex IX of the Renewable Energy Directive.
[17] See Article 2(33), Article 2(34) and Article 2(36) of Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast).
[18] Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0176
[19] Source : https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020SC0331

The staff working document accompanying the Sustainable and Smart Mobility Strategy describes the ramp-up trajectories for sustainable aviation fuels in more detail[20], drawing on the common economic analysis underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy. These trajectories are derived in a way that enables kick starting the scale-up of sustainable aviation fuels (SAF) from 2025 onwards and their large scale deployment by 2050, while ensuring the consistency with the required overall greenhouse gas emissions reductions by 2030 and 2050, preserving the competitiveness of the sector, promoting innovation, and ensuring feedstock availability for renewable and low carbon fuels in all energy and transport sectors in the transition towards a climate neutral economy. The pathways/scenarios delivering a reduction in the EU greenhouse gas emissions by at least 55% by 2030 and climate neutrality by 2050 suggest that SAF should represent 4 to 8% of the jet fuel used in 2030, for all flights departing from EU airports, and 63 to 68% by 2050.

When considering a pathway/scenario that strengthens and further expands the carbon pricing, be it via EU ETS or other carbon pricing instruments, to the road transport and buildings sectors, combined with low intensification of transport policies and no intensification of energy efficiency and renewables policies, the analysis shows that sustainable aviation fuels obligations should represent at least 4% of the jet fuel used in 2030, for all flights departing from EU airports, and 68% by 2050. When considering a pathway/scenario that assumes high increase of the ambition of energy efficiency, renewables and transport policies, while keeping the EU ETS scope unchanged, sustainable aviation fuels obligations should represent 8% of the jet fuel used in 2030 and 63% by 2050. Finally, the pathway/scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy shows that sustainable aviation fuels obligations should represent 5% of the jet fuel used by 2030, for all flights departing from EU airports, and 63% by 2050.

All the pathways described above are consistent with the increased ambition of cutting the economy-wide greenhouse gas emissions by at least 55% by 2030 and achieving climate neutrality by 2050. They all deliver a 90% reduction in transport emissions by 2050, in line with the European Green Deal Communication and the Sustainable and Smart Mobility Strategy. In addition, the impact assessment underpinning the 2030 Climate Target Plan[21] noted particular benefits in deploying a broad mix of policy instruments, including carbon pricing and increased energy and transport sectoral regulatory policy ambition, and clearly suggested that there is no single policy instrument being capable of achieving all the objectives considered in the assessment alone.

An update of the pathway/scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy for the purpose of the 'Fit for 55' package, while also reflecting the COVID-19 pandemic, the National Energy and Climate Plans and refining the policy design of the initiatives, confirms that air transport effectively contributes to the EU climate goals while considering the 5% share of sustainable aviation fuels obligations in the air transport fuel mix by 2030 and 63% by 2050.

It is essential to clarify that **the fulfilment of the newly adopted EU climate targets is not conditioned on a precise SAF ramp-up trajectory.** On the other hand, the level of ambition of the SAF ramp up should also ensure an effective contribution to reducing emissions in the air transport. The purpose of the SAF ramp-up trajectory suggested by the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy 2030 Climate Target Plan is to provide **an indication, i.e. an order of magnitude of the possible contribution of SAF** to the decarbonisation of air transport, in line with the EU's climate targets. The cornerstone of the EU's strategy to reach its climate objectives is the combined action of the EU ETS and the Effort Sharing Regulation. These two instruments ensure the overall consistency for the necessary reductions of emissions across the EU economy, and **act jointly as a safety net for the attainment**

[20] Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020SC0331
[21] Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0176

of the EU's climate targets. This means that there is some **flexibility** to decide on the exact level of ambition of individual measures (such as ReFuelEU Aviation) for the decarbonisation of the various sectors, such as air transport. The **corrective mechanisms** offered by the EU ETS, Effort Sharing Regulation, Climate Law and the Energy & Climate Governance Regulation (and the future evaluation of the current initiative), would allow to ensure overall consistency with the level of emission reductions necessary to reach EU climate targets.

This impact assessment considers the trajectory for **sustainable aviation fuels obligation that represent 5% of the jet fuel used by 2030 and 63% by 2050** in the scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy. The objective of the present impact assessment is to determine the design of the policy option that would best allow to reach this contribution. Nevertheless, a qualitative assessment of the implications of lower/higher sustainable aviation fuels obligation ramp-up is however provided in section 5.4.3**.**

The large-scale shift from fossil energy to sustainable aviation fuels is a significant challenge for the aviation sector, but also offers considerable economic opportunities, as well as potentially substantial environmental benefits. In particular, it means making European aviation a pioneer in the use of sustainable fuels, and the EU a global leader in the production of sustainable aviation fuels.

1.4. Coherence with the 'Fit for 55' initiatives

The ReFuelEU Aviation initiative is coherent with other initiatives of the 'Fit for 55' package. Regarding the revision of the Renewable Energy Directive (RED), its objectives converge with ReFuelEU Aviation, namely to increase the share of renewable energy in transport. Coherence is ensured as the aviation-specific SAF targets established under ReFuelEU Aviation will contribute to reaching renewable energy targets for transport as set out under RED. The coherence of the present initiative with RED will be further ensured as ReFuelEU Aviation will rely on several core pieces of the RED rules, with cross-references in the ReFuelEU Aviation legal text. This will be the case in particular regarding the sustainability framework of the RED to determine the eligibility of SAF, the use of monitoring, reporting and verification systems already established under the RED, and caps applying to different types of fuels. However, RED is a cross-sector framework and sets targets for overarching sectors, e.g. transport or for the economy as a whole. It has proven insufficient to boost the uptake of SAF due to the specificities of the aviation sector, including the high fuel quality specifications and the strong EU-wide and global competitive cost pressure. Also, the RED by its design leads to a different policy mix from one Member State to another, which is ill suited for the highly integrated and competitive EU aviation internal market and its global dimension. While **ReFuelEU Aviation is coherent with RED and contribute to the overarching objectives of RED**, it will lay down **fully harmonised requirements** to ensure a level playing field between airlines and the avoidance of competitive disadvantage between EU airports. Consequently, also monitoring and enforcement will need to be organised at EU level and will be carried out by existing EU aviation agencies such as EASA or Eurocontrol. Annex 10 gives further details on the interaction between ReFuelEU Aviation and RED II, and Annex 11 gives further details on the reasons why ReFuelEU Aviation objectives cannot effectively be implemented under the RED rules.

ReFuelEU Aviation is coherent with the revision of the EU Emissions Trading Scheme (ETS), which applies to aviation since 2012. Their objectives are aligned, namely to reduce CO_2 emissions in the aviation sector. The EU ETS contains an incentive for SAF usage, i.e. airlines are not required to surrender allowances when reporting the use of SAF (this benefit can be claimed only for the amount of 'net' SAF used, not for the fossil fraction of the jet fuel). As airline increase their use of SAF in the years to come as a consequence of ReFuelEU Aviation, this means that the volume of allowances needed by the aviation sector will decrease over time. The EU ETS will effectively further encourage airlines to decarbonise their operations, as airlines will continue to report the use of fossil jet fuel as fractions of their fuel mix. The effect of the EU ETS is expected to be strengthened in the context of its upcoming revision, with a reduction of the free allowances allocated to airlines and the increase of the linear reduction factor. In turn, this is expected to increase the price of carbon and provide additional incentives for airlines to decarbonise, for example with the use of SAF over and above the mandated minimum blend; and for investing in fuel economy measures, whether it is new fuel-efficient aircraft or operational measures such as flight path efficiency or alternative energy use on the ground at airports. Therefore, it is clear that the **ReFuelEU Aviation initiative and the revision of the EU ETS pursue the same objectives and will complement and reinforce each other**. As SAF becomes a gradually larger share of the aviation fuel mix over time, the air transport sector will decarbonise. In this context, the EU ETS will continue to play a major role in further reducing emissions from the sector by also driving improvements in energy efficiency. Finally, it is worth noting that coherence will be ensured as ReFuelEU Aviation will rely on the EU ETS as regards the monitoring, reporting and verification of SAF use by airlines. Annex 10 gives further details on the interaction between ReFuelEU Aviation and EU ETS.

ReFuelEU Aviation is coherent with the revision of the Energy Taxation Directive (ETD). Their objectives are aligned, i.e. providing the air transport market with the right (policy or fiscal) incentives to accelerate decarbonisation with the use of cleaner energy in the sector. Currently, the use of a number of innovative and sustainable energy products, such as advanced biofuels in transport are not incentivised. The revision of the ETD considers policy options for introducing e.g. a possibility to apply reduced tax rates for SAF. Even though the introduction of a SAF blending mandate may reduce the scope of pricing measures, considering that aviation is also already covered by carbon pricing through the EU ETS, it can be assumed that properly differentiated tax rates could help to some extent make SAF more economically interesting to airlines compared to fossil jet fuel and stimulate greater SAF uptake, i.e. over and above the mandated minimum SAF blend targets. In that sense, ReFuelEU Aviation and a revised ETD would work together towards the same objective of encouraging the deployment of SAF.

ReFuelEU Aviation is coherent with the revision of the Alternative Fuels Infrastructure Directive (AFID), but is expected to have limited interaction with AFID. The directive creates a common framework of measures for the deployment of alternative fuels infrastructure in the EU. AFID places a strong focus on the deployment of infrastructure mainly for the road and maritime sectors. For aviation, the revision of the Directive explores the need to install electricity supply at airports e.g. for stationary aircraft. As explained in the subsequent sections of the present impact assessment, SAF are fully fungible with conventional jet fuel and do not require any specific refuelling stations or dedicated infrastructure in addition to what currently exists for conventional jet fuel. It is therefore not expected that the revision of AFID would play a role to boost SAF deployment in the EU.

1.5. Effects of the COVID-19 pandemic on air transport

The COVID-19 pandemic changed the air transport landscape. Since its outbreak in early 2020, it has been having a **major impact on the international and European aviation industry**, as Member States have introduced various measures to contain the spread of disease, such as suspending flights from other EU Member States or third countries. According to Eurocontrol[22], while the number of flights operating daily in European airspace declined in April-May 2020 by 88% compared to the same period in 2019[23], the overall number of flights in 2020 could be 55% lower than in 2019, i.e. a drop of 6 million flights.[24] Because of the pandemic, the total loss for the air transport industry in 2020 could amount to €140 billon. The COVID-19 crisis' long-term effects on air transport activity are uncertain and depend on the global evolution of the pandemic, the coordination of States to address it, and the ability of the aviation sector to restore passenger

[22] Source: Eurocontrol – « Current Status Scenario » - 14/09/2020.
[23] Source: https://www.eurocontrol.int/sites/default/files/2020-04/draft-performance-review-report-prr2019.pdf
[24] Eurocontrol Draft Traffic Scenarios for September 2020-February 2021, available at: https://www.eurocontrol.int/publication/eurocontrol-draft-traffic-scenarios-september-2020-february-2021

confidence. Under current trends and policies, air transport activity is projected to go up by close to 45% by 2030 and close to 90% by 2050 relative to 2015[25].

2. PROBLEM DEFINITION

2.1. What are the problems?

2.1.1. *General problem*

Air connectivity is an essential driver of mobility for EU citizens, of development for EU regions and of growth for the economy as a whole. High levels of air connectivity within the EU, as well as to and from the EU, are best ensured when the EU air transport market functions as a level playing field, where all market actors can operate based on equal opportunities. When occurring, **market distortions risk putting aircraft operators or airports at disadvantage towards competitors**. In turn, this can result in a loss of competitiveness of the industry, and a loss of air connectivity for citizens and businesses.

In particular, it is **essential to ensure a level playing field across the EU air transport market, when it comes to the use of aviation fuel**. Indeed, aviation fuel accounts for a substantial share of aircraft operators' costs, i.e. up to 25% of operational costs. Variations in the price of aviation fuel can have important impacts on aircraft operators' economic performance. Furthermore, differences in the price of aviation fuel between geographic locations, as is currently the case between EU airports or between EU and non-EU airports, can lead aircraft operators to adapt their **refuelling strategies for economic reasons**.

GHG emissions from the air transport sector have increased since the early 1990's at EU and global level **and are expected to further grow by 2050.** The total air passenger traffic in Europe has more than doubled since 1990[26] and has more than tripled at global level over the same period. This important growth has been accompanied by a steady rise in EU GHG emissions from the sector, i.e. an increase by 28% from 2005 to 2018[27]. In 2018, aviation was accountable for around 3.6% of the EU's greenhouse gas emissions (2% at global level) and for 13.2% of the emissions from EU transport[28].

Aviation is under growing pressure to accelerate its decarbonisation without hampering its highly integrated internal market. Over the past decades, fleet replacement by air carriers, investments in research and development for cleaner aircraft technologies, more efficient air traffic management systems and market-based measures have allowed to slow down the increase of GHG emissions of the sector. While industry and policy efforts have brought environmental benefits (e.g. -24% fuel burn per flight in 2017 compared to 2005), this has not compensated the overall growth of the sector. As aviation emissions are projected to keep increasing in the years to come[29], public and political pressure is continuing to build for aviation to accelerate its decarbonisation. **The decarbonisation of the aviation sector will come from a combination of carbon pricing and regulatory measures acting as a whole** to reduce the CO_2 emissions of aviation in line with the EU's climate objectives. The common economic analysis underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy shows that, in the pathway/scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy, these measures will contribute to this objective, reducing CO_2 emissions from aviation by 52% by 2050 compared to 2015 (equivalent to 14% reduction relative to 1990). When also accounting for the impacts of the COVID-19 pandemic and the National Energy and Climate Plans, emissions reductions of around 59% are projected in the

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25 The Baseline scenario projections, reflecting the COVID-19 pandemics, are explained in Annex 4.
26 From 1995 to 2018, air transport activity increased by 140%: https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2020_en
27 EU Transport in figures – Statistical Pocketbook 2020: https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2020_en
28 Ibid.
29 According to the Baseline scenario, emissions from aviation could increase by 21% from 2015 to 2050.

air transport by 2050 relative to 2015 (equivalent to 26% reduction relative to 1990). Those reductions are consistent with the EU's long term climate objectives.

SAF are expected to play an increasing role from 2025 onwards to bring aviation in line with the EU's climate targets. Indeed, SAF would need to account for around 2% in 2025 and 4-8% in 2030, going up to 63-68% of the total EU jet fuel consumption by 2050. However, in 2020, the production and use of SAF in the EU aviation market amounts to less than 0.05% of total jet fuel use. This very low use of SAF in the aviation fuel mix can be partly explained by the fact that **the EU's aviation industry is almost exclusively reliant on fossil energy** that is currently significantly less costly than SAF. EU transport, and in particular air transport has been reliant on the use of high-emitting fossil-based fuels, notably imported in the EU from third countries. In 2018, EU transport depended on oil products for about 93% of its energy needs. Europe imports around 87% of its crude oil and oil products from abroad. This dependency could be reduced by increased SAF supply in the EU.

The very strong reliance of the aviation sector on oil products can be explained partly[30] because of the **lack of mature and price-competitive alternatives to power commercial aircraft in a sustainable way in the short- to medium-term.** Powering a commercial aircraft requires fuel with high energy density. Currently, only liquid jet fuel known as Jet A and Jet A-1 (including certified SAF), are sufficiently energy-dense to meet this requirement. Other options such as **electricity and hydrogen are promising research options as potential sources of energy to power aircraft in the long-term.** Research for technologies such as battery-powered aircraft engines have made substantial progress in the past years and have the potential to play an important complementary role in the decarbonisation of aviation in the long-term. Experts recognise that in the short- and medium-term, their use will be limited to very short or short-haul flights for aircraft carrying small numbers of passengers. Similarly, hydrogen-powered aircraft are expected to play a role in the decarbonisation of the aviation sector beyond 2040. However, the emergence in the EU aviation market of a meaningful share of commercial fleets powered by electric batteries or hydrogen fuel cells is conditional on both a shift of aircraft engine technology and the build-up of fuelling infrastructure. Research and innovation costs associated with the emergence of such technologies represent important barriers. Given the long research and development cycles in aviation, including lengthy aircraft certification processes, the long lifespan of aircraft and the considerable costs associated with such technological shifts, it is unlikely that hybrid or full electric aircraft or hydrogen-powered aircraft will account for a substantial share of the EU airlines' fleets before 2050[31].

SAF are a technologically viable solution to replace conventional fossil jet fuel. As drop-in fuels, they can be blended[32] with conventional kerosene. SAF can power existing aircraft engines without any technological changes. Analyses show that there is potential to reach a gradually increasing shares of EU aviation with SAF by 2030 and 2050, if additional policies are implemented. This implies to overcome the two major problems faced today: production and demand in the current market conditions are very low.

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[30] Other factors explaining this strong reliance include the low prices relative to SAF and the advantageous fiscal framework for fossil jet fuel.

[31] Hydrogen-powered aviation A fact-based study of hydrogen technology, economics, and climate impact by 2050 - https://www.fch.europa.eu/

[32] A maximum blending ratio of 50% is currently imposed by certification. However, this ratio may be lifted in the coming years to allow for flights to operate on 100% of SAF. Demonstration flights have successfully proven that this is possible.

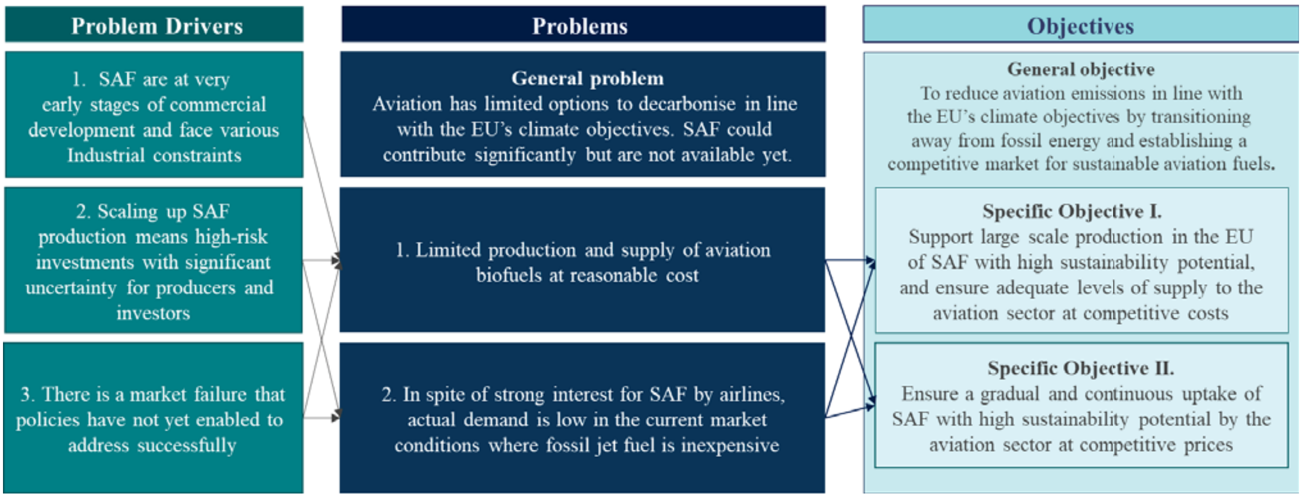

Figure 1 - Problem definition.

The ReFuelEU Aviation initiative is under preparation at the same time as the FuelEU Maritime initiative. While the two initiatives are similar in their objective, i.e. increasing the uptake of sustainable fuels in transport modes with a prominent global dimension with a view to accelerate their decarbonisation, the problems these two sectors face in this respect are inherently different and require each a tailored approach. The differences between the two initiatives relate mainly to the legal and regulatory context, technical constraints and opportunities (e.g. number and type of fuel alternatives), operating conditions (fuel autonomy, etc.).

2.1.2. *Problem 1 – Limited production and supply at reasonable cost*

Europe is a global leader in transport biofuel production, with a significant number of commercial plants in operation. However, **the fuel output of EU bio-refineries focuses almost exclusively on road biofuels.** Indeed, out of the 17.8 Mtoe of biofuels consumed in the EU in 2018, around 80% was biodiesel and 19% was bioethanol for road transport[33]. While the EU has a potential SAF production capacity estimated at 2.3 million tonnes per year[34] (corresponding to 4% of the total jet fuel demand in the EU), this production capacity is not optimised for aviation fuels, as it is used almost exclusively for the production of bio-based fuel for the road transport sector, i.e. biodiesel and bioethanol. **There is currently no plant in the EU producing SAF at commercial scale on a regular basis**. Out of the approximately 47 Mtoe of jet fuel sold in 2018 in the EU, SAF accounts for less than 0.05%, the rest being conventional fossil jet fuel produced from crude oil[35].

The absence of SAF production at commercial scale is one of the reasons[36] why **SAF production costs, and in particular capital and operation costs, are high in comparison with that of conventional fossil jet fuel**. Indeed, the SAF production sector does not benefit from the economies of scale that would allow the capital and operation cost of production of a batch of SAF to be lower. Depending on the production pathway used, the production costs of SAF are generally estimated to be between 1.5 to 6 times higher than for conventional fossil jet fuel[37].

90% of respondents to the survey[38] agreed or strongly agreed that low production and supply of SAF at reasonable cost in the EU is a problem. This finding is in accordance with the OPC where 64% of the

[33] Source: Biofuels Barometer - A study carried out by EurObserv'ER. – 2020.
[34] This means that the biofuel production infrastructure currently installed in the EU could produce up to 2.3 million tonnes of SAF on a yearly basis. However, this is currently not the case because this available capacity is used to produce other outputs. Using the 2.3 million tonne capacity to produce SAF would mean reducing the output of other types of fuel or chemicals. Source: European Aviation Environmental Report 2019 – EASA, EUROCONTROL, EEA.
[35] Source: Eurostat.
[36] The main drivers of this problem include high capital and operational costs, inadequate regulatory and fiscal framework and others (see problem drivers 1, 2 and 3).
[37] Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.
[38] Ibid.

stakeholders rated the price of SAF and the excessive production cost of SAF as the top barriers for not using SAF.

This problem directly affects various parties. First, it directly affects air carriers, who do not have access to regular supply of SAF. As a result, airlines are not in a position to purchase SAF on a regular basis with a view to reducing the GHG impact of their operations. This problem also affects those responsible for the reduction of GHG emissions from aviation such as EU Member States, in view of the European Green Deal and compliance with the EU's commitments with respect to the Paris Agreement and other international commitments such as CORSIA[39]. Ultimately, this problem also affects European citizens, considering the carbon footprint of individual flights, and subsequently of each air traveller. European citizens tend to become increasingly concerned by the environmental impact of their travel.

2.1.3. *Problem 2 – In spite of strong interest for SAF from the aviation sector, demand is low in the current market conditions*

The aviation industry is setting ambitious emission reduction targets, which increasingly rely on the use of SAF. Already in 2008, the aviation industry decided on an aspirational goal of reducing net emissions from aviation at global level by 50% by 2050 compared to 2005 levels[40]. In October 2020, ATAG published "Waypoint 2050"[41], outlining the sector's vision on concrete pathways towards meeting the 50% objective. All scenarios consider that at least 50% of emissions reductions will need to come from SAF. One of the scenarios considers that 75% of the emissions reductions achieved will need to come from SAF.

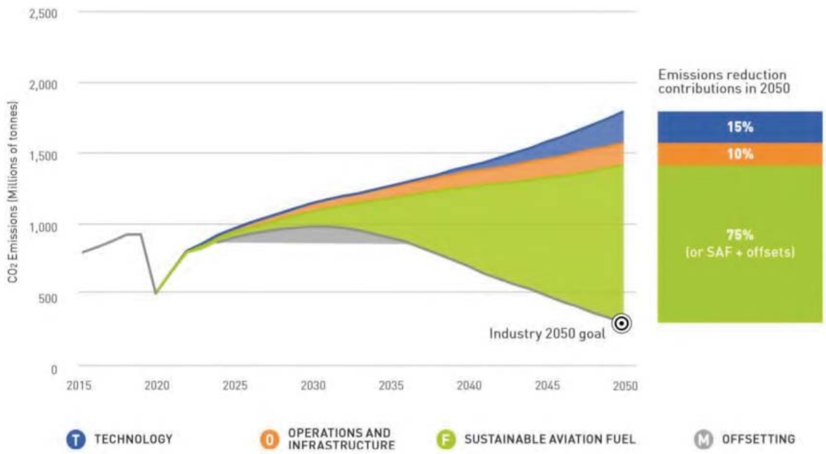

Figure 2 - Scenario "aggressive deployment of SAF" - Waypoint 2050 report.

Waypoint 2050 further shows that achieving carbon neutrality in aviation is feasible around 2060. Similarly, several aviation actors, including those with differing business models (passenger airlines, cargo) publically announced commitments to reduce their carbon footprint with similar levels of ambition, with the use of SAF.

In spite of the strong and increasing interest of some airlines in sustainable aviation fuels, **actual demand is very limited in the current market conditions.** While generally airlines show increasing interest to use SAF in the future, actual projects and partnerships remain an exception. Many airlines groups are still not engaging in concrete partnerships or contracts to boost their SAF use in the future, because in the current conditions the business case is rarely perceived as economically attractive. This is particularly the case in a market where the **price gap between conventional fossil jet fuel and SAF is significant** (see problem drivers 2 and 3). As a

39 Source: https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx
40 Source: https://www.atag.org/our-activities/climate-change.html
41 Source: https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/

result, demand for SAF as an alternative to fossil jet fuel remains very low. In fact, as airlines are sensitive to the market price of jet fuel due to the global competition, this can lead to **fuel tankering practices**, whereby airlines choose to uplift more jet fuel than necessary at airports where prices are low. Such practices could lead to additional emissions[42]. Such practices are detrimental to healthy competition on the aviation market as they can put some **airlines and airports at competitive disadvantage** with others.

66% of respondents to the survey[43] strongly agreed or agreed that low demand for SAF in the current market conditions is an issue hindering the use of SAF in the EU. The respondents to the OPC agreed as 46% were of the view that low demand for SAF is hindering the use of SAF in EU.

2.2. What are the problem drivers?

2.2.1. *Problem Driver 1 - SAF are at very early stage of commercial development and face various constraints (feedstock availability, sustainability, costs, certification)*

A scale up of SAF production requires at the same time the existence of certified production routes and the availability of sufficient feedstock. As of October 2020, seven SAF production pathways have been certified to comply with the technical and safety standards of ASTM International[44] (see Annex 14) for use in commercial aircraft, and several others are in the process of being certified. These pathways can produce SAF from different feedstock, at different production costs, and are currently at different stages of commercial development.

Annex IX Part B biofuels[45] can play a role to decarbonise aviation, but their potential is limited, due to feedstock availability constraints. The most commercially mature pathway in line with the Renewable Energy Directive is the HEFA[46] pathway (TRL 9) that produces SAF from vegetable oils and waste lipids (used cooking oil and animal fats). When produced from waste lipids, this pathway is referred as "Part B biofuels" in this impact assessment. The vast majority of biofuel production in the EU and globally using Part B feedstock are produced for the road transport sector[47]. Therefore, there is potentially a large production capacity for HEFA that is already installed in the EU[48]. Part B biofuels can achieve emissions savings as high as 85% and 76% compared to conventional jet fuel when produced respectively from used cooking oil and animal fats[49]. HEFA is also currently the least expensive SAF pathway to produce (see problem driver 2), but the availability of feedstock currently included in Annex IX Part B is already a strong limiting factor and will be even more in the future. Indeed, they are **highly demanded for the production of other transport biofuels** and their aggregation (collection and supply chain) is not always well organised at EU level. Besides, their decarbonisation potential is limited compared to that of advanced biofuels (produced from Annex IX Part A

42 A Eurocontrol analysis for the European Civil Aviation Conference's (ECAC) airspace (composed of 44 countries, including the EU Member States) shows that 16.5% of flights are able to perform full tankering and 4.5% partial tankering with negative impacts both on the sales of European jet fuel producers and on CO2 emissions, because of carrying more fuel than necessary which increases fuel consumption. In addition, interviews with several pilots from airlines, business aviation dispatchers and handling agents, were conducted during this analysis. They reported that in practice full tankering is performed on 15% of flights, and partial tankering performed on a further 15% of flights.

43 Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.

44 American Society for Testing of Materials. https://www.astm.org/. To note that the DefStan (UK Defence Standardization - https://www.gov.uk/guidance/uk-defence-standardization) plays a similar role for the certification of jet fuel, in the UK.

45 Biofuels produced from feedstock listed in Annex IX part B of the Renewable Energy Directive.

46 Hydro-Processed Esters & Fatty Acids (see Annex 15). Source: Analysis of current aviation biofuel technical production potential in EU28 – M. Prussi, A. O'Connell, L. Lonza.

47 HVO (hydro-treated vegetable oil) is the pathway used to produce biofuel for the road transport sector from the same feedstock as those required to produce HEFA jet fuel.

48 Around 20% of road transport biofuels is produced from Annex IX Part B feedstock. Increasing the production of aviation biofuel from those feedstock would likely result partly in a shift of production from the road sector.

49 ICAO document - CORSIA Default Life Cycle Emissions Values For CORSIA Eligible Fuels. Emissions savings are determined relative to a baseline for fossil jet fuels of 89gCO2e/MJ.

feedstock[50]) that can be provided from renewable independent feedstock sources. Finally, the contribution of Part B biofuels to EU renewable energy transport target is capped under the Renewable Energy Directive.

Advanced biofuels[51] have significant potential but are not yet available at commercial scale. SAF can be produced from feedstock such as lignocellulosic (e.g. agricultural or forestry residues, grass materials), algae, bio-waste feedstock (biogenic content of municipal solid waste) and others (see Annex 15). This type of feedstock is potentially abundant but is also likely to be subject to strong demand as input for bioenergy processes in other sectors of the economy. Feedstock supply chains, including necessary infrastructure and logistics, also need to be improved by the industry and relevant authorities. Advanced biofuels are recognised to be among the most promising resources[52] for the production of sustainable transport fuels. They have high potential for the decarbonisation of aviation since they can achieve high emissions savings compared to conventional jet fuel (e.g. respectively 94% and 91% emissions savings over their lifecycle when produced from forestry residue and municipal solid bio-waste, respectively[53]). Advanced biofuels can be produced through the approved and certified Gasification + Fischer Tropsch (Gas+FT) (TRL 6-8)[54] and Alcohol-to-Jet (ATJ) (TRL 7-8) pathways. These pathways are generally associated with high production costs (see problem driver 2) relative to those of fossil fuels and of HEFA. The production of advanced biofuels is currently only at demonstration phase, meaning that only a handful of industrial projects in the EU are effectively able to produce them at this stage. Substantial investments are needed to scale them up to the commercialisation stage.

RFNBOs[55] (i.e. synthetic liquid fuels) have significant potential to decarbonise aviation but face resources availability and technology readiness challenges. Synthetic liquid fuels (also called Power-to-Liquids) are produced through the conversion of renewable electricity (e.g. produced based from wind and solar) into liquid hydrocarbons, via the electrolysis of water (TRL 9) to produce green hydrogen followed by a synthesis[56] (TRL 5-6) with CO_2 captured directly from air (TRL 6)[57], from biogenic origin or from industrial processes. RFNBOs have considerable potential for large-scale production and replacement of fossil jet fuel. RFNBOs can be produced using two different production routes, namely the Fischer-Tropsch (FT) or the methanol route (see Annex 15). At this stage, only the FT route (TRL 9)[58] is approved and ASTM-certified for blending with conventional kerosene up to 50%. Like the FT route, the methanol pathway relies on process steps already used in refineries, but ASTM certification is pending. While RFNBOs offer significant opportunities to decarbonise aviation (emissions savings compared to conventional jet fuel can exceed 85%[59]), their large-scale deployment currently face challenges when it comes to the availability of renewable electricity in the EU and CO_2 direct air capture technology. In addition, in the short-term, RFNBOs are also faced with high production costs compared to conventional jet fuel (see problem driver 2).

Crop based biofuels are commercially mature but feedstock availability is limited and those biofuels raise important sustainability concerns. Biofuels produced from vegetable oils such as soybean, rapeseed, palm oil or others are a well-proven technology relying on the HEFA production route (TRL 9) and used in large amounts in the EU and worldwide notably in the form of hydrogenated vegetable oil for road transport

50 Advanced biofuels produced from feedstock listed in Annex IX part A of the Renewable Energy Directive.
51 Ibid.
52 Narendra Naik Deshavath, Venkata Dasu Veeranki and Vaibhav V. Goud - Sustainable Bioenergy - Chapter 1 - Lignocellulosic feedstocks for the production of bioethanol: availability, structure, and composition – 2019.
53 ICAO document - CORSIA Default Life Cycle Emissions Values For CORSIA Eligible Fuels. Emissions savings are determined relative to a baseline for fossil jet fuels of 89gCO2e/MJ.
54 Analysis of current aviation biofuel technical production potential in EU28 – M. Prussi, A. O'Connell, L. Lonza.
55 According to Renewable Energy Directive 'renewable liquid and gaseous transport fuels of non-biological origin' means liquid (or gaseous) fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass. For the purpose of aviation, only liquid drop-in synthetic fuels are relevant.
56 A Reverse-Water-Gas-Shift (RWGS) reaction is required in order to generate Carbon monoxide (CO).
57 Power-to-Liquids Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel – German Environment Agency – September 2016.
58 Source: SunFire presentation at VDMA workshop – 22/10/2020.
59 Clean Skies for Tomorrow: SAF feasibility and sustainability – McKinsey study – September 2020.

diesel. Crop based biofuels' life cycle emissions differs from one type of crop to another, but these fuels generally deliver lower emissions savings than Part A and B biofuels or RFNBOs. As crop based biofuels usually compete directly with the food and feed industry for the use of farming land, sustainable feedstock availability is limited, which increases their life cycle emissions. Finally, crop based biofuels may generate non-negligible indirect land use change emissions[60] (ILUC) as a result of displacing other agricultural crops. ILUC can reduce importantly their sustainability potential or even lead to an increase in CO_2 emissions compared to the use of fossil fuel. Under RED II, biofuels produced from high ILUC risk feedstock are capped at 2019 level and phased out by 2030[61]. Finally, in the past year, companies producing or using certain types of crop-based biofuels have been subject to criticism. Indeed, such biofuels are associated by the public with issues such as deforestation and damage to biodiversity, notably in developing countries. Airlines are generally discarding the possibility of using crop-based biofuels.

SAF technologies currently stand at different stages of commercial development and face various challenges. Their respective **trajectories towards large-scale deployment follow different timelines** ranging from short- to medium-term. While Part B biofuels could be available in meaningful volumes in the short-term (i.e. before 2025), it is clear that their contribution will be limited notably because of feedstock availability constraints. Advanced biofuels and RFNBOs have significant potential to increase the sustainability of the aviation sector. However, they currently exist only at demonstration level and still face industrial challenges, which means their emergence at commercial scale on the market could be expected towards 2030 if specific incentives are in place. Crop-based biofuels are unlikely to play a role in the decarbonisation of aviation.

There is a broad consensus between fuel producers and airlines that a wide spectrum of production pathways and feedstock (including more innovative, sustainable and cost-effective pathways) will be necessary to contribute effectively to decarbonising aviation. Several pathways are currently under certification, and more should follow in the years to come. However, **fuel certification[62] is a lengthy and costly process that can be a barrier for new small and medium fuel producers.** Aviation fuel certification is currently performed by the American Society for Testing and Materials (ASTM – see Annex 14). Given the strict and technical safety requirements related to the use of fuel aviation, SAF need to pass a stringent multi-tier certification process which spreads over time (3-5 years) and require significant financial investments (between €1 and €5 million). The certification process can prove highly resource consuming in particular for small to medium-size fuel producers aiming to introduce new SAF pathways to the market. Such fuel producers may not always have the necessary human and financial resources to dedicate to the process. Significant volumes of fuel are also needed for testing purposes, which represent an additional strong constraint.

55% of respondents to the survey[63] strongly agreed or agreed that the costs and time needed for the fuel certification processes contribute to the limited production and uptake of SAF in the EU.

2.2.2. *Problem Driver 2 - Scaling up SAF production means high-risk investments with significant uncertainty for producers and investors*

As explained in section 2.1.2, the potential SAF production capacity already installed in the EU amounts to an estimated 2.3 million tonnes per year (around 4% of total jet fuel sold at EU airports). However, **EU biofuel producers optimise their production setup for other outputs than SAF.** The current most important biofuel technology in terms of installed nominal production capacity in the EU is the HEFA/HVO process. HEFA

60 The land use change impact of biofuels consumed in the EU – IIASA, Ecofys, E4Tech – 2015.
61 Source: https://ec.europa.eu/energy/sites/ener/files/documents/2_en_act_part1_v3.pdf
62 Fuel certification here refers to the certification of new innovative fuel technologies. It does not refer to the routine certification of jet fuel batches for introduction in the fuel system.
63 Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.

(aviation biofuel) is obtained from HVO (road transport biofuel), thanks to additional process steps[64]. Biofuel production facilities operating with biomass feedstock are typically optimized to produce biodiesel for road transport. When road biofuel is the main desired output, the typical share of SAF could result in the range of 10-15% of total output. For ATJ and Gas+FT, SAF output can be respectively 25% and 20%[65]. Maximising the SAF output is possible, but tends to reduce the refinery output destined to road transport. **The choice of biofuel producers to favour road transport biofuels to the detriment of SAF is driven by a higher return on investment and regulatory obligations**. Indeed, the road transport biofuel market is well established and supported by a robust regulatory framework at European and Member States level, which secures a continuous demand (see problem driver 3). This is not yet the case for the SAF market, which is in its very infancy and where no regulatory obligations exist on SAF supply or demand. If HEFA/HVO plants would adjust their production mix to include the SAF production, up to 55% to 60% of the total refinery output could be directed to air transport. Similarly, for the other production pathways, maximum yields for SAF could vary from to 32% for FT route[66], 60% for Gas+FT route[67] and 77%[68] to 85% for the Alcohol-To-Jet route, while for RFNBOs it could be around 60%[69].

While a reasonable share of SAF could come in the short term from the production capacity already installed in the EU, this will be far from sufficient for SAF to contribute to the decarbonisation of aviation in line with the EU's climate targets by 2030 and 2050. A major scale-up of the SAF production capacity and a shift towards advanced biofuels and RFNBOs is necessary in the years to come. However, **building and operating new SAF production facilities means high-risk and costly upfront investment expenditures.** It is especially the case for SAF production routes that rely on innovative conversion technologies like advanced biofuels and RFNBOs. These incur **high upfront investment expenditures (CAPEX)** as they require e.g. gasification units (Gas+FT route), pre-treatment, hydrolysis and fermentation units (ATJ route). Setting up first-of-a-kind SAF production plants is costly and risky in a context where there is high uncertainty of policy framework and demand from airlines (see problem driver 3). Furthermore, large-scale investments in energy production generally have a long amortisation period, i.e. around 15 years, which adds to the investment risks and expectations of higher returns for investors, further increasing investment costs.

The high SAF production costs are also driven by high operational expenditure (OPEX) for certain production routes. For installations producing through the HEFA route, costs are driven for 80-90% of their share by the cost of feedstock, as e.g. used cooking oil is expensive. The costs to produce RFNBOs are driven by the costs of additional renewable electricity as well as the cost of CO_2-capture and purification. A smaller part of the costs can be attributed to the synthetic fuel production (FT or methanol route). The costs to produce advanced biofuels via Gas+FT and ATJ routes are primarily driven by the upfront investment expenditures for conversion facilities, but feedstock cost (municipal solid waste, agricultural residues, etc.) is expected to represent an important driver in the transition towards a climate neutral economy due to the increased competition over feedstock with other energy and transport sectors. Finally, because advanced biofuels or RFNBOs are novel or emerging fuel technologies, the CAPEX costs for conversion facilities are estimated rather than based on existing facility data. This adds a layer of uncertainty and risk.

85% of respondents to the survey[70] strongly agreed or agreed that high upfront capital costs and operational costs for novel conversion processes are a challenge for SAF production. Similarly, 74% of the respondents to the OPC were of the view that excessive production costs for SAF is one of the most important barriers

64 These additional process steps include fractionation and isomerization.
65 Clean Skies for Tomorrow: SAF feasibility and sustainability – McKinsey study – September 2020.
66 Analysis of current aviation biofuel technical production potential in EU28 – M. Prussi, A. O'Connell, L. Lonza.
67 Clean Skies for Tomorrow: SAF feasibility and sustainability – McKinsey study – September 2020.
68 Ibid.
69 Ibid.
70 Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.

which hinders an extensive use of SAF.

It is difficult to put a precise figure on SAF production costs because these are partially based on past experience, partially estimated, and expected to evolve over the coming years and decades to come, as production volumes increase. **Economies of scale, 'learning curve' and lower renewable electricity prices are expected to bring SAF production costs down gradually by 2050.** Large scale production volumes lead to decreasing CAPEX of novel technology applications. For example, electrolysers (used to produce RFNBOs) are currently tailor-made and the production process is not yet automated. Yet, the technology is ready for industrial scale-up. Furthermore, the efficiency and productivity of plants is expected to increase over time thanks to the learning curve. OPEX are also expected to evolve as the price of resources, in particular the levelled cost of renewable electricity at global level could go down by 40% to 70% by 2050[71]. **On the other hand, the cost of feedstock for advanced biofuels is expected to go up over time in view of the competition with other energy and transport sectors.** The estimated current production costs of various production routes are represented in the Table 1, and compared with the production costs of convention fossil jet fuel. Annex 16 provides detailed information on the economies of scale, as well as the cost structure of SAF production per pathway, and explains the key differences between Part A and Part B biofuel production costs.

Table 1 - Current SAF price ranges from literature and industry consultation.

Production route	*Fossil jet fuel*	*HEFA*	*Gas+FT*	*ATJ*	*RFNBOs*
Estimated production cost[72] in 2020 (k€/tonne)	0.6	0.95-1.14	1.7-2.5	1.9-3.9	1.8-3.5

2.2.3. *Problem Driver 3 - There is a SAF market failure that policies have not yet enabled to address successfully*

The important price differential between SAF and conventional jet fuel explains the low demand for SAF. While conventional jet fuel prices vary around 0.5€/litre[73], the minimum market price of SAF is estimated to be 1.5 to 6 times more expensive, depending on the type of SAF considered. The very low price of fossil jet fuel can be explained by several reasons. Indeed, fossil jet fuels are available in significant quantities around the world, there are many producers and suppliers in competition with each other at global and regional scale, their supply chain infrastructures are well established, demand from the aviation sector has increased steadily over the past decades, and they are subject to tax exemptions at various levels. While the important price gap between SAF and conventional jet fuel is explained by higher SAF production costs and tax exemptions for conventional jet fuel (see problem driver 2), it is also to some extent a consequence of the fact that prices in aviation (of which jet fuel represent a non-negligible part of airlines' expenses, i.e. 17% to 25%) do not fully internalise the environmental cost of the sector[74].

96% of respondents to the survey[75] agreed that high market prices of SAF compared to conventional jet fuel represent a challenge for SAF production and uptake. Similarly, 84% of the respondents to the OPC were of the view the price of conventional jet fuel as one of the most important barriers preventing uptake of SAF.

The existing fiscal and regulatory framework contribute to maintaining fossil jet fuels' low market prices. Indeed, while aviation is subject to several types of taxes (VAT, ticket taxes)[76], jet fuel is generally

71 Clean Skies for Tomorrow: SAF feasibility and sustainability – McKinsey study – September 2020.
72 Based on rough estimates sources from Clean Skies for Tomorrow: SAF feasibility and sustainability – McKinsey study – September 2020. Values have been converted from USD/tonne to EUR/tonne at an exchange rate of 1USD for 0.85EUR.
73 Source: ICCT – The cost of supporting alternative jet fuels in the EU – March 2019.
74 Source: https://op.europa.eu/en/publication-detail/-/publication/0efedf2c-a386-11e9-9d01-01aa75ed71a1.
75 Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.
76 Taxes in the Field of Aviation and their impact – CE Delft – June 2019.

exempt from excise duty in international aviation. The ICAO Chicago Convention[77] requires tax exemption of fuel on-board when landing, whereas fuel delivered to aircraft is exempted through most existing air services agreements between States[78]. At EU level, the Energy Taxation Directive[79] contains a mandatory tax exemption for fuel used in air navigation[80], contrary to rail and road transport. It however permits Member States to tax jet fuel on domestic flights[81] or flights between Member States based on bilateral agreements. **Price gaps between fossil fuels and biofuels do not exist to the same extent in other transport modes**.

Low prices of fossil jet fuel and strong competition in the aviation market explain the negligible actual demand for SAF. Airlines operate in an environment of strong competition, i.e. in the EU aviation internal market and on international routes where they also compete with non-EU airlines[82]. The strong competition in the aviation market means that airlines' net profit margins are overall tight. The price difference between SAF and conventional jet fuel means that using SAF would represent additional fuel expenses for airlines, since fuel costs account for between 17% and 25% of airlines operating expenses[83]. In this context of strong competition and the current regulatory framework, absorbing the SAF cost premium or passing it on to passengers may not be a viable strategy, in particular if competing airlines do not use SAF.

Practices such as 'fuel tankering' occur when aircraft operators, for economic reasons, uplift more aviation fuel than necessary at a given airport, with the aim to avoid refuelling partially or fully at a destination airport where aviation fuel is more expensive. When performed for economic reasons, i.e. in 90% of cases, **fuel tankering undermines fair competition in the air transport market**, as certain aircraft operators are able to use favourable aviation fuel prices at their home base, as a competitive advantage towards other airlines operating similar routes. This **affects the competitiveness of some aircraft operators and can also reduce the attractiveness of certain airports.**

84% of respondents to the survey[84] agreed that competitive air services with low profit margins reduce the willingness of airlines to pay a premium for fuel.

There is a strong ongoing interdependency between the demand and supply sides of the SAF market, i.e. the lingering "chicken-or-egg" issue. The absence of effective demand for SAF is explained by the high SAF market prices relative to low fossil jet fuel prices. In turn, this absence of effective demand means that biofuel producers on the supply side of the market do not produce SAF. This causes SAF production costs to remain high (absence of economies of scale and learning curve – see problem driver 2) and SAF to remain economically not attractive on the market compared to fossil jet fuel. This situation has been ongoing for more than a decade, i.e. since the first certification of SAF and the first demonstration flights in the late 2000's.

EU policies on renewable energy for transport have so far proved insufficient to boost the production and uptake of SAF. Indeed, **the regulatory framework of the past decade focused predominantly on driving renewable energy to road and rail transport.** While this can be justified by the fact that road is by far the largest energy consumer of all transport modes (72.2% of the total in 2018[85]), it means that incentives to supply

77 Source: https://www.icao.int/publications/pages/doc7300.aspx
78 Nevertheless, most EU comprehensive aviation agreements, as well as many Member States' bilateral agreements (as modified by EU horizontal agreements) signed with third countries secure the right of the Member States to tax aviation fuel for domestic or intra-EU flights in line with Council Directive 2003/96/EC.
79 OJ L 283, 31.10.2003, p. 51-70.
80 Air navigation other than private pleasure air transport. The objective of introducing such a mandatory exemption was to respect existing international obligations, while safeguarding the competitiveness of European industry vis-à-vis third countries.
81 As of September 2020, the Netherlands is currently the only Member State that levies taxes on fuel for domestic flights.
82 Non-EU airlines might have access to more advantageous fuel prices at the home hubs, compared to EU airlines.
83 EUROCONTROL - Aviation Intelligence Unit – Think Paper #1 – June 2019.
84 Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.
85 EC Transport in figures – statistical pocketbook 2020.

renewable energy to aviation[86] were very limited. As explained below, the Fuels Quality Directive and the Renewable Energy Directive have contributed to the positive effects of reducing the CO2 emissions from road transport, and of increasing the share of biofuels in transport from 3.4% to 8.3% between 2007 and 2018[87]. However, due to the absence of specific incentives, **EU policies on renewable energy in transport have not led to a reduction of CO_2 emissions in aviation.**

The original 2009 Renewable Energy Directive[88] (RED I) set a **mandatory target for the transport sector to be supplied with 10% of renewable energy** including transport biofuels by 2020. It contained no specific target for the air transport sector. The 2018 recast Renewable Energy Directive[89] (RED II)[90] revised the mandatory target for transport to 14% by 2030. There is **no specific mandatory target for the air transport sector**, but RED II allows[91] Member States to account for biofuels supplied to the aviation sectors towards meeting the renewable energy target[92]. In addition, biofuels directed to the aviation sector can benefit from a multiplier of 1.2, meaning that such biofuels can account towards the renewable energy target for 20% more of their energy content. A multiplier of 1.2 for aviation represents however a very limited incentive in comparison with the multiplier of 4 encouraging the use of renewable electricity in the road and rail sector.

The amendment to the Fuels Quality Directive[93] (FQD) adopted in 2009 establishes that fuels used for road transport in the EU must meet strict quality requirements and contains a **mandatory target requiring a reduction of 6% of road fuels** greenhouse gas intensity by 2020. This was a strong regulatory push to drive renewable energy towards the road sector, as the target could be met notably[94] with the use of biofuels and RFNBOs. **Aviation fuels were not subject to a target** as they were not covered by the scope of FQD. Similarly to RED I, the FQD also included the 'opt-in' clause since 2019.

Aviation CO_2 emissions have been covered by the EU Emissions Trading System (EU ETS) since 2012. The EU ETS[95] includes incentives for airlines to use SAF by allowing them to benefit from a "zero emissions-rating" if they use SAF[96]. In practice, this means that airlines are not required to surrender any allowances for CO_2 emissions where fossil jet fuel is replaced with SAF. This mechanism may provide a true incentive for airlines to use SAF if the savings from having to buy fewer allowances, or being able to sell more allowances, would match the additional cost of using SAF, compared to the cost of fossil fuels. However, **the EU ETS on its own has not been sufficient to boost SAF uptake by airlines**. Since 2012 the price of CO_2 emission allowances in the EU ETS has oscillated from around EUR 4 to over 40 per tonne of CO_2. Provided that the price of SAF would be EUR 1 per litre, and that the EU ETS would constitute the only financial incentive towards the use of SAF, the price of CO_2 emission allowances should be at least EUR 160 to incentivize the use of SAF by airlines[97]. Hence, only Germany and Sweden reported the use of SAF under the EU ETS in 2016 and 2017[98].

At global level, the regulatory framework relating to SAF consists mainly of the dedicated mechanism contained in the Carbon Offsetting and Reduction Scheme for International Aviation[99] (CORSIA) under the International Civil Aviation Organization (ICAO). The scheme, which pilot phase starts in January 2021, aims

86 Aviation accounted for 12.7% of the transport sector's energy demand in 2018. Same source as above.
87 EUROCONTROL - Aviation Intelligence Unit – Think Paper #1 – June 2019.
88 OJ L 140, 5.6.2009, p. 16-62.
89 OJ L 328, 21.12.2018, p. 82-209.
90 While RED II entered into force in 2018, EU Member States have until June 2021 to transpose it into national legislation.
91 The inclusion of this provision followed the introduction of an opt-in for aviation in Directive (EU) 2015/1513.
92 This possibility is known as the aviation "opt-in".
93 OJ L 140, 5.6.2009, p. 88-113.
94 Other types of renewable energy can be used to decrease the greenhouse gas intensity of road fuels, notably electricity and less carbon intense fossil fuels.
95 Source: https://ec.europa.eu/clima/policies/transport/aviation_en
96 This is conditional on their compliance with the sustainability framework of the RED.
97 Study on biofuel for aviation for the Swedish Government, SOU 2019:11.
98 Source: https://op.europa.eu/en/publication-detail/-/publication/fc2b7891-704d-11e8-9483-01aa75ed71a1/language-en
99 Source: https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx

to cap CO_2 emissions from international air transport by requiring airlines to offset emissions beyond 2019 levels. Instead of purchasing emissions offsets, aeroplane operators can choose to use SAF that comply with a dedicated strict sustainability framework. In a similar way as for the EU ETS, in the short-term, given the current conditions of the carbon market, **it is likely that CORSIA on its own will not provide a sufficient economic incentive for airlines to use SAF**, as the market price of carbon offsets is expected to be lower than the additional market price of SAF. Further work is ongoing at ICAO level to define the possible contribution of SAF (among other types of fuels[100]) in international aviation. In 2017, the Conference on Aviation and Alternative Fuels (CAAF/2) adopted recommendations and approved a declaration[101], calling for a significant proportion of aviation fuels to be substituted with sustainable aviation fuels by 2050. In 2019, the 40th ICAO General Assembly adopted a Resolution[102] calling on the ICAO Council to explore the feasibility of a long-term global aspirational goal for international aviation (LTAG). SAF are identified as a building block in this exercise. The same Resolution calls for ICAO States to "*consider the use of incentives to encourage the deployment of clean and renewable energies sources for aviation, including SAF*". **Policy work at global level to support SAF deployment in aviation is advancing, but progress is slow**. Discussions on lower carbon aviation fuels under CORSIA are diverting the attention from SAF, which effectively can achieve much higher emissions savings.

Finally, the treatment and eligibility of SAF under CORSIA and RED II differs today in several ways, notably in terms of sustainability framework, accounting system and reporting. This adds a layer of complexity and uncertainty for producers and investors.

84% of respondents to the survey[103] agreed that lack of clear policy signals and limited impact of existing legal framework contribute to the challenges for SAF production and uptake.

2.3. How the problem will evolve

SAF are expected to continue facing unequal commercial development and important industrial challenges (problem driver 1). In the years to come, the potential production capacity for Part B biofuel might increase slightly, albeit at a very slow pace[104]. This is because Part B biofuels are the most commercially mature and the least costly to produce. However, feedstock availability constraints will continue to be a barrier to more significant use of Part B biofuels in aviation. In addition, they provide the least benefits in terms of emissions reductions.

