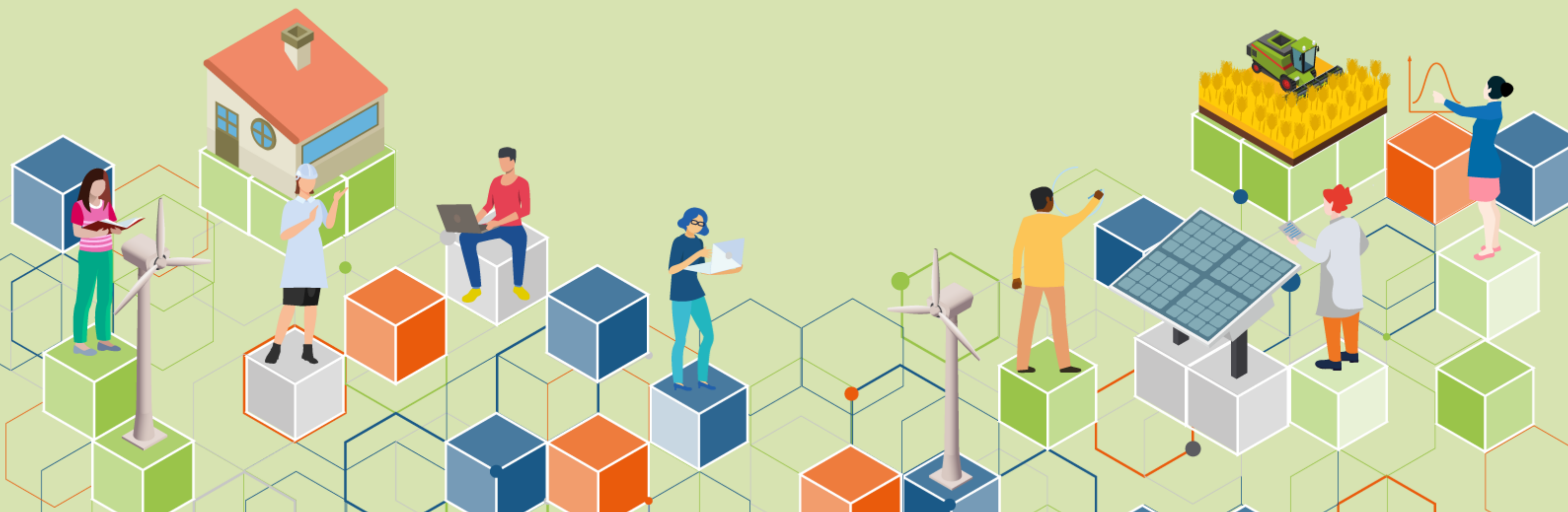
SUPEERA

Support to the coordination of national research and innovation programmes in areas of activity of the European Energy Research Alliance