Regarding advanced biofuels for air transport, only very few demonstration sites are expected to scale-up to commercial production without further EU level intervention. RFNBOs capacity productions for aviation are also projected to make no significant inroads without additional EU level intervention. In the absence of regulatory and financial support, this will be insufficient for these technologies to benefit from the necessary economies of scale and learning curve that widespread scale-up would deliver. In addition, feedstock prices for biofuels are expected to increase over time, due to the competition with other energy and transport sectors in the transition towards a climate neutral economy. The industrial challenges faced by advanced biofuels and RFNBOs in air transport are thus expected to remain in the medium- to long-term. While new production pathways will become certified, these new technologies will have very low market maturity and will need to be demonstrated at small scale. Finally, it is possible that the certification process could become lighter for fuel

[100] "Lower carbon aviation fuels" are crude oil based jet fuels that are slightly less greenhouse gas intensive than conventional jet fuel. The small emissions savings are achieved by implementing certain practices at extraction sites or oil refineries, such as avoided flaring/venting or use of renewable energy in the supply chain.
[101] Source: "2050 ICAO Vision for Sustainable Aviation Fuels" - https://www.icao.int/environmental-protection/GFAAF/Pages/ICAO-Vision.aspx
[102] ICAO Assembly Resolution A40-18.
[103] Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.
[104] As it can be projected based on the latest projects and partnerships between biofuel producers and airlines.

producers in the future, as the ASTM may set up a 'Fast Track' certification. This would speed up the process to some extent, but it is not clear whether it would make it less resource-intensive in particular for small producers.

Upfront capital costs investment are expected to remain high, as well as the level of risk for investors (problem driver 2). Investors and biofuel producers are expected to take a low-risk approach when investing in new production capacity, i.e. by ensuring that the plants are versatile enough to be optimised for other outputs than SAF e.g. road biofuel or chemical industry, where demand is expected to remain relatively stable in the years to come. Concerning investments in plants to produce advanced biofuels for air transport, it is likely that the situation will remain unchanged[105], meaning that very few demonstration projects will be scaled up to commercial size, and levels of investments will continue to be very low. This is even more the case for RFNBOs whereas the capital costs are higher than those for advanced biofuels. As a result, production cost of SAF will continue to be substantially higher than that of fossil jet fuel and upfront investments in production capacity will continue to represent high risk for investors, in particular early movers. Finally, whether biofuel producers will durably optimise their installations to produce SAF on a regular basis will depend on the emergence of a stable, long-term demand on the side of airlines. This is unlikely to happen without further EU level intervention, as explained in the following paragraph.

The existing regulatory framework is not expected to drive biofuels or RFNBOs towards use in aviation (problem driver 3). The SAF market prices are expected to remain substantially higher than those of fossil jet fuel under current trends and policies, with oil prices projected at 72 €/bbl by 2030 and 106 €/bbl by 2050.[106] In addition, fossil jet fuels are subject to highly volatile prices, linked to the evolution to the oil prices that react to an array of factors far beyond the dynamics of the aviation market. Furthermore, it is not clear whether the airlines will be subject to less intense competition in the future and achieve higher profits allowing them to invest sufficiently in sustainable fuels. The higher SAF market prices relative to that of fossil jet fuel and the high level of uncertainty surrounding the two factors mentioned above will continue deterring biofuel producers and investors from further deploying or investing in SAF. The chicken-or-egg situation is thus likely to continue. This problem is unlikely to be solved if the current regulatory framework is maintained. Indeed, for the EU ETS to make uptake of SAFs economically interesting, a price of CO_2 emission allowances of at least €160 would be necessary, which is unlikely in the short- or medium-term. Similarly, without further EU level intervention, the RED II and the FQD are expected to continue driving the vast majority of transport biofuels towards the road sector. The current option given to Member States under the RED II to account for biofuels supplied to the aviation sectors is expected to lead to different rules and incentives introduced by individual Member States with very few of them taking the advantage of the opt-in.

Given the elements explained above, **problems of (A) low production and (B) low demand are expected to remain present in the medium to long term in the absence of further regulatory action.** They will continue to be strongly driven by problem drivers 1 to 3. The projected baseline uptake of SAF is limited to 0.1 Mtoe in 2030, increasing gradually to 1.5 Mtoe in 2050, which would account for 0.2% of total fuel consumption in aviation by 2030 and 2.9% by 2050. In turn, **the persistence of Problems 1 and 2 is expected to aggravate the general problem**. Air traffic is projected to increase by close to 45% by 2030 and close to 90% by 2050, relative to 2015, following the recovery from the COVID-19 pandemic. CO_2 emissions would increase by 17% by 2030 and slightly over 20% by 2050, relative to 2015, despite the significant improvements in energy efficiency. Annex 4 provides more explanations on the baseline scenario, reflecting the impacts of the COVID-19 pandemic. While other sectors of the economy and other transport modes will likely continue reducing their carbon footprint, the aviation sector would remain one of the few sectors where emissions keep rising. In this context, the public and political pressure on aviation would continue to build, with important risk of

[105] In the current context driven by the COVID-19 crisis, the scarcity of investments could be accentuated.
[106] Please see Annex 4 for more explanations on the baseline scenario.

reputational damage for the sector. Potentially, this could also threaten jobs in the air transport industry, connectivity, as well as growth of businesses and regions.

The revision of the Renewable Energy Directive, part of the ‘Fit for 55’ package is expected to help scaling up the production of advanced biofuels and RFNBOs. It will however not enable setting specific requirements on airlines and aviation fuel suppliers in a harmonised way across the EU. This is expected to lead to different rules and incentives introduced by individual Member States. It may also lead to uncertainty for the fuel and airline industry if Member States obligations support different types of SAF with differing fuels eligibility and sustainability requirements. As a result, this would likely still divert the advanced biofuels and RFNBOs towards the road transport sector instead of air transport. On the other hand, the present initiative can support the review of the Renewable Energy Directive by reinforcing the delivery of renewable energy in the transport sector, including in the air transport sector. The revision of the Energy Taxation Directive, part of the ‘Fit for 55’ package, will revisit the tax exemptions for conventional jet fuel. This would however not allow to address problem drivers 1 and 2 of the present initiative (SAF face industrial challenges; scale-up of SAF production means high risk investments), because is unlikely to provide, on its own, a sufficient incentive for the fuel industry and airlines to make the necessary investments in SAF production and uptake. Finally, as explained above, for the EU ETS to make SAF economically interesting for airlines, a price of CO_2 emission allowances of at least €160 would be necessary. By comparison, the impact assessment[107] accompanying the 2030 Climate Target Plan projects carbon prices for the ETS sector in the range of 32 to 65 €/tCO2, to cut the economy-wide GHG emissions by at least 55% by 2030. The EU ETS is therefore unlikely, by itself, to drive SAF uptake in aviation in the medium-term.

3. WHY SHOULD THE EU ACT?

3.1. Legal basis

The Treaty on the Functioning of the European Union confers to the EU the competence to lay down appropriate provisions in the air transport sector (Article 100(2)). Transport is a shared competence between the European Union and the EU Member States.

This initiative is fundamentally about air transport, maintaining high levels of connectivity, competition and industry competitiveness level in the aviation internal market while stepping up its sustainability. Sustainability is an inherent trait of transport, as safety and security are. The legal text will include detailed aviation-specific provisions to cater for the complexities of the sector.

3.2. Subsidiarity: Necessity of EU action

Air transport, climate and renewable energy are matters of high EU relevance. Aviation is a highly integrated market operating in a network dimension across the whole of the EU. The cross-border dimension is inherent to air transport, which makes any fragmented regulatory framework a significant hurdle for economic operators. The CO_2 emissions from aviation are also of transboundary nature and as such cannot be addressed at national or local level only. Therefore efforts to reduce CO_2 emissions of the air transport sector and to promote its use of renewable energy sources should be addressed at EU level. Market players should benefit from clear climate and energy rules applying in a harmonised way across the EU.

An intervention at EU level is necessary, as the scaling up SAFs can contribute to reducing air transport emissions and is in line with the EU’s climate objectives. The Commission’s 2030 Climate Target Plan identifies an increase in the use of SAF as one of the important contributors to the goal of reducing GHG emissions by 55% by 2030 and achieving a climate-neutral economy by 2050.

[107] SWD(2020) 176 final.

An EU-level intervention is necessary to avoid a patchwork of national measures with possible unintended effects. National initiatives to incentivise the supply and use of SAF in the Netherlands (by an aviation opt-in to the RED II targets) and Nordic States (with the emergence of national blending mandates) are expected to have only limited effects on the use of SAF at EU level. Such national initiatives risk creating a patchwork of different obligations for the aviation and fuel supply industry. Different levels of obligations per Member State could potentially distort the aviation market encouraging adverse practices such as fuel tankering[108], whereby airlines would refuel in Member States with less strict obligations in order to save on fuel costs. **National frameworks could lead to unintended negative impacts** by inducing inefficiencies in air navigation (longer flight trajectories, higher volumes of fuel lifted) that could lead to a fragmented regulatory framework, inducing higher compliance costs for economic operators. It may also lead to uncertainty for the fuel and airline industry if Member States obligations support different types of SAF with differing sustainability requirements. Finally, it could lead to higher fuel burn and GHG emissions.

EU-level regulatory action on SAF is widely supported by consulted Member States and industry stakeholders.

68% of respondents to the ReFuelEU Aviation open public consultation considered that regulatory action on SAF was best suited at EU level.

Stakeholders consulted[109] from across the EU agree that the supply and uptake of SAF will remain relatively low across the EU and the price gap with conventional jet fuel will persist in the absence of an EU-wide approach to incentivise the production and use of SAF.

3.3. Subsidiarity: Added value of EU action

EU-level action is expected to set a clear policy direction for the market players from both the aviation and fuels industries. As explained in section 2, a part of the problem is due to the absence of specific incentives to reduce aviation CO_2 emissions in the EU policy framework. This was confirmed by the desk research and stakeholders' consultation[110]. One clear set of EU rules on the supply and uptake of SAF will mean that SAF producers and airlines can operate based on equal opportunities across the EU, creating level playing field for airlines to compete. It will give clear signals on the need to develop specific types of SAF. A single set of rules also means reduced compliance costs for market players.

EU-level action on SAF would contribute to achieving the desired climate change policy targets. The 2030 Climate Target Plan establishes that SAF have a major role to play to reduce emissions from aviation by 2030 and 2050 and attain EU climate goals. Therefore, establishing EU rules on SAF production and use allows taking a "tailored" approach towards meeting the targets. Relying on national measures only with likely different targets (if any) would incur the risk that the aggregated level of ambition is not sufficient. The current initiative can also support the forthcoming review of the Renewable Energy Directive by reinforcing the share of renewable energy in the transport sector.

EU-level action may have positive effects at international level. As EU intervention would have effects on the entire aviation and SAF EU market, it is expected to have higher prominence towards third countries than isolated national initiatives. Spill-over effects are also likely to occur more easily, whereby third countries may consider adopting similar measures. In turn, this could accelerate the ongoing work at ICAO level on the use of SAF. In short, EU action could spur further developments on the production and uptake of SAF outside of the

108 Fuel tankering is a practice whereby an airline refuels with an excessive amount of jet fuel at a given airport, causing the flight to carry more fuel than necessary and leading to excessing, avoidable emissions from additional fuel burn due to excessive weight on board. https://www.eurocontrol.int/publication/fuel-tankering-european-skies-economic-benefits-and-environmental-impact
109 Study supporting the ReFuelEU Aviation Impact assessment – Ricardo – 2020 – See stakeholders consultation report.
110 Ibid.

EU, which could help create a level playing field at global level, as well as reduce air transport emissions at a wider scope.

4. OBJECTIVES: WHAT IS TO BE ACHIEVED?

4.1. General objectives

The air transport sector needs to maintain a level playing field and accelerate its decarbonisation urgently in the years to come in order to be in line with the Union's climate targets for 2030 and the Union's ambition to become carbon neutral by 2050. As explained in section 1.3, while considering a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy, the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy identifies the trajectory of SAF ramp up from 2025 to 2050 in order to bring aviation in line with the climate ambition of the Union. The general objective of this initiative is to **reduce aviation CO_2 emissions in line with the 2030 and 2050 climate objectives of the EU, by transitioning away from fossil jet fuel and tap into the high decarbonisation potential of sustainable aviation fuels by establishing a competitive SAF market, while at the same time ensuring a level playing field on the aviation market.**

Strengthening ongoing efforts at EU and global level only will not be sufficient if the aviation sector remains entirely dependent on fossil jet fuel. The decarbonisation of aviation can only be achieved if the EU deploys a clear and comprehensive aviation fuels policy. In the aviation fuels landscape, there are very promising alternatives to fossil jet fuel: (i) liquid sustainable aviation fuels (advanced biofuels and RFNBOs), (ii) hydrogen fuel cells, and (iii) electric batteries. It is clear that **the decarbonisation of aviation will come from a combination of these alternatives**. However, these will become available at different points in time. While liquid sustainable aviation fuels should be commercialised as early as 2022, with potential for significant scale-up as of 2025, electric aircraft and hydrogen-powered aircraft could play a role in commercial aviation in the long-term. This **requires targeted action on each of these initiatives to ensure that they can be delivered in time.** ReFuelEU Aviation therefore specifically targets the drop-in liquid sustainable aviation fuels.

In addition it should be noted that **this initiative does not target GHG emissions as a whole but targets CO_2 emissions and some of the non-CO_2 emissions from aviation**. It should lead to simultaneous reductions of CO_2 emissions, of non-volatile particulate matter and sulphur emissions. However due to the remaining scientific knowledge gaps on the impact of the non-CO2 emissions from aviation, these will be analysed only qualitatively in this report (see section 6.1.4 and Annex 13).

The initiative will contribute to the achievement of the general objective by pursuing the following two specific objectives.

4.1.1. *SO1: To achieve large-scale production and supply of SAF in the EU with high decarbonisation potential, at competitive costs*

Specific objective 1 is to **achieve the large-scale production in the EU of sustainable aviation fuels** with high decarbonisation potential, and to ensure adequate levels of supply to the aviation sector at competitive costs. In concrete terms, taking an industrial policy perspective, this means that the aim is to develop the SAF production capacities on several fronts. First, the objective is to **support the use of the existing SAF production capacity** in order to increase significantly the SAF output. As explained under problem 1, there is an important SAF production capacity already installed and potentially available in the EU, but it is currently not used for SAF production due to the reasons outlined previously (see section 2.2). Second, the objective is to **boost the development of new additional production facilities in the EU for SAF with the highest**

decarbonisation potential, i.e. advanced biofuels for aviation and RFNBOs.[111] Third, the objective is to **lead to the emergence on the market of new, sustainable and more cost-effective SAF pathways, taking a technology-neutral approach**. New pathways, using innovative technologies and sustainable low-cost feedstock can broaden the spectrum of available SAF and unleash the potential for higher emission savings. A technology-neutral approach in the regulatory framework can ensure that a wide spectrum of innovative fuels technologies can reach the market, and can contribute to the aviation fuel mix in the future. Fourth, the objective is **to reduce SAF production costs relative to the current levels**. Due to economies of scale, learning effects, and the technology maturity over time, production sites will be able to reduce their capital costs gradually. This will be counterbalanced to some extent by an increase in the feedstock costs, given the competition over feedstock with other energy and transport sectors. This will allow nevertheless SAF to be available on the market at lower prices than estimated currently (see Specific Objective II).

4.1.2. *SO2: To ensure a level playing field in the aviation market and achieve a gradual and continuous uptake of SAF with high decarbonisation potential at competitive prices*

Specific objective 2 is to **maintain a level playing field in the aviation market** and **achieve a gradual and continuous uptake of SAF** with high decarbonisation potential by the aviation sector at lower prices than estimated today and based on the uniform obligations ensuring the integrity of competition within the internal market. For this objective to be achieved, it needs policy intervention on several fronts. First, the objective is **to ensure that airlines have access to SAF at airports**. This means that the logistics of the supply network for SAF-blended jet fuel must be well organised and that the necessary volumes and qualities of SAF must be physically distributed at airports, and made accessible to airlines for refuelling on a regular basis. The logistics of SAF-blended jet fuel need to be geared to cater for gradual increase of SAF production and supply at airports over time. Second, the objective is to **boost the uptake of the most sustainable types of SAF in a technology-neutral way**. In order to maximise the decarbonisation potential of SAF, to accelerate the decarbonisation of aviation and to deliver environmental benefits in line with the EU's climate targets, it is also necessary to ensure that the uptake of the most sustainable SAF increases over time. Third, the objective is that **airlines can purchase SAF at lower prices than estimated today** and based on uniform obligations across the Union. This means that the selling price of SAF goes down relative to current price estimates, bridging to some extent the gap between conventional jet fuel and SAF prices[112]. Other initiatives like the forthcoming review of the ETS Directive and the Energy Taxation Directive could also play a role in further bridging this gap. Fourth, the objective is to **ensure a level playing field between airlines to purchase aviation fuel and in particular SAF**. This means that distortion of competition must be avoided across the internal market, as well as between EU and non-EU airlines. In particular, airlines should be able to purchase SAF at competitive prices regardless of the nature or geographical spread of their operations. Fifth, the objective is to **avoid carbon leakage resulting from increased fuel tankering**. This means that this initiative should not lead to airlines carrying excessive volumes of fuels or changing their refuelling locations and strategies in order to avoid using SAF and incurring higher fuel costs. In this context, it is also necessary that the competition between airlines within the internal market is not distorted.

Due to the "chicken-or-egg" situation on the SAF market, as described in section 2, Specific Objectives 1 and 2 mutually support and reinforce each other. This means that it will be easier to successfully achieve Specific objective 2 (gradual and continuous uptake of SAF) if Specific objective 1 is successfully achieved (achieve large-scale SAF production), and vice versa.

[111] According to the World Economic Forum, developing the advanced biofuels for aviation and Power-to-Liquid technologies would allow tapping into abundant resources with high environmental benefits.

[112] Not prejudging other measures which may impact the price of conventional jet fuel itself.

5. WHAT ARE THE AVAILABLE POLICY OPTIONS?

5.1. What is the baseline from which options are assessed?

The baseline scenario reflects developments under current trends and adopted policies as described in section 2.3, without further EU level intervention. It builds on the baseline scenario underpinning the impact assessment accompanying the 2030 Climate Target Plan and the staff working document accompanying the Sustainable and Smart Mobility Strategy, but it additionally considers the impacts of the COVID-19 pandemic and the National Energy and Climate Plans. In this scenario, the total intra and extra-EU air transport activity is projected to increase by close to 45% by 2030 and close to 90% by 2050, relative to 2015, following the recovery from the COVID-19 pandemic. The pace of the recovery builds on the GDP projections but also considers some structural changes due to limited shifts towards digital meetings. The overall impact of the COVID-19 pandemic on the air transport activity is however significant, with lower growth projected relative to pre-COVID projections (i.e. around 11 percentage points lower growth for 2015-2030 relative to the pre-COVID projections and 14 percentage points lower growth for 2015-2050). More details are provided in Annex 4.

The energy demand in aviation is projected to grow from around 40 Mtoe in 2015 to 50 Mtoe in 2050, following the significant decrease estimated for 2020 (to 21 Mtoe) due to the COVID-19 pandemic. Aviation is projected to remain almost entirely reliant on conventional jet fuel by 2050 without further EU level intervention, as explained in section 2.1.1. Air transport tank to wing CO_2 emissions are projected to increase by 17% by 2030 and slightly more than 20% by 2050, relative to 2015. This is due to the strong growth in activity, following the recovery from the COVID-19 pandemics and despite the significant improvements in energy efficiency over time. Well-to-wing emissions would follow a similar trend. The baseline scenario underlines an aggravation of the general problem (see section 2.1.1.). The share in the total transport CO_2 emissions[113] is projected to go up from around 12% in 2015 to 20% in 2050. More details on the baseline scenario are available in Annex 4, drawing on the impact assessment support study. The very low and slow market penetration of SAF by 2030 and 2050 means that problems 1 and 2 (see sections 2.1.2 and 2.1.3) remain largely valid, underpinned by the drivers identified in section 2.2.

The COVID-19 pandemic's long-term effects on air transport activity are highly uncertain and depend on the global evolution of the pandemic, the coordination of States to address it, and the ability of the aviation sector to restore passenger confidence. A discussion of the effectiveness of this initiative in relation to the possible effects of COVID-19 pandemic is included in section 7.

The baseline scenario does not include the other 'Fit for 55' initiatives. This ensures a consistent approach with the impact assessments accompanying the other 'Fit for 55' initiatives. However, a qualitative assessment of their possible impact on how the problem will evolve is provided in section 2.3, section, 7.2 and Annex 10.

In addition, as explained in section 1.3, the trajectory of SAF ramp up from 2025 to 2050 in the policy options is based on the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy while considering a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy. This ensures a consistent approach for delivering the EU climate ambition by 2030 and 2050, while at the same time identifying the impacts of the design of the policy option that would best allow to reach this contribution. Nevertheless, a qualitative assessment of the implications of lower/higher trajectory for the SAF ramp up is provided in section 5.4.3.

[113] Total transport CO_2 emissions including international maritime.

5.2. Policy measures under consideration and approach taken

Achieving the desired objectives of this initiative requires a holistic approach to the possible levers of action to address the problems and drivers. **A comprehensive and consistent set of actions is therefore necessary**, which individually may not be sufficient to achieve the desired objectives, but will need to mutually complement each other. This is for example the case with the problem of the price differential between SAF and conventional jet fuel (see problem driver 3). The measures proposed in this section cannot fully bridge the price gap on their own, but can contribute to reducing it. A list of policy measures (outlined and briefly described below) is considered after extensive consultations with stakeholders, expert meetings, independent research and the Commission's own analysis (see Annex 5).

The measures included in the scope of the present initiative are structured around **a regulatory requirement consisting of a SAF blending obligation.** It is important to note that such mandate can be designed in multiple ways. Each design has different chances of reaching the objectives depending on their practical applicability, political feasibility and expected market and industrial behaviour (e.g. choice to invest in specific SAF types). These regulatory measures are complemented by **a set of 'flanking' measures** that support the intervention to address the problems and drivers identified along the SAF supply chain (also at global level), and meet the identified objectives. All flanking measures provide an enabling framework for policy options although they are not directly included and assessed in the policy options. They consist of the following:

- Intensifying European efforts at ICAO level to raise ambition on SAF use;
- A strategic alliance on advanced biofuels and electro-fuels;
- Steering financial support towards SAF development in the EU;
- Facilitating the certification of new SAF pathways.

Measures addressed as part of the revision of other pieces of EU regulatory framework, part of the 'Fit for 55' package and for which dedicated, in-depth impact assessments have been prepared by the Commission services, are beyond the scope of this impact assessment. This relates namely to:

- Revision of the Energy Taxation Directive;
- Revision of the EU Emissions Trading System;
- Revision of the Renewable Energy Directive;
- Revision of the Fuels Quality Directive;
- Reform of the Single European Sky.

Annex 10 provides information on each of these measures. These measures may additionally contribute to the achievement of the desired policy objectives. Annex 10 provides a qualitative assessment of how these measures could contribute and establishes a clear reference to the impact assessments, which provide in-depth qualitative and quantitative analysis. This document also assesses the interplay between these measures and the preferred policy option of the present initiative, and explains how some of these measures could contribute to reaching the objectives of the present initiative. It also explains how the present initiative complements and reinforces the objectives of other initiatives part of the 'Fit for 55' package.

5.3. Description of the policy options (PO)

The table below provides an overview of the various policy measures considered under this initiative and the way in which they are grouped in policy options (POs) A1, A2, B1, B2, C1 and C2. It is important to note that all POs (except PO B2, due to its reduced scope) are designed to achieve the same CO_2 savings on a well-to-wing basis over time.

Table 2 - Description of policy measures. Key: P1 = Problem 1; P2 = Problem 2; D1 = Problem Driver 1; D2 = Problem Driver 2; D3 = Problem Driver 3; S1 = specific objective 1; S1 = specific objective 2; ✓ = included;

	Policy measure	**Driver Problem Specific Objective**	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**
	SAF obligation							
1	**Fuel suppliers** are obliged to supply only jet fuel that is blended with a minimum share of SAF across all EU airports.	D1, D2, D3 P1, P2 S1, S2	✓	✓			✓	✓
2	**Transition period:** from 2025 to 2030, **fuel suppliers** are obliged to supply a minimum share of SAF over their total jet fuel supply on a yearly basis. All jet fuel supply must contain SAF in the range 0% - 50%.	D1, D2, D3 P1 S1					✓	✓
3	**Transition period:** from 2030 to 2035, **fuel suppliers** are obliged to supply a minimum share of SAF over their total jet fuel supply on a yearly basis. All jet fuel supply must contain SAF in the range 2% - 50%.	D1, D2, D3 P1 S1					✓	✓
4	**Airlines** are obliged to use a minimum share of SAF as part of their total fuel consumption on intra and extra-EU flights on a yearly basis.	D3 P2 S2			✓			
5	**Airlines** are obliged to use a minimum share of SAF as part of their total fuel consumption on intra-EU flights on a yearly basis.	D3 P2 S2				✓		
	Obligation of jet fuel uplift							
6	**Airlines** departing from EU airports are required to uplift the amount of jet fuel needed for their planned flight.	D3 P2 S2					✓	✓
	Target setting: volumes or CO2 intensity							
7	The minimum target is expressed in terms of SAF volumes blended into jet fuel, expressed as share.	D3 P1, P2 S1, S2	✓		✓	✓	✓	
8	The minimum target is expressed in terms of GHG intensity reduction of the jet fuel used.	D3 P1, P2 S1, S2		✓				✓
	Ramp-up of SAF obligation							
9	The required minimum share of SAF blended in total jet fuel supplied increases over time from 2025 to 2050, in line with the EU climate objectives.	D1, D2, D3 P1, P2 S1, S2	✓		✓	✓	✓	
10	The required reduction in CO_2 intensity of total jet fuel supplied increases over time from 2025 to 2050. It is designed to achieve the same emissions reductions in the air transport sector over time as measure 9.	D1, D2, D3 P1, P2 S1, S2		✓				✓
	Additional incentives for e-fuels							
11	RFNBOs are subject to a sub-mandate gradually increasing from 2030 to 2050.	D1, D2, D3 P1, P2 S1, S2	✓		✓	✓	✓	
12	A multiplier applies to the accounting of RFNBOs towards meeting the SAF obligation.	D1, D2, D3 P1, P2 S1, S2		✓				✓
	Penalties for non-compliance[114]							
13	**Fuel suppliers** are subject to penalties applied at national level in case of non-compliance with the SAF supply obligation.	P1 S1	✓	✓			✓	✓

[114] Funds collected from non-compliance penalties are injected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

	Policy measure	Driver Problem Specific Objective	A1	A2	B1	B2	C1	C2
14	**Airlines** are subject to penalties applied at national level in case of non-compliance with the SAF use obligation.	D3 P2 S2			✓	✓		
15	**Airlines** are subject to penalties applied at national level in case of non-compliance with the jet fuel uplift obligation.	D3 P2 S2					✓	✓
	SAF transaction for accounting purposes							
16	**Fuel suppliers** may request SAF transactions between them for accounting purposes, to comply with the supply obligation.	D3 P1 S1					✓	✓
17	**Airlines** may request SAF transactions between them for accounting purposes, to claim the use of SAF.	D3 P2 S2			✓	✓		
	Monitoring, reporting, verification							
18	**An existing EU agency (e.g. EASA)** is required to compile the data provided by fuel suppliers and report to the Commission.	D3 P1 S1	✓	✓			✓	✓
19	**An existing European organisation** (e.g. Eurocontrol) is required to compile the information on SAF use reported by airlines, and report it to the Commission.	D3 P2 S2			✓	✓	✓	✓
20	**An existing EU agency** or organisation (e.g. Eurocontrol) is required to consolidate the data sent by airlines to comply with the jet fuel uplift obligation on a flight basis, and report to the Commission cases of fuel tankering.	D3 P2 S2					✓	✓

5.3.1. *Policy Option A1: Obligation on the supply side (volume-based approach)*

This policy option consists of imposing an obligation on fuel suppliers to supply physically at least a minimum share of SAF (expressed in volume terms) at all EU airports at all times. Certain categories of airports, such as remote or insular airports may request to be out of the scope. This means that every litre of jet fuel supplied to airports must be blended with a minimum share of SAF from 2025 onwards. Airlines operating on intra-EU and extra-EU routes have no alternative than to use SAF-blended jet fuel when departing from EU airports. This minimum share of SAF to be supplied corresponds to the expected trajectory of the SAF market ramp up for 2025-2050, as explained in section 1.3. A supply sub-obligation applies to RFNBOs as of 2030, meaning that every litre of jet fuel must contain a minimum share of RFNBO as of that date (see section 5.4.2). Monitoring, reporting and verification[115] of the fuel supply obligation is ensured through the dedicated mechanisms under RED II, i.e. the Union Database established under RED II Article 28. An existing EU agency (e.g. European Aviation Safety Agency EASA), is required to compile the information provided on SAF supply under the Union Database and reports to the Commission on the compliance of each fuel supplier with their supply obligation. Penalties imposed on fuel suppliers in case of non-compliance are determined at EU level, reviewed yearly if needed, and enforced at national level. Funds collected from penalties are reinjected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

5.3.2. *Policy Option A2: Obligation on the supply side (CO_2 intensity reduction approach)*

This PO is similar to PO A1, with the exception of the target setting. The obligation imposes on fuel suppliers a minimum reduction of the CO2 intensity (meaning the lifecycle CO2 emissions per unit of energy) of the

[115] Annex IX contains more details on the monitoring, reporting and verification arrangements for each PO.

overall jet fuel supplied. This PO aims to take a technology-neutral approach by using the CO2 intensity reduction-based obligation and therefore it does not set a specific sub-mandate on RFNBOs. An incentive is however set in place, i.e. a multiplier[116] applying to RFNBOs, to bridge the gap in production costs between RFNBOs and advanced biofuels. The value of this multiplier decreases over time, as the cost efficiency of RFNBOs improve. Its value is 1.6 and 1.2 respectively in 2030 and 2040. From 2045, its value is 1. The values of the multipliers are tailored to provide a boost to RFNBOs, and correspond to the value necessary to bridge the price difference between RFNBOs and advanced biofuels. As the price difference evolves over time, i.e. RFNBOs prices go down, the value of the multiplier also decreases over time from 1.6 to 1.2. By 2045, as RFNBO prices become aligned with advanced biofuel prices, the multiplier value is 1. The reduction in the CO2 intensity of fuels in Policy Option A2 is designed to achieve the same CO2 emissions reductions in the air transport sector over time as in Policy Option A1. Monitoring, reporting and verification of SAF supply is the same as under PO A1, with the exception that fuel suppliers are required to enter into the Union Database information on the CO_2 intensity of the SAF supplied.

5.3.3. *Policy Option B1: Obligation on the demand side (intra and extra-EU scope)*

This policy option consists of imposing an obligation on airlines to use a minimum share of SAF (expressed in volume terms)[117] as part of their total jet fuel use on intra-EU flights and flights from any EU airport to an extra-EU airport. This minimum share of SAF corresponds to the trajectory of the SAF ramp up as explained in section 1.3 and it is the same as that of Policy Option A1. An airline is not strictly required to use SAF on each flight as long as it can demonstrate that it has used the minimum share of SAF on average over the course of each reporting period of one year. As some airlines may not have physical access to SAF at the airports where they focus their operations, a transaction system allows them to purchase SAF and claim their use even if they do not use it physically, provided that it is used elsewhere in the EU aviation system. Such a system would not require any additional IT structure or services (it would work under the EU ETS) and would represent a very limited number of transactions by airlines on a yearly basis, hence negligible administrative costs. See section 5.4.4 for more details on the functioning of this system. A sub-mandate applies to RFNBOs as of 2030, meaning that airlines are required to use a minimum share of RFNBOs as part of their total jet fuel consumption over the course of a year. Monitoring, reporting and verification of SAF use is ensured through the dedicated mechanisms under the EU ETS Monitoring and Reporting Regulation[118], meaning that airlines operating intra-EU flights report SAF use within their individual emissions reports Airlines operating extra-EU flights report their SAF use under their emission reports as established in CORSIA rules[119]. An existing European organisation (e.g. Eurocontrol) is required to compile the information contained in the EU ETS and CORSIA emission reports regarding SAF use, and reports to the Commission on the compliance of individual airlines with their SAF use obligation. Penalties imposed on airlines in case of non-compliance are determined at EU level, reviewed on a yearly basis if needed, and enforced at national level. Funds collected from penalties are injected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

[116] The multiplier applies to the formula calculating the CO_2 intensity reduction, and does not apply to the actual emissions savings. This avoids the flaws of a system where a multiplier would lower the amount of emissions savings achieved.

[117] Both POs B1 and B2 are designed with a volume-based approach because airlines, to the difference of fuel suppliers, have less control over the CO2 intensity of the fuel produced and introduced in the system. Imposing an obligation on airlines to meet a CO2 intensity reduction over their total jet fuel use would reduce the chances of successfully meeting the obligation, since airlines traditionally purchase, monitor and record fuel use in volume terms. While CORSIA uses a GHG approach to determine the benefits to be granted from the use of SAF, the CORSIA system for SAF does not consist of an obligation, but rather an incentive. It is worth recalling that all POs (except PO B2 for reasons related to its scope) are designed with the same climate ambition. The choice of the volume or GHG based approach does not determine the climate ambition of the PO.

[118] C/2018/8588, amended by C/2020/8769 with specific provisions applying to biofuels (article 54).

[119] ICAO SARPs – Annex 16 Volume IV – Chapter 2. Monitoring, reporting and verification of aeroplane operator annual CO2 emissions.

5.3.4. *Policy Option B2: Obligation on the demand side (intra-EU scope)*

Same as PO B1, with the exception that the scope is reduced to cover only intra-EU flights. This means that an obligation is imposed on airlines to use a minimum share of SAF (expressed in volume terms)[120], as part of their total jet fuel consumption on intra-EU flights only. Airlines operating such flights are not expected to compensate for the reduced scope, meaning that they are required to use the same minimum share of SAF as in PO B1 but only applied to the total jet fuel used on intra-EU flights. As a result, PO B2 achieves lower emissions reductions from intra- and extra-EU air transport than all other POs[121]. Monitoring, reporting and verification of SAF use by airlines is ensured through the dedicated mechanisms under the EU ETS Monitoring and Reporting Regulation, meaning that airlines operating intra-EU flights report SAF use within their individual emissions reports. An existing European organisation (e.g. Eurocontrol) is required to compile the information contained in the EU ETS emission reports regarding SAF use, and reports to the Commission on the compliance of individual airlines with their SAF use obligation.

5.3.5. *Policy Option C1: Obligation on supply and uplift (volume-based approach)*

Fuel suppliers are obliged to supply physically a minimum share of SAF (expressed in volume terms) at all EU airports at all times, post-2035 (following a transition period). Certain categories of airports, such as small airports could be exempted. This should be done by setting a threshold e.g. on the volume of traffic per airport[122]. This means that every litre of jet fuel supplied to airports must be blended with at least a minimum share of SAF. Airlines (EU and non-EU) operating on intra-EU and extra-EU routes taking off from airports located on EU territory have no alternative than to use SAF-blended jet fuel. This minimum share of SAF to be supplied corresponds to the trajectory of the SAF market ramp up as explained in section 1.3 and is the same as in PO A1 and PO B1. A specific supply sub-mandate applies to RFNBOs as of 2030; its level is the same as in PO A1 and PO B1. A system of SAF transactions for accounting purposes is established to allow fuel suppliers to meet their obligation in a more cost-effective way. This system is only in place during the transition period, i.e. between 2025 and 2035 since beyond 2035 all fuel suppliers are required to distribute only SAF-blended jet fuel at all airports. Hence, during this period there is no possibility for suppliers to supply fossil jet fuel. Such a system could be set out under the present initiative. Section 5.4.4 contains detailed information on the nature and functioning of this system.

Monitoring, reporting and verification of the fuel supply obligation is ensured through the dedicated mechanisms under RED II, i.e. the Union Database already established under RED II Article 28. An existing EU agency (e.g. European Aviation Safety Agency), is required to compile the information provided on SAF supply under the Union Database and reports to the Commission on the compliance of each fuel supplier with their supply obligation.

Monitoring, reporting and verification of SAF use by airlines is ensured through the dedicated mechanisms under the EU ETS Monitoring and Reporting Regulation, meaning that airlines operating intra-EU flights report SAF use within their individual emissions reports. An existing European organisation (e.g. Eurocontrol) is already required today to compile the information contained in the EU ETS emission reports regarding SAF use, and reports to the Commission on the compliance of individual airlines with their SAF use obligation. The jet fuel uplift obligation applicable to all airlines departing from EU airports will be monitored through a direct reporting by all airlines to an existing European organisation or EU agency (e.g. Eurocontrol). The information on jet fuel uplift at flight level per airline will be processed by this agency or organisation to identify cases of fuel tankering and reported to the Commission.

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120 Same explanation as for PO B1.

121 At EU level, considering that energy use for intra-EU flights represent only about one third of the total aviation fuel use, post-2030 it would not be possible to achieve the same level of emissions savings as in PO B1 even if considering 100% SAF in the intra-EU fuel mix.

122 For instance, setting the threshold at 0.5 million passengers per year means that around 98% of passenger traffic would be captured in the scope. An analogous threshold could be set to cover airports where the vast majority of air cargo traffic takes place.

Penalties imposed on fuel suppliers in case of non-compliance are determined at EU level, reviewed yearly if needed, and applied at national level. Funds collected from penalties are reinjected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

In order to allow for a more cost-effective SAF supply in the first years of the supply obligation, a two-stage transition period applies from 2025 to 2035.

- From 2025 to 2030, fuel suppliers are required to meet the ramp up target and can supply EU airports with jet fuel containing SAF in the range 0% - 50% (which corresponds to the maximum limit for certified SAF blends). This means that fuel suppliers are not required to distribute SAF at all airports. Nevertheless, they are individually required to meet the overall ramp up target over the course of a one year reporting period.
- From 2030 to 2035, fuel suppliers are required to meet the ramp up target overall (i.e. 5% in 2030 and 20% in 2035) but must all supply EU airports with jet fuel containing SAF in the range 2% - 50%[123]. This means that every litre of jet fuel supplied to all airports must be blended with at least 2% of SAF. Fuel suppliers are required to supply overall 0.7% of RFNBOs from 2030, and every litre of jet fuel supplied at airports must contain RFNBOs in the range 0.3%[124] - 50%.

Level playing field (anti-tankering) safeguard: All airlines (EU and non-EU) departing from EU airports are obliged to uplift jet fuel prior to departure. The amount of jet fuel uplifted must correspond to the volume of jet fuel necessary to operate the planned flight (including the fuel safety margins), regardless of the destination. All airlines are required to report their jet fuel uptake to a European organisation which will be in charge of detecting and reporting cases of obvious fuel tankering on a yearly basis to the Commission (e.g. Eurocontrol). It is not strictly necessary to request reporting on a per-flight basis. Indeed, this measure can be just as efficient if the fuel uplift is monitored over the course of a year for all flights departing from a given EU airport. This means that an airline would be required to ensure that its total jet fuel uplift at a given EU airport corresponds to the cumulative amount of fuel necessary to operate all of its flights departing from that airport. A degree of flexibility could be relevant to cater for airlines' operational constraints. For instance, the measure would achieve its objective if airlines were to demonstrate that they uplifted at least 90% of the fuel required to operate all of their flights departing from a given airport. Penalties imposed on airlines in case of non-compliance would be determined at EU level, reviewed on a yearly basis if needed, and enforced at national level. Funds collected from penalties are injected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

This measure has a double purpose. First, it allows to preserve a level playing field for all flights departing from EU airports, including extra-EU flights. Indeed, as all airlines (regardless of whether they are established in the EU or not) will be required to uplift the jet fuel available at EU airports, higher jet fuel costs will apply to all. This reduces the possibility of competitive disadvantage for EU airlines and for EU hub airports. Section 6.2.8 provides details on the level playing field (anti-tankering) safeguard. Secondly, this measure aims to prevent the risk of increased fuel tankering as a result of higher fuel costs for airlines at EU airports over time. While the risks of additional tankering is expected to be low in the early stages of the obligation (see section 6.2.8), this measure should be implemented already from 2025 as it cannot be excluded that market prices for jet fuel and SAF fluctuate to a point that could make fuel tankering economically interesting. Moreover, the prevention of tankering brings immediate benefits by removing avoidable emissions caused by the additional fuel carried, regardless of the reasons airlines may have for tankering. A study[125] conducted by the International

[123] The choice of 2% as a minimum of SAF to be supplied at all airports was retained as it is a reasonable, attainable target by 2030. It allows all suppliers to smoothly transition to a system where all airports must be supplied with SAF-blended jet fuel, and gradually develop their supply chain for this purpose.

[124] The choice of 0.3% for RFNBOs follows the same logic. The ratio is the same between 0.3% and 0.7%, as it is between 2% and 5%.

[125] https://theicct.org/publications/tankering-eu-SAF-mandate-apr2021

Council on Clean Transportation in 2021 concluded that additional tankering stemming from the SAF blending mandate could result in a 22% lower SAF uptake by airlines by 2035. In turn, this could reduce the CO_2 benefits of the initiative by a quarter by 2035. Mitigation measures identified in the study include defining and prohibiting fuel tankering on flights departing from EU airports.

5.3.6. *Policy Option C2: Obligation on supply and uplift (CO_2 intensity reduction approach)*

Same as PO C1, with the exception of the target setting. The obligation imposes on fuel suppliers a minimum reduction of the CO_2 intensity of the overall jet fuel supplied. This PO aims to take a technology-neutral approach by using the CO_2 intensity reduction-based obligation. For consistency with the technology-neutral approach, this PO does not set a specific sub-mandate on RFNBOs. An incentive is however chosen, i.e. a multiplier applying to RFNBOs, designed in a way to bridge the production costs between RFNBOs and advanced biofuels. The value of this multiplier decreases over time, as the cost efficiency of RFNBOs improve. Its value is 1.6 and 1.2 respectively in 2030 and 2040. From 2045, its value is 1. The values of the multipliers are tailored to provide a boost to RFNBOs, and correspond to the value necessary to bridge the price difference between RFNBOs and advanced biofuels. As the price difference evolves over time, i.e. RFNBOs prices go down, the value of the multiplier also decreases over time from 1.6 to 1.2. By 2045, as RFNBO prices become aligned with advanced biofuel prices, the multiplier value is 1.

The monitoring, reporting and verification of SAF supply and use are the same as in PO C1, with the exception that fuel suppliers and airlines are required to report information on the CO_2 intensity of the SAF supplied/used, respectively into the Union Database established under RED II and EU ETS emissions reports. The reporting, monitoring and verification of the jet fuel uplift is identical to that of PO C1.

5.4. Common elements for all policy options

5.4.1. *Types of SAF supported and sustainability requirements*

Under all policy options described in section 5.3, eligible SAF is restricted to the following types of **ASTM-certified drop-in fuels**, where **compliance with the RED II sustainability framework**[126] can be demonstrated:

- "Biofuels" produced from feedstock listed in Part B of Annex IX, in the meaning of Article 2(33) of the Renewable Energy Directive.
- "Advanced biofuels" in the meaning of Article 2(34) of the Renewable Energy Directive (Annex IX Part A).
- "Renewable fuels of non-biological origin" (RFNBOs), in the meaning of Article 2(36) of the recast Renewable Energy Directive. For this initiative, the synthetic liquid fuels are relevant[127].

The selection of the above three SAF categories to be supported under the present initiative is a clear policy choice based on the following five criteria: sustainability, market readiness, expected feedstock availability, production costs and regulatory fitness. From this analysis, it derives that Part B biofuels, advanced biofuels and RFNBOs present overall the highest potential to reduce aviation emissions, for their ability to be gradually deployed in aviation already in the short- and medium-term, at reasonable costs and with sufficient feedstock availability. Crop based biofuels are capped under RED II and present limited decarbonisation potential when considering their indirect land use effects; they are thus not considered in this impact assessment. Hydrogen and electricity have the potential to bring important climate benefits, but significant

[126] Sustainability and greenhouse gas saving criteria set out in Article 29 of recast Renewable Energy Directive as well as GHG emission savings requirements for RFNBOs. Biofuels and advanced biofuels produced in new installations are required to achieve 65% savings and RFNBOS are required to achieve at least 70% savings. Actual emission savings are typically higher.

[127] As per Article 2(36) of the Renewable Energy Directive, RFNBOs can also be gaseous fuels.

additional research and development must continue in the coming decades and major technological changes are needed for aircraft engines and fuelling infrastructure. Therefore at this stage, **it is too early to consider regulatory action on fuel technologies such as hydrogen or electricity** as primary fuels for aircraft. Indeed, these are expected to reach the market in the coming decades and play a role at market scale in commercial aviation in the long-term.

5.4.2. *SAF blending mandate*

All POs consider different designs to establish a SAF blending mandate. It should be noted that a blending mandate sets an obligation for economic operators (fuel suppliers or airlines) to integrate SAF in their fuel supply or use. The SAF obligation alters the jet fuel mix, which de facto becomes SAF-blended jet fuel. In particular in POs where all EU airports are supplied with only SAF-blended jet fuel (i.e. POs A1, A2, and C1, C2 beyond the transition phase), the consideration of a price gap between SAF and fossil jet fuel is no longer relevant, as fossil jet fuel is no longer available. The price of jet fuel becomes the price of SAF-blended jet fuel, and reflects the weighted participation of different types of fuel (SAF, fossil) in the blend. The price gap between SAF and fossil jet fuel is no longer a factor determining the economic choices of airlines when purchasing jet fuel. It should be noted that it is still desirable for SAF prices to decrease over time. Indeed, this limits the costs of the jet fuel mix to be borne by airlines. However, the elimination of the price gap is no longer a sine qua non condition for SAF uptake.

5.4.3. *SAF ramp-up trajectory*

For POs A1, B1, B2 and C1, the mandatory shares of SAF to be supplied (A1 and C1) or used (B1 and B2) with respect to total jet fuel supply/use respectively in a given reporting period is shown in the following table. For policy option B2, where the obligation applies only for intra-EU flights, the figures in the table below apply, meaning that airlines are obliged to use the below SAF shares as part of their total jet fuel consumption on intra-EU flights.

As explained in section 1.3, the ‘central’ SAF ramp-up trajectory has been based on the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy while considering a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy. It has been derived in a way that enables kick starting the scale-up of sustainable aviation fuels from 2025 onwards and their large scale deployment by 2050, while ensuring the consistency with the required overall greenhouse gas emissions reductions by 2030 and 2050, preserving the competitiveness of the sector, promoting innovation, and ensuring feedstock availability for renewable and low carbon fuels in all energy and transport sectors in the transition towards a climate neutral economy. An update of the pathway/scenario for the purpose of the ‘Fit for 55’ package focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy, while also reflecting the COVID-19 pandemic, the National Energy and Climate Plans and refining the policy design of the initiatives, confirms that air transport effectively contributes to the EU climate goals while considering the SAF ramp-up trajectory in the table below.

The impact of considering different SAF ramp-up scenarios would be as follows.

A lower SAF ramp-up by 2030 require airlines to surrender more emission allowances as aviation CO_2 emissions are covered by the EU Emissions Trading System (EU ETS). However, considering the limited share of aviation CO_2 emissions in the total stock, the effect on the price of ETS allowances is expected to be low by 2030. This would not allow intensifying the efforts of the aviation sector to reduce its emissions by 2030. At the same time, with a lower ramp-up by 2030, the build-up of SAF capacities could be delayed, due to path dependency effects, diverting advanced biofuels and RFNBOs towards the road transport sector, where more promising options (like for example large scale electrification) are available. Post-2030, a steeper trajectory for the reduction in the air transport emissions would be needed to contribute towards EU climate neutral economy by 2050. This would require a steep build-up of SAF production capacities, starting from a low base and under a limited time horizon, which may not be feasible. It may also require substantially higher effort when approaching 2050. The latter could result in steep reductions in air transport activity, with negative consequences on the jobs in the air transport industry, connectivity, as well as growth of businesses and regions.

A higher SAF ramp-up by 2030 would push to some extent the price of the EU ETS allowances downwards and would require less emissions reduction efforts in other sectors. Yet, a higher SAF ramp-up by 2030 would lead to higher jet fuel costs for airlines, increase in the ticket prices for the consumers than in the central trajectory, with further reduction of air transport activity and possible associated effects on air connectivity. On the other hand, more options for emissions reduction would be available in other sectors at lower costs. At the same time, some advanced biofuels would still be required in the road transport sector by 2030 considering that the electrification of the sector takes time due to the gradual replacement of the vehicle fleet. The higher SAF ramp-up would intensify the competition for biomass feedstock with other transport and energy sectors, pushing the feedstock prices further up. A faster ramp-up could also mean that fuel suppliers have to resort to more imports of feedstock from third countries. It would also mean higher needs in renewable electricity for the production of RFNBOs, which would increase the competition with other sectors for access to such electricity (see section 6.1.2). A higher ramp up would mean a need to for increased production capacity compared to the central scenario, and thus an increase in investment needs (see section 6.2.5).

Overall, as explained in section 1.3, a range of 4 to 8% for the share of SAF in the jet fuel mix is feasible by 2030, while keeping in mind the considerations above. The possibilities of lower or higher SAF ramp-up post-2030 are more limited while ensuring the consistency with the required overall greenhouse gas emissions reductions by 2050, preserving the competitiveness of the sector, promoting innovation, and ensuring feedstock availability for renewable and low carbon fuels in all energy and transport sectors in the transition towards a climate neutral economy. This assessment takes into account the current knowledge related to the possible evolution of technology costs and feedstock costs. If higher decrease in these costs would materialise in the future, higher SAF ramp-up could be possible post-2030. On the other hand, lower ramp-up post-2030 may require substantially higher effort when approaching 2050, with the associated risks explained above.

Table 3 – Central SAF ramp-up trajectory[128] (volume based approach).

Total shares in the fuel mix (in %)	2025	2030	2035	2040	2045	2050
SAF ramp up out of which:	**2**	**5**	**20**	**32**	**38**	**63**
Biofuels (including Part A and Part B biofuels)	2	4.3	15	24	27	35
Specific sub-mandate on RFNBOs[129]	**-**	**0.7**	**5**	**8**	**11**	**28**

For POs A2 and C2 with a **CO2 intensity reduction-based** obligation, fuel suppliers are required to supply jet fuel that achieves a minimum CO2 intensity reduction compared to the baseline for fossil fuel[130] over the course of a reporting period[131]. All CO2 intensity reductions achieved with the use of SAF that are compliant

[128] Where SAF shares in the jet fuel mix indicate values superior to 50%, this implies that airlines would be required to uplift jet fuel blended at a higher ratio than the currently certified maximum blending ratio of 50%. As such values are reached beyond 2040, the assumption is made that the maximum blending ratio imposed by current certification will be lifted by then.

[129] The choice of 2030 as starting date of the sub-mandate for RFNBOs is justified by the fact that in the baseline scenario, this technology only appears in 2050. The sub-mandate allows to bring this technology to the market 20 years earlier than under the baseline scenario.

[130] The baseline for fossil fuel is 94gCO_2e/MJ, as defined in RED II.

[131] No policy option includes an obligation on airlines expressed in terms of jet fuel CO2 emissions reduction because airlines have limited control on the CO2 intensity of the SAF that is placed on the market, as this depends on the fuel suppliers. Hence, whereas the CO2 intensity reduction approach can influence the economic behaviour of fuel suppliers when applied on the supply side, the same approach would have limited effects on the demand side.

with the sustainability requirements (see section 5.4.1) count towards the obligation. This approach is currently used under CORSIA and the FQD.

The target setting and the approach chosen (volumes or CO_2 intensity reduction) can influence the way the market will react to the obligation, in terms of resulting fuel mix and costs.

The following table shows the mandatory reduction in the well-to-wing jet fuel CO_2 intensity that fuel suppliers are required to comply with under options A2 and C2[132].

Table 4 - SAF ramp-up trajectory (CO2 intensity reduction approach).

WTW jet fuel CO2 intensity reduction (in %)	2030	2040	2050
Resulting from the use of SAF	- 5%	- 29%	-59%

5.4.4. *SAF transactions for accounting purposes*

In the early years of the SAF obligation, it is expected that fuel suppliers may not all be in the same position to meet the obligation. While some may be able to supply more than required SAF-blended fuel - due to e.g. scaled-up production capacity, well established commercial partnerships and fit for purpose logistics, others may fall short of meeting the obligation. This could be the case if e.g. meeting the last 10% of the SAF supply target would mean significant additional costs for e.g. expanding production capacity. In such cases, a system of SAF transactions for accounting purposes could be useful (but not indispensable) to allow fuel suppliers to meet their targets in a more cost-effective way. Over achievers (suppliers with an excess of SAF supplied) could allow under-achievers to account for part of their over-supply so as to allow them to meet their obligation. Legal provisions establishing such a system could be set up under the present initiative. The functioning of this system would be the following. By the end of each reporting year, fuel suppliers (over-achiever) would be able to inform the existing EU agency (e.g. EASA) in charge of SAF monitoring at EU level and request transactions of SAF volumes to another supplier (under-achiever). Such transactions would be documented and reflected in the SAF monitoring process of the EU agency. The monitoring process should ensure that transactions between suppliers are traceable and verifiable. The EU agency in charge of the monitoring at EU level would only deal with reflecting the transaction for SAF volumes/CO_2 intensity accounting purposes, verifying it and recording it. The financial transactions between fuel suppliers for the amount of SAF transacted is out of the scope of this work. This system represents flexibility for the fuel industry to meet supply targets. It is only relevant for policy designs where suppliers have flexibility to supply SAF where it is the most cost effective to do so, i.e. in POs C1 and C2 during the transition phase (2025-2035). Indeed, in the case of POs A1 and A2 and in the case of POs C1 and C2 beyond 2035, suppliers are required to supply only SAF-blended jet fuel at all airports. In this case, it is not desirable to allow SAF transactions, since this would jeopardise the physical supply of minimum shares of SAF to all EU airports. Indeed, one could imagine that a given fuel supplier would continue supplying fossil jet fuel at certain airports, and fulfil its obligation by 'acquiring' SAF (for accounting purposes) from other over-achieving suppliers. This would not be compliant with the requirement that SAF suppliers shall supply all airports with a minimum SAF share. Therefore such a system is compatible only with POs C1 and C2 for the first and second transition periods.

A system of SAF transactions could also be relevant, in particular for POs B1 and B2 where airlines have to meet their SAF use obligation. This needs to come with the appropriate safeguards to avoid double counting. Such transactions for airlines could be set up under the auspices of the EU ETS and would work in the same way as the trading of allowances. Such a transaction system between airlines would only be relevant for POs B1 and B2, and is <u>not relevant</u> for POs A1, A2, C1 and C2, as airlines are not subject to SAF obligations.

[132] The well-to-wing jet fuel CO2 intensity reduction reported here does not include the multiplier, to show the actual reduction in the CO2 intensity of fuels.

As shown in Table 2, section 5.3, there is no policy option where the transaction system applies at the same time to airlines and fuel suppliers. It applies only to airlines in POs B1 and B2, and only to suppliers in POs C1 and C2. It should be noted that such a system does not require additional new IT support or structure, as it relies on existing schemes, i.e. the EU ETS (POs B1 and B2) or the monitoring process of the EU agency (POs C1 and C2), for which administrative costs are already accounted (see sections 6.2.9 and Annex 3). It can be operationalised through the legal text of the current initiative or in the case of POs B1 and B2 under the ETS. It does not strictly need to be operational as from entry into force of the present initiative, but only by 2025, when the SAF obligation begins.

5.5. How do policy options differ?

5.5.1. *Technology-neutrality, volume-based and CO2 intensity reduction-based approaches*

This initiative aims to operate a gradual transition in the fuel mix of aviation. Concretely, this means replacing a fuel technology (conventional fossil kerosene) that leads to high emissions, with fuel technologies (SAF) that achieve much lower emissions on a lifecycle basis. Therefore, a choice is made between different technologies, based on their ability to deliver the expected climate benefits in a cost-effective way. **Not all fuel technologies can be treated in the exact same way** simply because certain technologies (advanced biofuels, Part B biofuels, RFNBOs – synthetic fuels) have much higher potential to attain the objectives in the short term, as the situation requires. Some (crop-based biofuels) have too limited decarbonisation potential and others (hydrogen and electricity) have potential only in the longer-term and still require significant research and development. Furthermore, the RED II framework promotes certain promising technologies (advanced biofuels) to count more towards meeting the target via multipliers[133], or incentivises them with specific sub-mandates[134].

Because of the facts explained above, it is difficult to design perfectly technology-neutral policy options. The proposed policy options in section 5.3 take the following approaches for the SAF target setting:

- **Volume-based approach.** Policy options A1, B1, B2, C1 contain a volume-based obligation and a sub-mandate on RFNBOs. The **volume-based approach is moderately technology-neutral** and it is generally associated with technology choices. It proves efficient to support the scale up of SAF. Indeed, it de-risks investments by providing certainty about the mandated amounts. It is also easier to implement as supplied amounts can be measured and thus easily verified. On the contrary, emissions savings can only be estimated based on a complex life cycle assessment usually conducted by the fuel producer. The sub-mandate on RFNBOs is justified by the high potential of this fuel technology to deliver important climate benefits, the high price difference in comparison to conventional jet fuels and other SAF options, and the need for a swift scale up of production capacity that facilitates the reduction of technology costs.
- **CO_2 intensity reduction-based approach.** Policy options A2 and C2 contain a CO2 intensity reduction-based obligation and a multiplier on RFNBOs. The **CO_2 intensity reduction-based target is generally recognised as technology-neutral** because it does not impose the scaling up of certain technologies to determined levels, but lets the market react based on the CO_2 performance of each technology. SAF can count towards meeting the target to the extent of the CO_2 intensity reduction they achieve. To respect the technology-neutrality dimension of this approach, it was preferred to opt for a multiplier on RFNBOs, to help reduce the gap of cost-effectiveness between RFNBOs and advanced biofuels. A multiplier is a lighter form of support, compared to a sub-mandate. It provides less certainty

133 Pursuant to the recast Renewable Energy Directive - Article 27(2a), the share of biofuels and biogas for transport produced from the feedstock listed in Annex IX may be considered to be twice its energy content

134 Pursuant to the recast Renewable Energy Directive - Article 25(1), the contribution of advanced biofuels and biogas produced from the feedstock listed in Part A of Annex IX as a share of final consumption of energy in the transport sector shall be at least 0.2 % in 2022, at least 1 % in 2025 and at least 3.5 % in 2030.

that innovative types of fuel are developed at commercial scale. Claims about achieved CO_2 emission reduction may also be more difficult to verify. The value of this multiplier decreases over time, as the cost efficiency of RFNBOs improve. The values of the multipliers are tailored to provide a boost to RFNBOs, and correspond to the value necessary to bridge the price difference between RFNBOs and advanced biofuels. As the price difference evolves over time, i.e. RFNBOs prices go down, hence the value of the multiplier also decreases over time from 1.6 to 1.2. By 2045, as RFNBO prices become aligned with advanced biofuel prices, the multiplier value is 1.

It is essential to highlight that under the present initiative, all policy options (except PO B2)[135] achieve the same reduction of CO2 emissions overall. Therefore, **the choice of approach (volume or CO2 intensity) will not determine the level of climate ambition of this initiative**. Rather, it will determine how the market will make choices and orient SAF production towards scaling up the different SAF technologies.

5.6. Options discarded at an early stage

5.6.1. *Obligation on airlines, reduced scope, higher SAF blend ratios*

This option consists of the same as PO B2, with the exception that the SAF blend ratios are increased to compensate for the reduction of scope (only intra-EEA) and achieve the same climate ambition as PO B1. This means that airlines operating intra-EEA traffic are required to uptake around 3 times as much SAF as under PO B2. This is explained because jet fuel used for intra-EEA traffic amounts to around one third of the total jet fuel used for intra and extra-EU flights departing from EU airports. The remaining two-thirds are used for extra-EU flights departing from EU airports. This means that airlines would be required to use already 100% SAF by 2040. Post-2040, even with 100% SAF they will not be able to deliver on the same climate ambition as PO B1. For this reason, this option has not been retained.

5.6.2. *Voluntary agreements*

This option consists of relying on the evolution of the market, with the expectation that airlines and the fuel industry will increasingly engage in offtake agreements. This option was initially suggested by certain market actors. However, it appears from the research conducted in the context of this impact assessment and other stakeholders' views that the efficiency of this option would be limited, as there are no reasonable grounds to believe that market forces alone would achieve the desired level of SAF production and uptake by 2050, and therefore, contribute effectively towards meeting the EU climate objectives.

6. WHAT ARE THE IMPACTS OF THE POLICY OPTIONS?

6.1. Environmental impacts

6.1.1. *Impacts on the aviation fuel mix*

All POs lead to a significant increase of the share of SAF in the aviation fuel mix driven by the fuel obligations, gradually starting from 2025. By 2030, under all POs except for PO B2, SAF accounts for 5% (i.e. 2.3Mtoe of SAF) of total jet fuel consumption at EU airports (i.e. an increase of 4.8 percentage points compared to the baseline). In PO B2 SAF accounts for only 1.6% (i.e. 0.7Mtoe of SAF) of total jet fuel demand (i.e. an increase of 1.4 percentage points compared to the baseline). This is explained by the fact that the SAF obligation under PO B2 applies to intra-EU traffic only[136]. **In the early years of the SAF obligation, advanced biofuels (ATJ route) and Part B biofuels (HEFA route) are the main types of SAF fulfilling the**

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[135] PO B2 achieves lower emissions reductions because the scope is limited to intra-EU.

[136] This difference in scope between PO B2 and the other options is an important driver of the differences in impacts. The energy use in intra-EU air transport represents only around one third of the total air transport energy demand. For the sake of readability, the text does not repeat this.

obligation under all POs (except for PO B2), with respectively 1.8-1.9% and 1.6-1.7% and of jet fuel used. Imported biofuels account for a more limited share, projected at 0.9% of all jet fuel use. Under PO B2, only Part B biofuels and imported biofuels are used to meet the obligation. The predominant use of advanced biofuels (ATJ route) and Part B biofuels by 2030 is explained by the fact that advanced biofuels (Gas+FT route) emerge in 2035, 10 years later than the ATJ route[137]. RFNBOs would represent about 0.2 to 0.7% of the fuel mix in 2030 (0.2% in PO B2, 0.5% in PO A2, 0.6% in POs C2 and 0.7% in POs A1, B1 and C1). This highlights that **POs following a volume-based approach and a sub-mandate on RFNBOs** (POs A1, B1 and C1) **achieve higher RFNBOs supply/uptake** (except PO B2, for scope reasons). POs following a CO2 intensity reduction approach, including a multiplier on RFNBOs (POs A2 and C2), achieve somewhat lower RFNBOs uptake. This trend is confirmed over time. The multiplier provides an incentive for the uptake of RFNBOs under the CO2 intensity reduction approach; in its absence the uptake of RFNBOs would be lower.

Table 5 - Aviation fuel mix by production pathway in the policy options in 2030 and 2050.

Aviation fuel mix (in %)	PO A1		PO A2		PO B1		PO B2		PO C1		PO C2	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
Biokerosene	4.3%	34.8%	4.5%	38.7%	4.3%	34.8%	1.4%	10.9%	4.3%	34.8%	4.5%	38.7%
HEFA route	1.6%	4.0%	1.7%	4.5%	1.6%	4.0%	1.1%	2.5%	1.6%	4.0%	1.7%	4.5%
Gas+FT route	0.0%	12.9%	0.0%	14.4%	0.0%	12.9%	0.0%	0.3%	0.0%	12.9%	0.0%	14.4%
ATJ route	1.8%	12.9%	1.9%	14.3%	1.8%	12.9%	0.0%	4.8%	1.8%	12.9%	1.9%	14.3%
Imports	0.9%	5.0%	0.9%	5.6%	0.9%	5.0%	0.3%	3.3%	0.9%	5.0%	0.9%	5.6%
RFNBOs	0.7%	27.9%	0.5%	23.9%	0.7%	27.9%	0.2%	8.7%	0.7%	27.9%	0.6%	23.9%
Electricity	0.0%	0.5%	0.0%	0.5%	0.0%	0.5%	0.0%	0.5%	0.0%	0.5%	0.0%	0.5%
Kerosene	95.0%	36.8%	95.0%	36.8%	95.0%	36.8%	98.4%	79.9%	95.0%	36.8%	95.0%	36.8%

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling

Towards 2040 and 2050, as SAF take over a large part of the aviation fuel mix, the SAF mix becomes more diversified under all POs. By 2050, under all POs, SAF accounts for around 63% (i.e. 28-29Mtoe) of total jet fuel use (i.e. an increase of around 60 percentage points compared to the baseline), except for PO B2 where SAF accounts for only 20% of total jet fuel use at EU airports. **RFNBOs and advanced biofuels are the largest contributor to the aviation fuel mix under all POs (except for POB2) by 2050.** For POs with a volume based target including a sub-mandate on RFNBOs (A1, B1, and C1), RFNBOs account for 28% of the total jet fuel mix, i.e. 13Mtoe (except for PO B2 where a share of 9% is projected, explained by the intra-EU scope). Where SAF obligations are expressed in terms of CO2 intensity reduction (POs A2 and C2), RFNBOs account for 24% (i.e. 11Mtoe) of the total jet fuel mix. Thanks to technology development supported by the increase of the SAF ramp-up, advanced biofuels (Gas+FT route) reach commercial scale around 2035. The share of Gas+FT route and ATJ route is projected to be relatively similar by 2050, providing together 26-29% of the aviation fuel mix under all POs (except B2). As Gas+FT route biofuels, ATJ route biofuels and RFNBOs are deployed on large scale by 2050 and significantly contribute towards the fuels obligations, the share of **HEFA route biofuels and imported biofuels would be limited**, representing 2-5% and 3-6% of the aviation fuel mix respectively. By 2050, electricity use is projected to represent around 0.5% of the aviation fuel mix in all POs.

The aviation fuel mix differs across Member States depending on the flexibility allowed in the SAF supply. Under POs A1, A2 and B1, the fuel mix is estimated to be the same in each Member State. This is explained because fuel suppliers (in POs A1 and A2) are required to respectively supply and use the same minimum share of SAF at all EU airports, and because under POs B1 and B2, all airlines are required to use the same minimum share of SAF. For PO B2 the shares are the same for all Member States when considering the

137 While the production costs of these two routes become rather similar, the earlier deployment of the ATJ route is due to its technology maturity and availability that is enabled earlier in time by developments in ethanol production from lignocellulosic feedstocks, as opposed to biomass gasification and conversion of syngas to fuels.

intra-EU scope[138]. On the other hand, differences in the aviation fuel mix can be observed between EU airports and Member States under POs C1 and C2. This comes as a result of the transition period allowing for flexibility in the supply from 2025 to 2035. Section 6.2.2 explains the benefits of this flexibility in terms of logistics costs. Until the end of the transition period, the shares of SAF can be lower in some Member States that have low passenger traffic and low feedstock availability (e.g. CY, MT). It can be higher for Member States with the busiest airports and highest feedstock availability (e.g. FR, DE, IT). It is worth noting that **even with flexibility in the SAF supply by 2035, SAF is used in all Member States by 2025**. The details at Member State level are provided in Annex 4.

All POs result in a reduction of the fossil fuels use relative to the baseline. By 2030 the reduction is estimated at 3% relative to the baseline in PO B2 (i.e. 1.6Mtoe) and at around 7% in all other POs (i.e. 3.2Mtoe). By 2050 PO B2 would reduce the fossil fuels used in aviation by about 22% relative to the baseline (i.e. 11 Mtoe) and all other POs by around 65% (i.e. 31-32 Mtoe).

6.1.2. *Impact on feedstock and renewable electricity needs*

From 2025 to 2050, there is sufficient used cooking oil in the EU to ensure Part B biofuels production for aviation and other transport modes in all POs. The needs for used cooking oil to produce Part B biofuels for aviation increases steadily over time. By 2030, under POs A1, A2, B1, C1 and C2, the production of Part B biofuels for aviation requires 28% of the total available used cooking oil (UCO) in the EU[139]. The remaining 72% of EU's stocks of used cooking oil are consumed in other transport sectors such as road transport and maritime. **Towards 2040 and 2050, aviation would need more used cooking oil, while other sectors such as road transport would need it less due to the high potential for the electrification in the sector[140].** By 2040 and 2050, Part B biofuels for aviation would consume respectively up to 43% and 53% of the EU's total available used cooking oil, meaning that by 2040 and 2050, respectively 57% and 47% of the EU's UCO stocks will be available for biofuel production in other transport modes. This coincides with the large scale electrification of the road transport vehicle fleet, and the resulting decrease in demand for biofuels that will take place in the sector. Under PO B2, Part B biofuels would require around 19% and 33% of the available used cooking oil in the EU, respectively in 2030 and 2050.

This analysis considers that other types of Part B feedstock would remain entirely dedicated to biofuel production for other transport modes. It should be noted that animal fats are another important source of feedstock for Part B biofuels production, representing 25% of total Part B feedstock use for EU biofuel production in 2019[141]. For simplicity, this section considers that all animal fats will be used for biofuel production in other transport modes. Finally, the revision of RED II may lead to the enlargement of Annex IX Part B to other types of waste lipids, thereby allowing for even greater feedstock availability in the EU. **The potential displacement of biofuels from road to aviation is expected to be low.** With Part B feedstock contributing by 15% to EU27's road biofuel production[142], used cooking representing around 75% of Part B feedstock used for this production[143], and an anticipated 28% and 53% use of used cooking oil for SAF production respectively by 2030 and 2050, all POs of the present initiative would result in a potential displacement of biofuels from road to aviation of 3.2% and 5.9% by 2030 and 2050. This would be even lower under PO B2, i.e. 2.1% and 3.7%.

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138 When reporting the share of SAF in total aviation fuel mix at Member State level, the shares of intra- and extra-EU aviation also play a role thus leading to different shares by Member State.

139 The policy context of POs is established within the Climate Target Plan ambition, which means that significant quantities of bioenergy are demanded also by other transport modes (including international maritime) and energy sectors. The high demand context refers to POs A1, A2, B1, C1 and C2 while low demand context refers to PO B2.

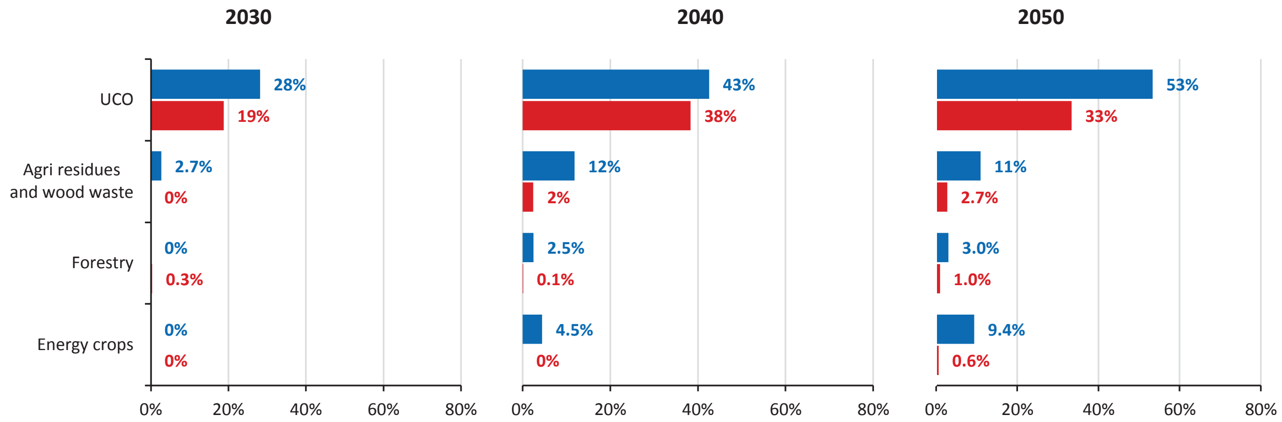
140 This conclusion is supported by the analysis underpinning the impact assessment accompanying the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy.

141 Source: Biofuels Annual – USDA 2020.

142 Biofuels Barometer - A study carried out by EurObserv'ER. – 2020.

143 Source: Biofuels Annual – USDA 2020.

Table 6- Share of the available feedstock in the EU used for SAF production. Blue: all POs except PO B2. Red: PO B2.



Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling
Note: UCO stands for used cooking oil. Solid biomass refers to feedstock included in Annex IX Part A.

The substantial production of advanced biofuels for aviation would rely on a diversity of feedstock sourced in the EU, and available stocks should be sufficient. The needs for solid biomass feedstock[144] to produce advanced biofuels for aviation increase steadily over time. By 2030, under POs A1, A2, B1, C1 and C2, the production of advanced biofuels for aviation requires 2.7% of the EU's total available potential of agricultural and wood waste. By 2040 and 2050, as advanced biofuels reach significant shares of the fuel mix, the demand for solid biomass increases. The supply of advanced feedstock diversifies over time with the use of forestry residues and energy crops, which limits the strain on specific supply chains. By 2050, advanced biofuels (ATJ and Gas+FT routes) require about 11% of the EU's available potential of agricultural residues and wood waste, 3.0% of the available potential of forestry products and residues, and 9.4% of the available potential of energy crops. Under PO B2, demand for solid biomass reaches 2.0% of the EU's total potential available agricultural and wood waste in 2040 and 2.7% in 2050. Forestry residues and energy crops also play a minor role between 2040 and 2050.

Table 7 - Feedstock consumption for biofuel production in 2030 and 2050.

Mtonnes	2030		2050	
	UCO	Solid biomass	UCO	Solid biomass
Baseline	0.05	0.02	0.69	0.43
Policy Option A1	1.10	5.52	2.8	62.5
Policy Option A2	1.14	5.72	3.1	69.8
Policy Option B1	1.10	5.52	2.8	62.4
Policy Option B2	0.59	0.00	1.4	7.6
Policy Option C1	1.10	5.53	2.8	62.5
Policy Option C2	1.14	5.72	3.1	69.8

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling.
Note: UCO stands for used cooking oil. Solid biomass refers to feedstock included in Annex IX Part A

While Part B feedstock will play a non-negligible role to bring (affordable) SAF to aviation in the first years, overall the largest share of SAF will be produced from Part A feedstock. Looking at the total feedstock volumes needs in the table above, under all POs, Part B feedstock such as used cooking oil represent around 17% of total SAF feedstock by 2030. PO B2 would fully rely on used cooking oil by 2030 but the level of feedstock used would be lower than in all other POs. The share of used cooking oil in the biomass feedstock consumption decreases significantly over time. By 2050 it would only represent about 4% of the total feedstock

[144] Solid biomass means feedstock included in Annex IX Part A and includes feedstock such as agricultural and forestry residues, wood waste, forestry products (e.g. round wood), annual and perennial energy crops.

consumed in aviation in POs A1, A2, B1, C1 and C2 and 16% in B2. By then, Part A feedstock account for around 84-96% of total feedstock needs under all POs.

Competition with other energy and transport sectors for access to feedstock will increase, but SAF production will require a limited share of feedstock with regards to total feedstock availability. The POs are fully consistent with the policy context where the EU must reach its climate targets of 55% emission reductions by 2030 and climate neutrality by 2050. This results in a **significant increase of the demand for bioenergy** from other energy and transport sectors, **by around 82% between 2015 and 2050** (from about 140 Mtoe to 255 Mtoe). This means higher competition between sectors of the economy for access to feedstock. On the supply side, the results show that there is abundance of EU-sourced available biomass to meet the demand increase. **SAF production in the EU is expected to require less than 10% of all biomass feedstock** used to meet bioenergy demand in a climate neutral context by 2050.

Energy needs for the production of Part B and advanced biofuels are relatively low. Bioenergy production requires energy inputs in several steps in the production process, from biomass collection, to transport, and conversion of biomass to bioenergy. The present analysis (using the PRIMES Biomass model) takes into account the energy requirements across the production chain. Accordingly, the production of all bioenergy commodities projected in the context of EU climate neutrality, requires around 36 Mtoe of electricity, liquid fuels and gas in 2050. This corresponds to less than 3% of the overall energy supply (of electricity, liquid fuel and gas) for the same year. **The share of energy inputs needed to produce Part B and advanced biofuels for aviation is less than 0.2% of the total energy supply in 2050**.**The production of RFNBOs is highly energy-intensive and drives an increase in the demand for renewable electricity in the EU.** RFNBOs require electricity that is 100% renewable to produce hydrogen as an intermediate product, before the production of synthetic kerosene. By 2030, the electricity demand for RFNBOs production represents between 0.04% to 0.13% of the EU's gross electricity generation or between 0.1% and 0.4% of the EU's renewable electricity generation. By 2050, the shares increase to 0.7-2.2% of the EU's gross electricity generation, or 1.8% to 5.5% of the EU's renewable electricity generation[145]. POs expressed with a volume-based target (A1, B1, C1) are slightly more demanding in terms of renewable electricity requirements than those expressed with a CO2-intensity reduction based target (POs A2 and C2). This is due to the lower supply of RFNBOs resulting from the CO2-intensity reduction based approach, even when accounting for the multiplier. Finally, electricity needs are the lowest in PO B2 which, by design, only applies the SAF obligation to intra-EU flights.

Table 8 - Share of renewable electricity generation used for the production of RFNBOs.

	2030	2050
Policy Option A1	0.4%	5.5%
Policy Option A2	0.3%	4.7%
Policy Option B1	0.4%	5.5%
Policy Option B2	0.1%	1.8%
Policy Option C1	0.4%	5.5%
Policy Option C2	0.3%	4.7%

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling.

6.1.3. *Impacts on CO2 emissions*

All POs lead to significant reductions[146] in EU27 CO2 emissions[147] in the aviation sector on the well-to-wing basis, compared to the baseline. The levels of reduction are similar between all POs by 2030 and 2050 by design, except PO B2 where the scope of the obligation covers only intra-EU flights. By 2030, CO2 emissions

[145] The relative shares are based on the MIX scenario of the impact assessment accompanying the 2030 Climate Target Plan which was quantified with the PRIMES energy systems model.

[146] Emissions savings achieved by specific SAF technologies are expressed relative to the RED II baseline for fossil fuel, i.e. 94gCO2e/MJ.

[147] Well-to-wing emissions: this take into account emissions over the entire life cycle of the jet fuel, from production to combustion.

are lower by up to 6.6% in all POs compared to the Baseline, except B2 where the reduction is limited to 3.3%. The impact of POs becomes even more evident in the years leading to 2050. By 2050, CO2 emissions in the aviation sector are lower by around 60-61% in all POs compared to the Baseline, except for B2 where the reduction is limited to around 17%. The fact that all POs except B2 achieve very similar high levels of CO2 reductions by 2030 and 2050, by the design of the POs, shows that similar level of climate ambition can be achieved regardless of the choice of the obligated party (fuel suppliers as in PO A1 or airlines as in PO B1). This also holds true for the choice of the target setting (volume-based target as in A1 or CO2 intensity reduction target as in A2). On the other hand, the level of climate ambition strongly differs depending on the scope chosen for the obligation (jet fuel used on all intra and extra-EU flights as in B1 or only intra-EU as in B2). At EU level, considering that energy use for intra-EU flights represent only about one third of the total aviation fuel use, post-2030 it would not be possible to achieve the same level of emissions savings even if considering 100% SAF in the intra-EU fuel mix.

Table 9 - Changes in the tank to wing and well to wing CO2 emissions in POs relative to the baseline.

Air transport CO2 emissions (% change to Baseline)	Baseline (Mt CO2)			PO A1			PO A2		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Tank to wing emissions	140	143	144	-6.8%	-34.1%	-65.3%	-6.8%	-33.9%	-65.2%
Well to wing emissions	183	187	189	-6.5%	-31.4%	-60.8%	-6.5%	-31.0%	-60.2%
Air transport CO2 emissions (% change to Baseline)	**Baseline (Mt CO2)**			**PO B1**			**PO B2**		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
Tank to wing emissions	140	143	144	-6.9%	-34.1%	-65.3%	-3.4%	-11.7%	-21.8%
Well to wing emissions	183	187	189	-6.6%	-31.4%	-60.9%	-3.3%	-10.1%	-17.4%
Air transport CO2 emissions (% change to Baseline)	**Baseline (Mt CO2)**			**PO C1**			**PO C2**		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
Tank to wing emissions	140	143	144	-6.8%	-34.1%	-65.3%	-6.8%	-33.9%	-65.2%
Well to wing emissions	183	187	189	-6.5%	-31.4%	-60.8%	-6.5%	-31.0%	-60.2%

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling.

On the tank to wing basis, the emissions reductions are projected to be slightly higher in the POs relative to the baseline, as shown in the table above, because by assumption biofuels are assigned a zero emission factor[148]. The 65% tank-to-wing CO_2 emissions reductions relative to the baseline in 2050, projected to be achieved in all POs except for PO B2, translate in reductions of 58% in CO_2 emissions by 2050 compared to 2015 and 24% emissions reductions relative to 1990. As explained in section 2.1.1, this is fully consistent with the climate neutrality objective for 2050.

All POs achieve emissions reductions for the transport sector by 2030 and 2050. Total transport emissions (including international shipping) would reduce by 0.6% in 2030 relative to the baseline in PO B2 and by 1.1-1.2% in all other POs. This is mainly driven by the SAF uptake in the aviation sector but also by the limited reduction in the transport activity relative to the baseline, driven by the higher air ticket prices. By 2050 PO B2 would result in around 4% reduction in transport emissions relative to the baseline and all the other POs in about 13-14% reduction. In relative terms the reduction is relatively similar when considering the tank to wheel and the well to wheel emissions.

6.1.4. *Impacts on air pollutant emissions and non-CO2 emissions*

The introduction of increasing shares of SAF in the aviation fuel mix leads to somewhat higher ticket prices and a subsequent reduction of air transport activity compared to the baseline (see section 6.2). As a result, some **reductions in air pollutant emissions (CO, NOx and PM)[149] would take place in the aviation sector for all POs by 2030 and 2050**. By 2030, air pollutant emissions would be 3.3 to 3.5% lower compared to the baseline

[148] Commission Regulation (EU) No 601/2012.
[149] The air pollutants considered include: CO (carbon monoxide), NOx (nitrogen oxide) and PM2.5 (particulate matter emissions).

in all POs. For 2050, PO B2 would result in about 7% reduction in air pollutant emissions relative to the baseline and all other POs in about 9-10% reduction. In addition to the air pollutant emissions reductions resulting from lower air transport activity, the substitution of fossil jet fuel with SAF may also deliver non-CO2 benefits under all POs. Indeed, it is considered that the introduction of increasing shares of SAF in aviation could lead to reductions of other non-CO_2 emissions such as non-volatile particulate matter (nvPM) or sulphate (SO4)[150]. See Annex X for more information on non-CO2 benefits from SAF use.

6.1.5. *Environmental costs of aviation*

The environmental costs of aviation are reduced significantly under all POs relative to the baseline. In the Baseline scenario, the present value of external costs due to CO2 emissions is estimated at EUR 330 billion for the period 2021-2050 (i.e. CO2 emissions from air transport multiplied by the price of CO2[151]). The introduction of the SAF mandates leads to a reduction in the order of EUR 86-87 billion in all POs relative to the baseline, with the exception of PO B2, in which external costs are lower by around EUR 30 billion.

6.2. Economic impacts

6.2.1. *Impacts on SAF prices and the cost of jet fuel blend*

SAF prices are derived drawing on relatively conservative assumptions, considering the uncertainty associated to their future developments. The cost structure is such that variable non-energy costs[152] of biofuels production are maintained within a range of 35% to 47% of total production costs (depending on the year and production pathway), which constitutes the second largest cost component for advanced biofuels and Part B biofuels, and the largest cost component in the case of Gas+FT route.

SAF prices projections are fully embedded in the 2030 Climate Target Plan policy context, where the EU economy is moving towards carbon neutrality by 2050. This leads to strong competition for biomass feedstock with other energy and transport sectors. Feedstock and renewable electricity are considered to be sourced predominantly in the EU, in order to support the reduction in energy dependence. This further contributes to driving feedstock prices upwards.

Prices for Part B biofuels (HEFA route) remain relatively stable over time and become lower than the projected conventional jet fuel prices by 2030 under all POs. They remain close to the current estimates (i.e. around EUR 1050 per tonne) under all POs (see *Figure 3*). They have limited scope for price reductions due to economies of scale[153], since the technology is mature and their capital costs are already low (i.e. around 4% of the production costs). Feedstock costs are projected to slightly increase over time, due to the competition with other sectors. As fossil jet fuel prices are projected to increase over time, linked to the projected evolution of the oil prices, Part B biofuels prices reach the break-even point and become more economically attractive by 2030. They are projected to be around 2% lower by 2030 (close to EUR 1005 per tonne) and 16% lower by 2050 (around EUR 1048 per tonne) relative to fossil jet fuels under all POs.

Prices for advanced biofuels (ATJ route) decrease significantly by 2035 relative to the current estimates under all POs. Post-2035 their prices follow an increasing trend, driven by the feedstock costs. The early emergence on the market of advanced biofuels (ATJ route) is a consequence of the mandatory SAF targets for 2030, for which Part B biofuels are no longer sufficient. Advanced biofuels (ATJ route) are therefore the next least expensive SAF type (EUR 2086 per tonne in 2030) that the supply industry turns to in all POs (except PO

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150 Updated analysis of the non-CO2 climate impacts of aviation and potential policy measures pursuant to the EU Emissions Trading System Directive Article 30(4). https://ec.europa.eu/clima/news/updated-analysis-non-co2-effects-aviation_en

151 CE Delft et al. (2019), Handbook on the external costs of transport.

152 Costs such as those of catalysts, enzymes, other utilities used in the conversion processes, as well as waste management.

153 Annex 16 provides details on how economies of scale are achieved for SAF technologies.

B2), since RFNBOs are still more expensive by that time (estimate at around EUR 2968 per tonne in 2030). While economies of scale allow to decrease capital costs and operational costs over time under all POs, this is outweighed by the increase of feedstock prices post-2035. By 2030, advanced biofuels (ATJ route) are still 2 times more expensive than fossil jet fuels. However, the price gap ratio decreases slowly over time. By 2040 and 2050, these fuels are respectively 1.9 and 1.7 times more expensive than fossil jet fuels.

Prices for advanced biofuels (Gas+FT route) are projected to decrease compared to the current estimates. Their level would however remain relatively stable during 2035-2050 due to increasing feedstock costs over time. These fuels are projected to emerge in the market in large volumes between 2035 and 2040 in all POs (except PO B2) at a price of around EUR 2039 per tonne. Capital costs would decrease by around 23% between 2035 and 2040 due to economies of scale and learning effects and stabilise thereafter. During 2040-2050 these reductions are however outweighed by the rise in feedstock costs in all POs (except PO B2[154]). All POs nevertheless contribute to reducing the Gas+FT biofuels prices compared to the currently estimated levels. The advanced biofuels (Gas+FT route) prices are projected to be 1.9 times higher than those of fossil jet fuels in 2035, going down to 1.8 in 2040 and 1.7 times by 2050. The projected prices for the Gas+FT route draw on relatively conservative assumptions for variable non-energy costs, which decrease by 4% during 2035-2050 and constitute the largest cost component (45% of total production costs by 2050[155]), ahead of feedstock costs (33% of total production costs by 2050). If variable non-energy costs are assumed to decrease at faster pace the impact on reducing the Gas+FT biofuels prices relative to the currently estimated levels would be higher.

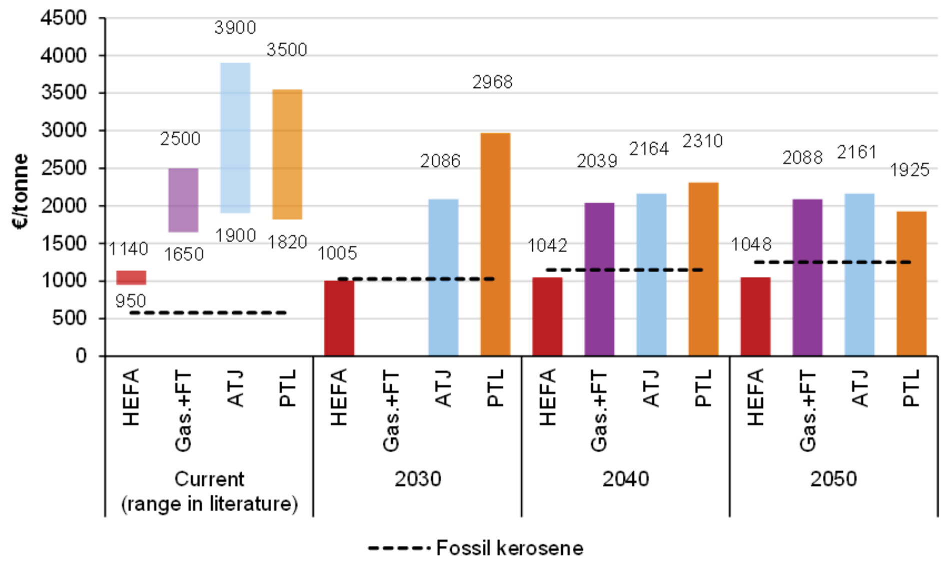
RFNBOs reach the market much earlier than under the baseline and prices decrease significantly by 2050 under all POs. Whereas in the baseline scenario, RFNBOs do not make inroads in the fuel mix, all POs allow to introduce them on the market as early as 2030. RFNBOs prices decrease by 22% from 2030 to 2040 and by an additional 17% from 2040 to 2050 and follow very similar trends over time across all POs. The decrease in prices is explained by a reduction in the costs of electrolysers needed for the production. Whereas by 2030, RFNBOs are projected to be 2.9 times more expensive than fossil jet fuel, this gap ratio reduces over time and becomes 2 and 1.5 respectively by 2040 and 2050 under all POs.

It should be noted that current estimates for the SAF prices, drawing on literature review (see *Figure 3*) and discussed above in relation to the evolution of the SAF prices, do not consider a profit margin on production costs, while the model projections consider a profit margin of 10%. This means that the SAF prices are projected to decrease even more over time relatively to the current estimates.

Figure 3: SAF prices – current estimates and projections in the policy options (except PO B2).

154 In PO B2 no significant decreases in the capital costs take place during 2035-2040 as the Gas+FT biofuels are not deployed at scale.

155 Such contribution levels to the total production costs are in line with the literature (Baker et al., 2017; de Jong 2015, IRENA 2016, WEF2020).



Source: Ricardo at al. Impact assessment support study; PRIMES Biomass and PRIMES-TREMOVE models, E3Modelling.
Note: Current cost range is based on literature review and do not include a profit margin. The projected SAF prices for 2030-2050 also include a profit margin of 10% on top of production costs.

Overall, SAF prices become more competitive with fossil jet fuel over time in all POs, although the average jet fuel blend remains more costly than conventional jet fuel. This is the result of a combination of factors. First, under all POs, the current costs of SAF decrease over the next decade compared to current estimates, due to the introduction of the blending mandate. This provide strong and long-term market certainty for fuel producers and investors. Second, in the baseline scenario and all POs, fossil jet fuel prices are expected to rise gradually over time (+21% between 2030 and 2050) in line with the development of international oil prices. This contributes to bridging the price differential and making SAF gradually more economically attractive compared to conventional jet fuel over time.

Economies of scale and learning effects allow SAF production costs to decrease over time. The analysis assumes that advanced biofuel producers implement measures with a view to improve their production process, which results in the scale-up of production at lower cost. This is particularly relevant for advanced biofuel production routes (ATJ and Gas+FT routes) and RFNBOs that are not yet deployed at commercial scale. The scale-up of SAF production contributes to the **reduction of scalable cost components such as capital and variable costs**. This is the case because SAF production costs evolve from the current state of the market where SAF production is in its infancy and SAF production capacity is extremely limited. Similarly to advanced biofuel routes, the demand for RFNBOs drives an increase in hydrogen demand and eventually leads to large-scale deployment of hydrogen generation technologies. The modelling considers learning-by-doing effects, reducing the costs of electrolysers over time, which is a critical cost component. At the moment, SAF production consists essentially of demonstration projects where SAF outputs are negligible, hence production costs and resulting prices are high. In the presence of a blending mandate, cost reductions are expected to take place in particular in the short to medium term, i.e. 2025-2030. In addition, a regulatory intervention such as a SAF blending mandate, obliging one side of the market to supply SAF provides the necessary **long-term certainty for investments to take place to develop new or expand existing SAF production capacity, leading to economies of scale**. This translates into the conversion of demonstration plants into full-size commercial plants as well as in the construction of new SAF production plants, and thereby helps achieving economies of scale, bringing SAF prices down. More information on the role of economies of scale is available in Annex 16.

Under all POs, while the SAF blending mandate allows to bring SAF costs down compared to current estimates, it results in an increase in the average price of the blended jet fuel over time. Indeed, the average jet fuel blend price increases as a result of the participation of more expensive fuels in the mix. Policy options A1, A2, B1, C1 and C2 which foresee a similar and significant participation of SAF in the average fuel mix, result in small differences mainly caused by the different composition of the fuel mix resulting from the use of volume-based and CO_2 intensity reduction-based targets. On the contrary, Policy option B2 which foresees lower SAF participation results in a lower overall price increase.

When looking at competition for feedstock by various sectors of the economy, and the relative impacts on the price of SAF, it is also important to consider possible price rigidities on the supply or the demand sides of the market.

Table 100 - Average jet fuel blend prices in the baseline and policy options in EU27.

	2030 (€/toe)	Increase on baseline	2040 (€/toe)	Increase on baseline	2050 (€/toe)	Increase on baseline
Baseline	1028.4		1146.9		1246.1	
PO A1	1062.5	**3.3%**	1401.9	**22.2%**	1653.5	**32.7%**
PO A2	1060.2	**3.1%**	1393.0	**21.5%**	1651.4	**32.5%**
PO B1	1062.5	**3.3%**	1401.9	**22.2%**	1653.6	**32.7%**
PO B2	1033.8	**0.5%**	1195.1	**4.2%**	1332.6	**6.9%**
PO C1	1062.7	**3.3%**	1402.1	**22.3%**	1653.5	**32.7%**
PO C2	1060.5	**3.1%**	1393.1	**21.5%**	1651.2	**32.5%**

Source: Ricardo at al. Impact assessment support study; PRIMES Biomass and PRIMES-TREMOVE models, E3Modelling

6.2.2. *Impacts on SAF supply logistics*

The design of POs have different impacts in terms of logistic costs, due to the way distribution of SAF-blended jet fuel to airports takes place. SAF production in the early years of the obligation (from 2025 to 2030) is expected to be centralised to a limited number of SAF production plants (see section 6.2.5). Imposing SAF distribution at each EU airport is possible, but may result in higher logistics costs. POs A1, A2, and B1 follow this logic and incur roughly the same logistic costs (e.g. annual additional costs for 2030 are estimated at €14 million at EU level). PO B2 also incurs logistic costs following the same logic, but to a lower extent given the supply of lower SAF volumes. On the other hand, **SAF supply is achieved in a more cost-effective way if fuel suppliers have the flexibility to focus their SAF distribution to a more limited number of airports**, in particular airports connected to pipelines[156]. This is the case under POs C1 and C2 from 2025 to 2030, where no extra logistic costs are estimated. From 2030 to 2035, fuel suppliers retain a degree of flexibility in their SAF distribution, but must nevertheless supply all airports with a minimum of SAF. Over this period, logistic costs under POs C1 and C2 increase but would be lower than for POs A1, A2 and B1, since suppliers would still make best use of the flexibility to distribute in a cost-effective way. **Towards 2040 and 2050, supplying all EU airports becomes less costly[157], as SAF production is more de-centralised**. As the number of SAF plants across the EU increases, with a more homogeneous spread across the EU, distances to blending facilities, oil terminals and airports are shortened, which reduces logistic costs. Therefore under all POs, the logistical costs per unit of SAF supplied decreases between 2040 and 2050. Annex 4 describes the methodology for calculating the logistics costs. The additional SAF supply logistics costs relative to the baseline, expressed as present value over the 2021-2050 horizon, are estimated at €0.27 billion in PO A1, A2 and B1, €0.09 billion in PO B2 and €0.19 billion in PO C1 and C2.

6.2.3. *Impacts on the total cost of aviation*

All policy options lead to some small reductions in the total cost of aviation[158] in 2030, compared to the baseline**.** The reduction is the highest in PO B2 (€1 billion or 0.3% lower relative to the baseline) and around

156 Distributing SAF-blended jet fuel at airports that are connected with pipelines incurs low logistic costs per unit of fuel. All volumes of SAF can be shipped to the same location for introduction in the fuel system.

157 Less costly on average per unit of fuel supplied.

158 Total cost of aviation accounts for capital costs, fixed and variable non-fuel costs, and fuel costs.

€0.5-0.6 billion for all other POs (0.1-0.2% lower than the baseline). This is primarily due to the somewhat lower passenger air transport activity compared to the baseline, which leads to lower capital and operation costs that outweigh the higher fuel costs. **In the long term, by 2050, higher SAF blending rates result in higher total aviation cost** compared to the baseline estimated at €9-10 billion (1.8-2.1% increase relative to the baseline)**.** Only PO B2, due to the reduced scope of intervention, shows lower costs relative to the baseline in 2050 (€1 billion or 0.2% decrease relative to the baseline).

Over the entire time horizon up to 2050, the total costs of aviation (expressed as present value over the 2021-2050 period) increase by EUR 14 to 20 billion relative to the baseline (0.2 to 0.3% increase compared to the baseline). PO B2 is the only option which shows lower costs due to its reduced scope. Expressed in terms of share of GDP these additional costs are however very limited at below 0.01% of GDP in all POs.

Table 111 - Total costs for the air transport sector in the policy options relative to the baseline (present value over the 2021-2050 period).

Difference in costs compared to baseline - present value 2021-2050 (bil. €'2015)	**Baseline (bil. €'2015)**	**PO A1**	**PO A2**	**PO B1**	**PO B2**	**PO C1**	**PO C2**
Capital costs	2,442	-31.1	-27.2	-30.9	-12.1	-31.0	-27.2
Fuel costs	792	103.5	88.3	102.7	14.7	103.5	88.2
Operation costs	3,064	-52.9	-47.2	-52.6	-23.5	-53.0	-47.3
Total costs for the air transport sector	6,298	19.6	13.9	19.2	-20.9	19.5	13.8

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling.

Total aviation costs are lower in the policy options where the SAF targets are expressed in terms of jet fuel CO_2 intensity reduction compared to those expressed in volume based terms. Indeed, POs A2 and C2 lead to lower additional costs of €6 billion (29%) than POs A1 and C1, when compared to the baseline (expressed in present value terms). The lower cost projected for the jet fuel CO_2 intensity reduction approach in this case is due to the flexibility allowed to fuel suppliers, even when considering the multiplier on RFNBOs, to choose the SAF fuel blend that delivers the required reduction in the CO2 intensity at lowest cost. This is also illustrated in section 6.1.1, showing that the share of RFNBOs in the jet fuel mix is lower under POs A2 and C2 compared to POs A1 and C1. On the other hand, supporting the uptake of RFNBOs at early stages may have other benefits in terms of learning effects and lowering the demand pressure on the biomass feedstock to some extent.

6.2.4. *Impacts on air ticket prices*

The impact on air ticket prices has been based on the following assumptions. First, the extra fuel cost due to SAF purchase is fully passed on to the passengers, resulting in an increase of the ticket price. Ticket price increases however can be lower should airlines absorb part of the additional costs, meaning that these impacts represent the maximum ticket price increase projected. Second, the share of fuel costs in total aviation costs is 25%. This is the higher bound of the estimated range of the share of fuel costs in the total air transport costs that is most common in the literature, i.e. between 17% and 25%[159]. PO B2 results in significantly lower ticket price increase relative to the baseline when compared to all other options, since the SAF obligation applies only to intra-EU flights. As explained in section 6.2.2, this reduced scope lowers the fuel cost for the sector, hence the lower ticket price increases compared to the baseline. All other options show very similar increases in ticket prices relative to the baseline by 2050 (0.8% increase in 2030, 5.4-5.6% in 2040 and 8.1-8.2% in 2050).

159 EUROCONTROL - Aviation Intelligence Unit – Think Paper #1 – June 2019.

Table 122 – Changes in fuel costs and ticket prices in the policy options relative to the baseline.

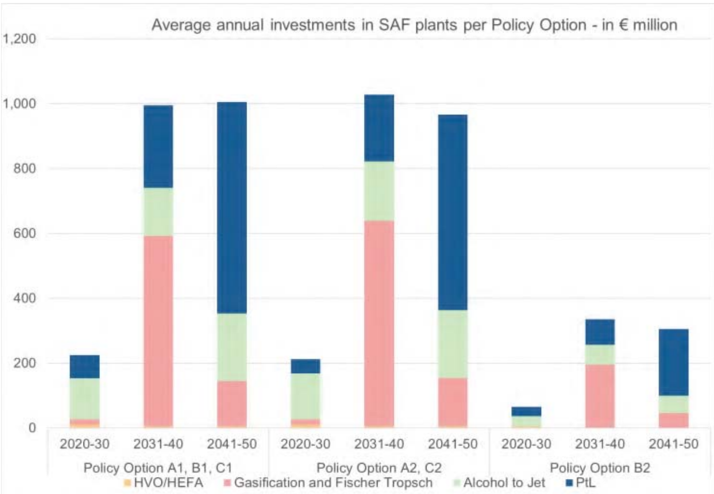
	Fuel cost increase			Ticket price increase		
	2030	2040	2050	2030	2040	2050
PO A1	3.3%	22.2%	32.7%	0.8%	5.6%	8.2%
PO A2	3.1%	21.5%	32.5%	0.8%	5.4%	8.1%
PO B1	3.3%	22.2%	32.7%	0.8%	5.6%	8.2%
PO B2	0.5%	4.2%	6.9%	0.1%	1.1%	1.7%
PO C1	3.3%	22.3%	32.7%	0.8%	5.6%	8.2%
PO C2	3.1%	21.5%	32.5%	0.8%	5.4%	8.1%

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling.

6.2.5. *Impacts on SAF production capacity and investment needs*

All POs require building additional SAF production capacity. By 2030, 7 additional SAF plants[160] are needed to meet the SAF obligation under all POs, except for PO B2 where only 3 additional SAF plants are needed. The increase is production capacity needs go up over time. By 2050, a total of 104-106 SAF production plants[161] are needed across the EU to satisfy the SAF obligation under all options, except in PO B2 where only 33 SAF plants are necessary across the EU. POs where the SAF obligation is expressed in CO_2 reduction terms (A2 and C2) show slightly higher needs for plants producing advanced biofuels (ATJ and Gas+FT route), and less needs for RFNBOs production facilities.

Figure 4 - Capital cost investments needed for SAF production plants (in € million).



Source: Ricardo at al. Impact assessment support study.

The need to scale up SAF production capacity in the EU translates into significant investment needs under all POs. Investments needs over the period 2021 to 2050 amount to €10.4-10.5 billion under all POs, except for PO B2 where they are around €3.3 billion. Overall, additional RFNBOs production sites, followed closely by advanced biofuels (Gas+FT route) require the highest investment needs. This is also the case under PO B2.

[160] 7 additional plants, corresponding to an increase in production capacity of 2.2 million tonnes of SAF per year.

[161] 104 to 106 additional plants, corresponding to an increase in production capacity of around 25.5-25.6 million tonnes of SAF per year for all POs, except for PO B2, 8.4 million tonnes of SAF per year.

6.2.6. *Impacts on the EU's energy dependence*

The EU reduces significantly its dependency on oil imports under all POs. All POs (except PO B2) lead to a reduction in fossil jet fuel use of about 7% (i.e. around 3 Mtoe) in 2030 and 65% (i.e. around 31 Mtoe) in 2050 relative to the baseline. This is due to the substitution with SAF and to more limited extent caused by the lower overall energy demand in air transport. The reduction of fossil fuel use under PO B2 is lower, i.e. 3% by 2030 and 22% by 2050 relative to the baseline. On the other hand, by 2030 and 2050, respectively 0.4 Mtoe and 2.3-2.5 Mtoe of biofuels used are imported (see section 6.1.1). This represents less than 1% of EU's total jet fuel use in 2030 and 3% to 6% of EU's total jet fuel use by 2050. As such, the net reduction in energy imports remains substantial, driven by the significant reduction in oil imports, and in spite of a small increase in biofuel imports. **Oil imports are largely substituted with feedstock and renewable electricity sourced in the EU.** All the feedstock used to produce SAF in the EU is sourced in the EU. In other terms, no feedstock is imported in order to produce SAF in the EU under all POs. The renewable electricity required to produce RFNBOs is also sourced in the EU. As such, including RFNBOs, **EU-produced SAF represent 83% and 92% of total SAF use respectively in 2030 and 2050, under all POs.**

6.2.7. *Impacts on passenger air transport activity*

Under all POs, the intra-EU total passenger air transport activity grows steadily up to 2050, but less than in the baseline. All POs have similar impact on the internal market's air passenger activity (only intra-EU flights). Indeed, under all POs, intra-EU passenger air transport grows by 80% by 2050 relative to 2015. The level of air transport passenger activity is slightly lower than in the baseline, i.e. by respectively 1.3% and 4.5-4.7% in 2030 and 2050 due to higher ticket prices. **Total passenger air transport activity however grows steadily up to 2050 under all POs, but less than in the baseline.** Passenger air transport activity on intra- and extra-EU flights is expected to grow under all POs, i.e. by around 77% by 2050 relative to 2015 (except for PO B2). In PO B2 the growth in activity during 2015-2050 is projected to be higher (81%), as the SAF obligation does not apply to extra-EU traffic. For all POs, the level of passenger activity on intra and extra-EU flights is however lower than in the baseline, by 1.9-2% in 2030 and 3.4-5.9% in 2050. It should be noted that the reduction in activity relative to the baseline is marginally higher in POs A1, B1 and C1 relative to POs A2 and C2. This is a consequence of the slightly higher increase in the ticket prices relative to the baseline in POs A1, B1 and C1 as explained in section 6.2.4.