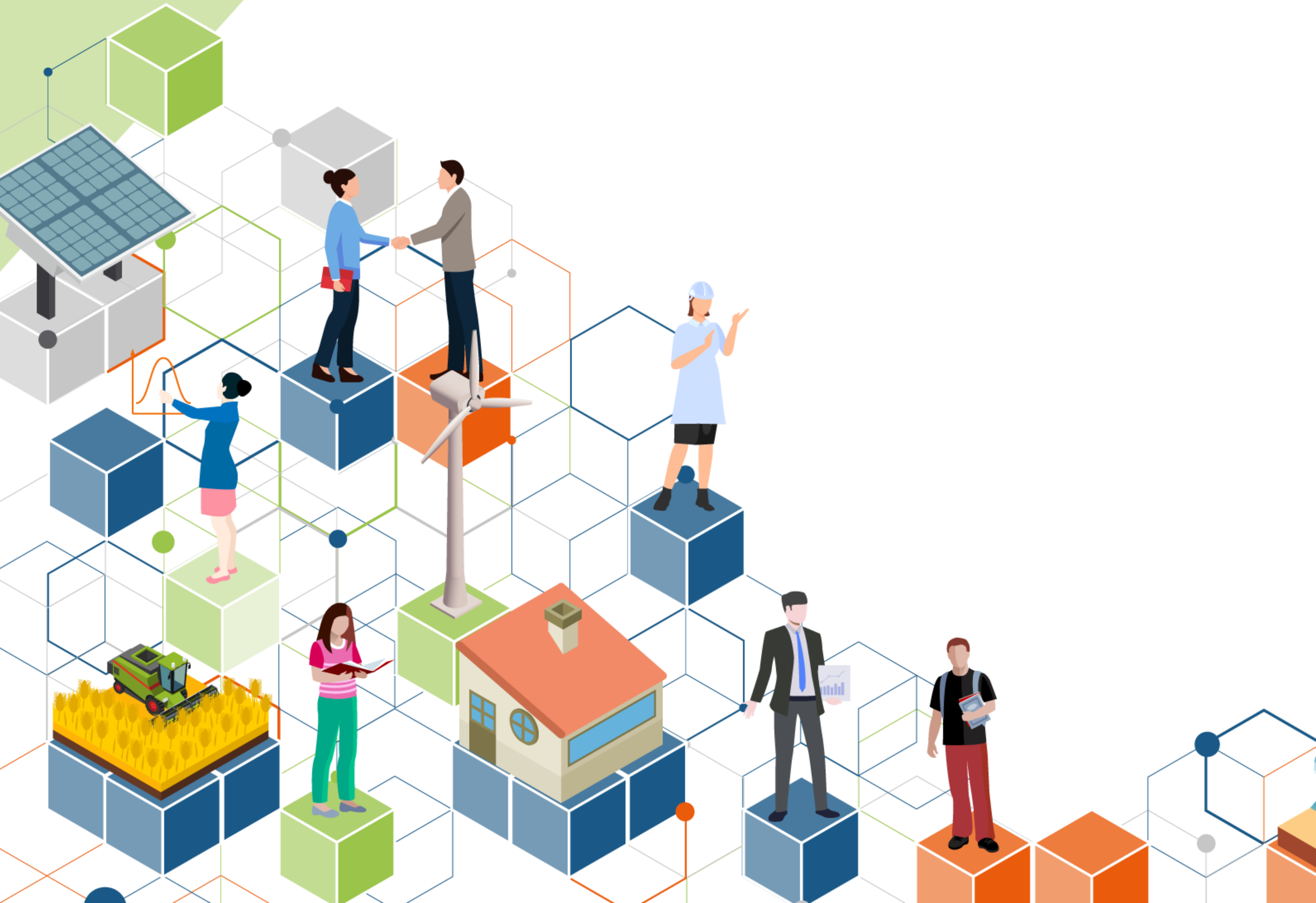
SUPEERA

Policy Brief



ReFuelEU

CHALLENGES AND
OPPORTUNITIES AHEAD



Setting the scene

The year 2022 represented a watershed moment for the EU energy system. After a long period of high-volume trade with Russia, led by the conviction that commercial relations could ease the diplomatic ones, the invasion of Ukraine by the former has turned the tide on energy markets in the EU.

The events have created the conditions for strong action on the EU side, marked first and foremost by the launching of one of the most ambitious policy packages to date, the REPower EU Plan. According to it, the EU should cut all ties with Russian-based fossil fuels by 2030, freeing Europe from burdening dependencies and boosting its renewable energy capacity at home.

In this context, the research community is called to be an integral part of the transformation of the EU energy system. EU policymaking will need to boost research efforts now more than ever, as the ambitious goals set in the REPowerEU Plan and in the legislations surrounding it will be vain if not accompanied by targeted efforts in investigating new solutions. The research community remains, therefore, a core piece of the EU policymaking puzzle, although sometimes not recognised as such. Its enormous contribution in aligning political priorities with empirical findings plays a crucial part in the creation of realistic and ambitious policies alike, opening the door to a greener future for the energy system.