6.2.8. *Impacts on internal market and industry competitiveness*

Competitiveness of airlines. Under POs A1, A2, C1 and C2**, all airlines (EU and non-EU) flying out of EU airports, will operate on a level playing field** with regards to SAF**.** Indeed, under these POs, every litre of jet fuel supplied will be SAF-blended, which means airlines will have no alternative than to use SAF-blended jet fuel at EU airports. Airlines will have bargaining power to decide on the attribution of jet fuel supply contracts based on the most economically attractive bid submitted by fuel suppliers[162]. This market dynamic will contribute to keeping jet fuel prices at competitive levels. This means that EU and non-EU airlines alike will use SAF when departing from EU airports and will operate on equal footing. POs C1 and C2 contain a transition period, in the first phase of which (2025-2030) as not all airports may be supplied with SAF. This is not expected to affect the competitiveness of airlines since fuel suppliers, with a view to spread as evenly as possible additional fuel cost across the market, are expected to sell SAF to as many airlines as possible, at the majority of medium and large EU airports. Only airlines performing point to point operations between small airports, e.g. in remote areas may not have physical access to SAF at airports. Under POs C1 and C2, the level playing field between airlines is reinforced thanks to the jet fuel uplift obligation, which means that all airlines will be required to refuel at EU airport with the amount of fuel needed for the planned flight. With this

[162] On a yearly basis, airlines issue calls for tender to receive jet fuel provision at their destination airports. Competition occurs between fuel suppliers who bid to provide airlines with the most economically attractive offer.

safeguard, airlines cannot refuel more than needed outside of the EU in order to avoid the cost of refuelling at EU airports. Under PO B1, similar economic behaviour is expected between airlines and fuel suppliers. PO B2 presents risks of competitive distortion within the internal market, whereby EU airlines performing a large share of international extra-EU traffic would be subject to the obligation to a much smaller extent than airlines operating mostly intra-EU routes. This could lead to a difference in average jet fuel costs between intra-EU and extra-EU flights increasing from 2.6% in 2030 to 20.5% in 2050. Under PO B2, EU airlines performing only intra-EU traffic would be put at a competitive disadvantage, as they would not be able to spread the increase in fuel costs over the cost of intra and extra-EU flights, as would be the case for airlines flying to and from the EU. Under all POs, **a risk of competitive disadvantage for EU airlines compared to non-EU airlines is assessed as low at least by 2030.** That could be the case where an EU airline operating long-haul flights from an EU airport competes on a similar route with a non-EU airline connecting via a non-EU hub airport. The competitive disadvantage for the EU airline could come from extra fuel costs due to SAF-blended jet fuel uptake. For non-EU airlines only the connecting flight to the non-EU hub would need to operate on SAF, whereas the second leg of the journey (from non-EU hub to long-haul destination) could operate without SAF. However, additional fuel costs for airlines are expected to be passed on to passengers. As projected ticket price increase are low by 2030, i.e. +1% relative to the baseline. Such a price increase is in itself not expected to justify a switch of customer behaviour from direct flights to connecting flights, or even to select an alternative hub connection. Therefore, by 2030, the risk of competitive disadvantage for EU airlines vis-a-vis non-EU airlines is very low. **By 2040, the risk of competitive disadvantage for EU airlines is more pronounced but it is mitigated by several factors.** By 2040, the ticket price increase on flights departing from the EU would amount to +5% compared to the baseline. The possible economic gain on fuel costs for non-EU airlines flying via non-EU hubs is mitigated by three factors mainly. (1) Connecting flights from the EU to the non-EU hub will also be subject to a price increase from the use of SAF. This comes as a result of the jet fuel uplift obligation (level playing field safeguard) that requires all airlines departing from EU airports to refuel with the jet fuel (SAF-blended) available at the airport. (2) Reaching a long-haul destination by connecting via a non-EU hub instead of flying directly to the long-haul destination means flying a less direct route, hence additional fuel burn resulting in extra costs for airlines. (3) While airlines operating direct long-haul flights from EU airports will be able to claim economic benefits under CORSIA from their use of SAF, this will not be the case for airlines operating long-haul flights from non-EU hubs if those hubs are not supplied with SAF. The economic gain for non-EU airlines flying via a connecting non-EU hub may therefore be limited. As a result, the risk of loss of competitiveness for airlines exists but is limited. Moreover, other factors could further mitigate the risk. By 2040, while the ticket price increase will be relatively low (+5%), airlines flying from the EU will be using at least 32% of SAF. Flying more responsibly could encourage passengers to incur a low ticket price increase. Nevertheless, the most effective avenue to prevent an erosion of competitiveness of EU airlines will be to promote SAF use across the world, thereby promoting climate action but also restoring a level playing field. This will need to be a priority for EU action in coming years. Further, it is likely that by 2040, neighbouring countries will have developed their own SAF policies. Several strategic aviation third country partners - including the UK[163] and the US[164] - are accelerating their national reflections on the increase of SAF deployment for air transport. Should policy developments in these regions lead to an increase use of SAF from their side, this would further provide for a level playing field for airlines operating international flights and mitigate the risk for EU airlines. It is also not excluded that SAF use targets could be established at ICAO level in the future, or that more and more bilateral aviation agreements would include agreements on the use of SAF. Finally, it should be noted that the levels of ticket price increase raise competitiveness risks only towards 2040. This provides time and several opportunities for the Commission to report on the effectiveness of the legislation, as per usual practice. Should such reports conclude to a real risk of competitive disadvantage

[163] Source: https://www.gov.uk/government/news/new-regulations-to-double-the-use-of-sustainable-renewable-fuels-by-2020

[164] Source: https://juliabrownley.house.gov/brownley-introduces-sustainable-aviation-fuel-act/

beyond 2040, a review clause in the Regulation should allow to consider appropriate complementary measures and safeguards. As the potential impact on airlines competitiveness is assessed as limited, it is **not expected to impact the effective functioning of the regulation**. Indeed, as explained in section 6.2.7, the air transport sector is expected to keep growing by 2050, with a projected growth by 77% by 2050 relative to 2015. This means that the sector will be able to uptake gradually increasing levels of SAF while at the same time continue to function. It should be acknowledged that the present analysis is subject to uncertainties notably linked to the evolution of the jet fuel price. While section 6.2.1 provides exhaustive information on the most likely evolution of SAF prices and hence of the average jet fuel mix price, this is also dependent on the evolution of the price of fossil jet fuel. The price of fossil jet fuel expected to increase steadily over time by 2050, but could be subject to volatilities due to economic or geopolitical events out of the control of the regulator and independent of the air transport sector. It is not expected that the price gap between SAF and conventional jet fuel would increase (on the contrary it should decrease over time), but if this would happen, this could accentuate the phenomenon described above and if possibly lead to competitive distortions or put EU airport hubs and EU airlines at competitive disadvantage with their competitors. For instance, in case of an important increase of the price gap between SAF and conventional fuel, non-EU airlines could benefit from an advantage compared to EU airlines, when flying 'indirect' long-haul flights via non-EU hubs. However, this would be easily assessed and should be considered under the review mechanism of the instrument in order to remedy the situation.

Competitiveness of airports. By imposing SAF supply obligations at all airports, POs A1 and A2 bear the risk of increasing jet fuel prices (due to logistics costs) at remote or regional airports where jet fuel prices are already higher than average. This may reduce the economic attractiveness of small airports to the benefits of medium and large airports. This issue is expected to be mitigated under POs C1 and C2 where suppliers will distribute SAF-blended fuel in the most cost-effective way at the start of the obligation, i.e. until 2035. Under this scenario, suppliers will likely supply the majority of medium and large size airports. This means airports competing in the same category range of traffic levels will be affected in the same way. Smaller airports are expected to be unaffected. **The risk of loss of competitiveness for EU hub airports with intercontinental traffic due to airlines' re-routing is low**. Under all POs (except PO B2 where the scope is reduced to intra-EU traffic), EU hub airports with large international traffic could be put at competitive disadvantage if passengers - for economic reasons, would choose to avoid direct long-haul flights from EU hubs but rather reach their long-haul destination by re-routing and connecting via neighbouring non-EU hubs. This risk could materialise if the ticket price increase for flights departing from EU airports justifies it from a passenger perspective. However, as explained section 6.2.4, the ticket price increase for flights departing from EU airports is projected to be limited, i.e. +1% by 2030 and +5% by 2040 relative to the baseline. The same reasoning is valid as explained for airlines in the above section. As the potential impact on EU airports competitiveness is assessed as low, it is not expected to impact the effective functioning of the regulation.

Impact of fuel tankering on the internal market. There is little literature available or concrete evidence demonstrating the magnitude or impacts of fuel tankering. In 2019, a study by Eurocontrol[165] estimated that around 20% of flights in the ECAC area were able to perform fuel tankering. For the purpose of this impact assessment, a case study has been performed, aiming to determine at what point in time airlines would be incentivised to tanker fuel outside the EU, given the increase of SAF content in the jet fuel, and the resulting price changes. The case study considers the level of SAF ramp up used under the POs, and shows that the incentive to tanker fuel abroad is limited until 2035. By 2035, it would become interesting to tanker fuel in excess outside the EU on short-haul flights, e.g. Istanbul-Frankfurt or London-Dublin, where an airline could save respectively around 0.75% and 3% on fuel cost. By 2040, such practice may become also interesting for long-haul flights where an airline could save around 1% on fuel costs when operating a New York-Paris route. The incentives to tanker outside the EU increase to more than 3% for long-haul flights and 10% for short haul

165 Fuel Tankering: economic benefits and environmental impacts – Eurocontrol – June 2019.

flights by 2050. While this suggests that the tankering issue gains in magnitude beyond 2035, the existence of a financial incentive to do so to the detriment of emission savings, warrants the need for a robust safeguard to be implemented already in the short term. **The level playing field (anti-tankering) safeguard should be implemented already by 2025** mainly for three reasons. First, it cannot be excluded that market prices for jet fuel and SAF fluctuate to a point that could make fuel tankering economically interesting. Moreover, the prevention of tankering brings immediate benefits by removing avoidable emissions caused by the additional fuel carried, regardless of the reasons airlines may have for tankering. Finally, this measure allows to preserve a level playing field for all flights departing from EU airports, including extra-EU flights. Indeed, as all airlines (regardless of whether they are established in the EU or not) will be required to uplift the jet fuel available at EU airports, higher jet fuel costs will apply to all. This reduces the possibility of competitive disadvantage for EU airlines and for EU hub airports. The anti-tankering safeguard included in POs C1 and C2 is expected to reduce significantly aviation emissions caused by airlines carrying an excess of fuel. This reduction cannot be quantified with high accuracy, but according to Eurocontrol, it could avoid an estimated average 136kg of excess fuel burn per flight, representing 428kg of CO_2. A study[166] conducted by the International Council on Clean Transportation in 2021 concluded that additional tankering stemming from the SAF blending mandate could result in a 22% lower SAF uptake by airlines by 2035. In turn, this could reduce the CO_2 benefits of the initiative by a quarter by 2035. Mitigation measures identified in the study include defining and prohibiting fuel tankering on flights departing from EU airports. This measure can be easily implemented, as airlines keep records of their tank levels and levels uplift for each flight. This information needs to be transferred to a European organisation for control and reporting of manifest cases of excess fuel uplift. Airlines could also be requested to send such information aggregated per airport, instead of per flight. This safeguard is expected to be considered by the airline community as a positive step towards reinforcing the level playing field in intra- and extra-EU air transport and contribute to reducing fuel burn and the emissions of the aviation sector. It may however face opposition from airlines currently performing fuel tankering or intending to benefit from access to inexpensive jet fuel out of the EU. It should be noted that this safeguard would a priori not raise legal challenges.

Competitiveness of aircraft manufacturers. Under all POs, aircraft manufacturers will continue to benefit from the growth of the aviation sector by 2050, albeit at slightly lower pace than in the baseline scenario. The fact that SAF are drop-in fuels compatible with existing aircraft engines is a significant technological advantage, as it means that there will be no necessity for aircraft manufacturers to retrofit existing fleets or disrupt their existing business model to develop new technologies for the purpose of SAF. This is expected to avoid substantial investments otherwise needed to adapt aircraft engines currently in use. While it is expected that aircraft manufacturers will invest and support the scaling up of SAF production, there is no indication that this would lead to a displacement of investments from R&D programmes targeting other technologies (hydrogen, electric aircraft). Such programmes are expected to follow their course and intensify in the decades to come as aircraft manufacturers will aim to remain at the cutting edge of innovation. Flanking measures such as steering European funding towards SAF deployment or the creation of an EU strategic alliance for advanced biofuels and synthetic fuels will further contribute to the best possible allocation of resources towards SAF deployment.

Competitiveness of the fuels industry. The EU (renewable) fuel industry is expected to benefit from this initiative, as it launches a new market with strong growth prospects. It is likely that SAF production at local level will develop, leading to the emergence of a diversity of producers on the market and actors of the SAF supply chain. This initiative is an opportunity for the fuels industry to take a pioneering and leading role in scaling up SAF at global level. It is not excluded that EU SAF production could also attract foreign airline markets wishing to green their own domestic operations. On the other hand, for reasons of resources

166 https://theicct.org/publications/tankering-eu-SAF-mandate-apr2021

availability mentioned previously, it is likely that an expansion of SAF production could result in lower production of road biofuels produced from Part B feedstock. This could lead to a reduction of activity notably in the bio-diesel industry in the short to medium term. On the other hand, the road transport sector is projected to be largely electrified in the medium to long term, considering the analysis underpinning the impact assessment accompanying the 2030 Climate Target Plan. This means that the demand for biofuels in aviation sector could create alternative business opportunities for the fuel industry.

6.2.9. *Impacts on administrative costs*

No additional administrative costs are expected on the side of *fuel suppliers* under all POs. Additional administrative costs occur for *airlines* under POs C1 and C2, i.e. annually €16.8 million by 2025 and around €24 million by 2050. In terms of present value over the 2021-2050 horizon this is equivalent to €0.34 billion additional costs relative to the baseline. Additional costs for Member States range from €186 million (POs A1, A2 and B2) to €264 million (POs C1 and C2) and €293 million (PO B1). Additional costs for EU authorities range from €0.7 million (POs A1, A2 and B2), €2.0 million (PO B1) to €2.7 million (POs C1 and C2). In terms of present value over the 2021-2050 horizon the costs for the *public authorities* relative to the baseline are estimated at €0.19 billion for PO A1, A2 and B2, at €0.27 billion for PO C1 and C2 and €0.3 billion for PO B1. More details on the administrative costs are provided in Annex 4. It should be noted that costs associated with the system of SAF transactions for accounting purposes is negligible, as it relies on the monitoring process of EU agency or the EU ETS (which costs are accounted for in the relevant POs under costs for EU authorities, as explained above in this paragraph), depending on the policy options and does not require the setting up of any additional specific IT structure. It is expected to consist of a limited number of transactions per year, which costs would be marginal and cannot be estimated.

6.3. Social impacts

6.3.1. *Impact on employment*

Overall, all POs (except PO B2) lead to significant net job creation in the EU compared to the baseline in the long term. This net job increase is largely driven by the high employment needs of the SAF industry from 2030 to 2050. Combining employment effects in the air transport and SAF industries, all POs (except PO B2) provide for net additional 95,700 (PO B1) to 96,800 (PO C2) jobs compared to the baseline scenario in 2040 and 201,300 (PO B1) to 202,100 (PO C1 and C2) in 2050. In PO B2 the impacts would be more limited (20,000 additional jobs in 2040 and 53,200 in 2050). The impacts of all POs would be more limited in 2030 in terms of net additional jobs relative to the baseline (4,200 to 4,800 net additional jobs) while PO B2 would show some net losses relative to the baseline (7,200). Still, even in PO B2 employment increases significantly relatively to the current levels.

6.3.2. *Impact on public health*

All POs lead to a reduction of external costs of air pollution over time. The impacts on public health from air pollution are quantified in terms of reduction in the negative externalities compared to the Baseline. Air pollutants are projected to decrease in all POs compared to the baseline. The reduction of air transport activity, as a result of the more expensive fuel mix over time, leads to lower fuel burn. For all POs, this eventually leads to a reduction in the present value of external costs from air pollution of about €1.5 billion over the period 2020 to 2050, compared to the Baseline.

7. HOW DO THE OPTIONS COMPARE?

7.1. Effectiveness and efficiency

The effectiveness of the options is examined against the policy objectives identified in Section 4. The criteria presented below are used to help assess the effectiveness.

Table 133 – The effectiveness of the options examined against the policy objectives.

Specific objectives	**Indicator**
General objective Reduce aviation CO2 emissions in line with the 2030 and 2050 climate objectives of the EU, by transitioning away from fossil jet fuels and tap into the high sustainability potential of sustainable aviation fuels by establishing a competitive SAF market that ensures level playing field on the aviation internal market.	
Specific objective 1 To achieve large-scale production and supply of SAF in the EU with high decarbonisation potential.	Increase existing SAF plants output and develop new production facilities.
	Sufficiency of feedstock available for SAF production compared to overall needs for SAF as defined in the impact assessment accompanying the Climate Target Plan.
	Reduction of EU's energy dependence on oil imports.
	Development of sustainable and cost-effective SAF pathways, taking a technology-neutral approach.
Specific objective 2 To achieve a gradual and continuous uptake of SAF with high sustainability potential.	Reduction of well-to-wing CO2 emissions from air transport
	Increase uptake of SAF in line with the objectives of the 2030 Climate Target Plan of achieving at least 55% economy-wide emissions reductions by 2030.
	Ensure that airlines have access to SAF at airports.
	Ensure a level playing field between airlines.
	Avoid carbon leakage resulting from increased fuel tankering.

Table 144 – The expected key impacts of the policy options.

Key: Impacts expected				
××	×	O	✓	✓✓
Strongly negative	**Weakly negative**	**No or negligible impact**	**Weakly positive**	**Strongly positive**

	PO A1	**PO A2**	**PO B1**	**PO B2**	**PO C1**	**PO C2**
Effectiveness						
Increase existing SAF plants and developing new production facilities.	✓✓ 25.6Mt of additional SAF capacity[167] deployed by 2050 to match the SAF production necessary to meet the mandate. Minor portions of the SAF needed are imported.	✓✓ 25.5Mt of additional SAF capacity deployed by 2050 to match the SAF production necessary to meet the mandate. Minor portions of the SAF needed are imported.	✓✓ 25.6Mt of additional SAF capacity deployed by 2050 to match the SAF production necessary to meet the mandate. Minor portions of the SAF needed are imported.	×× 8.3Mt of additional SAF capacity deployed by 2050, insufficient to meet the 2030 Climate Target Plan objectives by 2030 and 2050 due to the reduced scope of the SAF mandate.	✓✓ 25.6Mt of additional SAF capacity deployed by 2050 to match the SAF production necessary to meet the mandate. Minor portions of the SAF needed are imported.	✓✓ 25.5Mt of additional SAF capacity deployed by 2050 to match the SAF production necessary to meet the mandate. Minor portions of the SAF needed are imported.
Sufficiency of feedstock available for SAF production compared to the overall needs of biomass feedstock for achieving the 2030 Climate Target Plan objectives.	✓ 53% of UCO,11% of agri and wood residues and 12% of energy crops required by 2050.	✓ 53% of UCO,11% of agri and wood residues and 12% of energy crops required by 2050.	✓ 53% of UCO,11% of agri and wood residues and 12% of energy crops required by 2050.	✓✓ 33% of UCO, 3% of agri and wood residues and 1% of energy crops required by 2050.	✓ 53% of UCO,11% of agri and wood residues and 12% of energy crops required by 2050.	✓ 53% of UCO,11% of agri and wood residues and 12% of energy crops required by 2050.
Sufficiency of renewable electricity for SAF production compared to overall needs of renewable electricity for achieving the 2030 Climate Target Plan objectives.	✓✓ 5.5% of renewable electricity used for synthetic kerosene.	✓✓ 4.7% of renewable electricity used for synthetic kerosene.	✓✓ 5.5% of renewable electricity used for synthetic kerosene.	✓✓ 1.8% of renewable electricity used for synthetic kerosene.	✓✓ 5.5% of renewable electricity used for synthetic kerosene.	✓✓ 4.7% of renewable electricity used for synthetic kerosene.

[167] Assuming fully used capacity.

Reduction of EU's energy dependence on oil imports (compared to the baseline).	✓✓ Reduction in oil products used by air transport by 65% (i.e. around 31 Mtoe) by 2050.	✓✓ Reduction in oil products used by air transport by 65% (i.e. around 31 Mtoe) by 2050.	✓✓ Reduction in oil products used by air transport by 65% (i.e. around 32 Mtoe) by 2050.	✓ Reduction in oil products used by air transport by 22% (i.e. around 11 Mtoe) by 2050.	✓✓ Reduction in oil products used by air transport by 65% (i.e. around 31 Mtoe) by 2050.	✓✓ Reduction in oil products used by air transport by 65% (i.e. around 31 Mtoe) by 2050.
Development of sustainable and cost-effective SAF pathways, taking a technology-neutral approach.	✓ Advanced biofuels and RFNBOs emerge to the market earlier and account for the majority of SAF volumes by 2050.	✓✓ A technological neutral approach allows advanced biofuels and RFNBOs to emerge on the market earlier and account for the majority of SAF volumes by 2050.	✓ Advanced biofuels and RFNBOs emerge to the market earlier and account for the majority of SAF volumes by 2050.	✓ Advanced biofuels and RFNBOs emerge to the market earlier and account for the majority of SAF volumes by 2050.	✓ Advanced biofuels and RFNBOs emerge to the market earlier and account for the majority of SAF volumes by 2050.	✓✓ A technological neutral approach allows advanced biofuels and RFNBOs to emerge on the market earlier and account for the majority of SAF volumes by 2050.
Achieve a gradual and continuous uptake of SAF in line with the analysis underpinning the impact assessment accompanying the 2030 Climate Target Plan.	✓✓ Share of SAF in the aviation fuel mix achieved (63% by 2050).	✓✓ Share of SAF in the aviation fuel mix achieved (63% by 2050).	✓✓ Share of SAF in the aviation fuel mix achieved (63% by 2050).	✗✗ The share of SAF use in the fuel mix of approx. 20% is significantly lower than the 63% objective.	✓✓ Share of SAF in the aviation fuel mix achieved (63% by 2050).	✓✓ Share of SAF in the aviation fuel mix achieved (63% by 2050).
Ensure that airlines have access to SAF at airports.	O Delivering SAF at all airports means additional logistical challenges in the first years.	O Delivering SAF at all airports means additional logistical challenges in the first years.	O Obligation on all traffic assumes equally challenging logistics in the first years.	O Obligation on intra-EEA traffic assumes equally challenging logistics in the first years.	✓ Flexibility on the supply means easier logistics in the first years.	✓ Flexibility on the supply means easier logistics in the first years.
Ensure a level playing field between airlines.	O All airlines expected to be treated equally by fuel suppliers. Moderate risk of competitive disadvantage with non-EU airlines on some international routes.	O All airlines expected to be treated equally by fuel suppliers. Moderate risk of competitive disadvantage with non-EU airlines on some international routes.	O All airlines expected to be treated equally by fuel suppliers. Moderate risk of competitive disadvantage with non-EU airlines on some international routes.	✗ Risks of competitive distortion between EU airlines within the single market.	O All airlines expected to be treated equally by fuel suppliers. Moderate risk of competitive disadvantage with non-EU airlines on some international routes.	O All airlines expected to be treated equally by fuel suppliers. Moderate risk of competitive disadvantage with non-EU airlines on some international routes.
Avoid carbon leakage resulting from fuel tinkering.	✗ Risks of fuel tankering for international traffic beyond 2035.	✗ Risks of fuel tankering for international traffic beyond 2035.	✓ Low risk of tankering due to SAF obligation on airlines.	x Risks of fuel tankering for international traffic beyond 2035.	✓✓ Very low risk of tankering as a result of jet fuel uplift obligation.	✓✓ Very low risk of tankering as a result of jet fuel uplift obligation.
Reduction of well to wing CO2 emissions from air transport compared to the baseline in 2050.	✓✓ 115 Mt of CO2 emission reductions.	✓✓ 114 Mt of CO2 emission reductions.	✓✓ 115 Mt of CO2 emission reductions.	✗✗ 33 Mt of CO2 emission reductions.	✓✓ 115 Mt of CO2 emission reductions.	✓✓ 114 Mt of CO2 emission reductions.

Reduction of external costs of CO2 emissions relative to the baseline, expressed as present value over 2021-2050 (accounting also for the increased external costs due to logistics).	✓✓ €86.2 billion (i.e. €86.5 billion reduction due to the SAF uptake and €0.33 billion increase due to logistics).	✓✓ €85.7 billion (i.e. €86.0 billion reduction due to the SAF uptake and €0.33 billion increase due to logistics).	✓✓ €86.4 billion (i.e. €86.7 billion reduction due to the SAF uptake and €0.33 billion increase due to logistics).	✓ €29.7 billion (i.e. €29.8 billion reduction due to the SAF uptake and €0.11 billion increase due to logistics).	✓✓ €86.3 billion (i.e. €86.5 billion reduction due to the SAF uptake and €0.23 billion increase due to logistics).	✓✓ €85.8 billion (i.e. € 86.0 billion reduction due to the SAF uptake and €0.23 billion increase due to logistics).
Reduction of external costs of air pollution relative to the baseline, expressed as present value over 2021-2050.	✓ € 1.5 billion	✓ € 1.5 billion	✓ € 1.6 billion	✓ € 1.5 billion	✓ € 1.5 billion	✓ € 1.5 billion
Benefits relative to the baseline (PV over 2021-2050).	✓✓ **€ 87.7 billion**	✓✓ **€ 87.2 billion**	✓✓ **€ 87.9 billion**	✓ **€ 31.2 billion**	✓✓ **€ 87.8 billion**	✓✓ **€ 87.3 billion**
Efficiency (values indicated represent NPVs over the reference period)						
Additional costs of jet fuel relative to the baseline, expressed as present value over 2021-2050 - passed through to consumers.	× €103.5 billion Additional cost of supplying SAF.	× € 88.3 billion Additional cost of supplying SAF.	× € 102.7 billion Additional cost of supplying SAF.	× € 14.7 billion Additional cost of supplying SAF.	× € 103.5 billion Additional cost of supplying SAF.	× € 88.2 billion Additional cost of supplying SAF.
Reduction of operation and capital costs of air transport relative to the baseline, expressed as present value over 2021-2050.	✓✓ - €83.9 billion	✓✓ - €74.4 billion	✓✓ - €83.5 billion	✓ - €35.6 billion	✓✓ - €84.0 billion	✓✓ - €74.5 billion
Additional costs of logistics relative to the baseline, expressed as present value over 2021-2050.	O €0.27 billion Cost of logistics to supply SAF to all EU airports.	O €0.27 billion Cost of logistics to supply SAF to all EU airports.	O €0.27 billion Costs of logistics to supply SAF to all airlines.	O €0.09 billion Low logistic costs due to lower levels of SAF supply.	O €0.19 billion Transition period allows for improved logistics.	O €0.19 billion Transition period allows for improved logistics.
Impact on SAF producers – cost passed through to suppliers.	× Total capital investments needed of € 10.5 billion.	× Total capital investments needed of € 10.4 billion.	× Total capital investments needed of € 10.4 billion.	O Total capital investments needed of € 3.3 billion.	× Total capital investments needed of € 10.5 billion.	× Total capital investments needed of € 10.4 billion.
Additional cost for consumers per ticket (i.e. increase in ticket prices relative to baseline in 2050).	× Low ticket price increase 8.2% by 2050.	× Low ticket price increase 8.1% by 2050.	× Low ticket price increase 8.2% by 2050.	O Very low ticket price increase 1.7% by 2050.	× Low ticket price increase 8.2% by 2050.	× Low ticket price increase 8.1% by 2050.

Cost of uplift reporting for airlines relative to the baseline, expressed as present value over 2021-2050 - passed through to consumers.	O	O	O	O	O Cost of uplift reporting €0.34 billion	O Cost of uplift reporting €0.34 billion
Costs for authorities relative to the baseline, expressed as present value over 2021-2050.	O Cost of monitoring and enforcement €0.19 billion.	O Cost of monitoring and enforcement €0.19 billion.	O Cost of monitoring and enforcement €0.30 billion.	O Cost of monitoring and enforcement €0.19 billion.	O Cost of monitoring and enforcement €0.27 billion.	O Cost of monitoring and enforcement €0.27 billion.
Costs relative to the baseline (PV over 2021-2050).	✗ **€ 20.1 billion**	✗ **€ 14.4 billion**	✗ **€ 19.8 billion**	✓ **- € 20.7 billion**	✗ **€ 20.3 billion**	✗ **€ 14.6 billion**
Net benefits relative to the baseline (PV over 2021-2050).	✓✓ **€ 67.6 billion**	✓✓ **€ 72.8 billion**	✓✓ **€ 68.2 billion**	✓ **€ 51.8 billion**	✓✓ **€ 67.5 billion**	✓✓ **€ 72.7 billion**

7.2. Coherence

Coherence with the EU's high-level objectives. All POs except B2 are in line with the EU's objectives to decarbonise transport as set out in the Sustainable and Smart Mobility Strategy, in line with the 2030 Climate Target Plan and the EU Strategy for Energy System Integration. Similarly, all POs succesfully address the objective of reducing the EU's dependency on oil and increasing the EU's energy security, as identified in the 2018 "Clean Planet for All" Long Term Strategy. Finally, all POs further meet the objectives of promoting the use of renewable and low carbon fuels as one of the pathways available to decarbonise the transport sector as identified in the European Green Deal which recognises the importance of increasing the production and deployment of sustainable alternative transport fuels and makes this one of the priority areas for action.

Coherence with existing EU rules. All POs are coherent with the existing EU regulatory framework for transport, energy and climate. On the airlines side, all POs rely to a large extent on the use of existing mechanisms in place, e.g. on the EU ETS for monitoring, reporting and verification purposes. In particular, **all POs ensure coherence with the EU's renewable energy policy**. All POs are in line with the objectives of the Renewable Energy Directive to increase the share of renewable energy in transport. All POs are consistent with the EU's renewable energy framework. First, SAF eligible under this initiative are required to be compliant with the sustainability framework of the Renewable Energy Directive. Second, the objective of supporting certain fuel types e.g. advanced biofuels and RFNBOs, is aligned with the objectives of RED II. Concretely, this means that all SAF counting towards the SAF obligation under this initiative will be eligible to count towards the RED II overall renewable energy target, and in particular the RES-T target accounting for renewable energy in transport (14% by 2030 under RED II). It also means that features of RED II such as submandates, multipliers or caps that apply to certain categories of fuel will be fully applicable. For instance, advanced biofuel accounting for the present SAF obligation will be able to count towards the submandate for advanced biofuels across transport modes, as established under RED II. Similarly, Part B biofuels accounting towards the present SAF obligation will be subject to the cap established under RED II for accounting of Part B biofuels towards the target of renewable energy in transport. In addition, all POs gives supplementary direction to the fuel industry with respect to innovative and sustainable fuel technologies e.g. RFNBOs, in line with the overall objectives of RED II. Third, as explained in detail in section 6.1.2, there is no issue of feedstock availability. In spite of increased competition for access to feedstock in the decades to come, due to higher demand from sectors decarbonising with the use of bioenergy (+82% by 2050 relative to 2015), under all POs, the analysis shows that SAF production for aviation is expected to require less than 10% of all biomass feedstock used to meet bioenergy demand in the context of a climate neutral economy by 2050. Fourth, the initiative relies on the monitoring, reporting and verification framework put in place by the RED II (Union

Database) to ensure seemless monitoring and reporting on the supply side. **Under all POs, there is no risk of double regulation.** As explained under section 2.2.3, a key problem driver is the absence of regulatory framework imposing the substitution of fossil jet fuel with SAF. Under RED II rules, while Member States have the option to account the supply of SAF towards their national renewable energy targets, there is no requirement on Member States to impose obligations on jet fuel suppliers to supply SAF in a harmonised way across the EU's aviation internal market. Similarly, under the EU ETS, there is an option but no obligation for airlines to report their use of SAF. Finally, there are currently no rules requiring airlines to use SAF quotas or to report their jet fuel uplift on a flight basis prior to each departure from EU airports. Therefore, all measures envisaged notably in all POs would be strictly unique in EU rules and would not in any way conflict with other rules or lead to double regulation.

Coherence with the other initiatives of the 'Fit for 55' package. This initiative aims to fill an important gap in the EU regulatory framework on sustainable aviation fuels. By imposing mandatory SAF shares, it will oblige the market to reduce its dependence on fossil fuels and take up sustainable fuels, as was done in the past for the road transport sector. While the SAF blending mandate is expected to play an important role to deliver on the policy objectives of the present initiative, other pieces of EU legislation part of the 'Fit for 55' package, which also pursue as objectives the decarbonisation of transport, in some cases specifically air transport and are relevant to an increased role of SAF in the sector. Namely, these initiatives are the revision of the Renewable Energy Directive (RED II), the revision of the EU ETS, of the Energy Taxation Directive (ETD).

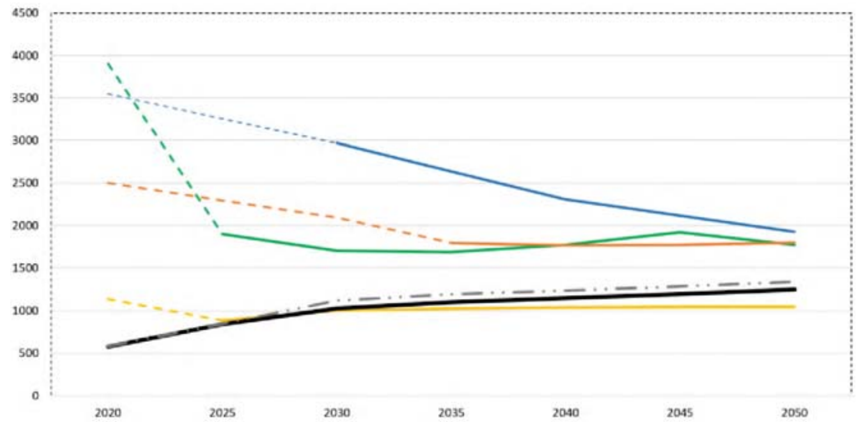
Coherence with the revision of RED II. The overall target for renewable energy in transport by 2030 is expected to increase. The submandate on advanced biofuels could be increased and a submandate for RFNBOs is expected to be introduced. Such developments would be fully in line and complementary to the ReFuelEU Aviation initiative. Indeed, ReFuelEU Aviation would fill a gap by providing for an aviation-specific SAF obligation in a way that is consistent with the needs of the aviation internal market. SAF supplied towards the aviation-specific obligation could be accounted for by States in their RED targets. It is not clear whether the cap on the contribution of Part B biofuels to the renewable energy target would evolve. Further restrictions on this cap are however unlikely, since Part B biofuels are likely to be produced in the future by biofuel producers for the road and the aviation sector. On the other hand, a lifting of the cap is also unlikely, as the objectives of the cap include limiting risks of fraud and driving investments in advanced biofuels listed in Part A of Annex IX. A substantial revision of the biofuel sustainability criteria is not expected under the RED II revision. Similarly, it is not expected that the list of feedstock contained in Part A and Part B of Annex IX be restricted or limited. In fact, RED II revision could possibly lead to extending said lists to a limited number of additional sustainable feedstock. This would be supportive to the objectives of ReFuelEU Aviation as it would open more possibilities for SAF producers, thus reducing competition for access to feedstock between transport modes and limiting feedstock price increase.

Coherence with the revision of the EU ETS. In the course of the revision, the allocation of free allowances to airlines could be reduced and the linear reduction factor could be increased. This means that airlines would be required to purchase more allowances than presently, which could have as an effect to increase costs of allowances. As a result, airlines would be further encouraged to decarbonise their activities. The incentive to use SAF under EU ETS is due to remain, i.e. airlines are not required to surrender allowances where they report the use of SAF, also referred to as "zero-rating" for SAF. Also, the eligibility of SAF under the EU ETS should remain conditional to the fulfilment of the RED sustainability framework, similarly as planned under the present initiative. Such evolutions of the EU ETS would be fully supportive and complementary to the ReFuelEU Aviation SAF obligation. It would further encourage airlines to use SAF. Even if it is unlikely that the increased price of allowances would mean that EU ETS by itself would drive SAF to aviation (see section 2.2.3, the price of a tonne of carbon would need to be around EUR 160), the zero-rating will contribute to making SAF more affordable for airlines. As the share of SAF in the aviation fuel mix would increase under all POs of the ReFuelEU Aviation initiative, the EU ETS for aviation would still have a major to play to cover the emissions resulting from the combustion of the fossil jet fuel fraction of the fuel mix (the ‘zero-rating’ applies only to the ‘neat’ SAF fraction of the fuel mix).

Coherence with the revision of the ETD. It is possible that taxation of jet fuel could be proposed. This could be done in a way to tax types of jet fuel according to their carbon intensity. This could lead to taxation of fossil jet fuel and possibly absence of or very low taxation rates for SAF. Such a system would provide fiscal preferential treatment for SAF. This could have as an effect to support further the uptake of SAF by airlines and be in line with this specific objective of ReFuelEU Aviation, by making SAF more economically interesting. In spite of possibly reducing the price difference between SAF and fossil jet fuel, and hence making SAF more affordable for airlines relative to fossil fuel, the achievement of the SAF obligation under ReFuelEU Aviation is rather insensitive to the revision of the ETD. Indeed, as explained under section 5.4.2, the imposition of a SAF blending mandate means that the reduction of price gap between SAF and fossil jet fuel is desirable (mostly if achieved thanks to a reduction of SAF costs) but is not a decisive factor for the attainment of the SAF obligation targets.

Coherence towards bringing down SAF prices. This impact assessment clearly acknowledges that other pieces of the EU regulatory framework can play a complementary role in bringing SAF to the aviation market at competitive prices. In particular, it is clear that non of the following policy mechanisms: SAF obligation, EU ETS, RED, ETD can alone bring SAF to a par with fossil jet fuel prices. However, as illustrated below (representative of the evolution of SAF prices under all POs, except B2), the SAF blending mandate allows to bring SAF prices down from their current estimates. Over time, SAF become increasingly price competitive. This is explained as SAF production costs benefit from economies of scale and learning effects as the industry scales up over time (see section 6.2.1 and Annex 16). Figure 5 shows that other measures (e.g. here the EU ETS[168]) can further help to reduce the price of SAF relative to conventional fossil jet fuel. Other relevant measures for this purpose (not represented under figure 5) could include fossil jet fuel taxation under the revision of the Energy Taxation Directive, as previously discussed. It is worth noting however, that in a context of POs C1 and C2, where all jet fuel available at EU airports is blended beyond 2035, the existence of a price gap between SAF and fossil jet fuel is no longer a factor on which SAF uptake depends. Indeed, airlines only have access to SAF-blended jet fuel, no longer to either SAF or fossil jet fuel. Therefore, whereas it is desirable from an economic point of view for airlines that the price difference between SAF and fossil jet fuel decreases over time (in particular as a result of a decrease of SAF prices) the reduction of this price gap is not a sine qua non condition for the successful uptake of SAF under this initiative.

Figure 5 - Production cost development for SAF production pathways – Sensitivity with ETS and low production costs (in € per tonne of fuel). Note: black: fossil, grey: fossil with ETS, yellow: HEFA, green: ATJ, red: Gas+FT, blue: RFNBOs.



[168] A weighted average ETS mark-up is also produced for fossil fuel to align with the CTP expectation of an EU ETS allowances at the level of €44 per tonne of CO2 in 2030. This is 100% attributed to intra-EEA flights but only by 50% to extra-EEA flights.

Source: Ricardo at al. Impact assessment support study.

Various 'market' climate initiatives affecting aviation (e.g. ETS, energy taxation, renewable energy) are coherent with the present initiative and their climate objectives are equally compatible. This is also the case as regards the objectives pursued by the present initiative. Indeed, the various 'market' initiatives allow to support SAF uptake, mitigate fuel price increase, lead to higher fuel efficiency and encourage the deployment of innovative aviation technology. For instance, the EU ETS will support the present initiative thanks to its 'zero-rating' mechanism for SAF. This will encourage airlines to take up SAF and at the same time will reduce SAF cost, since airlines will not be required to surrender allowances, as a result of SAF use. The EU ETS also supports fuel efficiency and the deployment of newer aircraft technology, as airlines are required to purchase allowances in proportion to their carbon emissions. This contribution of the EU ETS would be accentuated if the amount of free allowances for airlines would be reduced in the course of the EU ETS revision. The same holds true for the role of the energy taxation Directive, which would encourage the uptake of SAF and the deployment of more innovative aircraft technologies if fossil jet fuel would become subject to a tax.

Areas for further coherence with other initiatives. For the purpose of contributing to the policy framework aiming to boost the SAF market, adjustments under other pieces of the EU regulatory framework could also be helpful, although not strictly necessary. These adjustments could be considered under the upcoming revision of the relevant instruments or be considered at a later stage. For instance, the EU ETS emission reports template could be updated to allow for airlines to report their use of RFNBOs. Finally, adjustments to the RED II sustainability criteria for SAF could be considered to enhance the compatibility with CORSIA and facilitate SAF uptake by international airlines in the EU.

7.3. Subsidiarity and proportionality

All POs propose EU action in line with the intervention logic described in sections 1 to 4. The subsidiarity dimension of the intervention is the same as that explained under section 3 and therefore is not repeated in this section.

As proportionality, none of the POs go beyond what is necessary to achieve the objectives. PO B2, which scope is reduced to intra-EU flights, falls short of making an ambitious contribution to the decarbonisation of air transport and to the EU's climate goals. All POs provide a reasonable lead-period before fuel obligations enter into force (2025), considering the time needed to scale up SAF production at the capacity needed. All POs also foresee additional lead-time before mandating the introduction of RFNBOs, recognising the time and resources needed for cutting-edge technologies to mature.

Finally, POs C1 and C2 provide additional flexibility to the fuel industry at the early stage of the fuel obligation, accounting for the time needed for the production capacity to scale up at EU-level.

7.4. The impact of the Covid-19 pandemic

As explained in section 5.1, the baseline scenario considers the impacts of the COVID-19 pandemic on transport activity, energy use and emissions. The pace of the recovery builds on the GDP projections but also considers some moderate structural changes due to limited shifts towards digital meetings. The overall impact of the COVID-19 pandemic on the air transport activity is significant, with lower growth projected relative to pre-COVID projections (i.e. around 11 percentage points lower growth for 2015-2030 relative to the pre-COVID projections and 14 percentage points lower growth for 2015-2050). At this stage, the COVID-19 pandemic's long-term effects on air transport activity are highly uncertain and depend on the ever-evolving global situation of the pandemic, the coordination of States to address it, and the ability of the aviation sector to restore passenger confidence. Deeper structural changes may also take place due to the shifts towards digital meetings.

On the other hand, all policy options are either defined in terms of a minimum share of SAF (expressed in volume terms) or in terms of a minimum reduction of the CO_2 intensity (i.e. CO_2 emissions per unit of energy) of the overall jet fuel supplied, which proves robust to changes in transport activity. For example, if the air transport activity were lower than projected in this impact assessment, the total energy use (and thus fuel sold) and CO_2 emissions from air transport would also be lower – driven by the lower activity. When the policy option is expressed in volume terms, despite keeping the requirement for the minimum share of SAF unchanged, the absolute volumes of SAF that are required to meet the obligation would be lower. This is because of the lower total energy use in air transport. When the policy option is expressed in terms of a minimum reduction of the CO_2 intensity of the overall jet fuel supplied, the outcome would be similar as the CO_2 intensity is defined as the ratio between the CO_2 emissions and total fuel use in air transport. As the lower air transport activity drives a reduction in both CO_2 emissions and fuel use, the impact on CO_2 intensity would be only determined by the fuel mix and thus by the uptake of SAF. Similar considerations apply in case air transport activity would be higher than projected in this impact assessment, whereas the total energy use (and thus fuel sold) and CO_2 emissions from air transport would also be higher. As a result, the ranking of the policy options is not expected to change in case of different developments in air transport activity.

In addition, as already explained in section 1.3, an update of the pathway/scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy, while also reflecting the COVID-19 pandemic, confirms that air transport effectively contributes to the EU climate goals while considering the 5% share of sustainable aviation fuels obligations in the air transport fuel mix by 2030 and 63% by 2050.

8. PREFERRED OPTION

PO B2 is not compatible with the level of climate ambition expected by the 2030 Climate Target Plan. It also raises important risks of distortion between airlines within the Single Market. POs A1 and A2 regulate only one side of the market (the supply) without specific safeguards, which is likely to lead to undesirable effects of tankering practices by 2035. Furthermore, the obligation to supply SAF at all airports by 2025 is deemed premature at the early stages of the SAF market, and may lead to unintended additional logistics costs. This could also increase the price of SAF-blended jet fuel at small or remote airports. Finally, the acceptability of PO B1 is assessed to be its main weakness, as it may lead to controversial reactions from non-EU jurisdictions.

POs C1 and C2 are considered the most efficient and effective to achieve CO_2 reductions in the aviation sector in line with the EU's climate goals. This corresponds to a reduction of well-to-wing emissions by 60.8% and 60.2% by 2050, respectively for PO C1 and C2, relative to the baseline scenario. The difference in emissions savings achieved between both options is marginal and is due to the fact that the volume-based approach (PO C1) leads to a larger uptake of RFNBOs, compared to the CO2 intensity approach (PO C2). Both policy options allow to successfully scale up SAF production and uptake at EU level, i.e. by reducing the use of fossil jet fuel by around 65% by 2050, and substituting it with innovative and sustainable fuel technologies, which reach the market much earlier than in the baseline scenario. By 2050, under POs C1 and C2, the share of SAF in the aviation jet fuel mix amounts to 63%. By 2050, 92% of all SAF supplied to the EU market are produced in the EU, from feedstock and renewable electricity sourced in the EU.

The scale of the challenges at stake justifies requirements on both the supply and the demand sides of the market to act in a co-ordinated way. POs C1 and C2 ensure that all airlines operating intra and extra-EU flights will contribute to SAF uptake and will be able to compete on equal footing. Both POs will ensure a harmonised framework for the EU aviation single market, leading to a uniform spread of costs across air service providers, and therefore will limit market distortions. The supply side obligation is designed in a way to allow the SAF industry to scale-up its production capacity by the time SAF-blended fuel supply is required at all airports. This will contribute to avoiding higher SAF prices and additional emissions due to unnecessary logistics. It will avoid putting some airports e.g. small or remote airports at competitive disadvantage. SAF suppliers can operate transactions between over and under-achievers for accounting purposes towards meeting their SAF obligation during the transition period, i.e. 2025 and 2035. This will allow SAF suppliers to meet their obligations in a more cost-effective way, as explained in section 5.4.4. SAF transactions are not possible beyond 2035, since from that point in time all fuel suppliers will be required to supply airports with the exact minimum of SAF shares, as defined in the ramp-up. Therefore, it is not desirable to allow accounting transactions, whereby some suppliers could continue supplying low levels of SAF or only fossil fuel at certain airports while meeting their obligation through accounting transactions. It should be noted that under the preferred options there is no need for SAF transactions between airlines, as airlines are not subject to quantified SAF obligations. Gradually, once the SAF industry has developed across the EU by 2030 and 2035 respectively, all airports will be supplied with SAF. This will reinforce the level playing field within the aviation internal market since all airlines (EU and non-EU) will have no alternative than to use the SAF-blended jet fuel available at all airports. POs C1 and C2 include an important safeguard against the possible effects of tankering, as all airlines will be required to refuel before each departure, with the amount of fuel needed to operate the planned flight. This is expected to strengthen fair competition between EU and non-EU airlines on international routes, and contribute to reinforcing the level playing field between airlines and airports in the EU aviation internal market.

Therefore, **the preferred policy options are C1 or C2**. This impact assessment considers that both policy options allow to effectively and efficiently meet the policy objectives. As explained in detail in sections 5.3 and 5.5.1, the difference between C1 and C2 consists of the definition of the SAF targets. Under C1, the SAF targets are expressed in SAF volume terms. This means that fuel suppliers are required to supply a volume share of SAF as part of their total jet fuel supply, increasing over time (see section 5.4.3). Under C2, the SAF targets are expressed in CO_2-intensity reduction terms. This means that fuel suppliers are required to supply jet fuel to EU airports with a CO_2-intensity decreasing over time following defined targets. The other notable difference between the two options is that PO C1 contains a specific sub-mandate for RFNBOs, whereas PO C2 contains a specific multiplier for RFNBOs. The rationale for this difference is explained in section 5.5.1. It is essential to highlight that both C1 and C2 achieve the same reduction of CO_2 emissions overall by 2030 and 2050. Therefore, the choice between C1 and C2 does not determine the level of climate ambition of this initiative. Rather, it influences how the market reacts and it orients SAF production towards scaling up the different SAF technologies. This is explained in full detail in section 6, and a direct comparison of the impacts of options C1 and C2 is provided in Table 14 under section 7.1. Overall, the impacts of the two options are very similar on a wide range of indicators (including the amount of CO_2 emissions reductions achieved, the increased SAF production capacity in the EU, the capital investments needed to increase SAF production capacity, the reduction of EU's imports of oil products, the logistics costs of supplying SAF, the increase on ticket prices, and others). The notable differences on the impacts between C1 and C2 are the following. C1 leads to a slightly higher supply and uptake of RFNBOs, as a result of the specific sub-mandate. On the other hand, C2 results in marginally higher levels of advanced biofuels. This leads C1 to requiring slightly higher amounts of renewable electricity for RFNBOs production and to inducing higher fuel costs for airlines. On the other hand, C1 presents the advantage of being easy to implement from a regulatory point of view, but more importantly from the side of the industry. Monitoring, reporting and verifying fuel volumes is generally easier than fuel CO_2 intensity reductions, which is more complex from a methodological standpoint. There is no preference expressed for C1 or C2 as both POs are expected to deliver very similar results and have very similar impacts. Both POs would deliver on the policy objectives.

Stakeholders views of the preferred options. The large majority of stakeholders of the aviation (airlines, airports, aircraft manufacturers) and fuel industries, Member States and NGOs support establishing a SAF obligation as an effective policy mechanism to boost SAF production and uptake and successfully decarbonise the aviation sector. Stakeholders are quite divided on the specific design of the option but a majority of fuel suppliers, Member States, NGOs, airports and part of the airlines support a supply-side SAF obligation with flexibility in the fuel distribution, and covering jet fuel supplied for all flights departing from EU airports. At the same time, the majority of stakeholders see the need for measures preventing carbon leakage and distortion in the aviation internal market. A majority of stakeholders (airlines, airports, fuel industry, NGOs, Member States) also support specific incentives to support RFNBOs. All these measures are included in POs C1 and C2. Following wide **consultations on the preference between C1 and C2**, stakeholders have expressed mixed views. In the context of the targeted consultation accompanying this impact assessment, 40 respondents out of 73 favoured a volume-based target (C1), while 47 respondents out of 73 favoured a CO2 intensity-reduction based target (C2)[169]. Member States show a clear preference for a volume-based system (C1), while NGOs have a clear preference for a CO_2-intensity reduction based target (C2). There seems to be no consensus among the aviation industry nor among the fuels industry towards one or the other approach.

The present initiative must be rolled out swiftly and efficiently, as a key deliverable of the European Green Deal and the Sustainable and Smart Mobility Strategy, and as a necessary building block towards reaching EU's climate goals by 2030 and 2050 by ensuring that the aviation sectors speed up its own decarbonisation without jeopardising the well-demonstrated benefits of a highly integrated aviation internal market. As explained in section 1.4 and Annex 11, this can be achieved most successfully **by directly regulating economic actors at EU level through an internal market Regulation**. Indeed, common rules applying directly and uniformly to aviation and fuel market actors across the EU will provide clarity and uniformity. As the aviation single market is inherently integrated at EU level, it functions best when rules are applied to all airlines in the same way. **Imposing the same requirements to all market players reduces the risks of distortion of competition** and sends clear signals to non-EU aviation market actors, when flying in the EU. A uniform set of rules across the EU, as established under a Regulation, will allow to send loud and clear signals to the market. As the transition to SAF requires significant investments (see section 6.2.5), it is indispensable that the regulatory framework provides a single, long-term and robust set of rules to all investors EU-wide. In particular, it is crucial to **avoid the creation of a patchwork of differing measures** at national level, as would be the case if implemented under a cross-sectoral directive such as the Renewable Energy Directive. While this can function with transport modes like road or rail, it cannot be successful for transport modes that are so cross-border and global as aviation. The market scale of most airlines is EU-wide or even global. A patchwork of national transpositions could reduce the effectiveness of the policy and put in jeopardy the effective decarbonisation of air transport. It could also be conducive to different economic behaviours in the aviation and fuel industries from one Member State to another. This could lead to practices of cost avoidance (e.g. via fuel tankering) that would undermine the functioning of the Single Market. The present initiative will have an important impact on air transport actors and the aviation internal market as a whole. It is essential that obligations set on all airlines apply to all airlines uniformly, as can be ensured via a regulation. It is equally important for the effectiveness of this initiative that the fuel supply obligation be implemented and enforced in a uniform way. Differing fuel supply obligations in different areas of the EU (e.g. different targets, varying sustainability standards, etc.) would set differences of treatments between airlines and could induce competitive distortions between EU airports or put EU aviation actors at disadvantage with non-EU competitors. In terms of type of legal instrument, the present initiative should be implemented as a standalone Regulation in order to **cater for the specificities and complexities of the aviation single market.** Such detailed provisions regulating the aviation market cannot be established under the Renewable Energy Directive, which scope goes only as far as energy matters are concerned.

The timing of this initiative is an essential factor of success. This initiative is a key deliverable of the European Green Deal and a necessary building block towards reaching EU's climate goals by 2030 and 2050. Regulatory certainty is needed imminently. Indeed, to reach the SAF objectives of around 2% by 2025, a lead-time of 3-4 years is necessary for the industry to scale up its SAF production capacity. This means that **a SAF**

[169] Respondents were asked about their level of support

regulatory framework must be in force in Union law by 2022. This would be very difficult to achieve if implemented through a large economy-wide regulatory framework (e.g. RED). To illustrate this, the past experience of RED II shows that from adoption of the proposal by the Commission (2016), to transposition and entry into force in Member States (deadline for transposition is June 2021), the process took 5 to 6 years. Such a timeline of 5 to 6 years for the implementation of ReFuelEU Aviation would mean that a SAF framework would only enter into force at Member States level by 2026. This would jeopardise chances of effectively decarbonising aviation and contributing efficiently to the EU's climate goals, as SAF would likely not reach the market before 2029-2030 (a lead time of 3 to 4 years is necessary for investments to flow and the fuel industry to scale up, which is the absence of a robust regulatory framework is unlikely to happen). On the other hand, if adopted through a standalone Regulation, the present initiative would have higher chances of being adopted swiftly. It could become applicable with immediate effect after entry into force as early as end of 2022.