The focus on low Technology Readiness Level (TRLs) is needed now more than ever, even though it might sound counterintuitive when the EU targets are set for a short timeframe such as 2030. But, as the International Energy Agency (IEA) has underlined, many of the technologies that will enable the clean energy transition have not been developed yet. The triple helix of research, industry and policy needs to come together quickly, if we are to safely bring the EU towards a bright and developed future.

In the context of the SUPEERA project, a series of policy briefs are currently being developed to identify concrete R&I challenges in EU policies relevant to the energy research community. The final goal is to support the achievement of the Clean Energy Transition (CET). This Policy Brief will focus on the EC's Proposal for a Regulation on ensuring a level playing field for sustainable air transport (ReFuelEU), proposed in 2021 to regulate the sustainability and competitiveness of the European aviation system. Shortly after the completion of the analysis, a provisional agreement on the text was found by the European Council and European Parliament on 25 April 2023, now awaiting formal approval by the two co-legislators.

The Proposal for a Regulation on ensuring a level playing field for sustainable air transport

The Proposal for a Regulation on ensuring a level playing field for sustainable air transport, part of the legislative package known as “Fit for 55”, sets out the target to reach a competitive and fair aviation fuels market, introducing mandatory requirements for the use of sustainable aviation fuels (SAFs). According to the proposal, “*the aviation sector needs to reduce its current exclusive reliance on fossil jet fuel and accelerate its transition to innovative and sustainable types of fuels and technologies*”. In the coming years, market readiness, production and operability of sustainable aviation fuels will need be ramped up to support the EU air transport sector.

The table below summarises the main R&I challenges related to the proposal:

Identified R&I challenges
1. Develop innovative feedstock production technologies for biomass included in Annex IX Part A
2. Develop methods for feedstock traceability all the way to feedstock origin
3. Demonstrate and commercialize e-SAF and SAF produced from Annex IX Part A (lignocellulosic and marine feedstock), particularly on reducing production costs and increasing efficiencies
4. Explore the policy needs for a possible shift of the feedstock use for production of biofuels from the road to the aviation sector
5. Explore the policy needs to support the production of both SAF and e-SAF

ReFuelEU, the accelerator for production and use of sustainable aviation fuel

There is no doubt that aviation will keep on growing rapidly in the coming decades[1] as a strong driver to connect citizens, businesses and regions, despite the two-year difficult period the sector had to face during the COVID-19 pandemic, with severe travel restrictions and dramatic economic consequences. Although aviation only contributes to 2.1% of the global carbon emissions and 12% of the CO_2 emissions from the transport sector[2], it is one of the most hard-to-abate sectors, which means that its share of emissions is expected to increase. A recent publication[3] (September 2022) by the International Energy Agency indicates that aviation emissions reached ~720 Mt in 2021, regaining about one-third of the emissions reduction reported in the previous year, and it is expected that emissions will surpass pre-pandemic levels fairly soon.

While waiting for advances in long-term net-zero solutions such as electricity or hydrogen-powered aircrafts, which still require significant time and effort for commercialization, **sustainable aviation liquid fuels will be key in reducing the air transport carbon footprint in the short to mid-term**. Sustainable aviation fuel, when certified and mixed up to the blending limits of the American Society for Testing and Materials (ASTM) certification, is a drop-in fuel, i.e. it

[1] https://www.icao.int/Meetings/FutureOfAviation/Pages/default.aspx

[2] https://www.atag.org/facts-figures/

[3] https://www.iea.org/reports/aviation

is allowed to be used in the current infrastructure and aeroplanes without any restrictions, thus contributing to an immediate GHG emission reduction.