9. How will actual impacts be monitored and evaluated?

The impacts of this initiative will be monitored on two fronts, i.e. the supply of SAF by fuel suppliers and the uptake of SAF and jet fuel by airlines. As regards the supply of SAF, this will be performed through the existing processes set out under RED II for monitoring, reporting and verification of biofuels supply. In particular, the Union Database will serve for fuel suppliers to directly insert their data on SAF supply. The accuracy of such data will be verified at national level as per the processes and requirements already established in RED II rules. This data, providing information on SAF supply at supplier level, will then be processed by an existing EU agency (e.g. EASA) in order to determine whether fuel suppliers have met their obligation and will be reported to the Commission. Enforcement will be carried out at national level.

The SAF uptake of airlines will be monitored through the already existing monitoring, reporting and verification processes of the EU ETS. Airlines operating intra-EU flights will include information relative to their SAF uptake as part of their Aviation Emissions Reports. These reports will be made available to an existing EU agency or European organisation (e.g. EASA, Eurocontrol) to compile the information relative to SAF use at airline level. Regarding the jet fuel uplift obligation imposed on all airlines departing from EU airports, this be will monitored through a direct reporting by all airlines to an existing European organisation or EU agency (e.g. EASA, Eurocontrol). The information on jet fuel uplift at flight level per airline will be processed to identify cases of fuel tankering and reported to the Commission. Enforcement will be carried out at national level. More detailed information on monitoring, reporting and verification is included in Annex IX.

The monitoring of the implementation of the present initiative will be useful (and vice-versa) for the monitoring of other regulatory frameworks such as the EU ETS, RED II and ETD. For instance, data on the status of the jet fuel market, the price of SAF, and the level of uptake by airlines will be fully relevant to assess the effectiveness of specific provisions of the EU ETS (e.g. the zero-rating for SAF) and other initiatives. Based on such monitoring, it will be possible to assess the complementarity between the present initiative and others. This could also potentially provide useful insights on the need to review specific features of the EU regulatory framework to ensure further complementarity and that the various initiatives can continue to mutually reinforce each other.

Annex 1: Procedural information

1. Lead DG, Decide Planning/CWP references

Directorate General for Mobility and Transport (DG MOVE), Unit E1 – Aviation Policy, is the lead DG for this legislative proposal – 'ReFuelEU Aviation' aimed at boosting the production and uptake of sustainable aviation fuels in the air transport sector. This initiative's Decide reference is PLAN/2020/6623.The Inception Impact Assessment was published in March 2020.[170]

2. Organisation and timing

This impact assessment accompanying the legislative proposal ReFuelEU has been consulted within the Inter-Service Steering Group (ISSG) comprising the following members: Secretariat General (SG), Legal Service (LS), Directorate-General for Mobility and Transport (MOVE), Directorate-General for Competition (COMP), Directorate-General for Environment (ENV), Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (GROW), Directorate-General for Climate Action (CLIMA), Directorate-General for Energy (ENER), Directive-General of Regional and Urban Policy (REGIO), Directorate-General for Taxation and the Customs Union (TAXUD), Joint Research Centre (JRC-ISPRA), Directorate-General for Defence Industry and Space (DEFIS). In total, 4 meetings were organised to discuss this impact assessment. Some meetings were held by phone due to the COVID-19 crisis. Many written consultations of the ISSG took place by email at various stages and on various drafts of this impact assessment.

3. Consultation of the RSB

The Regulatory Scrutiny Board received the draft version of the impact assessment report on 18 December 2020. The Board meeting took place on 20 January 2021. On 22 January, the Board gave a negative opinion on the report. The Board made several recommendations. Those were addressed in the revised impact assessment report as follows in the first table below. On 3 March 2021, the Board gave a positive opinion on the report. The Board made several recommendations to be taken into account. Those were addressed in the impact assessment report, as follows in the second table below.

RSB recommendations for IA resubmission	Modification of the IA report
Main considerations	
1. The report is unclear about how it has established the fuel specific targets and pathways for the aviation sector, and what the key assumptions and uncertainties are. It does not show how, and under what conditions, they are compatible with the overall EU 2030/2050 climate targets. The report does not analyse the implications and feasibility of alternative targets and pathways.	A new section (section 1.3) has been added to the report, to explain the ramp-up of SAF obligations. It also explains the compatibility with the overall EU 2030/2050 climate targets. In addition, section 5.4.3 has been reinforced and now includes a qualitative assessment of the implications and feasibility of alternative ramp-up of SAF obligations.
2. The report is not sufficiently clear on how	A new section (section 1.4) has been added to the report to explain

[170] Source: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12303-Sustainable-aviation-fuels-ReFuelEU-Aviation

it ensures coherence with the other 'Fit for 55' initiatives. It does not explain how it takes into account the uncertainty on the future content of the most directly related climate initiatives.	the coherence with the other 'Fit for 55' initiatives**.** Additional explanation is provided in section 2.3 (How the problem will evolve) as well as in section 7.2 (Coherence with other initatives).
3. The report does not explain convincingly why the present initiative cannot be integrated into existing instruments that are part of the 'Fit for 55' package.	The report now contains a more in-depth analysis of the reasons why the present initiative cannot be covered by the RED. This is explained in section 1.4 on 'Coherence with the Fit for 55 initiatives', in section 8 on the 'Preferred Option' and in more details in Annex 11.
4. The report is not always clear on the content of the options and how they will function. It does not explain why there is no preferred option.	The relevant sections of the report (section 5.3 and 5.4.4) now provide more clarity on each policy option, including on elements such as the monitoring, SAF transaction system, anti-tankering measure, and others.
Adjustment requirements	
(1) The report should explain how the fuel-specific targets (or parameters) for aviation were chosen. It should make clear how the proposed pathways towards these targets align with the GHG reduction targets of the Climate Law, and how they follow or differ from the Climate Target Plan modelling scenarios. The report should explain the assumptions behind the aviation fuel targets, and under what conditions they are compatible with targets for the other transport sectors.	A new section (section 1.3) has been added to the report, to explain the ramp-up of SAF obligations. It also explains that they will contribute towards the overall EU 2030/2050 climate targets and with the objective of decarbonising the aviation sector. Section 1.3 also provides more context on the flexibility, which exists to decide on the exact level of ambition of individual measures such as ReFuelEU Aviation, given the corrective mechanisms offered under the ETS, the Effort Sharing Regulation, and other instruments to reach the EU's climate targets, but also the possibility to revise the level of ambition of measures as we get closer to the delivery of EU climate targets.
(2) The report should justify why it does not include any alternative aviation fuel targets and pathways. It should present at least a qualitative analysis of the feasibility and implications of deviating from the set target, including for the overall 'Fit for 55' package.	The new section 1.3 explains how the ramp-up of SAF obligations has been selected. In addition, section 5.4.3 has been reinforced and now includes a qualitative assessment of the implications and feasibility of alternative ramp-up of SAF obligations.
(3) The report should better explain how the initiative is coherent with the most directly related other 'Fit for 55' initiatives (in particular the Renewable Energy Directive, the Emissions Trading System, and the Energy Taxation Directive). Would this initiative make some of the others superfluous in the aviation sector? As the baseline does not include the envisaged changes of the other 'Fit for 55' initiatives, the report should explain why it does not include alternative policy scenarios in the options to reflect the uncertainty on the future of these other initiatives.	A new section (section 1.4) has been added to the report to explain the coherence with the other 'Fit for 55' initiatives. Additional explanation is provided in section 2.3 (How the problem will evolve) as well as in section 7.2 (Coherence with other initatives). Section 5.1 (What is the baseline from which options are assessed?) clarifies that the other 'Fit for 55' initiatives are not part of the baseline. It further explains how coherence is ensured.
(4) The baseline should further qualify the impact of the Covid-19 pandemic, its likely long-term consequences, and the degree of uncertainty of these estimates. It should conduct a sensitivity analysis to assess the	Section 5.1 (What is the baseline from which options are assessed?) has been reinforced and provides more insights on the impact of the COVID-19 pandemic relative to pre-COVID projections. More details are also provided in Annex 4. A new section (section 7.4) has been added to the report that provides a qualitative assessment

possible effects of different Covid-19 scenarios on the effectiveness of the initiative.	of lower/higher growth in air transport activity on the effectiveness of the initiative.
(5) The report should explain why this initiative cannot be covered by the Renewable Energy Directive, given that blending of jet fossil fuels with SAF seems to be the only (realistic) technological option.	The report now contains a more in-depth analysis of the reasons why the present initaitive cannot be covered by economy-wide, cross-sector regulatory frameworks such as the RED. This is explained in section 1.4, in section 8 on the 'Preferred Option' and in more details in Annex 11.
(6) The report should provide more detail on how far scaling up of SAF demand will contribute to reducing costs and prices. It should provide more detail about the sources of greater feedstock supply and competing demands. It should explain better the cost differences between standard and advanced biofuels. The report should also acknowledge the high-energy demand for producing biofuels. The impact assessment should be explicit about how coherence will be ensured with the EU's overall renewable energy policy (e.g. for competition for feedstock, or accounting of total renewable targets), and how the risk for overlapping regulation is avoided.	The report now contains a new paragraph in section 6.2.1 and a new Annex 16 dedicated to providing the reader with more information on the contribution of economies of scale to decreasing SAF production costs. The role of economies of scale is also explained in the problem definition in section 2.2.2, including a reference to Annex 16. The annex provides in-depth explanations on the cost structure for the production of SAF pathways and elaborates on the key differences in production costs between Part B and advanced biofuels. The report, section 6.1.2 now contains more explanations on the sources of feedstock used for Part B and advanced biofuels production. It also explain in detail what would be the feedstock requirements for SAF production, and how this would relate to the total amount of feedstock available for other transport and energy sectors. In addition, section 6.1.2 now better acknowledges the high enegy demand for the production of RFNBOs and provides detailed figures on energy needs, including with respect to total renewable energy supply in the EU. Under the same section, figures and information have also been added on the energy needs for biofuels production. The report, now contains a new section 1.4 that explains in detail the coherence of the present initiative with the initiatives from the 'Fit for 55' package. In addition, section 7.2 on 'Coherence' now contains an in-depth analysis of the coherence of ReFuelEU Aviation with the EU's renewable energy policy, in particular with the various features and mechanisms contained in the RED II. Section 7.2. clearly indicates how double regulation is avoided. It also includes information on the interaction with other relevant instruments such as the EU ETS and ETD, including by giving indications on the interactions of these instruments in view of their upcoming revision.
(7) The report should further specify the content of the options and how they will work. For instance, it should clarify the foreseen monitoring arrangements, the role and set-up of the foreseen Agency. It should explain the functioning of a SAF certificates trading system, and clarify why it would be needed under the preferred option. It should justify the choice of values for the renewable fuels of non-biological origin (RFNBO) multipliers. It should explain why anti-tankering measures should already be introduced during the transition period, when the risk of tankering only arises after 2035.	Section 5.3 (description of the policy options) has been reworked to provide more information and clarity on the functioning of each policy option. In particular, explanations have been added under the description of each policy option in section 5.3, on the functioning of the monitoring, reporting and verification on the supply side and the airlines side where relevant. Also, section 9 on how impacts will be monitored has also been reworked to provide more clarity. Finally, Annex 9 is entirely dedicated to the functioning of the monitoring, reporting and verification systems for each policy option. The report also clarifies the role of the existing EU agency that would be required to process SAF supply/use data and report to the Commission. This is clarified in several instances, including section 5.3 and Annex 9. The report (section 5.3 and 5.4.4) provides more detailed

	information on the need for and the functioning of a SAF transaction system for accounting purposes. It also clearly specifies whether this would be needed on the side of fuel suppliers or airlines, and under which policy option. It gives information about how such a system could be implemented and would function in practice. The report now provides more detailed information on the choice of numerical values for the multipliers applying to RFNBOs under POs A2 and C2. This is explained in section 5.3.2, section 5.3.6 and section 5.5.1. The report now contains more detailed explanations on the anti-tankering measure under sections 5.3.5 and 6.2.8. In particular, it clarifies why this measure is necessary already 2025.
(8) The competitiveness analysis should elaborate the risk that airlines will re-route longhaul flights to non-EU hubs. It should consider the consequences for the effectiveness of the Directive, and the competitiveness of EU airlines and intercontinental airports.	The report now provides a more in-depth analysis of the risks of loss of competitiveness by EU hub airports, and EU airlines as a result of SAF obligations. This is included in section 6.2.8. This section also provides indications on the effects this may have on the effectiveness of the ReFuelEU Aviation legislation.
(9) The report should more rigorously elaborate the impact analysis and comparison of options. It should clarify why it presents two alternative preferred options. To better inform policy makers' choice, it should clarify the main differences between them and indicate stakeholders' views.	The report now provides a more in-depth analysis of the policy options and of their impacts under section 6. In particular, under section 8, it discusses in detail the differences between the two preferred policy options C1 and C2. Section 8 also now clearly indicates stakeholders views, also indicating the views of various categories of stakeholders on the various aspects of the preferred policy options.

RSB recommendations after IA resubmission	**Modification of the IA report**
Improvements required	
(1) The report should briefly explain why the transport sector should reduce its CO2 emissions only by 90% by 2050. It should similarly clarify how this margin has been distributed across the transport sectors.	The report now provides with an explanation of why the transport sector is required to reduce its emissions only by 90% while the economy aims at carbon neutrality. An explanation is included on how other sectors need to compensate for the residual emissions accountable to transport. This is contained at the top of section 3 of Annex 4.
(2) The report shows that various climate initiatives affecting aviation (e.g. ETS, energy taxation, renewable energy) are coherent with the present initiative and that their climate objectives are compatible. However, it could still better demonstrate how direct regulatory measures (such as compulsory SAF uptake) interact with initiatives based on market incentives. The report could further develop this analysis and clarify how the various instruments contribute to the multiple objectives they pursue (SAF uptake, mitigating fuel price increase, fuel efficiency, promoting future technologies). The report should better	The report now provides further analysis on the combined role of direct measures (such as a SAF obligation) and market measures such as the energy taxation directive or the EU ETS. It is notably discussed how these measures can pursue the same objectives (SAF uptake, greater fuel efficiency, uptake of more innovative aircraft technologies, etc.) This is included in section 7.2. The report also now includes a new paragraph explaining how the monitoring for the present initiative and other relevant pieces of regulatory framework, pursuing the same objectives, can provide useful insights for each other and ensure complementarity. This could also be useful to assess the need for potential revisions of specific features of these instrument. This is explained in section 9.

explain how the monitoring and evaluation arrangements will help ensure complementarity between the various policy iniatives over time.	
(3) The report should be more transparent about uncertainities underlying the analysis. For instance, the report should better reflect the uncertainty as to the likely price level of SAF and how this will affect the competitiveness of the sector. It should consider the risks of an increasing price gap between conventional and advanced fuels for the competitivenesss of European intercontinental airport hubs. Given that third country network carriers will not be subject to EU anti-tankering and SAF obligations when competing for "indirect" longhaul traffic connecting via a third country hub, the impacts on cost-competitiveness of EU network carrier and EU hubs should be better assessed.	The report now clearly acknowledges that uncertainties exist in the analysis, notably related to the evolution of the price gap between SAF and conventional aviation fuels. In particular, the report explains that if the price gap increases (instead of decreasing, as the analysis projects), this could lead to providing non-EU airlines and non-EU airport hubs with a competitive advantage and put at risk the competitiveness of the EU aviation industry. This could be assessed and remedied in the framework of the review clause of the instrument. This is explained in section 6.2.8.
(4) Regarding the competition for feedstock, the report should not only look at aviation's share in fuel production, but also at the possible impact on fuel prices given certain demand or supply price rigidities.	The report now provides a paragraph to explain this point in section 6.2.1

4. EVIDENCE, SOURCES AND QUALITY

The Commission contracted an external, independent consultant (Ricardo) to support this impact assessment. Quantitative and qualitative data supporting this impact assessment has been collected from Member States, airports, airlines and fuel suppliers. This report draws on the extensive consultations with stakeholders.

Annex 2: Stakeholder consultation

1. INTRODUCTION

The Commission actively engaged with stakeholders and conducted comprehensive consultations throughout the impact assessment process. This stakeholder consultation annex provides an overview of the consultation strategy and present a summary of stakeholder inputs.

Stakeholder involvement was vital for the impact assessment in order to collect facts and data enabling the Commission to substantiate, validate, develop or modify the problems and their drivers, and the corresponding objectives identified in the inception impact assessment and to elaborate a list of specific possible policy measures and policy options which could address each of the problem drivers identified, with a different level of legislative and/or non-legislative intervention. The information collected from stakeholders was key in allowing the Commission to assess the economic, social and environmental impacts of each policy option, compare them and determine which of the policy options is likely to maximize the benefits/costs ratio for the society.

2. CONSULTATION STRATEGY

The objective of the consultation for this impact assessment aimed to gather the views of stakeholders on the problem definition, policy objectives, potential policy measures and expected impact of policy measures.

The consultation strategy[171] was developed from the start of the project and included as key stakeholders the following groups: (i) EU institutions and international organisations; (ii) Member States / national authorities / Civil Aviation Authorities; (iii) Air transport service providers; (iv) Fuel and feedstock producers, suppliers and retailers; (v) NGOs; (v) Other (including airports, aircraft manufacturers, air navigation service providers, aerospace research centres, employees, trade unions and professional organisations). Following the consultation process, the results were considered as part of the problem definition, the identification of different measures and policy options as well as the analysis of impacts and the design of the preferred policy option, to ensure that the views of key stakeholder groups were accounted for. The consultation results were used to support the identification and quantification of impacts, building on the findings from the modelling activities and desk research conducted as part of this study.

Table [x] below provides an overview of consultation methods and the extent of replies and engagement of different stakeholder groups across them.

Stakeholder category	Inception Impact Assessment (IIA)[172]	Open Public Consultation (OPC)[173]	Interviews [174]	Survey [175]	Workshops (4th March 2020 and 10 November 2020)[176]	Follow up survey[177]

171 Source: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12303-Sustainable-aviation-fuels-ReFuelEU-Aviation.

172 The IIA open public consultation was open from 24 March 2020 to 21 April 2020 (four weeks).

173 The Open Public Consultation was open from 5 August 2020 until 28 October 2020 (12 weeks). Respondents reside in 14 Member States: AT, BE, FI, FR, DE, HU, IE, IT, MT, NL, PL, PT, ES and SV) as well as Canada, Guinea, Hong Kong, Switzerland, the United Kingdom and the United States. Most responses were received from stakeholders from DE (29), BE (26), FR (14) and SV (14).

174 In order to get early involvement of key stakeholders, four exploratory interviews were conducted between 27 July 2020 and 11 August 2020 with the objective to help to better assess the intervention logic and policy measures that were considered at that time. These interviews were later supplemented by targeted interviews that took place 19 August 2020 and 9 October 2020 to obtain specific input from stakeholders on the identified problems and proposed policy objectives as well as to seek views on the expected impacts. Some interviews were followed up with email exchanges.

175 A survey was developed to obtain the views of a wide range of stakeholders, including national authorities and industry.

176 On 10 November 2020, the European Commission held a roundtable discussion on SAF. Participants from industry and Member States were invited to discuss the potential impacts of different policy options, which were based upon variants of a blending mandate with

EU institutions and international industry organisations	4	2	2	2	2	2
Member State authority	8	14	3	11	20	8
Fuel producer	46	37	7	13	14	11
Airline	11	24	5	19	12	10
NGO	8	13	2	1	2	1
EU citizens	2	0	0	0	0	0
Other[178]	34	66	2	27	16	10
N/A	4	4	0	0	0	0
Total	**117**	**160**	**21**	**73**	**66**	**42**

(Source: Ricardo)

3. SUMMARY OF INPUTS AND STAKEHOLDER VIEWS

Stakeholders provided significant input that helped validate the definition of the problem and development of policy options. The sections below summarise the input provided across all stakeholder consultation activities. Input came primarily from the OPC and targeted consultation activities and was validated through the IIA feedback and workshop.

4. POLICY CONTEXT

Out of the airlines and airports responding to the targeted survey, less than half (8 out of 19 airlines and 2 out of 6 airports) responded that either they use advanced biofuels or electro-fuels for commercial operations. Responses in the targeted survey and targeted interviews suggested there is no geographical region where advanced biofuels or electro-fuels are being used more than others. When asked what percentage of fuel volumes are currently SAF, a total of 9 industry stakeholders (7 airlines and 2 airports) provided responses ranging from less than 0.1% up to 1%.

The importance of SAF is widely accepted as 148 of 160 respondents in the OPC indicated that SAF is relevant for decarbonisation of the aviation sector and 112 respondents believe that significant SAF uptake is needed prior to 2030 in order to achieve climate neutrality by 2050. Despite this, only 74 respondents could provide an example of a successful introduction of SAF in air transport.

In terms of which specific SAF pathways are known to stakeholders, 55 of 73 respondents in the survey indicated they are familiar with Power-to-liquid (PtL) and Hydroprocessed Esters and Fatty Acids (HEFA-SPK), followed by Biomass Gasification + Fischer-Tropsch (Gas+FT) and Co-processing oils/fats with 53 and 52 positive responses, respectively. Only 37 of 73 stakeholders were familiar with Catalytic Hydrothermolysis (CHJ). For most of the production routes, fuel/feedstock producers had the greatest share of respondents that were familiar with that particular route. Exceptions to this were Hydroprocessed fermented sugars to synthetic Isoparaffins (HFS-SIP) and CHJ, for which other aviation industry representatives showed the highest level of familiarity, and PtL, which was best known by stakeholders from the other category.

supporting measures. In total, 45 industry organisations and 20 Member States were represented (AT, BE, BG, CY, CZ, FR, FI, DE, HU, IE, IT, LV, LU, MT, NL PL, PT, RO, ES and SV). In the first part of the workshop, industry stakeholders were invited to indicate a preference for policy options presented, providing justification, and to explain the potential impacts of specific mandate criteria. The second session was for Member States representatives only, who indicated their preference by reflecting on the earlier discussion.

177 As a follow-up to the roundtable, the study team distributed a survey to consolidate the preferences of relevant stakeholders regarding the presented policy options. The survey was distributed on 13 November 2020 and was open for responses until 18 November 2020. The objective of the survey was to acquire a conclusion to the discussions held at the workshop and allow participants to provide their final views on the ReFuelEU aviation initiative.

178 Including airports, aircraft manufacturers, air navigation service providers, aerospace research centres, employees, trade unions or professional organisations.

5. PROBLEM DEFINITION

In the survey, 65 of 73 stakeholders identified 'production and supply of SAF at reasonable costs in the EU is limited' as an issue hindering the use of SAF in the EU and 48 of 73 similarly identified that 'demand for SAF is low in current market conditions' as an issue. The results from these targeted survey questions indicate that the use of SAF in the EU has been hindered due to issues on both the production and demand side.

When exploring specific challenges for the production and uptake of SAF, 69 of 73 respondents in the survey either agreed or strongly agreed that 'high market prices of SAF compared to conventional jet fuel' are an issue with stakeholders indicating a price difference between 1.5 to 6 times the price of fossil jet fuel depending on the pathway. Furthermore, airlines noted further strain has been placed on the price differential challenge as a result of Covid-19. Similarly, 134 of 160 respondents in the OPC ranked the importance of this issue as 4 or 5 (on a scale of 1 to 5). The price gap between SAF and conventional fuel was by far the greatest challenge raised by stakeholders on the uptake side in the IIA feedback.

In the survey, the second most significant challenge identified was 'high upfront capital and operational costs for novel conversion processes at an early commercial stage', with 62 of 73 stakeholders agreeing or strongly agreeing. This is in line with the OPC results where the second most significant issue was 'excessive production cost and high investment risk in SAF plants'. This is evidenced by the limited production capacity in Europe, indicating that a small number of facilities are operating at commercial scale. In the IIA feedback, the most significant production cost raised by stakeholders related to the building of first-of-a-kind (FOAK) facilities, hence driving up the price of their offtake once they become active and hampering their ability to reach the critical mass of profitability.

61 of 73 respondents in the survey also identified 'lack of clear policy signals and limited impacts of existing legal framework for the aviation sector' as a challenge, including stakeholders from both the production and demand side. From the production side, the absence of long-term policy in the EU drives producers to focus on the existing road market and on the demand side airlines noted the need for policy instruments to reduce the price differential. The absence of a regulatory framework and the lack of incentives were also a common barrier for stakeholders in the IIA feedback as the necessary confidence for major investments in large scale SAF production is challenging due to difficulty in building a business case that is competitive with traditional fuel.

Price volatility of feedstock (an important part of the final fuel cost) was also a commonly cited barrier to the production of SAF in the IIA feedback. This contributes to the market uncertainty and acts as a disincentive to invest.

The other key challenge identified by 59 of 73 survey respondents was 'competitive air services market with low margins', although all other challenges identified still had more than half of respondents either agreeing or strongly agreeing. However, in the OPC there were several challenges that were not seen as important including 'lack of relevant infrastructure', 'lack of certainty on the environmental added value of SAF' and 'lack of technically mature SAF technologies' with only 27, 32 and 40 of 160 respondents rating the importance four or 5, respectively.

Supply and distribution of SAF – stakeholder views confirming the need for policy intervention. Replies to the targeted survey indicated that air transport service providers are more likely to either regularly or frequently supply fuel directly from fuel producers at each airport (8 out of 19); supply fuel from the airport operators at each location (6 out of 19); or supply fuel from intermediaries that do not produce fuel themselves (fuel distributors) (6 out of 19). In a follow-up survey with fuel producers specifically focusing on SAF supply and distribution, stakeholders were clear that blending should happen prior to supply at the airport and is generally done either at the refinery or a pre-airport fuel terminal. As blending takes place in the storage tank, there is no specialised infrastructure required beyond that present in the regular jet fuel system. Blending is either done by the SAF producer or by the fuel supplier responsible for distributing the jet fuel.

Stakeholders have reported a limitation in using the NATO-operated Central European Pipeline System (CEPS) to supplying SAF to airports. The general understanding is that not all NATO members have approved the use of SAF within their military hardware, and so CEPS cannot approve any SAF in the system. Some fuel producers point out that the formal reason is that one or a low number of older military aircraft have not been approved for SAF blends by their manufacturers, and that some decision makers from the national military organisations (notably Germany) regard this as a reason to not authorise CEPS for SAF blends. To lift the restriction, the member states concerned need to give their approval.

In the case of an obligation for suppliers to distribute a quota of SAF to all EEA airports, there was some dispute over whether this would be technically feasible with the current infrastructure. Some big fuel producers (2) stated that it is feasible, although it would rely on long supply chains, while another fuel/feedstock producer stated that the only barrier is the NATO pipeline challenge. Another fuel producer explained that it is only feasible with NATO CEPS approving SAF and modifications to existing terminals to install blending facilities since these are nonstandard for most terminals. In terms of cost, one fuel producer has estimated logistics costs to be as high as USD 500 per tonne of SAF delivered for certain supply chains with long truck legs. However, this cost would largely be borne by more remote regional airport, with major airports able to be supplied as low as USD 10 per tonne. The majority of stakeholders in the OPC (102 of 160) indicated that policy action at EU level to take into account the logistics and infrastructure of SAF supply is either relevant or very relevant.

Outlook, trends, views on the SAF production costs

Over half of the respondents in the OPC (97 of 160) believe that uptake of SAF will increase by 2025 under the baseline, while 51 respondents indicated that SAF uptake would not deviate from the current levels. Similarly, in the survey, stakeholders believe that SAF will account for 1% of aviation fuels in 2025. However, stakeholders see this figure increasing to 20%-35% by 2050, with fuel/feedstock producers holding the most optimistic view.

In the OPC, 63 respondents indicated that *synthetic fuels*[179] are the most promising liquid SAF versus 31 respondents selecting *advanced biofuels*[180]. However, 62 stakeholders answered with *other,* arguing that both types of fuel are needed to decarbonise the aviation sector noting that advanced biofuels should be used in the near-term, while synthetic fuels are needed in the longer term. This was in line with the survey responses where fuel/feedstock producers identified many SAF routes as important for decarbonisation, namely *HEFA-SPK, Co-processing oils and fats, PtL, Gas + FT* and *AtJ*[181]. Amongst the fuel/feedstock producers interviewed, there was a general consensus that the importance of each pathway will evolve over time.

In terms of availability of feedstock, stakeholders identified *renewable energy, vegetable and animal lipids* and *solid waste* as being the most available. Conversely, *microalgae oils* are seen to be the least available. For HEFA which is commercially available now, feedstock availability is limited. Waste oils, which provide the feedstock in the HEFA process, are already utilised in high quantities to produce road fuels and current EU demand has already necessitated imports from abroad, leading to some allegations of fraud. For *Gas+FT*, lignocellulosic wastes, residues and energy crops have some existing uses, but there are large quantities in the EU that could be available for SAF production without displacing other uses or causing indirect CO2 emissions. Electrofuels have low water and land-use requirements but are constrained by price and availability

[179] Synthetic forms of kerosene made through the conversion of hydrogen to hydrocarbons.
[180] Fuels that can be manufactured from various types of non-food biomass.
[181] All fuels listed come under advanced biofuels, with the exception of PtL, which is a synthetic fuel.

of renewable electricity. Furthermore, they require a carbon source, which in the future will have to be derived from direct air capture.

Stakeholders from both the targeted survey and targeted interviews agreed that the SAF costs are highly dependent on the production route but, in general, the costs consist of CAPEX for the production plant and the OPEX costs for the production inputs including feedstock, (renewable) electricity and CO_2. For HEFA-SPK fuels, the costs are 80-90% driven by the cost of feedstock, as used cooking oil and vegetable oil are expensive and the primary contributor to the levelised fuel cost. The cost drivers for producing electro-fuels are the high levelised costs of energy and the costs for electrolysis, as well as CO_2-capturing and purification. The costs for the other production routes are primarily driven by the upfront capital expenses for conversion facilities. Stakeholders in the interview and survey were not clear on the certification process and there were some varied responses with regard to requirements, cost and timeline. While fuel/feedstock producers recognised the importance of safety and certification, there was a shared view that the current process is too lengthy, costly and there is some ongoing duplication.

6. Policy objectives

In the survey 63 out of 73 stakeholder responses indicated that they either agreed or strongly agreed with the proposed policy objective A ('Support large scale production in the EU of SAF with high sustainability potential and ensure adequate levels of supply to the aviation sector at competitive costs'). In the targeted interviews, three fuel/feedstock producers and two NGOs stated that 'high sustainability potential' needs to be precisely defined to only consider fuels that meet sustainability standards that provide long-term certainty. With regard to policy objective B ('Ensure a gradual increase in the uptake of SAF with high sustainability potential by the aviation sector at competitive prices'), 66 out of 73 survey respondents also indicated that they either agreed or strongly agreed. Interviewees were also in agreement with this policy objective, although one national authority noted that competitive prices will be difficult to achieve without large amounts of subsidies. In the OPC, 101 out of 160 respondents stated that they believe that EU level regulatory intervention is best suited to achieve decarbonisation objectives, followed by international level intervention (by ICAO) with 41 respondents in support.

7. Policy measures

This sections provides stakeholders views on some of the key measures underpinning the policy intervention.

Blending mandate

In the survey, most stakeholders were of the opinion that a blending mandate would be either somewhat or highly successful in achieving policy objectives A and B (60 and 53 of 70, respectively). More than half of the 160 stakeholders in the OPC (93) ranked the importance of this measure as very important. It can be concluded that a blending obligation is supported by a majority of stakeholders. Nonetheless, several concerns were raised by stakeholders in the surveys and interviews including competition distortion, only current technologies being used and passing on current high costs onto consumers resulting in a fall in demand. In the roundtable discussion, the need for a blending mandate was recognised and supported by the vast majority of participants. A number of Member State experts argued that an EU mandate should be the minimum level of mandate and that Member States should be allowed to put forward more ambitious targets themselves. In general, respondents in the IIA feedback also agreed with the implementation of a blending mandate, with proponents arguing that mandates have proven to be effective and are quick to implement.

SAF-approval process for fuel producers and SAF incentives

The OPC results confirm a high level of support for the support and facilitate approval processes for fuel producers (92 out of 160) and the provision of specific incentives to use SAF, such as multipliers (81 out of 160). However, all other policy measures given in the survey were seen to be either somewhat or highly successful in achieving both policy objectives by more than half of respondents, indicating that all types of policy intervention would be welcomed by stakeholders and successful to some degree. Furthermore, the IIA feedback, the OPC and interview responses all indicated that a combination of policy measures are necessary to achieve increased production and uptake of SAF. Other policy measures suggested as supportive measures in the targeted interviews include feed-in-tariffs, contracts-for-difference, and adjustments to the certification process, carbon pricing, loan guarantees and ticket taxes.

Obligated party

More survey respondents indicated support or strong support for the supplier being the obligated party (45 of 73), compared to the user (36 of 73) and the producer (30 of 73). Arguments for an obligation on the user included the sustainability of the fuel would be prioritised and issues of tankering are more easily avoided, while support for an obligation on the supplier was justified by the fact it is a proven concept that applies in sectors where mandates already exist and it would be easier to manage due to a smaller number of suppliers. Other potential obligated parties suggested in the survey included national authorities, fossil fuel production and supply base, or multiple parties. In the OPC, however, an obligation on both the production/supply side and aviation demand side had the greatest support with 57 of 160 respondents in favour versus an obligation on the production/supply side with 36 and an obligation on the aviation demand side with 28. Many participants of the roundtable indicated a preference for the obligation to be on fuels suppliers only, while some also argued for flexibility for suppliers to organise their fuel distribution at airports of their choice to avoid unnecessary logistics constraints, additional costs and emissions related to the transport of SAF to all airports. However, other stakeholders argued that blending upstream in the value chain would have little impact on logistical costs. Nonetheless, there were participants in favour of a mandate on airlines and a mandate on both parties, although there some discussion over whether the later would introduce unnecessary complexity.

Scope of the mandate (intra-EEA / extra-EEA flights)

In terms of the scope of a mandate (i.e. covering intra-EEA and extra-EEA flights), there was no clear trend emerging in the roundtable discussion. Some argued that a reduced scope of the mandate to cover only intra-EEA flights is not desirable as it would only cover around a third of overall EU emissions. Furthermore, it would apply to all flights of some airlines (e.g. low cost carriers flying mainly the EEA market), while applying to only a fraction of flights of other airlines (e.g. legacy carriers with strong long haul international networks), which could lead to market distortions. On the other hand, a full scope obligation on all airlines would run the risk of being challenged by non-EU countries and airlines. Some argued that a full scope obligation on fuel suppliers would not pose the same issues, an option favoured particularly by NGOs. Some airlines or representative organisations recalled that a global approach to SAF should be the end goal.

Mandate – CO2-based / volume-based

Stakeholder views in the survey on the subject of the mandate target were similar for each option, with 47 of 73 supporting an obligation based on a CO2 emissions reduction target versus 40 of 73 supporting a volume based SAF target. The key argument in support of the former is that it will incentivise the use of feedstocks and fuels that have the greatest CO2 emissions reduction, while the latter is viewed as easier to measure and more likely to increase the availability of SAF at competitive prices. Furthermore, a percentage-based mandate would allow for easier implementation of sub-targets for certain categories of SAF. In the roundtable discussion, there was also a slight preference for a CO2-based target. It was also noted that this would require a more complex methodology for auditing and accounting. Of the stakeholders that made reference to the basis of the target in the IIA feedback, all preferred a CO2-based target.

SAF to be available at all airports / book-and-claim system

There was very little difference in the survey between the support for all aviation fuel available at EU airports to contain a percentage of SAF versus a book and claim system with 38 and 37 of 73 indicating support, respectively. Air transport service providers, national authorities, fuel or feedstock producers and 'other stakeholders' were very in favour of the book and claim system citing is essential to build investment in SAF. They believe it is not important whether that individual batch of fuel is green, but that green energy is fed into the system where possible, as this also avoids unnecessary transport. However, national authorities argued that all aviation fuel should be sustainable at least to a certain degree as it creates a level playing field across Europe, booking can then be used by those who want higher levels than required. In the roundtable discussion, a book and claim system was deemed necessary by the majority of participants. It would allow airlines to purchase tradeable SAF certificates even if they do not have physical access to SAF at airports. It would also allow fuel suppliers to trade obligations in order to meet the obligation in the most cost-effective way. Tracing the exact fuel blend composition in each flight was considered to be a challenging exercise, however.

SAF ramp-up over time

When asked in the targeted interviews about the target of the proportion of SAF blending in 2025, 2030 and 2040, most interviewees felt that a very gradual and flexible mandate would be the best to accommodate for any changes in technology, supply and demand. Lufthansa stated that a low single digit intermediate target is possible for 2025 (in the 1-2% range) and that by 2025 there will be a much better understanding of the commercially viable technologies available to make long term plans. Sunfire believes that by 2030 a target of 5% could be possible as the production pathways and plants would have matured along with the use of e-fuels. In the roundtable discussion, the proposed ramp-up[182] was generally supported, although some stakeholders argued for earlier and more ambitious targets. All stakeholders in the IIA feedback believe that the mandate should be harmonised at EU level as it would affect all airlines in the same way. It was also advised by NGOs and airlines that an EU wide blend mandate is announced at least three years in advance to allow airlines, airports, and other stakeholders time to prepare for SAF use and ideally this mandate should last for at least 10 to 15 years to generate confidence amongst investors and create an investible business case.

Sub-targets for categories of SAF

In the OPC 83 of the 160 respondents believe that it is relevant or very relevant to set sub-targets for the use of certain categories of SAF such as advanced biofuels or PtL fuels. In the roundtable discussion and interviews, some stakeholders stated that an e-fuels sub-mandate would be necessary in any case and that it could start as early as 2027. However, some Member State experts argued that a sub-mandate on e-fuels was premature. In addition, there were proponents for setting sub-targets for both REDII Part A and Part B feedstocks.

Penalties for non-compliance

In the roundtable discussion, penalties for non-compliance were deemed a key element of policy design by several participants. Some fuel producers explained that penalties act as a price ceiling and should be considered separate for specific sub-mandates. The need to think of the use of collected non-compliance fines

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[182] The ramp-up for SAF as proposed in the workshop was: 2% for 2025 (advanced biofuel only); 5% for 2030 (sub-mandates of 4.3% for advanced biofuels and 0.7% for synthetic fuels); 20% for 2035 (sub-mandates of 15% for advanced biofuels and 5% for synthetic fuels); 32% for 2040 (sub-mandates of 24% for advanced biofuels and 8% for synthetic fuels); 38% for 2045; (sub-mandates of 27% for advanced biofuels and 11% for synthetic fuels); 63% for 2050 (sub-mandates of 35% for advanced biofuels and 28% for synthetic fuels).

was brought up and there was significant backing for the money to be redistributed to funding support for SAF. The same suggestion had been made in the targeted interviews and surveys.

Feedstocks – sustainability framework

In the OPC, 96 out of 160 respondents either somewhat agree or fully agree that the RED II framework ensures that SAF would achieve significant emissions savings compared to conventional jet fuel. However, in the IIA feedback, several stakeholders stated that the existing sustainability criteria in the REDII are insufficient due to the inclusion of unsustainable feedstocks in Annex IX part A and the absence of accounting displacement effects. In the SAF roundtable discussion, there was consensus on the use of the REDII framework (or its successor) for sustainability. Some stakeholders stressed the need to align REDII sustainability framework for aviation biofuels with the CORSIA sustainability framework. This point was also highlighted by several stakeholders in the OPC and IIA feedback. In the survey, 29 of 73 stakeholders believe that feedstocks in both Annex IX Part A and Part B should be incentivised, while 19 stakeholders responded that only Annex IX Part A feedstocks should be incentivised and only two stakeholders believe that only Annex IX Part B feedstocks should be incentivised. In the roundtable discussion, there was a general support for the choice of Part A, Part B and e-fuels. The bio-diesel industry voiced strong concerns on making Part B feedstock eligible (waste lipids), as this could displace it from road biofuel production and instead proposed to extend the scope to all waste and residues. Some fuel producers proposed to extend the scope to crop based fuels (except high indirect land use change (ILUC) crops), but this was strongly opposed by NGOs. Many stakeholders in the survey were feedstock agnostic and stated that we should let the technology mature before funnelling investment into one area. Importance was placed on the ability to guarantee emissions savings. The aviation industry also only relies on one fuel so having a broad selection of sources to feed this is critical to scale up production. In the OPC, 92 of 160 respondents indicated support for prioritising aviation for the access to feedstock and production of SAF.

Funding

Respondents in the survey indicated that funding measures would be an effective contribution for achieving policy objectives. ‘Funding in support of SAF production deployment’ was seen to be successful for achieving policy objective A and B by 62 and 61 of 73 respondents and ‘Funding in SAF research & development’ was seen to be successful for achieving policy objective A and B by 66 and 53 of 73 respondents. Stakeholders believe that this would address the issue of excessive production costs and facilitate the commercialisation of SAF technologies and pathways, as well as promote new technologies for the long-term. In line with the survey responses, 125 of 160 stakeholders in the OPC ranked the importance of ‘encourage investments and make use of public financial instruments’ as very important followed by ‘accelerate research and innovation in new SAF’ (111). Concerning the funding instruments that could be used to help reduce the investment risk or bridge the price gap, the greatest support in the OPC was for an EU Emissions Trading System Innovation Fund with 89 respondents out of 160 ranking it as effectiv. Other funding instruments that were seen as important were NextGenerationEU (64) and Horizon Europe (63). A ‘modulation of air traffic control charges under the Single European Sky to create a fund’ and ‘an environmental levy on aviation’ were seen to be the least important, with 53 and 50 out of 160 respondents ranking these instruments less important, respectively. The responses in the survey were in line with those of the OPC, with the instruments receiving the greatest support being ‘EU Emissions Trading System Innovation Fund’, ‘Horizon Europe’, and ‘a strategical industrial alliance bringing together all actors on the SAF value chain’ with 36, 33 and 33 of 73 respondents rating these most relevant , respectively. Again, an ‘environmental levy on aviation’ was among the lowest scoring. Other instruments with low scores were the ’Just Transition Fund‘, ‘Connecting Europe Facility’ and a modulation of air traffic control charges under the Single European Sky to create a fund’ and with 12, 14 and 15 of 73, respectively.

8. POLICY OPTIONS

The European Commission presented its detailed policy design during a roundtable workshop held on 10 November 2020. The objective of the roundtable was to inform and exchange with Member States, aviation and fuel industries, international organisations, NGOs and academics on the progress of the RefuelEU Aviation initiative. In addition, the workshop provided an opportunity to discuss the possible policy options under consideration as part of this impact assessment. This section provides details of the stakeholders' views as expressed during the workshop on 10 November 2020. While the Commission presented its policy design in detail, the discussion focused on some key elements of the policy design. This section highlights the key discussion points and the observations made during the workshop.

Elements common to all the options presented during the workshop:

Sustainability

There was consensus on the use on the REDII framework (or its successor) for sustainability. However, some member States believe that the sustainability framework should be aligned with that of CORSIA to ensure can be claimed under the relevant schemes. Another Member State noted that some promising feedstocks (e.g. animal fats) may be excluded if only RED II Annex IX is considered.

Eligible SAF / feedstock

There was a general support for the choice of eligible SAF (Part A, Part B feedstock, and E-fuels). The bio-diesel industry voiced concerns on making Part B feedstock eligible (waste lipids), as this could displace it from road biofuel production and have negative effects on bio-diesel production plants. A fuel producer stated that the blending mandate as currently presented would result in the diversion of most waste-based lipids (used cooking oil and animal fats) from road transport to SAF at no real environmental value. This was reiterated by an airline. One NGO suggested that with a 5% mandate in 2030 Annex IX part B feedstocks will be diverted from use in the road sector to the aviation sector with no climate benefit. However, another fuel producer argued that there is huge value in a shift from road to aviation as SAF is also reducing the non-CO2 effects of aviation. This was also supported by a manufacturer but disputed by an airline. An airport explained that non-CO2 effects include no sulphur and lower particulate matter emissions which are significant particularly in local conditions. An airline agreed that some biofuels reduce sulphur, however, the contrail effect remains. One fuel producer added that the only way to drive investment to developing technologies (part A of annex IX) is introduce a safeguard for part B of Annex IX, otherwise there will be no real incentive to invest as there will be already enough waste lipids volumes to meet the proposed sub-target for 2030. A fuel producer stated that this issue can be addressed by allowing all sustainable waste and residue lipids, not just the Annex IX, as well as expanding to cover crops and farming on contaminated and degraded land, thus further increasing the availability of sustainable feedstocks. Furthermore, limiting feedstocks to just Annex IX Part A will severely limit the feedstock pool. This was agreed by some other fuel producers. However, a fuel producer stated that the volume of feedstock from just Annex IX Part A would be sufficient to achieve the 2030 mandate. Furthermore, an NGO stated that CO2 emission saving threshold as is does not include indirect land use change and that the vast majority of scientific evidence shows that food-based feedstocks do not provide a climate benefit so only Annex IX should be considered. One stakeholder raised an issue with restricting the eligible feedstocks to those in Annex IX, suggesting that this contradicts the most recent RED report. The inclusion of biofuels is important as it employs a large number in Europe, the feedstocks are sustainable and biofuels are cheaper than alternatives, thus reducing the economic burden for airlines. Another fuel producer added that by extending to feedstock outside of RED Annex IX to allow all sustainable non-ILUC feedstocks from RED, there are enough feedstocks available for both road and aviation sectors. This statement was supported by a manufacturer. One stakeholder disagreed with the inclusion of crop liquids because in the long-term HVO is not scalable without over-burdening vegetable oil markets.

A fuel producer agrees that we need to limit the total volume of food and feed crops entering the EU market. Whether or not that means further lowering the limit in the RED for road and allowing some food and feed biofuels into aviation or simply exclude these crops from an aviation mandate and keep road limits as they are is a matter for debate. Best to avoid an aviation mandate increasing the total volume of food and feed crops given the possible impacts described by those above, until such time as global markets for these feedstocks mean the ILUC risk is reduced (if that ever happens). A Member State made a plea to include recycled carbon fuels (e.g. non-bio municipal solid waste) and low ILUC crops as defined by RED to avoiding penalising ongoing projects.

Blending mandate

The need for a blending mandate was recognised and supported by a large majority of participants, particularly by Member States. One fuel producer, one airport managing company and two Member States argued that an EU mandate should be the minimum level of mandate and that Member States should be allowed to put forward more ambitious targets themselves and additional sub-targets to stimulate certain technologies.

Funding mechanisms

Several other stakeholders stated that financial incentives (such as Contracts for Difference) could be considered. These measures will help to flow capital or reduce risk of investment which will reduce costs significantly and ensure that technologies that are not currently mature will be developed. An energy stakeholder went on further to say there are lessons to be learned from feed-in-tariffs and contracts for difference in the electricity market. However, another energy stakeholder argued that mandates are necessary to guarantee the offtake of the fuel and secure the baseline business case for investing in advanced technologies. This would need to be combined with financial support (loan guarantees, development capital) to ensure the technologies are successfully commercialised. Similarly, a fuel producer was in favour of a mandate but stressed that mandates should be part of an overall policy framework supported by other fiscal measures to support investment and first plants. Some airlines noted that it is important to consider the fast-moving field of zero-carbon technology and that airlines should not be obliged to divert funding away from these technologies. Another airline raised the question that if an airline is willing to purchase new aircraft with carbon reductions, would they be obligated in the mandate.

SAF ramp-up and sub-mandates

The following ramp-up was presented during the workshop:

Shares in the fuel mix (%)	2025	2030	2035	2040	2045	2050
SAF ramp-up	**2**	**5**	**20**	**32**	**38**	**63**
Sub-mandate – green synthetic fuels	-	0.7	5	8	11	28

The proposed ramp-up was generally supported although some stakeholders argued for earlier and more ambitious targets. A fuel producer commented that the mandate could start earlier (2023) and that 5% in 2030 is too low, rather it should be 10%. By targeting 10% in 2030 and 45% in 2045, there would be a smooth uptake curve. Another fuel producer agreed with earlier targets, specifically for e-fuels, stating that projects are currently developing and the 0.7% could be reached earlier. The room for higher targets was also supported by some Member State experts. Some stakeholders questioned why the level of synthetic fuel remains low for the near-medium future given it will deliver the majority of CO_2 reductions. A fuel producer stated that synthetic fuel production will be basically unlimited in terms of technology and feedstock availability in the long-run at competitive prices enabling much larger volumes. A stakeholder commented that the low targets for synthetic fuels after 2030 seem counterintuitive. Some Member States are in favour of sub-quotas. However, a manufacturer said that a sub-target seems premature given the low level of supply at present. Furthermore, a NGO stated that too high a mandate for synthetic fuels can also cause displacement of renewable electricity from sectors where it would have been more efficiently used. A Member State was reluctant to have sub-targets for synthetic fuels as it may make the mandate more expensive to fulfil and they prefer to have a technology neutral system. One fuel producer stated that it is vital to have a sub-mandate for advanced biofuels to ensure that they are brought onto the market. However, the current proposal does not have a sub-mandate for second generation SAF (i.e. AtJ and gasification/FT pathways). They were concerned that if first and second generation SAF were grouped together, the mandate will only promote HEFA investments as this is cheaper. Another fuel producer and airlines agreed with this. However, other stakeholders pointed to the need to avoid a sub-mandate for Part B biofuels. A stakeholder believes that HEFA production does not move the other technologies forward in any substantial way and warned that a significant short-term HEFA mandate would threaten investment in the higher capex alternatives.

Monitoring, reporting and verifying

Some participants pointed to the need for a robust MRV system to avoid double counting. One NGO sees tankering as threat, particularly in a scenario where fuel is cheaper in larger airports. They stated that there is a need for robust data on fuel prices because, with a SAF certificate trading system there is potential for inaccuracies, as such a registry should be established to know who is using which fuel. One airline also stated it is important to have an appropriate registry to avoid risks of double counting. Up to now, mandate systems have not been transparent in terms of origins and sustainability of fuel. They noted that work done to improve traceability and visibility in CORSIA could be valuable in establishing a book and claim system. Apart from that, the proposal to use the RED framework for supply side and the EU ETS framework for demand side monitoring and reporting seemed uncontroversial.

Elements distinguishing between the options presented during the workshop:

Obligated party

Many stakeholders indicated a preference for the obligation to be on fuels suppliers only. A fuel producer stated a supply mandate will work if measures are in place to avoid tankering. Many participants also argued for giving flexibility to suppliers to organise their fuel distribution at airports of their choice, to avoid unnecessary logistics constraints, additional costs and emissions. Others though argued that blending upstream in the value chain would have little impact on logistical costs. In the supply side option, the impact of the mandate on tankering was also considered important by some. An airline went on further to say that competitive distortion is not limited to tankering. If there is a stopover outside of the EEA, only the first leg would be mandated, thus leading to competitive distortion with international airlines. Furthermore, evidence from Sweden suggests that an obligation on airlines may go against international agreements. Some favoured an obligation on airlines. An airline stated that it is feasible for airlines but helped by a functional SAF certificates trading system as this creates a more competitive market for SAF procurement. A stakeholder was in favour of an obligation on both parties, providing the same scope applies for both supply and demand side. A fuel producer believes a mandate on demand or both parties will work because this creates demand and another fuel producer thinks that the flexibility of this option would reduce cost. However, a Member State does not want an obligation on both because of the higher administrative costs. Furthermore, a fuel producer stated that if the SAF certificate trading system is used, only one part of the value chain needs to be obliged. Two obligated parties would be unnecessary as an airline mandate will interact with the supplier mandate. If a supplier surrenders the credit and releases the obligation, does the airline surrender the credit as well? This was supported by another stakeholder. An airline was impartial as an obligation on either party will give security to investments. They stated, however, that it is important that there is a right to access infrastructure.

Scope

This point was debated at length with no clear trend emerging. An airline was in favour of the full scope because limiting the scope to intra-EEA only would address only 33% of aviation emissions. Furthermore, they see it as important that the Commission is perceived to be making positive action by the rest of the world. This was supported by another airline. An NGO added that this approach would improve administrative simplicity. Furthermore, it is important to avoid an approach that applies to 100% of flights for some airlines and only 30% of other airlines. On the other hand, a full scope obligation on airlines would run the risk of being challenged by non-EU countries and airlines. A Member State asked whether the Commission foresees diplomatic/political issues because of the distinction between intra and extra-EEA. An airline stated that the full scope policy could have an impact on connecting traffic in the EU, suggesting that travellers will just connect outside the EU leading to carbon leakage and competitive disadvantage. Another airline agreed with this point. Nonetheless, a global approach to SAF should be the end goal.

Target setting

Participants were divided on this topic but there may have been a slight preference for a CO2 reduction based target over volume based targets as it is seen as incentivising the use of the best performing SAF in terms of achieving the goal of reducing CO2s. However, some participants explained that a CO2 based target requires a more complex methodology notably for auditing and accounting. A stakeholder agrees that CO2 emissions savings should be used as this is the same basis used for other schemes. Some other fuel producers agreed that a CO2 quota is better, providing there is a robust Life Cycle Analysis methodology and audit trail. A fuel producer stated that a volume/energy plus CO2 threshold is a proxy that is easier to audit and account. A fuel producer expressed concerns of just focusing on CO2 stating that, while it is the ultimate goal, it won't have the desired effect of bringing on the various generations of SAF. Volume and CO2 both need to be considered. An airport stated that in Norway a volume-based target is used, which NGOs approve of and suspect that issues may arise if a CO2-emissions target is established. A Member State was in favour of a volume target because it is easier to implement. An airline stated that it depends on who is the obligated party. A CO2 based mandate would make sense for a supplier mandate, but since airlines are looking at scope 1 emissions, the volume-based target would make sense for demand side obligation. An airport stated that both volume-based and CO2-based must be accompanied with clear rules that ensure sustainability.

SAF certificate trading system versus every drop blended

Overall a SAF certificate trading system was deemed necessary by the majority of participants. It would allow airlines to purchase tradeable SAF certificates even if they do not have physical access to SAF at airports. It would also allow fuel suppliers to trade obligations in order to meet the obligation in the most cost effective way. A stakeholder was in favour of such an approach allowing for SAF supply locations to roll-out progressively because transport of fuel will generate additional emissions and is logistically inefficient. An airline went on further to say that there are no environmental benefits from every drop blended approach, and it ignores the work underway to develop a functional trading process which is intended to reduce unnecessary inefficiencies and costs. Another airline considered the physical supply of SAF to all airports as practically challenging. It is technologically unnecessary as the fuels are drop in fuels and the separate and additional logistics are economically and environmentally disadvantageous. An airline was in favour of a SAF trading approach if reliable verification is in place, citing that it has been used for years in green electricity and biogas markets. Furthermore, a right to access infrastructure needs to be integrated to ensure that all producers can bring their fuel to the nearest reasonable access point of “the fuel system”. An airport (ACI) raised an issue concerning “the every drop blended” mandate and wanted clarification over whether the Commission foresees a continued supply of SAF to all European airports or if this applies over a certain a period as there will be different implications on the costs and effectiveness of logistics and airports need to be able to use the existing fuel supply at airports. Furthermore, a stakeholder (Energy Transition Commission) was in favour of a blending obligation for all fuel supplied for a company over a 1-year period, with a credit trading scheme allowing compliance by selling and purchasing credits. A fuel producer (BP) added that the basis is dependent on who the obliged party is. In a supplier mandate there is no difference from who will buy the SAF under an "all fuel" option as in option A and a trading approach. The only difference is the additional costs of logistics of getting SAF volumes to all airports, which will increase/exacerbate the existing differential in fuel prices at remote and regional airports. This will increase tankering - as we currently see today on fossil jet on routes to regional/remote airports. The same fuel producer (BP) added that with a trading scheme there will be a market of credits and a market for fuel but these won't necessarily match. Anyone who passes a charge on in the value chain can use credits, and thus is able to be the obligated party, the only question is the volume and level of compliance. They also stated there are a number of examples of traded compliance in road fuels. A fuel producer (Enerkem) raised an issue that a "book and claim system" is not possible under RED II due to concerns of fraud, rather a mass balance is allowed. An airport (ACI) stated that the objective of airport charges is to recover airports' internal costs. Airports do not sell fuel and don't in most cases own the fuel supply infrastructure, so SAF does not fall into their cost base. As such, it's not clear how airports should intervene through charges to address tankering. A Member State (Malta) was concerned how a SAF trading system would work in smaller airports. However, this was explained by an airport association (ACI) that can purchase SAF credits without physically burning SAF molecules. The MS (Malta) was also concerned that hedge funds will use the system to gain a profit.

Penalties for non-compliance

An airline (Lufthansa) asked that, in the case airlines are the obligated party, would there be an incentive for the supplier to provide their fuel at cost only slightly lower than the cost of the penalty. However, a fuel producer (BP) stated that any supplier charging more than the standard rate will lose out on competition and it is better to think of penalties as a price ceiling. An airline (IAG) and fuel producer (Shell) stated that penalties provide a signal for investment and there is a need to think about the floor price because that gives certainty to investors. An airline (IATA) agreed, as did another fuel producer (Velocys). A stakeholder (Cerulogy) agreed with this but stated that it is potentially difficult to set a floor price effectively. A fuel producer (SkyNRG) raised the topic of how the income generated form penalties is redistributed for the good of the sector. An NGO (T&E) agreed that the income should be retained for industrial policy to make up for any shortage in supply. A Member State (Sweden) explained that the penalty for non-compliance in their country is around 0.6 EUR per kg CO_2 that is missing from fulfilling the mandate, which is higher than the penalty in the road sector. Another Member State (France) stated that it is important to be able to modify the penalties based on how well they are working.

Annex 3: Who is affected and how?

1. Impacts on affected stakeholder groups

The ReFuelEU Aviation initiative aims at reducing CO_2 emissions from the aviation sector by transitioning away from fossil jet fuel and increasing the production and uptake of SAF. The objective is to set the aviation sector on the trajectory to contribute to the European ambition of climate neutrality by 2050.

The preferred policy options (POs C1 and C2) set an obligation on fuel suppliers to supply SAF at EU airports, and an obligation on all airlines to uplift jet fuel at EU airports before each departure. It also requires EU airlines to report their SAF use. The following sections explains in detail how the preferred option will affect the main stakeholder groups.

Airlines

Airlines will play a major role under the present initiative, as they will be the market actor using SAF-blended jet fuel and bearing the cost for it. Although airlines do not per se have an obligation to use SAF-blended jet fuel, the obligation on fuel suppliers to supply SAF will be mirrored back to airlines as they will have no other option than to use it. As of the start of the SAF obligation, airlines will be presented by fuel suppliers with commercial offers including SAF-blended jet fuel as part of the jet fuel mixed available at airports. The competition between several fuel suppliers to offer SAF-blended jet fuel at specific airports means that airlines will be able to benefit from bargaining power and have access to SAF at acceptable prices defined by the dynamics of supply and demand.

Whereas all airlines will have access to SAF at all airports as of 2030 (second stage of the transition period), some airlines may not have physical access to SAF at their destination airports in the first stage of the transition period, i.e. from 2025 to 2030. This is expected to be the case e.g. at remote or insular airports where fuel suppliers would incur higher logistical costs. Airlines flying to such airports will nevertheless be able to procure SAF by purchasing it directly with a fuel supplier. Purchased SAF volumes will be introduced elsewhere in the fuel system, but the airline will be able to claim its use, in accordance with the reporting system of the EU ETS that is based on SAF purchasing records. In general, airlines will be able to claim the use of SAF under the EU ETS or under CORSIA, as relevant with respect to the flights operated.

Under the present initiative, airlines are expected to incur higher costs for jet fuel. It is expected that the increase of jet fuel cost due to the blending of SAF will be evenly spread across the airline market and affect all airlines in the same way. The increase in jet fuel cost is expected to be fully passed on to passengers and therefore be reflected on ticket prices. The increase of ticket prices will be low, but nevertheless result in a small reduction of demand for air transport by 2050, compared to the baseline scenario. This will have the effect to reduce the capital and operational costs of airlines.

The increase in jet fuel cost will be partially compensated by a reduction in external costs of air pollution and of CO_2 emissions. As a result, the total cost for airlines, including external costs, decrease marginally by 2050 compared to the baseline scenario.

Airports

The present initiative is neutral towards airports. Airports are not expected to play a significant role in the scaling-up of SAF supply and uptake. The fuel logistics at airports are generally fit for a future large increase of SAF-blended jet fuel supply. Indeed, SAF being fully fungible with conventional jet fuel, there is no expected need for larger fuel tanks at airports. Indeed, SAF volumes will substitute pure fossil jet fuel volumes. Logistics at airports are organised in a way that all jet fuel arrives blended at the airport and is mixed in common fuel tanks. SAF blending does not take place at the airport, or otherwise requires certification renewal. Therefore, under the present initiative, it is not expected that major adaptations to the airports logistics will be necessary. Logistical adaptations will be required in the upstream parts of the SAF supply chain, as explained in the following section, but this is not expected to affect airports.

Fuel suppliers

Fuel suppliers are obliged to supply physically supply SAF at all EU airports at all times, post-2035 (following a transition period). This means that every litre of jet fuel supplied to EU airports must be blended with SAF. Fuel suppliers (the number of market players who would qualify as fuel suppliers under this initiative is limited – estimated at less than 30) are individually bound by this obligation with increasing targets over time. This obligation requires fuel suppliers to procure SAF-blended jet fuel from SAF producers or use their own production (if relevant) and integrate it to their fuel mix when distributing at airports. Fuel suppliers are expected to include SAF as part of their commercial offer to airlines, when responding to yearly calls for tender issued by airlines for the procurement of jet fuel at airports.

Fuel suppliers will need to ensure that their supply chain are fit for distributing SAF to all airports. This can be challenging and incur additional logistic costs, in particular in the first years of the obligation. For this reason, a transition period allows for some flexibility on the supply of SAF. From 2025 to 2030, fuel suppliers will have the flexibility to distribute SAF in the most cost effective way. This is expected to lead to a distribution of SAF mainly at medium and large airports already benefitting from well-established fuel supply chains. Fuel suppliers will nevertheless be required to meet their supply obligation, and therefore it is expected that they will seek to spread their supply to a maximum number of airlines and airports, while still acting in the most cost-effective way. From 2025 to 2030, suppliers will still have flexibility to supply in the most cost effective way, but will nevertheless be required to supply a minimum of 2% of SAF at all airports. This will encourage all fuel suppliers to develop the necessary supply chain and infrastructure to fulfil the obligation beyond 2035 where all airports need to be supplied to meet high SAF targets.

In the early years of the SAF obligation, it is expected that fuel suppliers will not all be in the same position to meet the SAF supply obligation. While some may be able to supply SAF-blended fuel more than required - due to e.g. well established commercial partnerships with producers and well established logistics, others may fall short of meeting the obligation. This could be the case if e.g. meeting the last 10% of the SAF supply target would mean significant additional costs for e.g. expanding production capacity. In such cases, a SAF certificate trading system could allow fuel suppliers to meet their targets in the most cost-effective way. Over achievers (suppliers with an excess of SAF supplied) could sell SAF certificates to under achievers. Such a system could be set up under the auspices of the present initiative, or alternatively be introduced in the revision of the Renewable Energy Directive. Such a trading system represents an additional flexibility for the fuel industry to meet supply targets.

Fuel suppliers will incur costs partly passed on to them by fuel producers, i.e. SAF production investments. These costs correspond to investments expenditures, and are one-off investment costs necessary to build the additional SAF production facilities needed to scale up the SAF industry in line with the SAF ramp-up over time. Fuel suppliers will incur higher fuel costs, corresponding to the procurement of SAF volumes. These will be accompanied by additional SAF logistics costs, necessary for the distribution of SAF to airports, as explained above. The net impact on fuel suppliers is neutral, as all costs incurred by fuel suppliers are considered to be passed on to airlines.

Fuel producers

Fuel producers will play an essential role in scaling up the SAF production capacity in the EU. They are expected to incur costs due to the investment needs to scale-up the SAF production capacity. These costs will be partly passed through to fuel suppliers.

EU Citizens / Society at large

Society is expected to be the largest beneficiary of this initiative. European citizens will benefit from the fact that aviation becomes significantly more environmentally sustainable by 2050. The introduction of this policy instrument leads to an important decrease in CO2 emissions in the aviation sector, and to a decrease in air pollutants. This means a reduction of aviation external costs of air pollution and greenhouse gas emissions.

At the same time, due to the aviation becoming significantly greener, citizens will incur higher ticket prices as the costs borne by airlines for more costly jet fuel will be passed through to passengers. This means a low increase of costs on a per-ticket basis, but overall the cost increase outweighs the reduction in external costs.

The European society is expected to benefit from large indirect positive macroeconomic impacts in the form of significant additional employment. Whereas employment in the aviation sector will increase at a slower rate than under the baseline scenario by 2050, the renewable fuels industry is expected to provide significant additional employment to European workers.

Member States

Member States will incur slightly higher costs due to the implementation of this policy initiative. Indeed, the obligations on fuel suppliers and airlines under the preferred policy options translate into additional monitoring, reporting, verification and enforcement costs for Member States.

2. SUMMARY OF COSTS AND BENEFITS

I. Overview of Benefits (total for all provisions) – Preferred Options - C1 and C2 (relative to the baseline, expressed as present value over 2021-2050)		
Description	***Amount***	***Comments***
Direct benefits		
Reduction of air transport CO_2 emissions (well to wing) in 2050 compared to the baseline	-60.8% (C1) -60.2% (C2)	Direct benefit to society at large. It is the effect of the increasing participation of sustainable aviation fuel in the aviation jet fuel mix, in replacement of fossil jet fuel.
Reduction of external costs of CO_2 emissions from air transport relative to the baseline; additionally including the external costs of logistics (i.e. present value over 2021-2050)	EUR 86.3 billion (C1) EUR 85.8 billion (C2)	
Reduction of external costs related to air pollution relative to the baseline (i.e. present value over 2021-2050)	EUR 1.5 billion (C1 and C2)	Direct benefit to society at large. This reflects a reduction of air pollutant emissions (CO, NOx, PM). It results from a decrease in air transport activity by 2050 relative to the baseline.
Increased use in air transport of innovative fuel technologies with high decarbonisation potential (expressed in % of the jet fuel mix by 2050, compared to the	(C1) RFNBOs: 27.9% Advanced biofuels: 25.8% (C2) RFNBOs: 23.9% Advanced biofuels: 28.7%	Significant increase of participation in the jet fuel mix of innovative technologies with high decarbonisation potential. These technologies are brought to the market earlier than under the baseline scenario. Prices of RFNBOs and advanced biofuels decrease over time compared to the current

baseline)		estimates.
Indirect benefits		
Employment (net additional jobs in 2050 compared to the baseline)	202,100 jobs (C1 and C2)	Increase in employment in the fuels industry compensate for employment reductions in air transport due to slight decrease of activity compared to the baseline.
Reduced dependence on oil imports in 2050 relative to the baseline	-65% (i.e. -31Mtoe) (C1 and C2)	Benefits for the EU's energy security and trade balance. Reduction of oil imports used for air transport, as a result of a decrease in fossil jet fuel use by 65% in 2050 (i.e. 31Mtoe) relative to the baseline.
Share of SAF produced in the EU (expressed as a share of total SAF supplied in 2050)	92% (C1 and C2)	Benefits for EU renewable fuels' industry and the EU economy at large. 92% of SAF supplied and used in the EU will be produced in the EU. 100% of feedstock and renewable energy used for SAF production will be EU-sourced.

(1) Estimates are relative to the baseline for the preferred option as a whole (i.e. the impact of individual actions/obligations of the preferred option are aggregated together); (2) Please indicate which stakeholder group is the main recipient of the benefit in the comment section;(3) For reductions in regulatory costs, please describe details as to how the saving arises (e.g. reductions in compliance costs, administrative costs, regulatory charges, enforcement costs, etc.; see section 6 of the attached guidance).

II. Overview of costs – Preferred Options - C1 and C2 (relative to the baseline, expressed as present value over 2021-2050)							
		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent	One-off	Recurrent	One-off	Recurrent
Compliance with SAF obligation	Direct costs (relative to the baseline in present value over 2021-2050)	None		Capital investments in SAF production capacity by fuel producers EUR 10.5 billion (C1) EUR 10.4 billion (C2) - partly passed on to fuel suppliers	Additional cost of fuel for airlines EUR 103.5 billion (C1) EUR 88.2 billion (C2) Additional administrative costs for airlines for fuel uplift EUR 0.34 billion (C1 and C2)		
	Indirect costs	None	Increase of ticket prices		Additional SAF fuel		

			by 8.2% (C1) and 8.1% (C2) by 2050, compared to the baseline		logistics costs EUR 0.19 billion (C1 and C2) - relative to the baseline in present value over 2021-2050 Reduced capital and operational costs of air transport due to lower transport activity. EUR 84 billion (C1) EUR 74.5 billion (C2) - relative to the baseline in present value over 2021-2050		
Administrative and enforcement costs	Direct costs			Cost for non-EU airlines to link to the new reporting stream on jet fuel uplift. Negligible.	No additional costs. Fuel suppliers report in Union database. EU airlines report in EU ETS.		Admin costs for Member States EUR 264 million (relative to the baseline in present value over 2021-2050) Admin costs for EU authorities EUR 2.7 million (relative to the baseline in present value over 2021-2050)
	Indirect costs						

Annex 4: Analytical methods

1. DESCRIPTION OF THE MODELLING TOOLS USED

The analytical framework used for the purpose of this impact assessment draws on the impact assessment support study[183] and builds on the PRIMES and PRIMES-TREMOVE models, complemented by the assessment of the administrative costs for businesses, the costs for authorities, the costs of SAF logistics, etc.

The main models used to produce the scenarios presented in this impact assessment (PRIMES and PRIMES-TREMOVE models) have a successful record of use in the Commission's energy, transport and climate policy assessments. In particular, they have been used for the impact assessment accompanying the 2030 Climate Target Plan[184], the Staff Working Document accompanying the Sustainable and Smart Mobility Strategy, the Commission's proposal for a Long Term Strategy[185] as well as for the 2020 and 2030 EU's climate and energy policy framework.

The PRIMES and PRIMES-TREMOVE models are the core elements of the modelling framework for energy, transport and CO2 emission projections. In addition, the POLES-JRC[186] model has been used for the world energy price projections and the GEM-E3 model[187] for the macro-economic developments by sector of activity, used in the baseline scenario.

For the purpose of this impact assessment, PRIMES and PRIMES-TREMOVE models cover:

- **The entire energy** (energy demand, supply, prices and investments to the future) and **transport systems**, and **all GHG emissions and removals** from the EU economy
- **Time horizon:** 1990 to 2050 (5-year time steps)
- **Geography:** individually all EU Member States
- **Impacts:** on the energy system (PRIMES and its satellite model on biomass), transport (PRIMES-TREMOVE).

The modelling suite has been continuously updated over the past decade. Updates include the addition of a new buildings module in PRIMES, improved representation of the electricity sector, more granular representation of hydrogen (including cross-border trade[188]) and other innovative fuels, improved representation of the maritime transport sector, as well updated interlinkages of the models to improve land use and non-CO_2 modelling. Most recently a major update was done of the policy assumptions, technology costs and macro-economic assumptions.

PRIMES model

The PRIMES model (Price-Induced Market Equilibrium System)[189] is a large scale applied energy system model that provides detailed projections of energy demand, supply, prices and investment to the future, covering the entire energy system including emissions. The distinctive feature of PRIMES is the combination

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183 Ricardo at al., Study supporting the impact assessment of the ReFuelEU Aviation initiative.
184 SWD/2020/176 final.
185 Source: https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf
186 The POLES-JRC model provides the global energy and climate policy context and is operated by the JRC. Source: https://ec.europa.eu/jrc/en/poles.
187 E3Modelling (https://e3modelling.com/) is a private consulting, established as a spin-off inheriting staff, knowledge and software-modelling innovation of the laboratory E3MLab from the National Technical University of Athens (NTUA).
188 While cross-border trade is possible, the assumption is that there are no imports from outside EU as the opposite would require global modelling of hydrogen trade.
189 More information and model documentation: https://e3modelling.com/modelling-tools/primes/

of behavioural modelling (following a micro-economic foundation) with engineering aspects, covering all energy sectors and markets. The model has a detailed representation of policy instruments related to energy markets and climate, including market drivers, standards, and targets by sector or overall. It simulates the EU Emissions Trading System in its current form. It handles multiple policy objectives, such as GHG emissions reductions, energy efficiency, and renewable energy targets, and provides pan-European simulation of internal markets for electricity and gas.

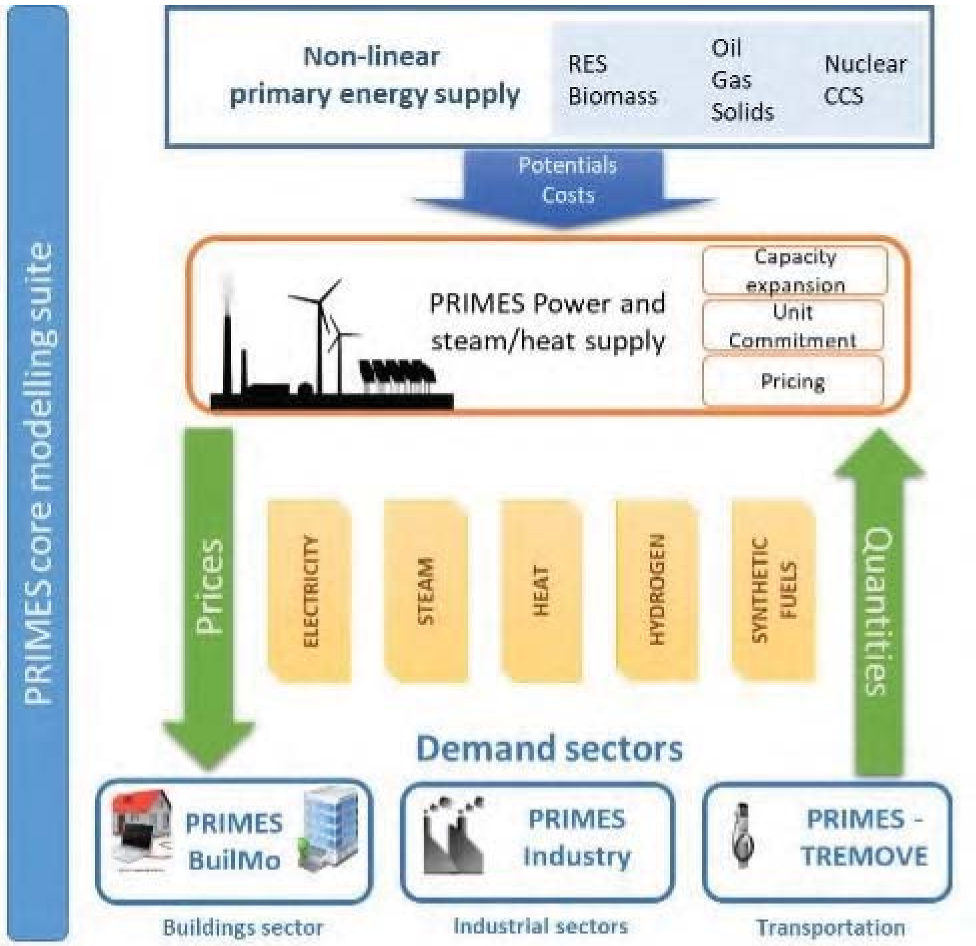
PRIMES offer the possibility of handling market distortions, barriers to rational decisions, behaviours and market coordination issues and it has full accounting of costs (CAPEX and OPEX) and investment on infrastructure needs. The model covers the horizon up to 2070 in 5-year interval periods and includes all Member States of the EU individually, as well as neighbouring and candidate countries. PRIMES is designed to analyse complex interactions within the energy system in a multiple agent – multiple markets framework.

Decisions by agents are formulated based on microeconomic foundation (utility maximization, cost minimization and market equilibrium) embedding engineering constraints and explicit representation of technologies and vintages; optionally perfect or imperfect foresight for the modelling of investment in all sectors.

PRIMES allows simulating long-term transformations/transitions and includes non-linear formulation of potentials by type (resources, sites, acceptability etc.) and technology learning. Figure 6 shows a schematic representation of the PRIMES model.

It includes a detailed numerical model on biomass supply, namely PRIMES-Biomass, which simulates the economics of supply of biomass and waste for energy purposes through a network of current and future processes. The model transforms biomass (or waste) feedstock, thus primary feedstock or residues, into bio-energy commodities which undergo further transformation in the energy system e.g. as input into power plants, heating boilers or fuels for transportation. The model calculates the inputs in terms of primary feedstock of biomass and waste to satisfy a given demand for bio-energy commodities and provides quantification of the required production capacity (for plants transforming feedstock into bioenergy commodities). Furthermore, all the costs resulting from the production of bioenergy commodities and the resulting prices are quantified. The PRIMES-Biomass model is a key link of communication between the energy system projections obtained by the core PRIMES energy system model and the projections on agriculture, forestry and non-CO_2 emissions provided by other modelling tools (CAPRI, GLOBIOM/G4M, GAINS).

Figure 6: Schematic representation of the PRIMES model



PRIMES is a private model maintained by E3Modelling[190], originally developed in the context of a series of research programmes co-financed by the European Commission. The model has been successfully peer-reviewed, most recently in 2011[191]; team members regularly participate in international conferences and publish in scientific peer-reviewed journals.

<u>Sources for data inputs</u>

A summary of database sources, in the current version of PRIMES, is provided below:

- Eurostat and EEA: Energy Balance sheets, Energy prices (complemented by other sources, such IEA), macroeconomic and sectoral activity data (PRIMES sectors correspond to NACE 3-digit classification), population data and projections, physical activity data (complemented by other sources), CHP surveys, CO_2 emission factors (sectoral and reference approaches) and EU ETS registry for allocating emissions between ETS and non ETS
- Technology databases: ODYSSEE-MURE[192], ICARUS, Eco-design, VGB (power technology costs), TECHPOL – supply sector technologies, NEMS model database[193], IPPC BAT Technologies[194]
- Power Plant Inventory: ESAP SA and PLATTS

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190 Source: https://e3modelling.com/
191 SEC(2011)1569 : https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1569_2.pdf
192 Source: https://www.odyssee-mure.eu/
193 Source: https://www.eia.gov/outlooks/aeo/info_nems_archive.php
194 Source: https://eippcb.jrc.ec.europa.eu/reference/

- RES capacities, potential and availability: JRC ENSPRESO[195], JRC EMHIRES[196], RES ninja[197], ECN, DLR and Observer, IRENA
- Network infrastructure: ENTSOE, GIE, other operators
- Other databases: District heating surveys (e.g. from COGEN), buildings and houses statistics and surveys (various sources, including ENTRANZE project[198], INSPIRE archive, BPIE[199]), JRC-IDEES[200], update to the EU Building stock Observatory[201]

PRIMES-TREMOVE model

The PRIMES-TREMOVE transport model projects the evolution of demand for passengers and freight transport, by transport mode, and transport vehicle/technology, following a formulation based on microeconomic foundation of decisions of multiple actors. Operation, investment and emission costs, various policy measures, utility factors and congestion are among the drivers that influence the projections of the model. The projections of activity, equipment (fleet), usage of equipment, energy consumption and emissions (and other externalities) constitute the set of model outputs.

The PRIMES-TREMOVE transport model can therefore provide the quantitative analysis for the transport sector in the EU, candidate and neighbouring countries covering activity, equipment, energy and emissions. The model accounts for each country separately which means that the detailed long-term outlooks are available both for each country and in aggregate forms (e.g. EU level).

In the transport field, PRIMES-TREMOVE is suitable for modelling *soft measures* (e.g. eco-driving, labelling); *economic measures* (e.g. subsidies and taxes on fuels, vehicles, emissions; ETS for transport when linked with PRIMES; pricing of congestion and other externalities such as air pollution; accidents and noise; measures supporting R&D); *regulatory measures* (e.g. CO_2 emission performance standards for new light duty and heavy duty vehicles; EURO standards on road transport vehicles; technology standards for non-road transport technologies, deployment of Intelligent Transport Systems) and *infrastructure policies for alternative fuels* (e.g. deployment of refuelling/recharging infrastructure for electricity, hydrogen, LNG, CNG). Used as a module that contributes to the PRIMES model energy system model, PRIMES-TREMOVE can show how policies and trends in the field of transport contribute to economy-wide trends in energy use and emissions. Using data disaggregated per Member State, the model can show differentiated trends across Member States.

The PRIMES-TREMOVE has been developed and is maintained by E3Modelling, based on, but extending features of, the open source TREMOVE model developed by the TREMOVE[202] modelling community. Part of the model (e.g. the utility nested tree) was built following the TREMOVE model.[203] Other parts, like the component on fuel consumption and emissions, follow the COPERT model.

195 Source: https://data.jrc.ec.europa.eu/collection/id-00138
196 Source: https://data.jrc.ec.europa.eu/dataset/jrc-emhires-wind-generation-time-series
197 Source: https://www.renewables.ninja/
198 Source: https://www.entranze.eu/
199 Source: http://bpie.eu/
200 Source: https://ec.europa.eu/jrc/en/potencia/jrc-idees
201 Source: https://ec.europa.eu/energy/en/eubuildings
202 Source: https://www.tmleuven.be/en/navigation/TREMOVE
203 Several model enhancements were made compared to the standard TREMOVE model, as for example: for the number of vintages (allowing representation of the choice of second-hand cars); for the technology categories which include vehicle types using electricity from the grid and fuel cells. The model also incorporates additional fuel types, such as biofuels (when they differ from standard fossil fuel technologies), LPG, LNG, hydrogen and e-fuels. In addition, representation of infrastructure for refuelling and recharging are among the model refinements, influencing fuel choices. A major model enhancement concerns the inclusion of heterogeneity in the distance of stylised trips; the model considers that the trip distances follow a distribution function with different distances and frequencies. The inclusion of heterogeneity was found to be of significant influence in the choice of vehicle-fuels especially for vehicles-fuels with range limitations.

Data inputs

The main data sources for inputs to the PRIMES-TREMOVE model, such as for activity and energy consumption, comes from EUROSTAT database and from the Statistical Pocketbook "EU transport in figures[204]. Excise taxes are derived from DG TAXUD excise duty tables. Other data comes from different sources such as research projects (e.g. TRACCS project) and reports.

In the context of this exercise, the PRIMES-TREMOVE transport model is calibrated to 2005, 2010 and 2015 historical data.

2. BASELINE SCENARIO

Main assumptions of the Baseline scenario

The baseline scenario used in this impact assessment builds on the baseline scenario underpinning the impact assessment accompanying the 2030 Climate Target Plan and the staff working document accompanying the Sustainable and Smart Mobility Strategy, but it additionally considers the impacts of the COVID-19 pandemic and the National Energy and Climate Plans.

Economic assumptions: The modelling work is based on socio-economic assumptions describing the expected evolution of the European society. Long-term projections on population dynamics and economic activity form part of the input to the energy and transport model and are used to estimate transport activity and energy demand in transport. Population projections from Eurostat[205] are used to estimate the evolution of the European population that is projected to change very little in total number in the coming decades. Macro-economic projections draw on DG ECFIN.[206] In particular, the Commission's Spring Economic Forecast 2020 projected that the EU economy would contract by 7.4% in 2020 and pick up in 2021 with growth of 6.1%. By 2030, real GDP in 2030 could be approximately 2.3% lower compared to the pre-COVID estimates, based on the Autumn Forecast 2019.

Energy prices assumptions: The COVID pandemics has had a major impact on international fuel prices. As a large part of the world went into lockdown, fossil fuel prices collapsed with crude oil spot prices halved compared to last year levels. The oil price is projected to gradually recover over time, reaching 80USD/bbl in 2030 and 118USD/bbl in 2050. It is however projected to remain below the projected pre-COVID-19 pandemic levels.[207] Figure 7 shows the fuel prices projections used in the baseline scenario.

Figure 7: International fuel prices assumptions

in USD'15 per boe	**'15**	**'30**	**'40**	**'50**
Oil	52.3	80.1	97.4	117.9
Gas (NCV)	43.7	40.9	52.6	57.8
in €'15 per boe	**'15**	**'30**	**'40**	**'50**

204 Source: https://ec.europa.eu/transport/facts-fundings/statistics_en

205 Source: https://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-projections-data

206 The long-term evolution of economic activity was estimated from three sources: DG ECFIN's short term economic forecast, updated t+10 projections up to 2029 and the 2018 Aging Report projections elaborated by the European Commission. For the short-term (2020-2021), the projections are based on growth forecast by the Directorate General for Economic and Financial Affairs (Spring 2020 Economic Forecast). Projections up to 2029 use the associated t+10 work from DG ECFIN, which is based on projections of potential output growth and a closure of output gap in the medium term. The long-term per capita GDP growth projections of the 2018 Ageing Report are used for the period 2030-2050, available at: https://ec.europa.eu/info/publications/economy-finance/2018-ageing-report-economic-and-budgetary-projections-eu-member-states-2016-2070_en

207 Communication from the Commission 'Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people', COM(2020) 562 final.

Oil	47.2	72.2	87.8	106.3
Gas (NCV)	38.7	36.2	46.6	51.2

Source: Derived from JRC, POLES-JRC model, Global Energy and Climate Outlook (GECO)

Source: Derived from JRC, POLES-JRC model, Global Energy and Climate Outlook (GECO)

Technology assumptions: Modelling scenarios on the evolution of the energy and transport system is highly dependent on the assumptions on the development of technologies - both in terms of performance and costs. For the purpose of the impact assessments related to the "Climate Target Plan" and the "Fit for 55" policy package, these assumptions have been updated based on a rigorous literature review carried out by external consultants in collaboration with the JRC[208].

Continuing the approach adopted in the long-term strategy in 2018, the Commission consulted technology assumption with stakeholders in 2019. In particular, the technology database of the main model suite (PRIMES, PRIMES-TREMOVE, GAINS, GLOBIOM, and CAPRI) benefited from a dedicated consultation workshop held on 11th November 2019. EU Member States representatives had also the opportunity to comment on the costs elements during a workshop held on 25th November 2019. The updated technology assumptions are published together with the EU Reference Scenario 2020.

Policies included in the Baseline scenario

The Baseline scenario projects developments under the current EU and national policy framework. It embeds in particular the EU legislation in place to reach the 2030 climate target of at least 40% compared to 1990, as well as national contributions to reaching the EU 2030 energy targets on Energy efficiency and Renewables under the Governance of the Energy Union. It thus gives a detailed picture of where the EU economy and energy system in particular would stand in terms of GHG emission if the policy framework were not updated to enable reaching the revised 2030 climate target to at least -55% compared to 1990 proposed under the Climate Target Plan[209].

In addition to the headline targets, some of the policies included in the baseline scenario are:

- The EU Emissions Trading System[210] (EU ETS) covers 45% of EU greenhouse gas emissions, notably from industry, the power sector and aviation. Emissions for the sectors under the system are capped to reduce by 43% by 2030 compared to 2005. The baseline scenario additionally assumes that the Market Stability Reserve (MSR) will ensure that the ETS contributes to the achievement of the overall target cost-effectively. MSR functioning is set to be reviewed[211] in 2021 and every five years after to ensure its aim of tackling structural supply-demand imbalances.
- Aviation emissions are also covered by the EU ETS. The EU, however, decided in 2014 to limit the scope of the EU ETS to flights within the EEA until 2016 to support the development of a global measure by the International Civil Aviation Organization (ICAO).[212] In light of the adoption of a Resolution by the 2016 ICAO Assembly on the global measure, the EU has decided to maintain the geographic scope of the EU ETS limited to intra-EEA flights from 2017 until the end of 2023.[213] The EU ETS for aviation is subject to a new review in the light of the international developments related to the operationalisation of CORSIA. This review considers how to implement the global measure in Union law through a revision of the EU ETS

208 JRC118275
209 COM/2020/562 final
210 Directive 2003/87/EC.
211 Decision (EU) 2015/1814.
212 Regulation (EU) 421/2014.
213 Regulation (EU) 2017/2392.

legislation. In the absence of a new amendment, the EU ETS would revert back to its original full scope from 2024.

- For aviation, in addition to implementation of the EU Emission Trading Scheme, the Baseline reflects the Union-wide air transport performance targets for the key performance area of environment, Clean Sky, Single European Sky and SESAR, and aircraft CO_2 emissions standards, as part of the so-called "basket of measures" that aim to reduce emissions from the sector.
- The revised Renewable Energy Directive[214] entered into force in 2018. It establishes a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023.
- The Fuel Quality Directive[215] requires a reduction of the greenhouse gas intensity of transport fuels by a minimum of 6% to be achieved by 2020.
- CO_2 emission standards for new cars and vans[216] and for new trucks[217] have been defined, and will contribute towards reducing emissions from the road transport sector. Besides the post-2020 CO_2 standards for new light duty and heavy duty vehicles, the Clean Vehicles Directive and the Directive on the deployment of alternative fuels infrastructure contribute to the roll-out of recharging infrastructure. Furthermore, the uptake of sustainable alternative fuels is supported by the Renewables Energy Directive and Fuel Quality Directive. Improvements in transport system efficiency (by making the most of digital technologies and smart pricing and further encouraging multi-modal integration and shifts towards more sustainable transport modes) are facilitated by e.g. the TEN-T Regulation supported by CEF funding, the fourth Railway Package, the Directive on Intelligent Transport Systems, the European Rail Traffic Management System European deployment plan, the Regulation establishing a framework for the provision of port services, and others.
- For maritime shipping, in addition to emissions being monitored under the Regulation on Monitoring, Reporting and Verification of Maritime Emissions[218], the Baseline scenario reflects the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) adopted by the International Maritime Organisation, as well as the Sulphur Directive. The Baseline also accounts for other initiatives addressing air pollution from inland waterways vessels, as well as road safety, and thus reducing the external costs of transport.
- The Effort Sharing Regulation[219] (ESR) sets binding annual reduction targets for member states, with an aim to reduce emissions by 30% compared to 2005 by 2030. The ESR targets are set according to national wealth and cost-effectiveness. The ESR allows for flexibilities such as transfers between member states.

The Baseline scenario considers existing national policies and those reflected in the National Energy and Climate Plans.

The Baseline scenario models the policies already adopted, but not the target of net-zero emissions by 2050. As a result, there are no additional policies introduced driving decarbonisation after 2030. However, climate and energy policies are not rolled back after 2030 and several of the measures in place today continue to deliver emissions reduction in the long term.

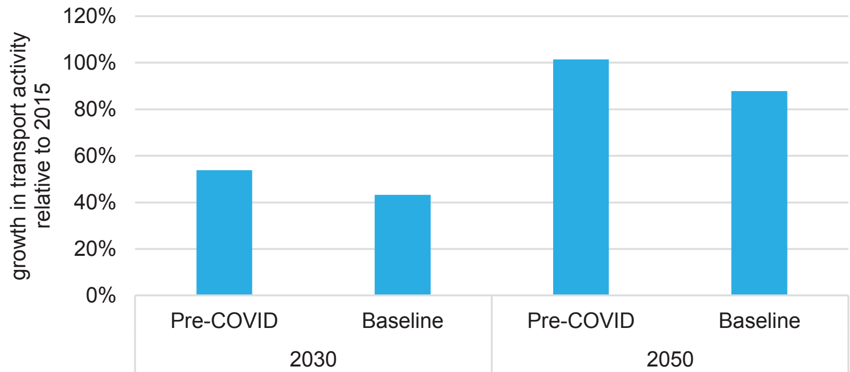
Main results of the Baseline scenario

[214] Directive 2018/2001/EU.

EU total passenger transport activity is projected to grow at a rate of 1% per year on average between 2010 and 2050, despite the significant impact of the COVID-19 pandemics. Growth rates per mode of transport would however be different (see Figure 9). The modal share of road transport (i.e. passenger cars, buses and coaches, and 2-wheelers) is projected to reduce from 69% in 2015 to 61% in 2050.

Air traffic (intra and extra-EU) would increase by 43% by 2030 and 88% by 2050, relative to 2015, following the recovery from the COVID-19 pandemic. That is despite the steep reduction in its activity due to the COVID-19 pandemics in 2020 (i.e. a reduction of 46% in 2020 relative to 2015 levels), as the sector is projected to recover beyond 2015 activity levels by 2025. The pace of the recovery builds on the GDP projections from DG ECFIN but also considers some moderate structural changes due to limited shifts towards digital meetings. The overall impact of the COVID-19 pandemics on the air transport activity is however significant (see Figure 8), especially by 2030, with lower growth projected relative to pre-COVID projections (i.e. around 11 percentage points lower growth for 2015-2030 relative to the pre-COVID projections and 14 percentage points lower growth for 2015-2050). The pre-COVID projections draw on the baseline scenario of the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy[220,221].

Figure 8 Air transport activity (intra and extra EU) in EU27 in the Baseline scenario and pre-COVID projections (% growth relative to 2015)

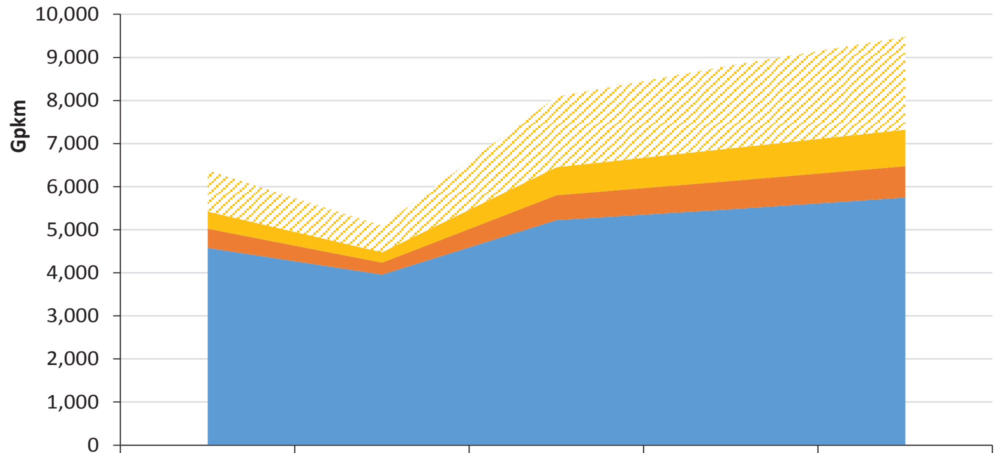


Source: PRIMES-TREMOVE model, E3Modelling

The modal share of aviation (intra and extraEU) in passenger transport activity would go up to 32% by 2050, compared to 24% in 2015, despite the increasing modal share of passenger rail.

220 SWD(2020) 176
221 SWD(2020) 331

Figure 9 Passenger transport activity in EU27 in the Baseline scenario



	2010	2020	2030	2040	2050
Extra-EU aviation	959	612	1637	1924	2154
Intra-EU aviation	398	244	655	764	850
Rail	444	274	577	653	728
Road	4579	3960	5222	5476	5745

Source: PRIMES-TREMOVE model, E3Modelling

Energy demand in transport (passenger and freight, excluding international shipping) is projected to reduce by about 60 Mtoe (or 20%) between 2010 and 2020 as a result of reduced transport activity due to the COVID-19 pandemics. As the activity recovers, the energy demand in the sector increases, peaking at around 280 Mtoe in 2030. The decline that is projected thereafter is mainly driven by the implementation of the CO_2 emission performance standards for new light duty and heavy duty vehicles post-2020, supported by the roll-out of recharging and refuelling infrastructure and also by the shift towards more energy efficient modes such as rail and waterborne transport.

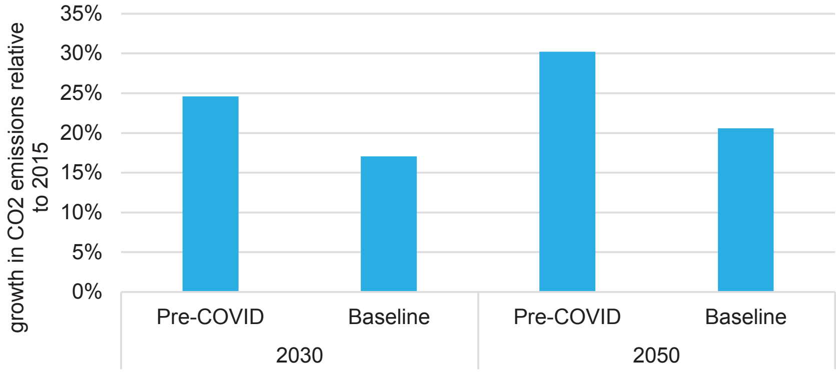
The energy demand in aviation is projected to grow from around 40 Mtoe in 2015 to 50 Mtoe in 2050, following the significant decrease estimated for 2020 (to 21 Mtoe) due to the COVID-19 pandemic Extra-EU flights are responsible for about two-thirds of energy consumption in aviation. Aviation is projected to remain almost entirely reliant on conventional jet fuel by 2050 in the Baseline scenario. The projected uptake of SAF is limited to 0.1 Mtoe in 2030, increasing gradually to close to 1.5 Mtoe in 2050, which would account for 0.2% of total fuel consumption in aviation by 2030 and 2.9% by 2050.

Transport tank-to-wheel (TTW) CO_2 emissions (including international shipping) are projected to decrease from approximately 994 Mtons in 2015 to about 888 Mtons in 2030 and 713 Mtons in 2050, or by 11% and 28%, respectively. The reduction in CO_2 emissions is primarily achieved in road transport due to the roll-out of efficient internal combustion engine vehicles and the uptake of electric vehicles, especially in the period after 2030, but also due to the shift to rail. Specifically, the emissions of road transport are projected to decrease from 732 Mtons in 2015, to 588 Mtons in 2030 (or 20% compared to 2015) and to 386 Mtons in 2050 (or 47% compared to 2015). Emissions from rail transport also decrease, by 3 Mtons in 2050 (or 65% compared 2015). The reduction in these segments compensates for the increase of CO_2 emissions in aviation, which from 120 Mtons in 2015, increases to 140 Mtons in 2030 (by 17%) and 144 Mtons in 2050 (by 21%), and international shipping that increases its emissions by 42 Mtons between 2015 and 2050. The share of air transport in the total transport CO_2 emissions[222] is projected to go up from around 12% in 2015 to 20% in 2050.

[222] Total transport CO_2 emissions including international maritime.

CO_2 emissions from air transport (see Figure 10) are however projected to grow at lower pace than in the pre-COVID projections (17% for 2015-2030 relative to 25% in the pre-COVID projections and 21% for 2015-2050 relative to 30% in the pre-COVID projections), driven by the lower transport activity projections.

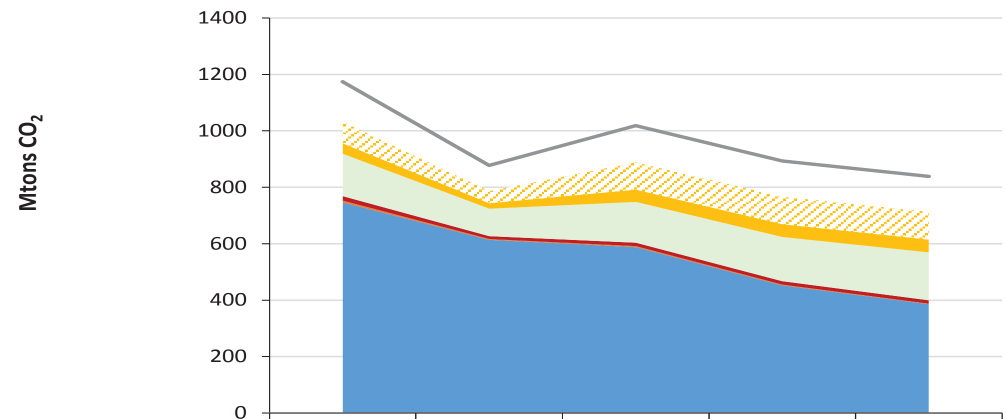
Figure 10 CO_2 emissions from air transport (intra and extra EU) in EU27 in the Baseline scenario and pre-COVID projections (% growth relative to 2015)



Source: PRIMES-TREMOVE model, E3Modelling

Well-to-wheel (WTW) emissions (including those from international maritime) are projected to follow a similar declining trend. In the Baseline scenario they decrease from 1,118 Mtons CO_{2eq} in 2015, to 1,019 Mtons CO_{2eq} in 2030 and 838 Mtons CO_{2eq} in 2050.

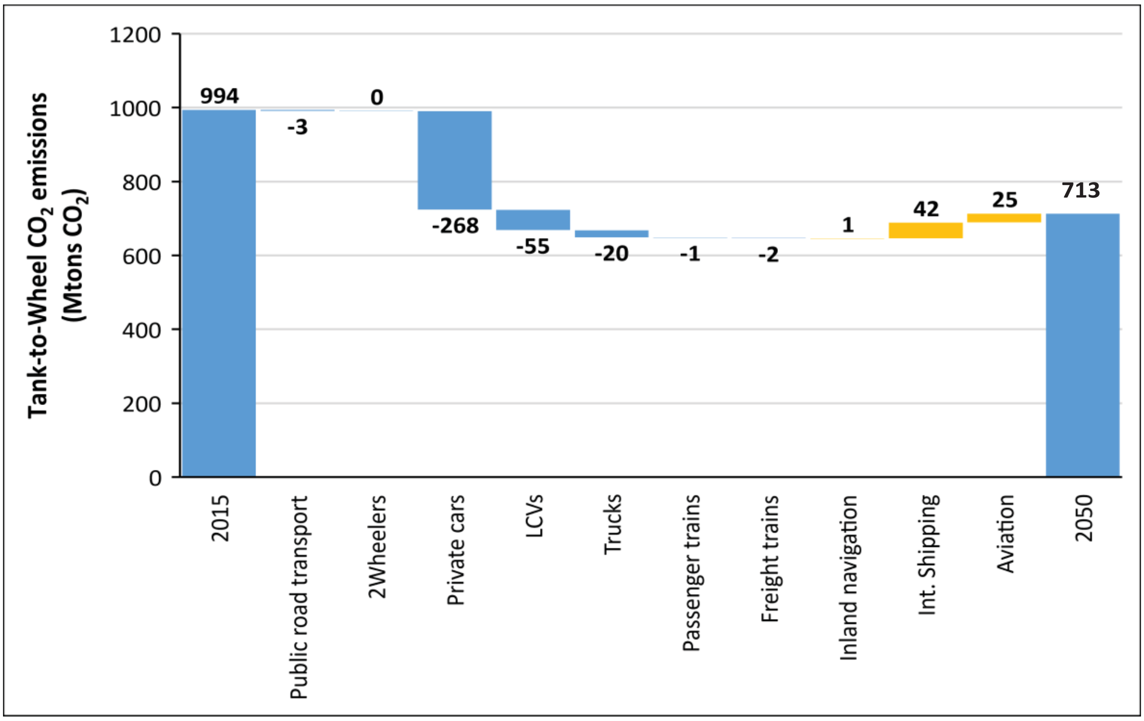
The Baseline scenario results are closely aligned to those of the EU Reference scenario 2020. Figure 11 Tank-to-Wheel CO_2 emissions by transport mode and Well-to-Wheel emissions in transport in the EU27 in the Baseline scenario



	2010	2020	2030	2040	2050
Extra-EU aviation	77	43	96	98	99
Intra-EU aviation	36	19	44	45	45
Int. maritime	150	98	145	157	169
Inland navigation	16	10	12	13	13
Rail	7	3	3	2	1
Road	746	614	588	452	386
Well-to-Wheel (CO2eq)	1174	878	1019	893	838

Source: PRIMES-TREMOVE model, E3Modelling

Figure 12 Reduction of Tank-to-Wheel CO_2 emissions by transport segment in the EU27 between 2010 and 2050 in the Baseline scenario



Source: PRIMES-TREMOVE model, E3Modelling

3. Methodological notes and additional results of the Policy Options

The European Green Deal has set the key objective to deliver a 90% reduction in transport-related greenhouse gas emissions by 2050, drawing on the in-depth analysis underpinning the 2050 long-term strategy[223]. The common scenarios underpinning the Impact Assessment accompanying the 2030 Climate Target Plan[224] and the Staff Working Document accompanying the Sustainable and Smart Mobility Strategy confirmed that for achieving climate neutrality by 2050 transport emissions (including intra-EU aviation and intra-EU maritime) would need to decrease by 95-96% by 2050 relative to 2015 (94-96% relative to 1990). When considering all intra-EU and extra-EU maritime transport, the emissions reductions are projected at around 91-92% relative to 2015 (89-90% relative to 1990). The lower emissions reductions in transport relative to other sectors like for example power generation is in recognition of the fact that emissions in some transport modes, in particular aviation and maritime, are more difficult to abate. The EU's pathway towards climate neutrality, covering all sectors of the economy, is provided in Figure 13.

[223] COM (2018) 773
[224] SWD/2020/176 final

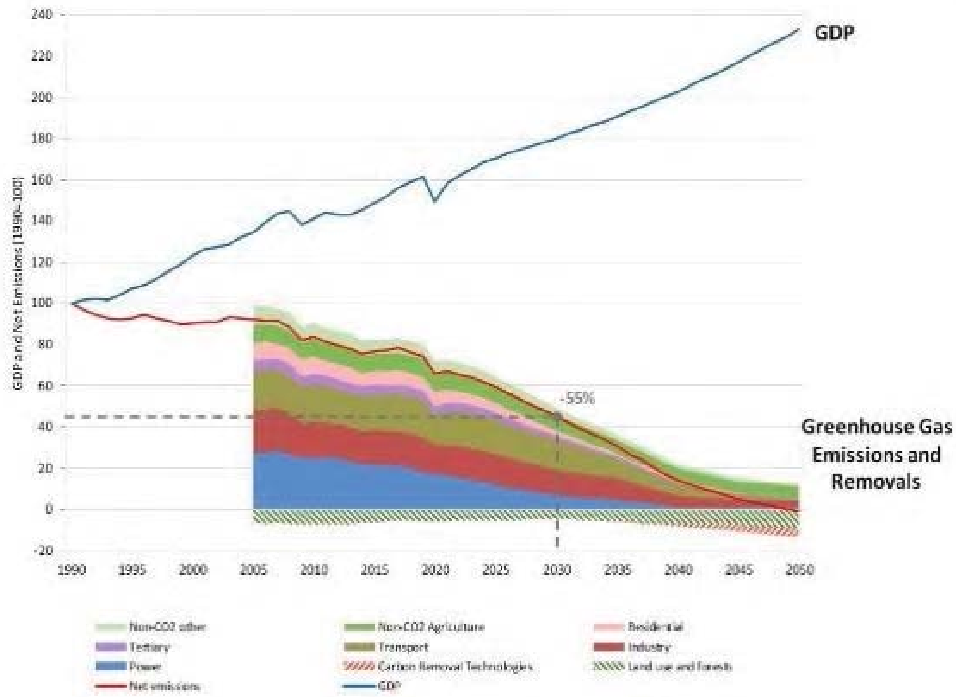


Figure 13- The EU's pathway to sustained economic prosperity and climate neutrality, 1990-2050

Source: COM(2020) 562 final. Commission Communication "Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit our people

Among the transport modes, road and rail transport would need to be almost fully decarbonised by 2050. Lower emissions reductions are projected in aviation and maritime, due to the more limited technological options available for these sectors. Nevertheless, air transport sector would need to achieve emissions reductions of at least 52-59% by 2050 relative to 2015 (equivalent to 14-25% reduction relative to 1990) and international maritime of at least 84-86% (equivalent to 80-82% emissions reductions relative to 1990).