> Currently, only a small amount of SAF is available on the market, so production must increase immediately to meet ReFuelEU obligations. In order to boost European production, it is necessary to act on these four dimensions:
>
> - Feedstock availability
> - Production costs
> - Sustainability
> - Policy landscape

To meet the expected activity growth while protecting the environment, **it will be imperative the increased production and use of SAFs**, and this is exactly what ReFuelEU aims at. Therefore, the proposed regulation focuses on advanced biofuels and synthetic aviation fuels (e-fuels). The EC's communication states the need for a SAF obligation to boost SAF production and uptake as well as lower production costs. Concretely, this policy supports the imposition of a SAF blending mandate on the fuel suppliers and a jet fuel uplift obligation on aircraft operators. The proposed targets would start with a minimum volume share of 2% of SAF by 2025, reaching a minimum volume share of 63% by 2050, of which a minimum share of 28% of synthetic aviation fuels. With such mandates, the EC wants to restore and preserve a level playing field, with equal opportunities for all aviation market actors across the EU and avoid fuel tankering practices which lead to larger fuel consumption and increased emissions. **Currently, only small amounts of SAF are available on the market with a price at least three times higher than Jet A-1**[4]. In order to accelerate the production and scale-up of SAF and e-SAF and bring larger volumes of these fuels into the market, there are four success factors to be considered, feedstock availability, production costs, sustainable SAF production and favourable policy landscape, with availability and costs being the main ones.

<u>Feedstock availability</u>

According to a study[5] published last fall (September 2022) by the Royal Netherlands Aerospace Centre, the amount of available biomass feedstock to produce SAF in Europe will be so scarce in the long run that it will only be sufficient to meet the ReFuelEU aviation mandate until 2030. Thereafter, the study projects a SAF supply below the legislative mandates, with an increased gap towards 2050. Hence, **it will be crucial to develop innovative feedstock production technologies that allow increasing affordable, sustainable biomass availability and feedstock diversification**.

The same study also looked into e-fuels and their availability potential until 2050. The authors revealed that from 2035 onwards, the amount of e-SAF combined with SAF potentially produced in Europe would be insufficient to meet the overall ReFuelEU mandates due to the limited amount of green hydrogen available for e-SAF production. The study, therefore, underlines the importance of feedstock and SAF imports to meet the overall RefuelEU targets. In a freshly published report[6], SkyNRG describes the building blocks for e-SAF production and the

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[4] https://a4e.eu/publications/production-and-deployment-of-sustainable-aviation-fuels-in-europe-refuel-eu-aviation/

[5] Novel propulsion and alternative fuels for aviation towards 2050 – Promising options and steps to take (TRANSCEND Deliverable D3.2). Royal NLR - Netherlands Aerospace Centre, September 2022. NLR-CR-2022-094.

[6] Framework for the development of an e-SAF facility (TULIPS Deliverable 5.1). SkyNRG, February 2023

success factors for the development of an e-SAF supply chain. The analysis concludes that 70% of the e-SAF production price originates from green hydrogen production. Around half of these costs are associated with renewable power production and the other half with the electrolysers needed to convert water into hydrogen and oxygen. Thus, **research is needed to further reduce the costs of both renewable power production and electrolysers. Besides, research efforts are required to deploy larger electrolyser capacities**[7].

Production costs

Seven neat SAF production routes[8] and two coprocessing pathways are ASTM certified, but only one of the neat routes, the hydroprocessed esters and fatty acids (HEFA-SPK) one, is developed at a commercial scale. Other important production value chains with high deployment potential are syngas-FT (FT-SPK), alcohols to jet (ATJ-SPK) and SAF via direct thermochemical liquefaction routes (not yet ASTM certified). Besides the currently produced and new planned production initiatives, additional production volumes can be unlocked by existing refinery conversion or coprocessing of bio-based materials, as well as by switching the production from Hydrotreated Vegetable Oil (HVO) to HEFA (in the US, the former is favoured). In order to reach the net-zero aviation goals in 2050, the annual SAF production capacity needs to be increased to 449 billion litres. The announced investment plans indicate that SAF annual production could expand from 125 million litres to 5 billion by 2025 and 30 billion litres by 2030 if efficient government incentives are in place[9].