Methodological approach for modelling Policy Options

For the quantification of the Policy Options, first the PRIMES-Aviation submodule was used in order to simulate in detail the changes in the travel demand induced by the changes in the cost of fuels driven by the SAF blending obligations. For this step, an initial set of assumptions on the biokerosene prices was used. Subsequently, the PRIMES-TREMOVE model was used in order to assess the impacts on all transport segments. The demand for biokerosene that was estimated using PRIMES-TREMOVE, was provided to the PRIMES Biomass supply model. The model was subsequently used to estimate the price of biokerosene that reflected the production costs based on the deployed biokerosene production pathways. The iterative process of the model runs was then repeated once again, Subsequently, the price of biokerosene was used in the PRIMES-Aviation submodule, re-iterating the PRIMES-TREMOVE and PRIMES-Biomass model runs in order to provide the quantified output for each Policy Option.

The price of biokerosene is based on the PRIMES Biomass supply model for two separated contexts that depend on the demand levels of biokerosene over time: the high biokerosene demand context is representative for Policy Options A1, A2, B1, C1, and C2 and the low biokerosene demand context is representative for Policy Option B2. This distinction is necessary since Policy Option B2 considers mandates only for the intra-EU air traffic, leading to substantially lower demand for SAF and biokerosene compared to the rest of the Policy Options. Biokerosene production costs are estimated based on feedstock costs, annualised capital investments (taking into account the utilisation of each conversion technology in each time period), operational expenditures (fixed and variable costs). Fixed operating costs account for the operating and maintenance, labour, taxes, overhead and administrative costs. Variable costs include energy costs, and process inputs such as enzymes, catalysts, hydrogen and non-energy utilities (e.g. water, waste treatment). The price is then determined based on a profit margin of 10% assumed for the producer.

SAF prices projections are fully embedded in the 2030 Climate Target Plan policy context, where the EU economy is moving towards carbon neutrality by 2050. This leads to strong competition for biomass feedstock with other energy and transport sectors. Feedstock and renewable electricity are considered to be sourced predominantly in the EU, in order to support the reduction in energy dependence. This further contributes to driving feedstock prices upwards.

In modelling, the assumption was made that the RFNBOs only can fulfil the aviation synthetic fuels obligations in 2030 and afterwards, which is in line with REDII currently in force. Low-carbon electricity for production of synthetic fuels could be considered in line with Energy System Integration Strategy. This may have impacts on some modelling results.

Methodological notes on Policy Option C

In Policy Option C, during a transition period that lasts until 2035, it is assumed that fuel suppliers may organise their logistics, distributing the jet fuel blend to different airports in the most cost-effective way, while meeting the overall blending mandate for sustainable aviation fuels at the EU level, whether prescribed (as in Policy Option C1) or determined on the basis of CO2 emission intensity of the fuel blend (as in Policy Option C2). In 2030, the SAF fuel supply in each airport may range between 0% and 50%, and in 2035 between 2% and 50%. The Policy Option C assumes that the largest airports, and those with proximity to blending facilities will be supplied with most of the jet fuel blends. After the transition period, the EU-wide blending mandates apply also to individual MS.

As such, the distribution of the sustainable aviation fuel blends up until 2035 will differ per MS. For the development of this Policy Option, the EU27 blending share for biokerosene and synthetic kerosene is distributed among the different MS, in line with the different weighing factors for key indicators (Table 15). In this respect, a multicriteria analysis has been employed, in which the different MS score differently on the two criteria considered. The criteria are then weighted to derive a single metric so as to rank the various MS in terms of their overall performance. The weighting factors were determined based on information deriving from questionnaires submitted to fuel suppliers.[225] In this way, the present analysis associates the weights with information from the market actors. As a proxy for the size of airport hubs, passenger air traffic in each MS is used, based on EUROSTAT data for 2019. As a proxy for proximity to blending facilities with biokerosene, it is assumed that it is more likely these to be developed in areas where there is feedstock availability. Feedstock production data for biomass feedstock availability per MS where used as a proxy, based on PRIMES Biomass model. In 2030, availability of UCO is assumed to be the key feedstock and for years leading to 2050, the proximity to solid biomass is prioritized. Ultimately, based on the weighing factors and the data for each MS, the scoring matrices presented in *Source: Ricardo at al. Impact assessment support study*

Table 16 and Table 17 where used to distribute the fuel blends across MS.

Table 15 Weighing factors for different assessment criteria used for the distribution of jet fuel supply to different MS

Indicator	2030	2050
Availability of UCO	50%	-
Availability of Solid biomass feedstocks	-	25%

[225] Responses received from BP, Fulcrum, Nest, Shell and SkyNRG representing both SAF and conventional fuel suppliers.

Synthetic kerosene production	-	25%
Passenger traffic in airports	50%	50%

Source: Ricardo at al. Impact assessment support study

Table 16 Scoring matrix for the distribution of jet fuel blends to different MS in 2030

	Proximity to feedstock			Airport traffic	Total score
	UCO	Solids	E-fuels		
DE	2.5	0	0	2.5	5.0
FR	2.5	0	0	2.5	5.0
IT	2.5	0	0	2.5	5.0
ES	2.5	0	0	2.5	5.0
SE	2.5	0	0	2	4.5
PL	2	0	0	2.5	4.5
NL	2	0	0	2	4.0
BE	2	0	0	1.5	3.5
AT	2	0	0	1.5	3.5
RO	2	0	0	1.5	3.5
PT	1.5	0	0	2	3.5
EL	1.5	0	0	2	3.5
DK	1.5	0	0	1.5	3.0
FI	1.5	0	0	1.5	3.0
IE	1	0	0	2	3.0
CZ	1.5	0	0	1	2.5
HU	1	0	0	1	2.0
BG	1	0	0	1	2.0
HR	1	0	0	1	2.0
SK	1	0	0	0.5	1.5
CY	0.5	0	0	1	1.5
LT	0.5	0	0	0.5	1.0
LV	0.5	0	0	0.5	1.0
SI	0.5	0	0	0.5	1.0
LU	0.5	0	0	0.5	1.0
EE	0.5	0	0	0.5	1.0
MT	0.5	0	0	0.5	1.0

Source: Ricardo at al. Impact assessment support study

Table 17 Scoring matrix for the distribution of jet fuel blends to different MS in 2050

	Proximity to feedstock			Airport traffic	Total score
	UCO	Solids	E-fuels		
DE	0	1.25	1.25	2.5	5.0
FR	0	1.25	1.25	2.5	5.0
IT	0	1.25	1.25	2.5	5.0
PL	0	1.25	1.25	2.5	5.0
ES	0	1	1.25	2.5	4.8
SE	0	1	1.25	2	4.3
RO	0	1.25	1.25	1.5	4.0
PT	0	0.5	1.25	2	3.8
FI	0	1	1.25	1.5	3.8

	Proximity to feedstock			Airport traffic	Total score
	UCO	Solids	E-fuels		
IE	0	0.5	1.25	2	3.8
NL	0	0.25	1.25	2	3.5
AT	0	0.75	1.25	1.5	3.5
EL	0	0.25	1.25	2	3.5
DK	0	0.5	1.25	1.5	3.3
HU	0	1	1.25	1	3.3
BE	0	0.25	1.25	1.5	3.0
CZ	0	0.75	1.25	1	3.0
BG	0	0.75	1.25	1	3.0
HR	0	0.75	1.25	1	3.0
LT	0	1	1.25	0.5	2.8
LV	0	0.75	1.25	0.5	2.5
CY	0	0.25	1.25	1	2.5
SK	0	0.5	1.25	0.5	2.3
EE	0	0.5	1.25	0.5	2.3
SI	0	0.25	1.25	0.5	2.0
LU	0	0.25	1.25	0.5	2.0
MT	0	0.25	1.25	0.5	2.0

Source: Ricardo at al. Impact assessment support study

The shares of biofuels and RFNBOs in Policy Options C1 and C2 are provided in the tables below.

Table 18: Share of biofuels in the EU air transport energy use in PO C1 and PO C2

Share of biofuels (in %)	PO C1				PO C2			
	2025	2030	2035	2050	2025	2030	2035	2050
AT	1.4%	3.2%	15.0%	32.3%	1.4%	3.3%	17.1%	36.3%
BE	1.4%	3.2%	15.0%	30.8%	1.4%	3.3%	17.1%	34.7%
BG	0.8%	1.8%	15.0%	30.8%	0.8%	1.9%	17.1%	34.7%
CY	0.5%	1.8%	15.0%	29.2%	0.5%	2.0%	17.1%	33.2%
CZ	1.0%	2.1%	15.0%	30.8%	1.0%	2.3%	17.1%	34.7%
DE	2.3%	5.0%	15.0%	36.9%	2.3%	5.1%	17.1%	40.9%
DK	1.1%	2.5%	15.0%	31.7%	1.1%	2.7%	17.1%	35.6%
EE	0.2%	1.9%	15.0%	28.6%	0.2%	2.1%	17.1%	32.6%
EL	1.4%	3.2%	15.0%	32.3%	1.4%	3.3%	17.1%	36.3%
ES	2.3%	5.0%	15.0%	36.0%	2.3%	5.1%	17.1%	40.0%
FI	1.1%	2.5%	15.0%	33.2%	1.1%	2.7%	17.1%	37.2%
FR	2.3%	5.0%	15.0%	36.9%	2.3%	5.1%	17.1%	40.9%
HR	0.8%	1.8%	15.0%	30.8%	0.8%	1.9%	17.1%	34.7%
HU	0.8%	1.8%	15.0%	31.7%	0.8%	1.9%	17.1%	35.6%
IE	1.1%	2.5%	15.0%	33.2%	1.1%	2.7%	17.1%	37.2%
IT	2.3%	5.0%	15.0%	36.9%	2.3%	5.1%	17.1%	40.9%
LT	0.2%	1.9%	15.0%	30.2%	0.2%	2.1%	17.1%	34.1%
LU	0.2%	1.9%	15.0%	27.7%	0.2%	2.1%	17.1%	31.6%
LV	0.2%	1.9%	15.0%	29.2%	0.2%	2.1%	17.1%	33.2%
MT	0.2%	1.9%	15.0%	27.7%	0.2%	2.1%	17.1%	31.6%
NL	1.7%	3.8%	15.0%	32.3%	1.7%	3.9%	17.1%	36.3%

Share of biofuels (in %)	PO C1				PO C2			
	2025	2030	2035	2050	2025	2030	2035	2050
PL	2.0%	4.3%	15.0%	36.9%	2.0%	4.4%	17.1%	40.9%
PT	1.4%	3.2%	15.0%	33.2%	1.4%	3.3%	17.1%	37.2%
RO	1.4%	3.2%	15.0%	33.9%	1.4%	3.3%	17.1%	37.8%
SE	2.0%	4.3%	15.0%	34.5%	2.0%	4.4%	17.1%	38.4%
SI	0.2%	1.9%	15.0%	27.7%	0.2%	2.1%	17.1%	31.6%
SK	0.5%	1.8%	15.0%	28.6%	0.5%	2.0%	17.1%	32.6%
EU27	2.0%	4.3%	15.0%	35.0%	2.0%	4.5%	17.1%	38.9%

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE model, E3Modelling

Table 19: Share of RFNBOs in the EU air transport energy use in PO C1 and PO C2

Share of RFNBOs (in %)	PO C1				PO C2			
	2025	2030	2035	2050	2025	2030	2035	2050
AT	0.0%	0.5%	5.0%	25.8%	0.0%	0.4%	2.9%	21.9%
BE	0.0%	0.5%	5.0%	24.6%	0.0%	0.4%	2.9%	20.7%
BG	0.0%	0.3%	5.0%	24.6%	0.0%	0.1%	2.9%	20.7%
CY	0.0%	0.2%	5.0%	23.4%	0.0%	0.0%	2.9%	19.4%
CZ	0.0%	0.3%	5.0%	24.6%	0.0%	0.2%	2.9%	20.7%
DE	0.0%	0.8%	5.0%	29.5%	0.0%	0.7%	2.9%	25.6%
DK	0.0%	0.4%	5.0%	25.4%	0.0%	0.3%	2.9%	21.4%
EE	0.0%	0.1%	5.0%	22.9%	0.0%	0.0%	2.9%	18.9%
EL	0.0%	0.5%	5.0%	25.8%	0.0%	0.4%	2.9%	21.9%
ES	0.0%	0.8%	5.0%	28.8%	0.0%	0.7%	2.9%	24.9%
FI	0.0%	0.4%	5.0%	26.6%	0.0%	0.3%	2.9%	22.6%
FR	0.0%	0.8%	5.0%	29.5%	0.0%	0.7%	2.9%	25.6%
HR	0.0%	0.3%	5.0%	24.6%	0.0%	0.1%	2.9%	20.7%
HU	0.0%	0.3%	5.0%	25.4%	0.0%	0.1%	2.9%	21.4%
IE	0.0%	0.4%	5.0%	26.6%	0.0%	0.3%	2.9%	22.6%
IT	0.0%	0.8%	5.0%	29.5%	0.0%	0.7%	2.9%	25.6%
LT	0.0%	0.1%	5.0%	24.1%	0.0%	0.0%	2.9%	20.2%
LU	0.0%	0.1%	5.0%	22.2%	0.0%	0.0%	2.9%	18.2%
LV	0.0%	0.1%	5.0%	23.4%	0.00%	0.01%	2.92%	19.4%
MT	0.0%	0.1%	5.0%	22.2%	0.00%	0.01%	2.92%	18.2%
NL	0.0%	0.6%	5.0%	25.8%	0.00%	0.47%	2.92%	21.9%
PL	0.0%	0.7%	5.0%	29.5%	0.00%	0.55%	2.92%	25.6%
PT	0.0%	0.5%	5.0%	26.6%	0.00%	0.36%	2.92%	22.6%
RO	0.0%	0.5%	5.0%	27.1%	0.00%	0.36%	2.92%	23.1%
SE	0.0%	0.7%	5.0%	27.6%	0.00%	0.55%	2.92%	23.6%
SI	0.0%	0.1%	5.0%	22.2%	0.00%	0.01%	2.92%	18.2%
SK	0.0%	0.2%	5.0%	22.9%	0.00%	0.03%	2.92%	18.9%
EU27	0.0%	0.7%	5.0%	28.0%	0.0%	0.6%	2.9%	24.0%

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE model, E3Modelling

Methodological note on the cost of SAF logistics

The required distribution of SAF to Member States (i.e. in PO A1 and PO A2) is different from the economically more flexible distribution in PO C1 and C2 (presented in the tables above). In the later, SAF would be used flexibly to fulfil SAF obligations of suppliers across the EU expecting the obligated parties to make the more economically beneficial choices. This means SAF supply lines would be developed earlier to supply either airports with large jet fuel demand, economic logistics or those in proximity to SAF production (and feedstock) capacity[226].

By comparing the allocation of SAF supply to different EU Member States under the different Policy Options, the additional logistics effort required to meet the fuel obligations can be identified. The calculation of the additional capacity assumes that countries presenting with a larger than required SAF usage in the PO C1 and C2, have a production surplus while countries that have a lower usage have a SAF production deficit. Additional logistics costs may also be induced within each Member State, however the working assumption is that within each country, SAF supply is expected to enter the conventional fuel supply chain with a reasonable level of logistic costs as more difficult to reach airports are exempt from the mandate obligation.

To calculate the additional logistics effort of transporting SAF between Member States, the SAF surplus has been allocated from the net-supplier to the net-user Member States. Excess supply has been distributed starting from the net-supplier countries that have less available markets of net-user countries in proximity and then progressively moving to allocate the excess SAF supply of countries with more access. Average Member State distances have been used from the TERCET database[227] to both indicate SAF supply Origin-Destination pairs of MS and to account for the average distances SAF fuel would need to be transported.

In calculating the cost of fuel logistics, the usage of 35 tonne trucks is assumed with a diesel consumption of 35 litres per 100 km (Lloyd, 2019) resulting in a fuel consumption of € 1.07 per 100 tonne-km. Other truck operating costs are derived from the average road freight transport costs as estimated for the countries exporting SAF in the national reports issued by CNR (Comité national routier, 2019). External costs of these additional logistics operations are calculated on a tonne-km basis using the unit value for external costs of freight transport as estimated in the 2019 Handbook on external costs[228].

Impact on energy use in air transport

The introduction of increasing shares of SAF in the aviation fuel mix leads to an overall decrease in jet fuel consumption relative to the baseline. This is driven by a decrease in air transport activity due to higher ticket prices (see section 6.2). By 2030, the energy use in air transport decreases for all POs by around 2% compared to the baseline, and by 8-9% by 2050 (except for PO B2). Small differences can be observed between POs, depending on the target setting (volume approach versus CO2 intensity approach). The reduction in energy use in air transport is slightly lower when the obligation is defined in terms of jet fuel CO2 intensity reduction (POs A2 and C2) compared to the volume-based obligations (POs A1, B1 and C1). This is explained by the slightly lower cost of the jet fuel blend in the CO2 intensity reduction approach versus the volume based approach, that is passed through to the ticket prices and results in slightly lower reduction in air transport activity. There is a notable difference in the reduction of energy use for PO B2 compared to other POs, where total jet fuel use is only reduced by 5% in 2050 compared to the baseline. This is due to the lower reduction in air transport activity in PO B2.

Table 20 - Changes in energy use in air transport in POs relative to the baseline

Air transport energy use (% change to	Baseline (Mtoe)	PO A1	PO A2

[226] Ricardo at al., Study supporting the impact assessment of the ReFuelEU Aviation initiative.
[227] Source: https://gisco-services.ec.europa.eu/tercet/flat-files
[228] Source: Handbook on the external costs of transport - Publications Office of the EU (europa.eu)

Baseline)	2030	2040	2050	2030	2040	2050	2030	2040	2050
Air transport energy use	47	48	50	-2.1%	-4.2%	-8.5%	-2.1%	-4.0%	-8.1%
Air transport energy use (% change to Baseline)	**Baseline (Mtoe)**			**PO B1**			**PO B2**		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
Air transport energy use	47	48	50	-2.2%	-4.3%	-8.6%	-2.1%	-3.0%	-5.3%
Air transport energy use (% change to Baseline)	**Baseline (Mtoe)**			**PO C1**			**PO C2**		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
Air transport energy use	47	48	50	-2.1%	-4.2%	-8.5%	-2.1%	-4.0%	-8.1%

Source: Ricardo at al. Impact assessment support study; PRIMES-TREMOVE, E3Modelling

The introduction of increasing shares of SAF in the aviation fuel mix leads to a marginal decrease in the energy use in transport (excluding international maritime) in 2030 and 2050 for all POs compared to the baseline. This is mainly due to the lower air transport activity. The decrease in energy use in transport is relatively similar across options, i.e. a decrease of 0.3 to 0.4% by 2030 and by 1.1 to 1.9% by 2050 (1.1% for PO B2 and 1.8-1.9% for the other POs).

Administrative costs

<u>Administrative costs for businesses</u>

<u>Reporting for fuel suppliers</u>

Under all POs, the reporting of fuel supply can be done via Union Database which is being developed as a requirement of the Renewable Energy Directive recast (Article 28). It should be ensured that the database takes into account the reporting needs as defined by the aviation mandate and is consistent with CORSIA MRV requirements for SAF. Therefore, it is assumed that no additional administrative burden will be caused for businesses via this initiative.

<u>Reporting for air transport service providers</u>

In the Policy Options that include a demand side mandate (Policy Options B1, B2), air transport service providers are the obliged body. They are in this respect required to report on their SAF uptake. For intra-EEA flights, the reporting stream established for the aviation ETS foresees the reporting of SAF uptake. Utilising this data stream means that no additional administrative burden will be required for reporting on this obligation. For extra-EEA flights under Policy Option B1, airlines will report SAF use to their administering state. For EU airlines, his information will be collected by EU States and could be made available with no additional administrative burden for air transport service providers. However, for non-EU airlines, this data will not be sent to EU authorities pursuant to CORSIA rules. It is therefore needed to request non-EU airlines to report directly SAF use to an EU agency (a new data stream will need to be established). This is not expected to incur significant additional costs as the data required are already available.

Additionally, for Policy Options C1 and C2, fuel users will need to report on the amount of fuel they have uplifted before each flight taking off from an EEA airport to showcase that they have uplifted the amount of fuel necessary for their upcoming trip (no more, no less – all safety and operation margins considered). This reporting could be done under the EU ETS reporting system for intra-EEA flights (via an adaptation of the reporting template) and via a new reporting stream for extra-EEA flights, where airlines report directly to an EU agency. It is expected that this reporting process should not take more than a couple of minutes per flight.

We assume a high estimate of 5’ needed to report per flight and considering the EU hourly average transport wage (€18.4/hour). These amount to annual costs of a total of €16.8 million for the first year of the mandate application in 2025 and around € 24 million in 2050 for both Policy Options. The calculation of the number of flights considers as a base year the 10.56 million flights counted in 2019 and the projected recovery until 2025 by Eurocontrol. From 2025 onwards, the number of flights is considered to increase proportionally to the projected air transport activity as modelled by the PRIMES-TREMOVE model runs.229

Table 21 Annual administrative costs for air transport service providers (in € million)

Policy Option	2025	2050
Baseline	-	-
Policy Option A1	-	-
Policy Option A2	-	-
Policy Option B1	-	-
Policy Option B2	-	-
Policy Option C1	16.8	24.2
Policy Option C2	16.8	23.5

Source: Ricardo at al. Impact assessment support study

Costs to authorities:

SAF supply enforcement and verification at MS and EU level

The costs to authorities for the options with a supplier mandate (A1, A2, C1 and C2) regard the cost of enforcing the mandate and the cost of monitoring via administering the information collection at an EU level and reporting on its implementation. Enforcing the mandate would be delegated to individual Member State authorities who would need to verify that suppliers meet their obligation on the individual fuel batches supplied by performing inspections to check compliance with the regulation. The FQD evaluation collected information from Member States regarding the costs of inspecting fuel suppliers and examining fuel samples, something that would need to be done by national accreditation bodies. The cost per Member State have been estimated in that respect to be between €173,000 and €650,000. For the purposes of this assessment, a central value from this range (€411,500) is applied to all MS as a conservative estimate. This leads to annual administrative costs of €11.1 million for the whole of the EU27.

The EU-level collection and reporting of the relevant information would be a task best assigned to a European organisation that would compile the information submitted in the Union Database into a reporting at a fuel supplier level. When asking stakeholders about the time they expect such a reporting would require, there has been limited reported experience. France has been the only Member State to estimate the effort they put in monitoring SAF supply to being around 0.5 FTE. A4A has also responded to collect and report on SAF usage by their member airlines. This they reported would not take more than a couple of days a year so we assume that the effort estimation provided by France would include also other relevant tasks. Since the data stream is expected to be digitalised, a level of effort similar to that reported by France (0.5 FTE) would seem reasonable to monitor, verify and report on the implementation for the supply mandate. The labour cost for this administrator category is calculated to be approximately €82.000 per year[230] leading to an overall estimation of administrative cost for the EU-level collection and reporting of information of €41.000 per year.

SAF demand enforcement and verification at MS and EU level

When it comes to administering the demand side mandate (Policy Options B1, B2) and the obligatory reporting of SAF consumed (Policy Options C1 and C2), Member States would again be assigned to verify the reporting and enforce the compliance of air transport service providers with the mandate provisions. For Policy Options B1 and B2, this process would similarly to the supply side mandate, require competent authorities to perform inspections and take fuel samples to check compliance with the obligation. As the number of regulated entities would be larger than in the supply side mandate, a higher enforcement cost than what is estimated for the

229 Source: https://www.eurocontrol.int/publication/eurocontrol-five-year-forecast-2020-2024
230 Assuming the average labour costs in Belgium (€ 48.4/hour) for the category of professional, scientific and technical activities (lc_lci_lev)

supply side mandate can be expected for Policy Option B1 that is involving both intra- and extra-EU. For this Policy Option the high cost estimate of the FQD evaluation is considered (€ 650,000 per Member State). For the Policy Option involving only intra-EU flights (B2), a lower estimated effort can be expected to inspect the smaller number of regulated airlines/flights and so the central value of the cost range is considered (€411.500 per MS). While for Policy Options C1 and C2 where Member State enforcement limits to verifying the data reported, this activity can be expected to be less burdensome and be closer to the lower band of the administrative burden reported by the FQD evaluation (€173.000)

Monitoring the application of the regulation would be best performed at an EU level assigning the collection of this information to a European organisation to compile it at an airline level. According to the scope of each Policy Option, the activities assigned to this EU agency would vary. Specifically, under Policy Option B1, where the EU agency would be required to i) compile data for SAF usage submitted through the EU ETS for intra-EEA flights, ii) compile data for SAF usage submitted under CORSIA for extra-EEA flights of EU carriers, and iii) compile date re reported by non-EU carriers related to extra-EEA flights. For the latter, the EU would need to build the digital infrastructure for non-EEA airlines to report on the SAF usage for extra-EE flights. Only the first point of the above is relevant for Policy Options B2, C1 and C2. Drawing a parallel to the effort estimated for combining reporting of data submitted via one database for the supply side mandate, Policy Options B2, C1 and C2 are expected to produce a similar administrative burden to that of POs A1 and A2 (€41.000 per year) while the combination of data from three different data streams can be expected to cause a proportionally higher effort under PO B1 (€123.000 per year)

Jet fuel uplift obligation

The verification of this obligation (under Policy Options C1 and C2) would, similar to the previous, better take place at an EU level by a relevant appointed agency. The verification of relevant information would as explained be submitted to this body for intra-EEA flights via the adapted ETS reporting structure and directly to the agency via a new reporting stream for extra-EEA flights. For verifying and compiling the information from the two data streams, and accounting for the fact that this will require reporting on a flight level, the administrative burden estimated for compiling and verifying the submitted data can be expected to be a bit more burdensome than what is expected for the demand side reporting obligation. Thus, we assume an administrative burden of about 1 FTE per year (€82.000 per year) for the EU body assigned with the task.

A summary of the administrative costs for authorities is provided in **Error! Reference source not found.** w hile Table 23 provides the Present Value estimation of these costs (in 2015 constant prices)

Table 22 Annual administrative burden for authorities (in €)

Present Value	PO A1	PO A2	PO B1	PO B2	PO C1	PO C2
SAF supply MS enforcement and verification – per MS	€411,500	€411,500	-	-	€411,500	€411,500
SAF supply EU info compilation	€41,000	€41,000	-	-	€41,000	€41,000
SAF demand MS enforcement and verification	-	-	€ 650,000	€411,500	€173,000	€173,000
SAF demand enforcement and verification at MS and EU level			€123,000	€41,000	€41,000	€41,000
Jet fuel uplift obligation - EU level					€82,000	€82,000

Source: Ricardo at al. Impact assessment support study

Table 23 Net Present Value of costs for authorities in 2020-2050 (in € million 2015 constant prices)

Present Value	PO A1	PO A2	PO B1	PO B2	PO C1	PO C2
Administrative cost for MS authorities	186	186	293	186	264	264
Administrative cost for EU authorities	0.7	0.7	2.0	0.7	2.7	2.7

Source: Ricardo at al. Impact assessment support study

<u>**Impacts on employment**</u>

Employment in air transport is expected to keep growing until 2050, but slightly less than under the baseline scenario. As air transport activity in the EU is projected to keep growing under all options between 2030 and 2050, direct employment from air transport will follow the same trend. While a total of 408,000 jobs were directly provided by the aviation sector in 2019, all POs show very similar results, i.e. a gain of around 62,400 jobs by 2030, or an increase by around 15%. This increase is however lower than under the baseline scenario, where 72,000 jobs would be created from 2019 to 2030. Finally, comparing the situation between 2030 and 2050, all POs show an increase of direct jobs of around 26%, except for PO B2 where the impact is estimate at around 29%. All POs mean slightly lower job creation between 2030 and 2050 compared to the baseline, which foresees around 31% increase. Aviation creates around three times as many indirect jobs as direct jobs. Therefore, the amount of indirect jobs created under all POs is expected to follow the same trend as for direct jobs, also with slightly lower job creation than in the baseline scenario. It is worth noting that under POs A2 and C2, slightly higher levels of job creation are achieved, compared to POs A1, B1 and C1. This is explained by the fact that the level of passenger air transport activity is marginally higher over time in the former set of options.

The SAF industry is expected to be a significant source of job creation in the EU by 2030 and 2050. With the increased SAF production and the fact that the majority of the SAF used are projected to be produced in the EU, all POs are expected to lead to job gains. Under all POs, the SAF industry provides more than 17,600 additional jobs by 2030 compared to the baseline scenario, except for PO B2 where an additional 5,300 jobs are created. By 2050, under all POs, the SAF industry could be responsible for providing as high as 248,100 additional jobs compared to the baseline scenario, and around 79,700 under PO B2.

Annex 5: Policy measures

A broad list of policy measures has been developed based in particular on: (i) Original ideas on options included in the Commission's Inception Impact Assessment (IIA); (ii) Targeted stakeholder consultations that enabled stakeholders to present their views (details on stakeholder consultation are included in Annex 2)[231]; (iii) the European Green Deal and Smart and Sustainable Mobility Strategy Communications; (iv) independent support study developed by the external consultant.

POLICY MEASURES

Obligation to supply SAF-blended jet fuel. This measure imposes on fuel suppliers an obligation to supply SAF-blended jet fuel at EU airports with a view to reaching a determined target, expressed either in terms of SAF ratio with respect to total jet fuel supply, or in terms of total jet fuel GHG intensity reduction. This target increases over time from 2025 to 2050, in line with the expected trajectory of the SAF market ramp up according to the 2030 Climate Target Plan. The obligation can require suppliers to achieve the target by physically supplying SAF-blended jet fuel at each individual airport (some airports may be exempted), or alternatively, with the flexibility to achieve the target on average over their total jet fuel supply (at least during a transition period).

Obligation to use SAF-blended jet fuel. This measure consists of imposing on airlines an obligation to use a share of SAF (expressed in volumes), increasing over time with respect to their total jet fuel use. The target increases over time from 2025 to 2050, in line with the expected trajectory of the SAF market ramp up according to the 2030 Climate Target Plan (see section 5.4.3). The scope of the obligation can cover either jet fuel used for all flights departing from EU airports (all airlines are covered regardless of their country of registration), or it can cover jet fuel used for flights between EU airports (mainly EU airlines are covered).

Obligation to uplift jet fuel. This measure aims to prevent fuel tankering. It consists of obliging airlines to refuel before departure at every EU airport, with a, amount of jet fuel corresponding to that necessary to operate the next flight (e.g. between 90% and 110% of the fuel necessary to operate the next flight – fuels safety margins being respected). This prevents airlines from carrying excessive amounts of jet fuel from one airport to another with the aim to avoid higher fuel costs, which leads to additional fuel burn and emissions, while undermining the level playing field between airlines.

Obligation to report SAF use. Airlines operating intra-EEA flights are required to report their use of SAF as per the EU ETS Monitoring and Reporting Regulation (MRR).

Sub-obligation on RFNBOs. Fuel suppliers or airlines are obliged to supply synthetic fuels as part of the overall SAF supply or use obligation, with a view to meet a gradually increasing targets. This measure is relevant when the target of the SAF obligation is expressed in terms of SAF volumes.

Multiplier on RFNBOs. A multiplier applies to synthetic fuels, in order to bridge the high production cost between advanced biofuels and synthetic fuels.

Transactions of SAF for accounting purposes. This measure is intended to allow the fuel industry to meet the supply obligation overall in a more cost effective way possible and/or to allow airlines with no access to SAF at airports, or wish to use more SAF than available, to do so. Indeed, while some suppliers may be in a better position than others to meet or even exceed the obligation (e.g. large production capacities, mature supply chain, etc.), a mechanism would allow certain suppliers to over-supply, while others would under-supply. This

[231] In designing and assessing the Options, the Commission consulted stakeholders on detailed individual measures aimed at tackling individual aspects of the problems identified in the evaluation.

measure is only relevant where the supply obligation is defined with the flexibility that not all airports are required to be physically supplied with SAF-blended jet fuel. Otherwise, there would be a risk that certain suppliers (under achievers) supply lower levels of SAF or pure fossil jet fuel, in a context where only SAF-blended jet fuel must be supplied at all airports. Similarly, airlines operating at airports with no or very reduced SAF supply may benefit of this system to fulfil their SAF use obligation.

Monitoring, reporting and verifying. Fuel suppliers shall report SAF supply quantity and quality (characteristics of the SAF supplied) into the Union database. Airlines operating intra-EEA flights report their use of SAF (and characteristics of the SAF used) as per the EU ETS MRR. An EU Agency is required to compile the SAF supply and use report data. An EU Agency is required to provide a yearly consolidated report to the Commission. A new reporting stream is created where all airlines report their jet fuel uplift per flight. An EU agency is required to verify the reports, detect cases of fuel tankering and report to the Commission on a yearly basis.

Penalties for non-compliance. Obligated parties (i.e. fuel suppliers and/or airlines) are subject to penalties for non-compliance in case of failure to meet their obligation. The level of the penalty is harmonised across the single market, determined at EU level, and can be reviewed every year to be adjusted to the developments of the SAF market and evolution of fuel market prices. Funds collected from non-compliance penalties are injected in an EU fund for the development of SAF, e.g. EU ETS Innovation Fund.

Annex 6 - Flanking measures

Intensify European efforts at ICAO level to raise ambition on SAF use. This non-regulatory measure aims to accelerate ongoing work and discussions at ICAO level on the role of SAF towards the long-term decarbonisation of aviation. While SAF is recognised as an important lever for reducing emissions of international aviation, there is still a high level of reluctance by certain influential ICAO States to commit to specific measures for the use of SAF on international routes. Such measures would allow to reduce the risks of competitive distortion between EU and non-EU air carriers, as well as to reduce the risks of fuel tankering and carbon leakage. Furthermore, European action at ICAO level should ensure that the general ambition on the role of fuels as a pillar for decarbonisation of aviation remains focused on fuels with high sustainability potential, not on lower-carbon fossil fuels.

Steer financial support towards SAF development in the EU. This measure consists of identifying relevant funding mechanisms and sources that can be put in place to support increased production and uptake of SAF in the EU. In particular in the present crisis context, funding will be particularly necessary to support research and development of innovative, sustainable and cost-effective SAF pathways and feedstock supply. It will also be relevant to support the development, scaling up and deployment of SAF production capacity and distribution infrastructure in the EU. High technology risk and high capital costs related to the not yet commercially SAF production pathways, notably from advanced biofuels and RFNBOs, could be supported by innovative financial products for the purpose of developing the production up to the commercialise stage. A combination of grants with financial instruments such as "contracts for difference" could be interesting to reduce the technology risks for investors.

Funding has an important role to play in developing and upscaling SAF production and deployment. It can take different forms and serve different purposes.

- As highlighted by Problem Driver 1 and Specific Objective 1, research and development is necessary to allow new innovative, sustainable and cost-effective pathways to emerge and reach the market. Funding R&D, pilot and demonstration projects up to commercialisation can speed the path to maturity for certain technologies. It can prove helpful for developing less mature technologies like advanced biofuels and RFNBOs.
- As highlighted in Problem Driver 2 and 3, and Specific Objective 1 and 2, substantial private and public investments will be necessary in the years and decades to come to reduce the gap between SAF prices and conventional jet fuel prices. This can be done by supporting CAPEX and or OPEX costs of new industrial-scale SAF production sites, at least in the first stages while the price gap remains a market barrier.

Aside from private investments, which are expected to play a major role in upscaling SAF production, public funding from Member States and the EU budget could be put to contribution in various ways.

- Funding from specific EU instruments can help to support boosting SAF production and uptake. The below instruments would be relevant for this purpose.
    - o **Horizon Europe** is the European Union's research framework programme with a budget €100 billion for the period 2021-2027. It is highly relevant to support R&D on SAF, as it targets research projects including on innovative transport and energy with climate dimension.
    - o **Connecting Europe Facility (CEF)** supports deployment of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport and energy, among others with a budget of €21.38 billion for transport over the period 2021-2027. CEF is very relevant to support SAF distribution projects in the EU.

- **InvestEU** will bring together the European Fund for Strategic Investments and thirteen EU financial instruments currently available. This will provide an EU budget guarantee of €75 billion in support of various investment areas. Of relevance are sustainable infrastructure and research, innovation and development windows to support the scaling up of production, and also SMEs window to support the emergence of new players in the SAF supply chain, notably for feedstock supply.
- **NextGenerationEU** aims to support public investments for Member States efforts to recover from the COVID-19 crisis, with a focus on recovering by accelerating the green transition. With a €750 billion envelope, it is highly relevant to support the roll out of SAF production capacity in Member States, notably via the Recovery and Resilience Facility, based on the respective national Recovery and Resilience Plans.
- **Innovation Fund under EU ETS** is a €10 billion fund over the period 2020-2030, aiming to drive low-carbon technologies to the market with a special focus on industrial sectors in the scope of EU ETS and renewable energy and carbon capture use (CCU) and storage (CCS). It is highly relevant to support demonstration plants for advanced biofuels and RFNBOs.

- European industrial alliances and state aid schemes and could also be highly relevant to providing financial support
  - **Important Projects of Common European Interests (IPCEI)** can provide significant support to emerging industries, if aligned with EU strategic objectives. IPCEIs (e.g. batteries, microelectronics) are largely bottom-up initiatives of Member States, highly ambitious on research and innovation, supported by private and public investments, including from the EU budget. SAF could be highly relevant for the creation of a new IPCEI, with the involvement of MS and relevant industrial actors. The creation of a European strategic alliance for SAF (see below) would be an excellent opportunity to put in place such an IPCEI.

Create a European strategic alliance for Renewable and Low Carbon Fuels. This measure consists of setting up a strategic industrial alliance, with the objective to create a competitive production value chain in the EU with advanced biofuels (Part A biofuels) and RFNBOs at its core. To support a smooth transition away from the dependence on fossil fuel, prevent a new technological dependence on our competitors and capitalise on the jobs, growth and investment potential of advanced biofuels and RFNBOs, the EU has to move fast in the global race. This alliance would consist of a cooperative platform gathering notably the European Commission, interested EU countries, European financial institutions, key industrial stakeholders, and research and innovation actors. It could include in its scope financial mechanisms to boost the production of SAF at EU level, such as the establishment of contracts for difference schemes or an IPCEI.

Facilitate SAF certification. As described in Section 2, the certification of new SAF production pathways performed by the ASTM International[232] or the DefStan[233] is a rigorous and lengthy process that involves significant financial, time, logistical and human resources (see problem driver 1). In the US, the FAA has set up a dedicated "Clearing House" that accompanies fuel producers in their process of obtaining ASTM approval for their product. Support could also be provided to SAF producers in the EU in a similar way. It could take different forms. Either, it could consists of increased European cooperation with the existing US Clearing House and e.g. appointing an EU representative. The EU representative would act as a contact point and provide support to EU SAF producers. On the other side of the spectrum, the EU could decide to establish its own EU Clearing House, by replicating the US undertaking.

[232] Source: https://www.astm.org/
[233] UK Defence Standardization - https://www.gov.uk/guidance/uk-defence-standardization

Annex 7 - Differences between policy options

This section provides additional elements to those already referenced in section 5.5 of this document.

1. DIFFERENCES IN THE SUPPLY OBLIGATION

Under policy options **A1 and A2**, fuel suppliers distributing jet fuel at EU airports are required to supply a minimum level of SAF-blended jet fuel to airlines at all EU airports. This means that every litre of jet fuel supplied and available at EU airports will contain at least a minimum percentage of SAF. This obligation applies to all jet fuel delivered in the EU. Certain categories of airports, such as remote or insular airports may request to be exempted. Airlines (regardless of their origin or destination) have no alternative than to use the SAF-blended jet fuel as the only jet fuel available when refuelling at EU airports.

Under policy options **B1 and B2**, there is no direct obligation on fuel suppliers.

Under policy options **C1 and C2**, fuel suppliers are obliged to supply physically a minimum share of SAF (expressed in volumes) at all EU airports at all times, post-2035 (following a transition period). This means that every litre of jet fuel supplied to airports must be blended with at least a minimum share of SAF. Airlines (EU and non-EU) operating on intra-EU and extra-EU routes taking off from airports located on EU territory have no alternative than to use SAF-blended jet fuel. This minimum share of SAF to be supplied corresponds to the trajectory of the SAF market ramp up according to the impact assessment accompanying the 2030 Climate Target Plan and is the same as in PO A1 and PO B1.

In order to allow for a more cost-effective SAF supply in the first years of the supply obligation, a two-stage transition period applies from 2025 to 2035.

- From 2025 to 2030, fuel suppliers are required to meet the ramp up target and can supply EU airports with jet fuel containing SAF in the range 0% - 50% (which corresponds to the maximum limit for certified SAF blends). This means that fuel suppliers are not required to distribute SAF at all airports, as long as the overall ramp up target is achieved. Fuel suppliers are nevertheless required to individually meet the target, i.e. the SAF ramp up.
- From 2030 to 2035, fuel suppliers are required to meet the ramp up target (i.e. 5% in 2030 and 20% in 2035) but must all supply EU airports with jet fuel containing SAF in the range 2% - 50%. This means that every litre of jet fuel supplied to all airports must be blended with at least 2%[234] of SAF. Fuel suppliers are required to supply overall 0.7% of RFNBOs from 2030, and every litre of jet fuel supplied at airports must contain RFNBOs in the range 0.3%[235] - 50%.

2. DIFFERENCES IN THE DEMAND OBLIGATION (AND UPLIFT OBLIGATION)

Under policy options **A1** and **A2**, there is no legal obligation on airlines to use SAF-blended jet fuel.

Under policy option **B1**, airlines are required to use a certain level of SAF-blended jet fuel with respect to their total jet fuel consumption on all intra-EU and extra-EU flights departing from EU airports. As certain airlines may not have physical access to SAF-blended jet fuel at their destination airports, a system of SAF transaction (for accounting purposes) allows airlines to secure the purchase of SAF volumes in order to meet their obligation.

234 The choice of 2% as a minimum of SAF to be supplied at all airports was retained as it is a reasonable, attainable target by 2030. It allows all suppliers to smoothly transition to a system where all airports must be supplied with SAF-blended jet fuel, and gradually develop their supply chain for this purpose.

235 The choice of 0.3% for RFNBOs follows the same logic. The ratio is the same between 0.3% and 0.7%, as it is between 2% and 5%.

Under policy options **B2,** the same obligation applies but it concerns only air traffic operating intra-EU flights**.**

C1 and C2 do not have a SAF obligation, but rather a jet fuel uplift obligation.

3. Target setting: volume or CO2 intensity reduction

Under policy options **A1**, **B1**, **B2** and **C1**, economic operators subject to the obligation (fuel suppliers and/or airlines) are required to supply/use at least minimum share of SAF, expressed as a volume percentage of the relevant total jet fuel supply/use, over the course of a reporting period of one year. All volumes of SAF that are compliant with the sustainability requirements (see section 5.3.1) are treated equally, and can contribute towards meeting the obligation in the same way. This approach encourages suppliers/airlines to supply/use SAF in terms of absolute quantity. It is currently the approach used under RED II[236] and to some extent under the EU ETS for aviation.

Under policy options **A2** and **C2**, economic operators subject to the obligation (fuel suppliers and/or airlines) are required to supply/use jet fuel that achieves a minimum CO2 intensity reduction compared to a baseline for fossil fuel over the course of a reporting period of a year.

4. Incentives for RFNBOs: sub-mandate or multiplier

When the obligation is volume-based, i.e. under policy options **A1**, **B1**, **B2** and **C1**, RFNBOs are subject to a gradually increasing sub-mandate as of 2030. This means that economic operators subject to the obligation (fuel suppliers and/or airlines) are required to supply/use a minimum volume share of RFNBOs in order to meet their obligation. The sub-mandate on RFNBOs is justified by the high potential of this fuel technology to deliver important climate benefits, their high production costs, and the need for a swift scale up of production capacity.

When the obligation is CO2 intensity reduction-based, i.e. under policy options **A2** and **C2**, RFNBOs are subject to a multiplier. Its value is 1.6 and 1.2 respectively in 2030 and 2040. From 2045, its value is 1. This means that RFNBOs can count “more” towards the CO2 intensity reduction target, than other types of SAF. Such multipliers are traditionally used to make a specific technology more attractive to economic operators because it has high potential to deliver the expected policy objectives. In the present case, RFNBOs are expected to play a key role as of 2030 in delivering on EU’s climate objectives for aviation, but market penetration is hampered by high prices and lower industrial maturity compared to other types of SAF, and even higher prices compared to conventional jet fuel. Hence, the proposed multiplier is expected to contribute bridging the price gap with advanced biofuels and increase RFNBOs economic attractiveness on the market.

[236] Although when transposing RED II into national legislation, member States have the possibility to use a GHG intensity reduction based target.

Annex 8 – Criteria for policy choice on SAF

Criteria	**Advanced Biofuels**	**Part B Biofuels**	**RFNBOs**
Sustainability	Very high potential. Emissions savings can reach e.g. 94% when using forestry residues, 91% when using bio-waste. No ILUC	High potential. Emissions savings can reach e.g. 85% when using used cooking oil or 76% when using tallow. No ILUC	Very high potential. Emissions savings can reach 100% when CO2 is captured directly from the air. No ILUC
Market readiness	At the stage of commercial pilots	Already mature and available at commercial scale for road transport.	In development
Feedstock or resources availability	High potential availability of feedstock e.g. bio-waste, agricultural and forestry residues. Potential competition with maritime.	Limited availability of used cooking oil and tallow. Strong competition with road transport sector.	Growing share of renewable electricity in the EU energy mix towards 2050. Source of CO_2 is potentially unlimited with direct air capture.
Costs	Production costs are currently around 2-4 times the price of fossil jet fuel[237]	Production costs are currently around twice the price of fossil jet fuel[238]	Production costs are currently around 3-6 times the price of fossil jet fuel[239]

Criteria	**Crop based fuels**	**Green hydrogen**	**Green electricity**
Sustainability	Low potential. Resource intensive. Accountable for ILUC.	Very high potential.	Very high potential
Market readiness	Mature and available at commercial scale for the road transport sector	Research stage. Expected to play a role in commercial aviation by 2040	Research stage. Expected to play a role in commercial aviation by 2040
Feedstock or resources availability	Availability of crop based feedstock is constrained by the used of land.	Very limited availability for aviation by 2050.	Very limited availability for aviation by 2050.
Costs	Production costs are around 2 times the price of fossil jet fuel[240]	No reliable information	No reliable information

237 ICCT – The cost of supporting alternative jet fuels in the EU.
238 Ibid.
239 Ibid.
240 Ibid.

Regarding **sustainability**, all three SAF categories have high to very high sustainability potential. For instance, Part B biofuels produced through the HEFA pathway with used cooking oil and advanced biofuels produced with bio-waste can achieve respectively 85% and 91% emissions savings compared to conventional jet fuel. RFNBOs can achieve as high as 85% emissions savings compared to conventional jet fuel. Whereas hydrogen and electricity are equally expected to have high sustainability potential, the sustainability of crop based biofuels is undermined by indirect land use chance effects, which tend to increase their life cycle emissions[241].

Regarding **market readiness,** SAF are drop-in fuels and compatible with existing aircraft engines and fuel supply infrastructure. Being either already commercially mature or at pilot stage, SAF can be deployed already in the short to medium term, i.e. by 2025 (advanced and Part B biofuels) or 2030 at the latest (RFNBOs). This is not the case of hydrogen fuel cells and electric batteries, both of which require major changes of aircraft engine design and technology, and are expected to become a meaningful market reality in commercial aviation at the earliest by 2040.

Regarding **feedstock availability**, Part B feedstock (waste lipids) availability is expected to remain limited in the future, advanced biofuels feedstock is expected to be abundant in the years and decades to come[242]. RFNBOs will also benefit from an expected increase of renewable electricity in the EU power generation mix by 2030 and 2050[243].

Regarding **production costs**, for SAF these vary from 2-6 times that of conventional jet fuel depending on the production route and the feedstock used. However, SAF production costs are expected to decrease as the market becomes more established over the years. As regards electricity and hydrogen, at present there is no reliable information available on the expected cost impact for airlines. Crop based biofuels production costs are usually estimated at around twice that of conventional jet fuel.

Finally, regarding **regulatory fitness**, while advanced biofuels and RFNBOs are promoted under RED II, Part B biofuels are subject to a cap[244]. Crop based biofuels are also subject to a cap[245], and in case of high indirect land-use change-risk, are due to be phased out by 2030.

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241 See Part A of Annex VIII of the recast Renewable Energy Directive.

242 World Economic Forum – Cleans Skies for Tomorrow feasibility study.

243 2030 Climate Target Plans MIX scenario.

244 Under the recast Renewable Energy Directive Art 27(1b), biofuels produced from feedstock listed in Part B of Annex IX cannot contribute towards the overall renewable energy target in transport for more than 1,7%.

245 The share of biofuels and bioliquids, as well as of biomass fuels consumed in transport, where produced from food and feed crops, shall be no more than one percentage point higher than the share of such fuels in the final consumption of energy in the road and rail transport sectors in 2020 in that Member State, with a maximum of 7 % of final consumption of energy in the road and rail transport sectors in that Member State.

Annex 9 – Monitoring, Reporting, Verification

Monitoring, reporting and verification (MRV) is an essential part of ensuring that the regulatory framework functions properly, that economic operators fulfil their obligations, to detect and avoid fraud, and to track indicators on the success of the policy objectives. It is essential that each of the policy options under consideration cater for a robust MRV system on the fuel supply side and on the airlines' fuel use side. The existing EU regulatory framework already contains MRV systems on both sides, under the RED II (supply side) and the EU ETS (fuel users' side). The following table explains for each policy option how the monitoring, reporting and verification of the SAF flows across the EU would function.

All POs require an existing EU agency (e.g. EASA) or European organisation (e.g. Eurocontrol) to perform data processing and to report to the Commission on the fulfilment of stakeholders' obligations. EASA could be well suited to be responsible for MRV purposes in connection with the SAF supply side and the Union Database established under RED II, as EASA has performed in 2019 extensive work[246] on possible ways to improve SAF monitoring in the EU. Eurocontrol could be well suited to be responsible for MRV purposes in connection with the demand side, as being involved already in the MRV of the EU ETS.

Option	Obligation[247]	Reporting	Verifying	Monitoring
A1	Suppliers must supply minimum % of SAF-blended fuel at all airports	Suppliers must report supply into Union database. (art 28(2)RED)	Member States enforcement. SCS verify compliance with sustainability (art 28(4) RED). Suppliers must arrange for auditing and prove it (art 30(3) RED).	Existing EU agency (e.g. EASA) must have access to Union database and compile data on fuel supply
	No obligation on airlines	Airlines report SAF use under ETS (art 14) with proof of jet fuel purchase and SAF sustainability certificate	Member States ensure that emission reports (AERs) are verified (art 15, ETS)	Airlines monitor their jet fuel use (art 14(3), ETS) MS must transmit AERs to existing EU agency (e.g. Eurocontrol) for to compile data on fuel use
A2	Suppliers must supply SAF to all airports to decrease jet fuel CO2 intensity by %	Suppliers must report supply into Union database (art 28(2)) in terms of CO2 intensity reduction	Member States enforcement. SCS verify compliance with sustainability (art 28(4)). Suppliers must arrange for auditing and prove it (art 30(3)).	Existing EU agency (e.g. EASA) must have access to Union database and compile data on fuel supply
	No obligation on airlines	Airlines report SAF use as per normal procedure under ETS (art 14(3)) with proof of jet fuel purchase and SAF sustainability certificate	Member States ensure that emission reports are verified (art 15, ETS)	Airlines monitor jet fuel use (art 14(3)) MS must transmit AERs to existing EU agency (e.g. Eurocontrol) for to compile data on fuel use
B1	No obligation on fuel	Suppliers report supply into	Member States	Monitoring by the

[246] Sustainable Aviation Fuel 'Monitoring System' – EASA - 2019

[247] The terminology and presentation of the policy options in this column are simplified. Section 5 of this document provides the accurate description of the policy options.

	suppliers	Union database (art 28(2))	enforcement. SCS verify compliance with sustainability (art 28(4)). Suppliers must arrange for auditing and prove it (art 30(3)).	Commission (Art 33)
	Airlines must use minimum % SAF-blended jet fuel overall intra-EEA consumption	Intra-EEA flights; Airlines shall report SAF use as per normal procedure under ETS (art 14(3))	Member States ensure that emission reports are verified (art 15, ETS)	Airlines monitor jet fuel use (art 14(3)) MS must transmit AERs to EU agency for to compile data on fuel use
		Extra-EEA flights: airlines report SAF use as part of CORSIA MRV system, as established under ICAO SARPs Annex 16 Volume IV, Chapter 2.	CORSIA rules require that aeroplane operators emission reports be verified by accredited bodies.	EU agency must compile data on SAF use
B2	No obligation on fuel suppliers	Suppliers report supply into Union database (art 28(2))	Member States enforcement. SCS verify compliance with sustainability (art 28(4)). Suppliers must arrange for auditing and prove it (art 30(3)).	Monitoring by the Commission (Art 33)
	Airlines must use minimum % SAF-blended jet fuel overall total consumption on intra-EU routes	Airlines report SAF use on intra-EU routesunder ETS (art 14(3))	Member States ensure that emission reports are verified (art 15, ETS)	Airlines monitor jet fuel use (art 14(3)) Existing EU agency must have access to Union database an compile data on fuel supply
C1	Suppliers must supply minimum % of SAF-blended fuel at all airports (with transition period)	Suppliers must report supply into Union database (art 28(2))	Member States enforcement. SCS verify compliance with sustainability (art 28(4)). Suppliers must arrange for auditing and prove it (art 30(3)).	Monitoring by the Commission (Art 33) Existing EU agency must have access to Union database an compile data on fuel supply
	Airlines must take up jet fuel for next flight at EU airports	New reporting system requiring all airlines to report fuel use per flight	Existing EU agency (e.g. Eurocontrol) verifies data submitted by airlines	EU agency must compile data on fuel use and report to Commission any cases of tankering
	Airlines must report SAF use on intra-EEA flights	Airlines report SAF use as per normal procedure under ETS (art 14(3)) with proof of jet fuel purchase and SAF sustainability certificate	Member States ensure that emissions reports are verified (ETS art 15)	Airlines shall monitor jet fuel use (ETS art 14(3)) EU agency must compile data from ETS on fuel use
C2	Suppliers must supply SAF to all airports to decrease jet fuel CO2 intensity by %	Suppliers must report supply into Union database (art 28(2)) in terms of CO2 intensity reduction	Member States enforcement. SCS verify compliance with sustainability (art 28(4)). Suppliers must arrange for auditing and prove it (art 30(3)).	Existing EU agency (e.g.EASA) must have access to Union database and compile data on fuel supply

	Airline must take up fuel for next flight at EU airports	New reporting system requiring all airlines to report fuel use per flight	Existing EU agency (e.g. Eurocontrol) verifies data submitted by airlines	Existing EU agency (e.g. Eurocontrol) must compile data on fuel use and report to Commission any cases of tankering
	Airlines must report SAF use on intra-EEA flights	Airlines report SAF use under ETS (art 14(3))	Member States ensure that reports are verified (ETS art 15)	Airlines monitor jet fuel use (ETS art 14(3)) Existing EU agency (e.g. Eurocontrol) must compile data from ETS on fuel use

Annex 10 – Interaction with ongoing revisions

Renewable Energy Directive

The ReFuelEU Aviation initiative sets out the objective to increase the supply and uptake of sustainable aviation fuels (SAF) at EU level in the aviation market. This objective converges with that of the Renewable Energy Directive (RED) framework, which is – among others, to increase the share of renewable energy in transport. The following section explains how the ReFuelEU Aviation SAF obligation and the RED framework (currently under revision) would interact, complement and mutually support each other in several areas.