There are two HEFA production plants in operation globally (2022), providing 0.1-0.2% of the global aviation fuel supply[10]: Neste in Porvoo, Finland and World Energy in Paramount, California. There are several initiatives to accelerate production; both Neste and World Energy are planning new facilities in addition to new stakeholders (SkyNRG). The production technology of HEFA is based on hydrotreating oils and fats into sustainable fuels. As mentioned earlier, **the feedstock resource, i.e. the availability of sustainably sourced oils and fats, is limited, and more efforts are needed to access or produce sustainable oils and fats for this pathway**.

As for syngas-FT to SAF, Fulcrum Bioenergy started operating its first commercial plant in 2022[11]. It converts household garbage to syngas and further to SAF. Total Energies has also demonstrated SAF production from waste and residues in France[12]. The main bottlenecks attributed to the syngas-FT technology are the high capital costs and to the need to develop and demonstrate new catalysts to selectively convert syngas into liquid products, including SAF.

With regards to alcohol-to-jet (ATJ) conversion, the company Gevo operates a corn biorefinery in the US where ATJ-SPK is produced,[13] and LanzaJet is planning to start up its first ATJ-SPK

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[7] https://www.iea.org/reports/electrolysers

[8] https://aviationbenefits.org/environmental-efficiency/climate-action/sustainable-aviation-fuel/producing-sustainable-aviation-fuel/

[9] https://www.iata.org/en/pressroom/2022-releases/2022-06-21-02/

[10] https://www.easa.europa.eu/eco/sites/default/files/2022-09/220723_EASA%20EAER%202022.pdf

[11] https://www.fulcrum-bioenergy.com/sierra-biofuels

[12] https://www.ifpenergiesnouvelles.com/article/biotfuelr-project-entry-industrialization-and-commercialization-phase

[13] https://gevo.com/about-gevo/our-facilities/silsbee/

production plant in the US[14]. When looking into this value chain, making ethanol from lignocellulosic biomass feedstock consists of pretreatment, hydrolysis and fermentation before the alcohol is converted to hydrocarbon fuels. One of the major bottlenecks is that the **enzymes needed in hydrolysis are very costly; therefore, research is needed to decrease operational costs.**

The pathways *via* direct thermochemical liquefaction are still under the ASTM certification process. Alder Fuels[15] aims to produce and certify 100% SAF by combining hydrocarbons achieved from direct thermochemical liquefaction and HEFA. In the direct liquefaction value chain, most of the research efforts at present are concentrated on the (advanced) upgrading of biocrudes originating from biomass feedstock which have been submitted to moderate temperatures – and, for some technologies, also to moderate pressures. Such biocrudes contain high concentrations of undesired components such as nitrogen and oxygen, which are detrimental to the quality of the SAF and challenging to remove.

Synthetic or e-SAF produced using green hydrogen from water electrolysis using renewable power and CO_2 from point sources or direct air capture are separately mandated in ReFuelEU and ASTM-certified if produced through Fischer–Tropsch (FT) but not through methanol. **When considering e-SAF, the main barrier for upscaling production today is the sky-high production costs[16]** associated first and foremost with the generation of and access to green hydrogen, as described above. **Substantial research work is currently ongoing on catalyst technologies in those aspects**[17,18]. **Access to CO_2 is a second major barrier for e-SAF production, requiring better understanding and investigation. The desired technology,** in the long run, **is known as Direct Air Capture (DACCS), but it is still immature, and it is first necessary to better understand the scientific, engineering, economic and socio-political challenges surrounding it**[19].