Sustainability framework

The ReFuelEU Aviation initiative relies on the sustainability framework of RED 2. This means that SAF qualifying to meet the obligation under all POs would be eligible if they meet the sustainability criteria defined under RED 2. This is essential to maintain uniformity in the EU regulatory framework and importantly, to provide the fuels industry with clear and consistent rules for all transport biofuels. Should the RED 2 sustainability criteria be revised, the revision would be also carried over and apply to the rules set out under the ReFuelEU Aviation initiative. The same applies as regards the definition of the types of SAF eligible. Should definitions of 'biofuels', 'advanced biofuels' or RFNBOs be revised, or should the types of feedstock listed in Annex IX Part A or B be revised, this revision would de facto be carried over to apply equally under the SAF obligation. This can be achieved easily in the ReFuelEU Aviation legislative proposal by making a cross reference to the relevant provisions of the RED rules. It should be noted that there would be strong merit in aligning the RED sustainability criteria for biofuels as close as possible to those of CORSIA. This would provide more clarity to the SAF and aviation markets and support SAF uptake by all airlines on intra- and extra-EU flights.

Monitoring, reporting and verification

The RED framework establishes clear provisions for the monitoring, reporting and verification of renewable fuel supply. The POs proposed under ReFuelEU Aviation rely to a very large extent on this existing system. Indeed, through cross references to the relevant provisions of RED 2 (e.g. Art 28), the legislative proposal would ensure SAF are treated in the same way as other transport biofuels. The objective is to avoid creating parallel reporting schemes that would add layers of administrative burden and increase risks of misreporting/accounting. In particular, the use of the Union Database (established under RED 2) should be the support for SAF suppliers to report the relevant data. This includes information on the transactions made and the sustainability characteristics of SAF, including their life-cycle greenhouse gas emissions starting from their point of production to the fuel supplier that places that fuel on the market. The information submitted by fuel suppliers should be verified under the authority of Member States as per RED 2 requirements. As the ReFuelEU Aviation obligation is imposed directly on the fuel suppliers, it is necessary that an EU agency compiles the information provided in the Database at fuel suppliers-level, and reports to the Commission on the fulfilment of the obligation by each regulated entity.

Fuel supply obligations

RED sets out an overarching renewable energy obligation with a target that is set as a share of renewable energy in road and the rail sectors, but is aiming to support renewable to some extent also in the aviation and maritime sector. It does not contain an aviation-specific obligation, but contains a multiplier of 1.2 on the contribution of aviation biofuels to the overarching target, although much smaller than the multiplier of the road sector (4). The introduction of an aviation-specific target under the ReFuelEU aviation initiative does not contradict the overall objectives of the RED. On the contrary, it complements the RED framework by targeting specifically a sector which can currently only use a very limited range of renewable energies and whose decarbonisation poses specific challenges. It thereby contributes to increasing the share of renewable energy in transport. With an aviation-specific target introduced under ReFuelEU Aviation, it would be possible, but not necessary to revise the design of the overarching RED target. Indeed, in the absence of change, Member States would be able to account for the supply of SAF to the aviation market on their territory towards meeting their national target for renewable energy in transport. All POs, including POs C1 and C2, foresee a rather uniform share of SAF to be supplied across all Member States. The decisions taken under the ReFuelEU Aviation initiatives would have to be taken into account in the approach taken to support renewable and low carbon fuels under the RED, which will be subject to a revision.

Incentives for fuel technologies

The RED 2 framework supports various fuel technologies in different ways. It is important that the ReFuelEU Aviation initiative takes a coherent approach towards those fuel.

- **Conventional biofuels**: RED 2 recognises the eligibility of such fuels (food and feed crop-based fuels) to meet the renewable energy target but their contribution to the target is capped to 7% of final consumption of energy in the road and rail transport sectors in that Member State and does not apply the 1.2 multiplier to such fuels if consumed in the aviation sector. Further, the contribution to the target of such fuels that have high ILUC risk is phased out by 2030. In coherence with the RED 2 approach, the ReFuelEU Aviation initiative does not make eligible biofuels produced from food and feed crops.
- **Part A 'advanced' biofuels**: RED 2 supports the production and supply of such fuels, notably with sub-mandates of 0,2 % in 2022, at least 1 % in 2025 and at least 3,5 % in 2030. A multiplier of 2 also applies to the supply of all such fuels. ReFuelEU Aviation supports such fuels, which are expected to make an important contribution to the aviation fuel mix under all POs. The high SAF obligation targets under ReFuelEU Aviation send a policy signal to the market that a major scale up of these fuels is necessary. The incentives under RED 2 are expected to further reinforce this signal. A dedicated submandate for Part A biofuels under ReFuelEU Aviation could provide further assurance that their deployment is necessary in aviation.
- **Part B biofuels**: RED 2 supports such fuels with a multiplier of 2. However, their contribution to the renewable energy target is capped at 1.7% of the energy content of transport fuels supplied for consumption or use on the market. ReFuelEU Aviation support the use of such fuels, but they are not subject to any specific incentive. Their role is expected to be limited from 2025 to 2050. As such fuels are currently used almost exclusively in the road transport sector, it is not excluded that there would be a shift of Part B biofuels from road to aviation. However, this potential shift would be of small magnitude, as explained under section 6.1.2.
- **RFNBOs**: these fuels are supported under RED 2. However, work is ongoing through the preparation of a Delegated Act to further define the conditions of their eligibility, notably when it comes to technical aspects on the accounting of the renewable electricity used for their production. ReFuelEU Aviation supports such fuels with a specific sub-mandate under POs A1, B1, C1, and a multiplier under POs A2 and C2 and will apply the same conditions as set out under RED II and the relevant delegated acts. Specific incentives are necessary to bring them to the market earlier than expected in the absence of regulatory action (emergence by 2050 in the baseline scenario).

EU Emissions Trading System

The EU ETS contains provisions aiming to encourage SAF uptake by airlines, i.e. the "zero emissions-rating" of aviation biofuels. As explained under section 2.2, the mix of incentives to increase the uptake of SAF, among which the EU ETS, has not successfully led to an increase in the use of SAF, the main reason being that the price of greenhouse gas emission allowances has remained significantly lower than what would have been necessary to make up for the additional the price of SAF. The EU ETS is under revision and the Commission is due to adopt legislative proposals by June 2021 to revise it. The revision of the general EU ETS Directive is likely to include and increase the linear emission reduction factor, in line with the adoption of the climate target for 2030, which is updated to reductions of 55% in comparison to 1990 levels. Additionally, the proposal for a revision of the EU ETS for Aviation, also due for June 2021, is likely to include a reduction in the share of allowances distributed for free and measures to implement additional elements of CORSIA in Union law.

Even if the EU ETS is unable to by itself trigger the uptake of SAF, it can still contribute to lowering the costs of the options under consideration in this impact assessment. The "zero emissions-rating" of aviation biofuels can help airlines recuperate part of the additional cost. A second way is through the ETS allowance purchases that airlines have done over the years[248] which to a large extent have helped funding the conversion from generation of fossil fuel-based power to renewable electricity thus both increasing the availability of renewable electricity for the production of electro-fuels and reducing its cost. A third potential way is through the ETS Innovation Fund that could help finance innovative and less costly SAF pathways. In this regard, the EU ETS (and likely also its upcoming revision) can be considered complementary to all the options under consideration.

This measure has the potential to help reducing the price gap between SAF and conventional jet fuel as SAF are considered CO2 emission free under the EU ETS, thus providing an economic benefit for airlines, which are covered by EU ETS (currently only in respect of their intra-EEA flights). The EU ETS could serve to create the necessary medium- to long-term carbon price signal with the aim to drive further decarbonisation. Strengthening the EU ETS is likely to include a decrease of quantities of free allocation to the aviation sector as well as steepening the linear reduction factor that defines the annual reduction of the cap beyond the current factor of 2.2%. This measure is currently being considered under the revision of the EU ETS. However, it is not a SAF specific measure and is unlikely to provide by itself the economic incentive for airlines to purchase SAF. In the context of the increase of ambition for emissions reductions for 2030, the price of ETS allowances is expected to grow, further pushing operators to find ways to reduce emissions.

As made clear above, the EU ETS on its own is not sufficient to drive SAF to the aviation market. The global market-based measure CORSIA will generate offsetting requirements from 2025, and it is not clear that it will constitute a meaningful driver for the uptake of SAF. The price of eligible offset units is likely to remain lower than that of ETS allowances. Therefore, similarly as for the EU ETS, it is not expected to be sufficient, by itself, to drive SAF to the aviation market.

Revision of the Fuels Quality Directive

The Fuels Quality Directive (FQD) is a regulatory framework setting quality standards for fuels (including biofuels) used in the road transport sector and in non-road mobile machinery. Aviation is not included in the scope of the FQD. The Commission services are currently working jointly on the revision of Article 7 of the FQD, which revised provisions will be included in the revision of the RED II framework, due for a legislative proposal by June 2021.

Alternative Fuels Infrastructure Directive (AFID)

This AFID creates a common framework of measures for the deployment of alternative fuels infrastructure in the EU. Building-up such infrastructure is meant to reduce oil dependence and mitigate environmental impacts specifically of road and waterborne transport. It should support a single market for alternative fuels

[248] Reaching over 100 million allowances (i.e. tonnes of CO2 reductions) over the period 2013 to 2017 (https://ec.europa.eu/transport/sites/transport/files/2019-aviation-environmental-report.pdf) and 32,5 million allowances in 2019 (https://ec.europa.eu/clima/news/emissions-trading-greenhouse-gas-emissions-reduced-87-2019_en).

infrastructure along urban areas and nodes and the core network of the Trans-European Transport Network (TEN-T). The revision of AFID will seek to ensure the availability and usability of a dense, wide-spread network of alternative fuel infrastructure throughout the EU. All users of alternatively-fuelled vehicle/vessel/aircraft shall circulate at ease across the EU, enabled by key infrastructure such as motorways, ports and airports. It should be noted however, that the AFID places a strong focus on the deployment of infrastructure for the road and maritime sectors. For aviation, the Directive may continue to explore the need to install electricity supply at airports e.g. for stationary aircraft. As explained in the present impact assessment, SAF are fully fungible with conventional jet fuel and do not require any specific refuelling stations/infrastructure in addition to what currently exists for conventional jet fuel. It is therefore not expected that the revision of AFID should play a role in facilitating SAF deployment in the EU.

Carbon Border Adjustment Mechanism

In the absence of binding global targets on the use of SAF in international aviation, an additional option to avoid an uneven playing field for European jet fuel producers from fuel tankering, and to prevent the associated carbon leakage, could be the application of a Carbon Border Adjustment Mechanism (CBAM). As set out in the European Green Deal: "should differences in levels of ambition worldwide persist, as the EU increases its climate ambition, the Commission will propose a carbon border adjustment mechanism, for selected sectors, to reduce the risk of carbon leakage". A proposal on such a mechanism is envisaged for June 2021. An ongoing study is assisting the Commission in identifying the most appropriate sectors. Initially, the risk of additional tankering is expected to be limited, as explained in section 6.2.8. The risk of fuel tankering is very low in POs C1 and C2, as it is mitigated by the anti-tankering safeguard.

Revision of the Energy Taxation Directive

The Commission is due to adopt a proposal on the revision of the Energy Taxation Directive (ETD) by June 2021. The inception impact assessment[249] for this revision recognises the problem that the use of a number of new energy products, such as advanced alternative fuels in transport, is currently discouraged since they can be taxed in the same way as the conventional fuels. The revision also recognise the problems related to the non-taxation of the aviation sector. The ETD revision will aim - among others, to help reach the EU's climate policy objectives. The impact assessment is supported by a study on the taxation of the air transport sector, which has not been finalised at the time of the submission of this impact assessment. The study considers policy options for introducing intra-EU harmonised fuel tax and/or a harmonised ticket tax, with a possibility to exempt or apply reduced tax rates for SAF in a context where the products will be taxed on the basis of energy efficiency and climate considerations. Currently under the ETD, the minimum excise duty rate for kerosene as a motor fuels is €0,33/litre. It can be assumed that properly differentiated tax rates could help to some extent make SAF more economically interesting to airlines compared to fossil jet fuel and lead to greater uptake of SAF.

Reform of the Single European Sky

The Commission proposal for a revised Single European Sky regulatory framework contains an obligation for air navigation service providers to modulate their charges to improve the environmental performance of aviation. In particular, this could be done based on the use of SAF by airlines. This could be useful to further help bridging the price gap between SAF and conventional jet fuel. This measure is being discussed as part of the ongoing legislative process.

[249] Source: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12227-Revision-of-the-Energy-Tax-Directive-

Annex 11 – Features of the legal instrument to implement ReFuelEU Aviation

The preferred policy options (C1 and C2) consist on the one hand of obligations on airlines to uptake jet fuel, report jet fuel uptake and SAF uptake; and on the other hand on an obligation on aviation fuels suppliers to supply SAF-blended jet fuel to airlines at EU airports. This section discusses the important aspects to take into consideration to decide on the best suited legal instrument to implement the preferred policy options. It explains the reasons why ReFuelEU Aviation would more successfully achieve the policy objectives if implemented through a standalone Regulation, rather than through an economy-wide, cross-sectors framework (e.g. the Renewable Energy Directive (RED).

The aviation market is one of the most integrated internal markets in the Union, where the European dimension has become essential for business to thrive, and citizens to connect and enjoy the advantages of the Union. However, regarding its potential to consume renewable energy, its size is small if compared with land transport, construction or agriculture. Besides, the range of renewable energy sources available for aviation are today much narrower than for those other bigger economic sectors, and those existing request a second layer of refinement or technological process than the same kind of renewable energy used for instance in land transport. These traits turn aviation market into a "niche" market which does not respond well to mandates or incentives through horizontal approaches. When confronted with horizontal targets, producers naturally focus on those allowing them the bigger economies of scales and the most reduced costs, making aviation a less interesting sector for them. When confronted with a target Member states as well incentivise measures on those sectors where the target can be easier achieved and where the impact is bigger. Since aviation is a very small market both in terms of capacity to absorb renewable energy and in share of carbon emissions, it is by nature ignored or relegated to the last mile while a horizontal target is at stake. This is part of the reason why previous horizontal targets (e.g. under RED I and RED II) have failed until now to incentivise the use of SAF in aviation.

The present initiative must be rolled out swiftly and efficiently, as a key deliverable of the European Green Deal and the Sustainable and Smart Mobility Strategy, and as a necessary building block towards reaching EU's climate goals by 2030 and 2050 by ensuring that the aviation sectors speed up its own decarbonisation without jeopardising the well-demonstrated benefits of a highly integrated aviation internal market. As explained in section 1.4 and Annex 11, this can be achieved most successfully by directly regulating economic actors at EU level through a Regulation. Indeed, common rules applying directly and uniformly to aviation and fuel market actors across the EU will provide clarity and uniformity. As the aviation single market is inherently integrated at EU level, it functions best when rules are applied to all airlines in the same way. Imposing the same requirements to all market players reduces the risks of distortion of competition and sends clear signals to non-EU aviation market actors, when flying in the EU. A uniform set of rules across the EU, as established under a Regulation, will allow to send loud and clear signals to the market. As the transition to SAF requires significant investments (see section 6.2.5), it is indispensable that the regulatory framework provides a single, long-term and robust set of rules to all investors EU-wide. In particular, it is crucial to avoid the creation of a patchwork of differing measures at national level, as would be the case if implemented under a cross-sectoral directive such as the Renewable Energy Directive. While this can function with transport modes like road or rail, it cannot be successful for transport modes that are so cross-border and global as aviation. A patchwork of national transpositions could reduce the effectiveness of the policy and put in jeopardy the effective decarbonisation of air transport. It could also be conducive to different economic behaviours in the aviation and fuel industries from one Member State to another. This could lead to practices of cost avoidance (e.g. via fuel tankering) that would undermine the functioning of the Single Market. The present initiative will have an important impact on air transport actors and the aviation internal market as a whole. It is essential that obligations set on all airlines apply to all airlines uniformly, as can be ensured via a regulation. It is equally important for the effectiveness of this initiative that the fuel supply obligation be implemented and enforced in a uniform way. Differing fuel supply obligations in different areas of the EU (e.g. different targets, varying sustainability standards, etc.) would set differences of treatments between airlines and could induce competitive distortions between EU airports or put EU aviation actors at disadvantage with non-EU competitors. The present initiative should be implemented in a standalone regulation in order to cater for the specificities and complexities of the aviation single market. Such detailed provisions regulating the aviation market cannot be established under the Renewable Energy Directive, which scope goes only as far as energy matters are concerned.

Timing is an essential factor

The timing of this initiative is an essential factor of success. This initiative is a key deliverable of the European Green Deal and a necessary building block towards reaching EU's climate goals by 2030 and 2050. Regulatory certainty is needed imminently. Indeed, to reach the SAF objectives of around 2% by 2025, a lead-time of 3-4 years is necessary for the industry to scale up its SAF production capacity. This means that a SAF regulatory framework must be in force in Union law by 2022. This would be very difficult to achieve if implemented through a large economy-wide regulatory framework (e.g. RED). To illustrate this, the past experience of RED II shows that from adoption of the proposal by the Commission (2016), to transposition and entry into force in Member States (deadline for transposition is June 2021), the process took 5 to 6 years. Such a timeline of 5 to 6 years for the implementation of ReFuelEU Aviation would mean that a SAF framework would only enter into force at Member States level by 2026. This would jeopardise chances of effectively decarbonising aviation and contributing efficiently to the EU's climate goals, as SAF would likely not reach the market before 2029-2030 (a lead time of 3 to 4 years is necessary for investments to flow and the fuel industry to scale up, which is the absence of a robust regulatory framework is unlikely to happen). On the other hand, if adopted through a standalone regulation, the present initiative would have higher chances of being adopted swiftly. It could become applicable with immediate effect after entry into force as early as end of 2022.

Annex 12 – Measures contributing to reducing the climate impact of aviation

There is no silver bullet to decarbonise aviation. Reducing the climate impact of aviation therefore relies on a mix of various policy instruments. At the international level, the International Civil Aviation Organization (ICAO) “basket of measures” is pursued, which is based on four pillars: market-based measures, aircraft technology improvements, operational improvements and sustainable aviation fuels. At the EU level, those have been implemented through a set of policy measures. The key essential policy instruments pursued by the EU under the first three pillars are described below, while the forth pillar of the basket of measures is addressed by this initiative.

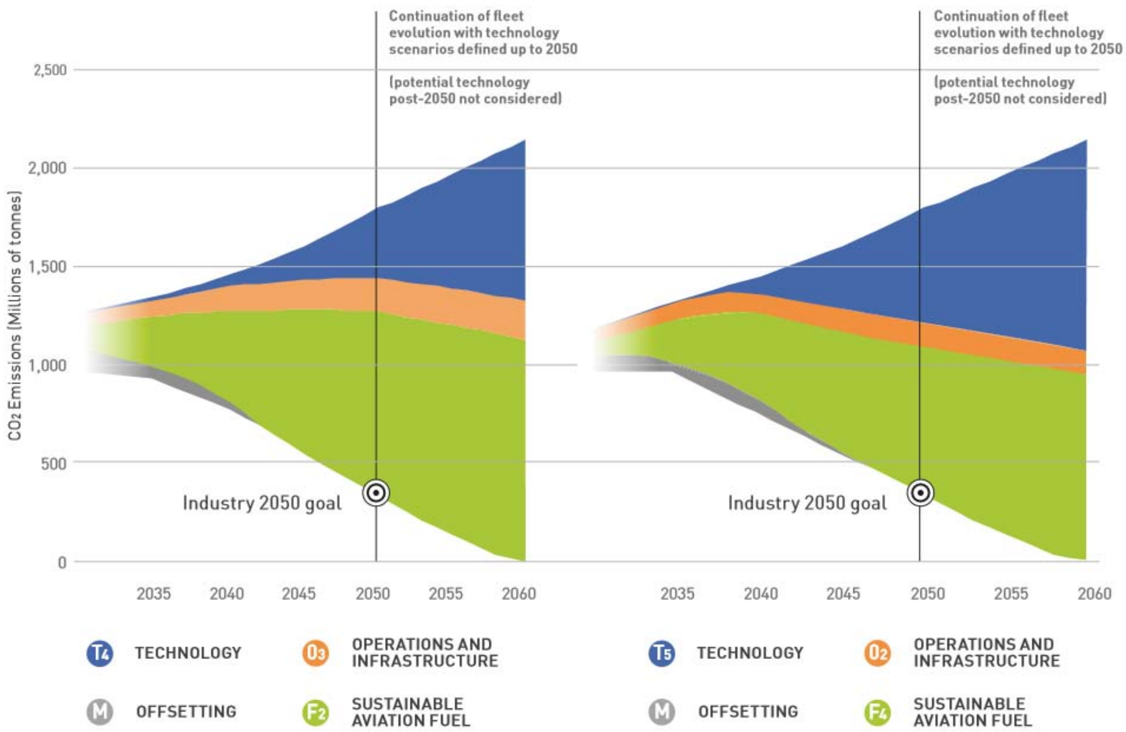
Recognising the need for long-term sustainability of aviation and the commitment to continue efforts to reduce aviation sector’s negative environmental impacts, European associations of the air transport sector collectively representing the entire European aviation called in 2020 for an EU Pact for Sustainable Aviation. Through collaboration between all stakeholders in the aviation eco-system and policy-makers, the Pact is to contribute to the implementation of the European Green Deal, by reaching the objectives of significant CO_2 emission reductions by 2030 and net-zero CO_2 emissions by 2050 from all flights within and departing from the EU. The Pact will also consider the feasibility of making 2019 the peak year for CO_2 emissions from European aviation while enabling the sector to continue delivering its social and economic benefits. In this context, the stakeholders’ report highlighted the urgent need for a comprehensive EU legislative framework to promote the uptake and deployment of SAF, as a key opportunity to accelerate the decarbonisation of aviation.[250] The important role of SAF in the decarbonisation of aviation is also recognised and assessed in the stakeholders’ decarbonisation roadmaps, such as ATAG’s Waypoint 2050[251], and European aviation stakeholders Destination 2050.

The below graph from ATAG’s Waypoint 2050 illustrates two scenarios for the future contribution of each measure to the decarbonisation of the global aviation.

[250] European Aviation Round Table Report on the Recovery of European Aviation, November 2020.
[251] Source: https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/

Plotting a path to net-zero emissions

While somewhat marginal pre-2050, the contribution from hybridisation, electrification and hydrogen becomes substantial in 2050-2060 timeframe. In addition, with emissions reduction factor from SAF reaching 100% by 2060, net zero emissions could be achieved by that date in the absence of offsets. However, offsets (in whatever form they may take in the 2040+ timeframe) could be used to bridge any gap and support a net-zero goal, either in 2050 or beyond. This was plotted using integrated scenario 1 (left) and 3 (right).



Other **key policy instruments pursued by the EU** under the **basket of measures**:

Pillar I on market-based measures, includes EU ETS and CORSIA.

Pillar II on aircraft technology improvements, includes CO_2 standards and Clean Sky Joint Undertaking. The EU adopted new standards for aircraft CO_2 emissions, which entered into force in 2019[252] and follow the global standards adopted by ICAO in 2017. They provide additional requirements into the aircraft design process to focus on fuel efficiency. In parallel, to develop the green and cutting-edge aircraft technology of the future the EU has supported the Clean Sky Joint Undertaking, with a budget of €4 billion (2014-2024) and composed of over 600 entities from 27 countries. The EU will continue this initiative with Joint Undertaking for Clean Aviation under the Horizon Europe programme. European stakeholders from aeronautics industry and research community have proposed a Strategic Research and Innovation Agenda (SRIA) for the envisaged partnership. It sets the ambition to have new disruptive technologies ready by 2030, creating the opportunities for industry to market these technologies towards 2035. The SRIA specifically identifies three main technology strands, setting the focus on disruptive solutions for hybrid-electric flying, on ultra-efficient propulsion and aircraft configurations for the short and medium range and on hydrogen-powered aviation.

Pillar III on operational improvements, includes Single European Sky and SESAR. The Single European Sky framework aims to make European skies more efficient, and can deliver important environmental benefits. The SESAR project, sponsored by the EU and the aeronautical industry, contributes to develop and deploy innovative air traffic management solutions with a potential to further reduce emissions. In 2013, the

[252] Commission Delegated Regulation (EU) 2019/897 of 12 March 2019 amending Regulation (EU) No 748/2012 as regards the inclusion of risk-based compliance verification in Annex I and the implementation of requirements for environmental protection.

Commission proposed to complete the SES through amendments that could allow to decrease emissions up to 10%.

Annex 13 – Non-CO2 emissions

When aromatics are present in fuels, they encourage non-volatile Particulate Matter (nvPM) formation during combustion. Hence, lower aromatics in fuels provide a cleaner burn and reduced nvPM emissions, which are directly linked to contrail cirrus formation that have a net positive (warming) climate forcing effect[253].

Sustainable Aviation Fuels (SAF) typically have lower aromatic concentrations and thus the overall aromatics concentration of fuels could be reduced through blending certain SAF with conventional Jet A-1 fuel, as long as the aromatics content in the fossil part of the blend does not increase and offset the benefits. In addition, the reduction in aromatics improves the energy density of the SAF, which can reduce the mass of fuel needed for a specific flight. Estimates suggest potential aircraft fuel efficiency gains of approx. 1%. Finally, SAF can also have lower sulphur content resulting in lower SO2 emissions.

A harmonised approach within the EU to promote the uptake in the use of SAF, while avoiding an increase in aromatics within traditional fossil-based kerosene, would contribute to reduce the non-CO2 climate change impacts. In this respect, engagement with the main fuel specification standardisation committees (e.g. ASTM, DEF STAN) would be useful to discuss the climate benefits of low aromatic fuels.

[253] Updated analysis of the non-CO2 climate impacts of aviation and potential policy measures pursuant to the EU Emissions Trading System Directive Article 30(4). https://ec.europa.eu/clima/news/updated-analysis-non-co2-effects-aviation_en

Annex 14 – ASTM Certification process

ASTM D7566, the specification controlling alternative fuel blends, has evolved to meet the challenge of introducing new raw materials, processing and blends[254] that are wholly compatible with distribution and aircraft hardware. Each Annex in ASTM D7566 is linked to a specific raw material, process and eventual feedstock. This division and specificity is to mitigate the risks of new products causing problems. Once produced and blended in compliance with ASTM D7566 the fuel is then designated as ASTM D1655 Jet A or Jet A-1 and handled as per conventional fuel. This is on the basis that these new blends have been shown to be technically equivalent to conventional fuels. Note also that jet distribution systems and aircraft hardware only allow Jet A/A-1 as approved.

ASTM D4054[255] defines the process by which a new feedstock, defined by raw material, transformation process and finishing requirements, must be evaluated before approval and inclusion within ASTM D7566 as a new Annex. Extensive testing on the feedstock and final blends is required to ensure the fuel is fit for purpose and performs within expected norms. Once approved, the new feedstock is codified within ASTM D7566 and the specification up-issued to incorporate the new material.

In summary D4054 is a tiered process that requires testing with increasing complexity, scale and therefore cost:

- Tier 1 - Basic standard specification testing.
- Tier 2 - Fit for Purpose testing which includes mainly laboratory scale testing of a wider range of properties, compositional analysis (bulk and trace), material compatibility and performance properties, etc.
- Tier 3 – Rig scale testing to assess behaviour under simulated airframe and/or engine conditions to cover such parameters as thermal stability, cold flow, combustion under adverse conditions (operability), etc.
- Tier 4 – full engine testing to assess impact on performance, durability, emissions, etc.

The ASTM D4054 has to be run with key industry stakeholder engagement as an integral part of the process. It has to be noted, that not all the tests are mandatory but is rather a list of tests that should be considered within a rational test programme design. Thus, testing requirements may be reduced for products similar to those already approved, or occasionally, more extended and/or bespoke testing may be required for products that are outside experience.

In any case, a key barrier to new entrants is the requirement to make significant (industry scale) volumes of fuel either for testing per se but also to demonstrate the production process at scale and show that it has a high enough technology readiness level.

ASTM introduced the so-called "Fast Track" process aims to reduce some of this burden. This rationalised process comprises a set of very stringent controls on any new blendstock which is to be submitted to Fast Track evaluation and approval. If the product meets these requirements (in summary: declaration of raw materials and processing, bulk properties, bulk hydrocarbon composition and purity, and down selected fit-for-purpose tests) then approval by the usual ASTM D4054 route is allowed but only Tier 1+ testing is required.

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254 ASTM D7566-19, Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons, ASTM International, West Conshohocken, PA, 2019, www.astm.org.

255 ASTM D4054-19, Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives, ASTM International, West Conshohocken, PA, 2019, www.astm.org.

Annex 15 – SAF Production Routes

Hydroprocessed Esters and Fatty Acids (HEFA)

This route was certified by ASTM as HEFA-SPK. HEFA-SPK is the only SAF currently used commercially (TRL 9, depending on sources) due to its simplicity and its low-cost production. The blend with kerosene is limited to 50%, which is the highest blend allowed under RED II.

Alcohols to Jet (AtJ)

This route, currently at TRL 7-8, is certified by ASTM as ATJ-SPK and consists of converting alcohol into jet fuel. The alcohol is the product resulting from the fermentation of sugar or starch crops (corn, sugarcane, wheat). Alternatively, the alcohol can also result from processed lignocellulosic feedstock (agricultural and forest residues). Regardless of the feedstock used, hydrogen is required in the process. The certification currently limits the blend of alcohol in jet fuels to 50%.

Biomass Gasification + Fischer-Tropsch (Gas+FT) (Part A biofuels)

This route was certified by the ASTM as FT-SPK and currently stands at TRL 6-8. Biogas, is obtained from the gasification of the feedstock followed by Fischer-Tropsch synthesis (E4tech, 2019). Blending is limited to 50%. Common feedstocks include energy crops (for example, miscanthus, willow, poplar), lignocellulosic biomass and solid waste. When energy crops are used as feedstock, CO2 emissions savings can reach up to 85-90%, and can reach even higher levels (95%) when forestry residues are used (Bosch, et al., 2017).

Summary

Table 24 presents a summary of the different advanced bio-fuels' main characteristics. Table 42 presents a summary of the different advanced bio-fuels' main characteristics.

Table 24: Summary of certified advanced biofuels and their technological maturity

Route	Feedstocks	Certification	TRL	CO2 emissions savings	Production capacity (kilotonne/year)
Hydroprocessed Esters and Fatty Acids (HEFA)	Vegetable and animal lipids	HEFA-SPK, up to 50% blend	9	20-69%[257]	Operational: 5,000 per year[258]
Alcohols to Jet (AtJ)	Sugar, starch crops, lignocellulosic biomass	ATJ-SPK, up to 50% blend	7-8	37-70%[259]	Operational: 30 In commissioning: 20 Planned: 324
Biomass Gasification + Fischer-Tropsch (Gas+FT)	Energy crops, lignocellulosic biomass, solid waste	FT-SPK, up to 50%	6-8	85-95%[260]	Under construction: 40 Planned: 215

RFNBOs (synthetic fuels)

Synthetic fuel are sustainable aviation fuels based on non-biologic origin, where the source of energy is not based on crops, or residues or waste, but obtained from renewable electricity. The development and

256 Data available as of June 2019.
257 Varies based on feedstock: soy (20-54%), jatropha (37%), camelina (46%) and used cooking oil (69%)
258 This is the global production of HEFA, of which only 100 kilotonne was produced for the aviation sector. This amount also includes the HEFA produced through the co-processing route.
259 Varies based on feedstock: corn (37%), corn stover (60%), sugarcane (70%).
260 Varies based on feedstock: energy crops (80-90%) and forestry residues (up to 95%).

commissioning of the first production plants for synthetic fuels on a relevant industrial scale seems to be feasible on a technical basis in 6 to 10 years from today (Ausfelder & Dura, 2019).

The below table presents a summary of the different production pathways with critical technical processes which have not reached commercial availability. Possible CO2 emission savings are not included in the table as they are mainly influenced by the characteristics of the electricity used for fuel production. A critical element for all electrofuel processes is the availability of sustainable CO2 as a Direct air capture (DAC) technology is at TRL 3-6 and energy consuming compared to more concentrated CO2 sources. CO2 emissions from fossil point sources will have to decrease over time to meet EU's CO2 mitigation targets and the technical maturity of capturing CO2 from combustion and industrial processes is at TRL 5-9 (depends on the process).

Table 25: Summary of electrofuel production pathways and their critical processes

Route	Certification	Critical technical processes
FT route (LT electrolysis)	FT-SPK, up to 50%	Reverse water gas shift reaction (TRL 5-6)
FT route (HT electrolysis)	FT-SPK, up to 50%	Solid oxide electrolysis (TRL 4-7) Reverse water gas shift reaction (TRL 5-6) or Co-Electrolysis (TRL <5)
Methanol route (two-step methanol synthesis / LT electrolysis	Not certified	Reverse water gas shift reaction (TRL 5-6) Final conversion to jet fuel (TRL 7-8)
Methanol route (two-step methanol synthesis / HT electrolysis	Not certified	Reverse water gas shift reaction (TRL 5-6) Final conversion to jet fuel (TRL 7-8) Solid oxide electrolysis (TRL 4-7) or Co-Electrolysis (TRL <5) Final conversion to jet fuel (TRL 7-8)
Methanol route (one-step methanol synthesis / LT electrolysis	Not certified	Methanol synthesis (TRL 6-7) Final conversion to jet fuel (TRL 7-8)
Methanol route (one-step methanol synthesis / HT electrolysis	Not certified	Methanol synthesis (TRL 6-7) Final conversion to jet fuel (TRL 7-8) Solid oxide electrolysis (TRL 4-7)

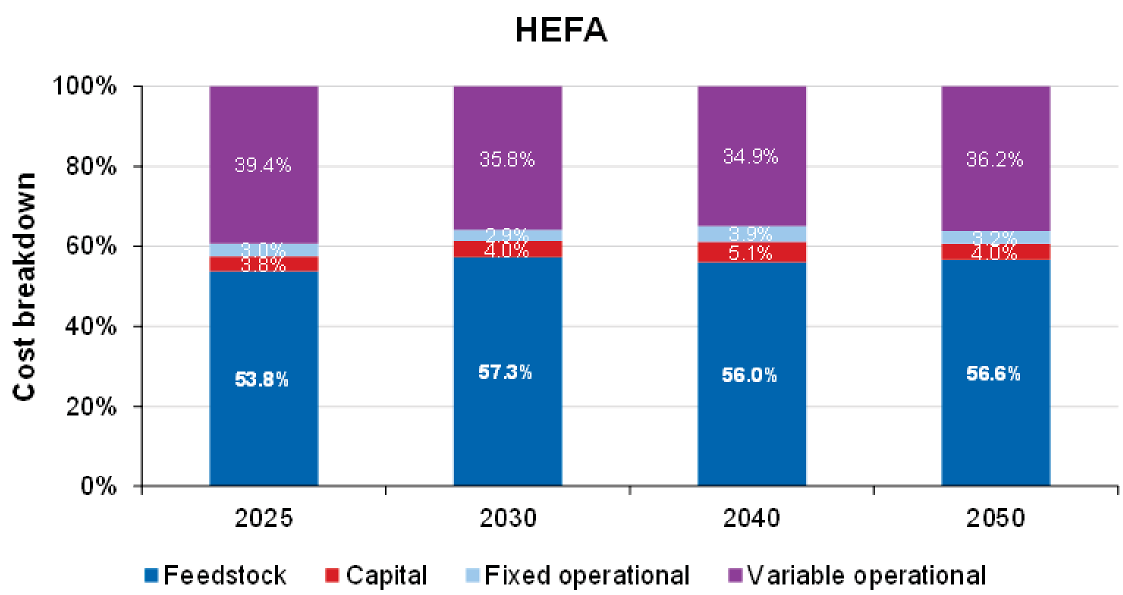
Annex 16 – SAF production costs and economies of scale

Evolution of SAF production costs

This section presents the expected development of the cost-structure of biofuel production per pathway and over time. The cost components are aggregated in main categories, which include capital costs, feedstock costs, fixed operational and variable costs (e.g. costs of energy, enzymes, catalysts, waste management). The costs presented here exclude the profit margin that was used to form the price of SAF. The cost-structure is presented per pathway from the first year of the technology implementation (i.e. 2025 for HEFA and ATJ, and 2035 for Gasification and FT) and the subsequent 10-year periods leading to 2050. The cost-structure is based on PRIMES Biomass.

The cost-structure of the HEFA route remains relatively unchanged over the time horizon, with the cost of HEFA jet showing small increase mainly driven by feedstock costs. The development of capital costs is in line with literature that expects minimal developments in capital cost component of the technology (ICCT 2019). Higher feedstock costs over time are a direct result of higher demand of jet fuel and the use of UCO. Feedstock costs and variable costs account for more than 90% of the HEFA production costs.

Figure 14 Cost-structure of biofuel production from the HEFA route in all POs except PO B2.



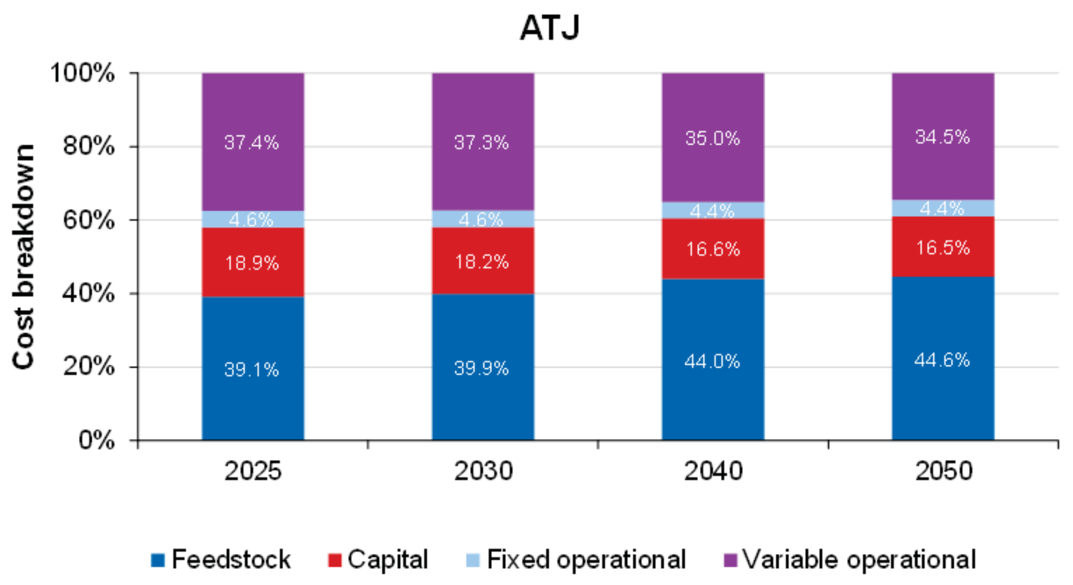
Source: PRIMES Biomass

Two drivers shape the slightly increasing trajectory of biokerosene production costs from the ATJ route and the Gas+FT route. The first driver is the decrease of non-feedstock components, such as capital costs, fixed operational costs and variable costs as a result of economies of scale, learning and technology utilisation. This becomes evident when comparing the capital and variable costs of the two routes, from the year they emerge with those of subsequent periods. Capital unit costs of the Gasification and FT route decrease by 30% between 2035 and 2040, and those of the ATJ route by 10% between 2025 and 2040. In both routes, variable costs decrease by about 2-3% in the same period.

A counterbalancing driver is the increase in production costs driven by feedstock costs. In early years, when the demand for bioenergy is lower, inexpensive feedstock (e.g. agricultural residues) are used by the two SAF production pathways. However, as bioenergy demand increases, competition for inexpensive feedstock rises from the energy sector and other transport sectors. As the modelling exercise is in the context of the 2030

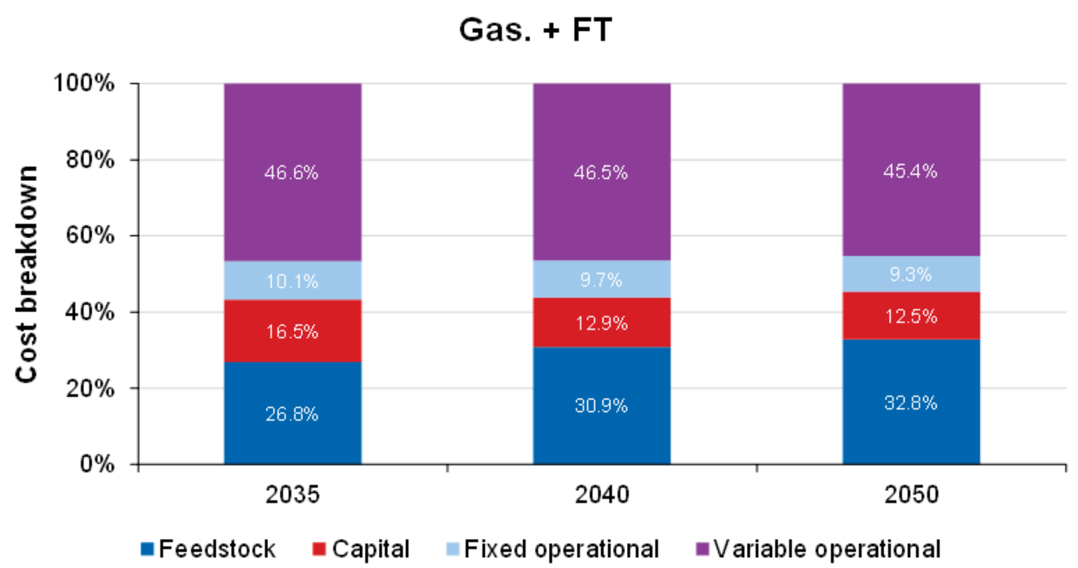
Climate Target Plan ambition for carbon neutrality, it also considers the effort from other sectors to decarbonise. As such, the lowest-cost feedstock are quickly depleted and the need for more expensive feedstock emerges, increasing the cost of feedstock used for SAF. This is reflected by the increasing share of feedstock in the cost structure of bioenergy in the years leading to 2050.

Figure 15 Cost-structure of SAF production from the ATJ route in all POs except PO B2.



Source: PRIMES Biomass

Figure 16 Cost-structure of SAF production from the Gas+FT route in all POs except PO B2.



Source: PRIMES Biomass

<u>Differences in production costs between Part B biofuels and Part A (advanced) biofuels</u>

Annex IX Part B biofuels are produced through the HEFA production route that uses waste lipids as feedstock, such as used cooking oil. This is a mature technology/pathway with production capacity estimated at 2.3 million tonnes per year. This production route is very similar to the one used to produced HVO (biofuels for the road sector) and therefore has benefited from cost reductions due to the surge of demand for HVO biodiesel in

the past decade. However, there is currently no production through this pathway going to aviation as a result of economic choices made by fuel producers, for the reasons detailed in sections 2.2.2 and 2.2.3. On the other hand, the production technologies of advanced biofuels (also referred to as Annex IX Part A biofuels) from the ATJ and/or Gas+FT routes face industrial challenges and are not yet available at commercial scale, and require investments in first-of-a-kind plants and their scale-up to benefit from economies of scale, learning effects and resulting lower costs.
As shown in Table 24 below, current cost estimates available in literature for Part B and Part A biofuels provide ranges which reflect larger uncertainty on the production costs of advanced biofuels. Cost estimates provide more certainty for Part B biofuels. Table 24 below and Figure 11 above show the cost difference between the two categories of biofuels.

Table 26 - Current SAF price ranges from literature and industry consultation.

Production route	*Fossil jet fuel*	*HEFA*	*Gas+FT*	*ATJ*	*RFNBOs*
Estimated production cost[261] in 2020 (k€/tonne)	0.6	0.95-1.14	1.7-2.5	1.9-3.9	1.8-3.5

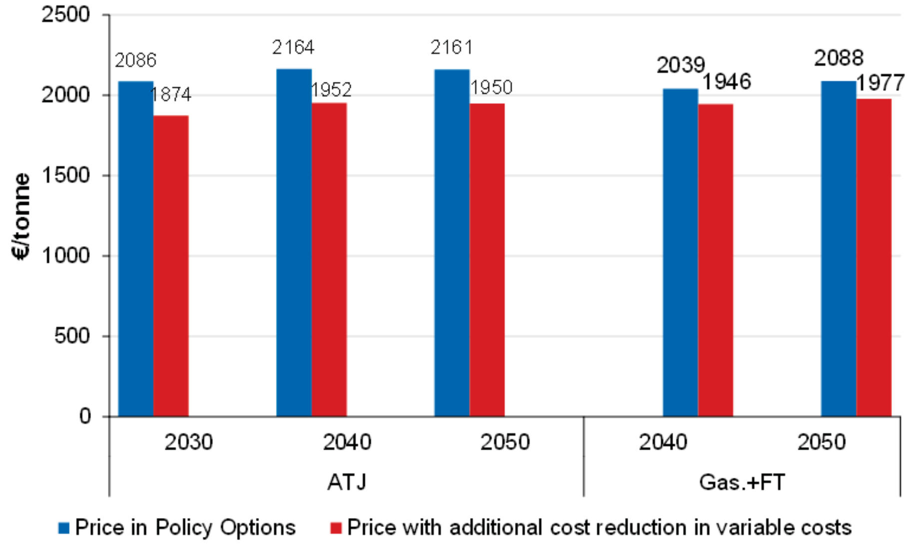
Besides capital costs, looking into other cost components provides additional insights in understanding the differences between Part B and advanced biofuels. First, the use of expensive enzymes or catalysts increases the variable costs of advanced biofuels production relative to that of Part B biofuels. Indeed, in absolute terms, the variable costs of Part B biofuels production is significantly lower than that of advanced biofuels. Second, advanced biofuels require higher amounts of biomass feedstock input compared to Part B biofuels that are produced from waste lipids, which leads to overall higher feedstock costs of advanced biofuels compared to Part B biofuels.

Sensitivity analysis on variable costs for advanced biofuels production

As highlighted in the above section, the contribution of variable costs in the production cost of Part B biofuels such as those of energy, catalysts, enzymes, other utilities and waste management is between 35% and 47% depending on the year and the technology[262]. Additional reductions of variable costs may be achieved due to faster technology developments or higher economies of scale. To assess the sensitivity of advanced biofuels prices to economies of scale and faster technological development, we use the cost reduction trajectory as per the work[263] performed by McKinsey on SAF variable costs. Following this approach, by 2050, variable costs decrease by 30% for the ATJ route and by 14% for the Gas+FT route, relative to 2020. Based on these trajectories, the effect on advanced biofuels prices are estimated as shown in **Error! Not a valid bookmark self-reference.** below. Price for advanced biofuels are lower by about 10% for ATJ and by about 5% for Gas+FT, bringing the price of advanced biofuels under the 2,000 €/tonne mark over time. It should be noted that the variable cost reduction assumed in the work performed by McKinsey occurs primarily early in the time horizon (by around 2030), and thereafter a slower improvement rate is shown. This is similar with the findings of the present analysis that shows a drop of current theoretical costs by 2030, and a rather constant price trajectory thereafter.

261 Based on rough estimates sources from Clean Skies for Tomorrow: SAF feasibility and sustainability – McKinsey study – September 2020. Values have been converted from USD/tonne to EUR/tonne at an exchange rate of 1USD for 0.85EUR.
262 Such contribution levels are in line with literature (Baker et al., 2017; de Jong 2015, IRENA 2016, WEF2020)
263 Clean Skies for Tomorrow: SAF feasibility and sustainability – McKinsey study – September 2020.

Figure 17 Sensitivity of biokerosene price on variable costs

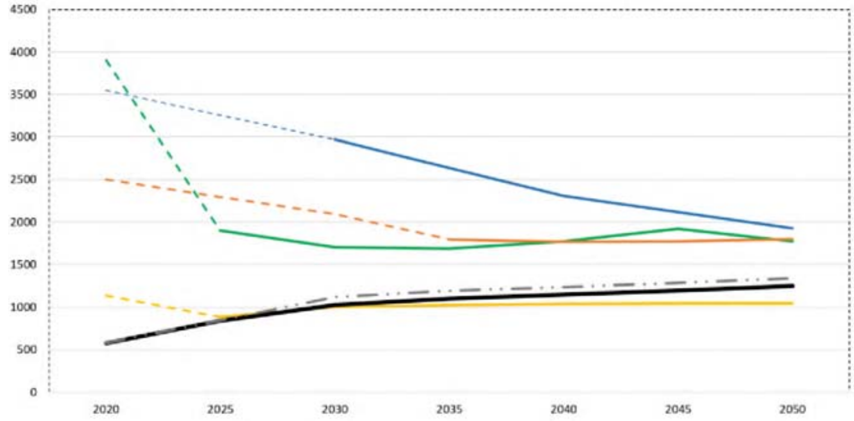


Note: Own calculations based on input from PRIMES-Biomass and literature review

Explanation of economies of scale

The analysis assumes that advanced biofuel producers implement measures with a view to improve their production process, which results in scale-up production at lower cost. This is especially relevant for advanced biofuel production routes (ATJ and Gas+FT routes) that are not deployed at commercial scale. The uptake of SAF already contributes to the reduction of scalable cost components such as capital and variable costs. Such cost reductions are expected to take place in particular in the short term, i.e. between 2020 and 2025-2030. This is the case because SAF production costs evolve from the current state of the market where SAF production is in its infancy and SAF production capacity is extremely limited. At the moment, SAF production consists essentially of demonstration projects where SAF outputs are negligible, hence production costs and resulting prices are very high. A regulatory intervention such as a SAF blending mandate, forcing one side of the market to supply SAF provides the necessary long-term certainty for investments to take place to develop new SAF production capacity. This translates directly into conversion of demonstration plants into full-size commercial plants and thereby helps achieving economies of scale, bringing SAF prices down. This can be seen on figure 11 below. The modelling shows a reduction of 9% and 5% for the capital and variable costs, respectively, between 2025 and 2035 for the ATJ route. Capital and variable costs for the Gas+FT route decrease by 30% and 5%, respectively, between 2035 and 2040.

Figure 18 - Production cost development for SAF production pathways – Sensitivity with ETS and low production costs (in € per tonne of fuel). Note: black: fossil, grey: fossil with ETS, yellow: HEFA, green: ATJ, red: Gas+FT, blue: RFNBOs.



On the other hand, this effect is counterbalanced by an increase of feedstock costs driven by the demand for biofuels, primarily by the demand of biomass feedstock from other sectors. It is highlighted that the modelling of the bioenergy routes has been established within the 2030 Climate Target Plan ambition context, which means that significant quantities of bioenergy are needed by other transport sectors (including international maritime) and energy sectors. Hence, the biomass system is pushed towards more expensive feedstock, outweighing to some extent the benefits from the scaling of production. Similarly to advanced biofuel routes, the demand for synthetic kerosene drives an increase in hydrogen demand and eventually leads to large-scale deployment of hydrogen generation technologies. The modelling considers learning-by-doing effects, reducing the costs of electrolysers, which is a critical cost component.