<u>Sustainability</u>

ReFuelEU clearly underlines that all aviation fuels defined within the EC's communication must comply with the sustainability criteria regulated through the Renewable Energy Directive (RED) currently under revision (version II is the one in force at the time of writing). The eligible feedstock for biobased SAFs is listed in RED II Annex IX part A and B. Part B includes most feedstock (used cooking oil and animal fat) for HEFA and stipulates that its maximum energetic share in transport is restricted to 1.7%[20]. For ReFuelEU the eligible feedstock base is extended, including the Annex IX Part B feedstock as well as low-carbon fuels as long as they comply with the 70% GHG emission reduction criteria[21]. The rules for calculating the GHG

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[14] https://www.lanzajet.com/where-we-operate/#georgia

[15] https://www.alderfuels.com/latest-news/alder-saf100-accelerating-development-for-next-generation-sustainable-fuelsnbspnbsp

[16] https://www.biofuelsdigest.com/bdigest/2022/03/14/what-is-esaf-why-the-buzz-and-whats-stopping-it-from-being-produced-at-scale-today/

[17] https://techxplore.com/news/2023-03-natural-catalysts-low-cost-green-hydrogen.html

[18] https://pubs.rsc.org/en/content/articlelanding/2023/gc/d2gc04205c

[19] https://pubs.rsc.org/en/content/articlehtml/2022/ee/d1ee03523a

[20] https://op.europa.eu/en/publication-detail/-/publication/46892bd0-0b95-11ec-adb1-01aa75ed71a1

[21] https://www.consilium.europa.eu/en/press/press-releases/2023/04/25/council-and-parliament-agree-to-decarbonise-the-aviation-sector/

impact of biofuels, including SAF with the default values to be used, are described in RED II Annex V[22].

In order to be able to make all these emissions calculations rigorously, **it is essential to develop standardized methods for feedstock traceability all the way to feedstock origin, especially for feedstocks with very uncertain origins, as is the case today of lipid wastes.**

The eligibility criteria for synthetic (e-)SAF feedstock (hydrogen and carbon dioxide) are described in two delegated acts linked to RED II. The terminology used for the synthetic part of the mandate is Renewable Fuels from Non-Biological Origin (RFNBO), where the term renewable indicates that the hydrogen used for fuel production is renewable (green). The first delegated act[23] includes additionality criteria for renewable hydrogen, and the renewable power used for this hydrogen production must be obtained at the same time and in the proximity of the RFNBO in addition to existing renewable power production and use. The second delegated act[24] describes the rules of the GHG emission calculation method (the minimum GHG savings criteria is 70% compared to fossil equivalents) and adds that the CO_2 must come from renewable point sources or direct air capture (non-renewable point sources are allowed until 2041).

The aviation sector in Europe will be not only regulated by ReFuelEU but also by the international regulation Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), a tool establishing the goals to achieve carbon-neutral growth from 2020 onwards and reach net-zero CO_2 emissions from 2050. **The so-called CORSIA-eligible fuels are an option for offsetting emissions.** CORSIA is composed of twelve sustainability requirements[25], among which two need to be complied with, the ones on greenhouse gas emissions[26] and carbon stock. Under CORSIA, not only SAF but also low carbon non-renewable fuels are eligible, as long as their GHG emissions reduction is at least 10% compared to fossil fuel equivalent. The carbon stock criteria state that fuels should not be produced from land with high carbon stock. CORSIA defines a set of lands that are excluded from production, and it also indicates that land use change (both direct and indirect) needs to be accounted for in the calculations.

Policy landscape

A final success factor in accelerating market penetration of all kinds of sustainable aviation fuels is a **strong synergy between the scientific community and political decision-makers through tailored-made policies regarding SAF and e-SAF complementing ReFuelEU to be soon approved**. In June 2022, ICAO published[27] an exhaustive guidance on potential

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22 ANNEX V Renewable Energy Directive - RULES FOR CALCULATING THE GREENHOUSE GAS IMPACT OF BIOFUELS, BIOLIQUIDS AND THEIR FOSSIL FUEL COMPARATORS (lexparency.org)

23 https://energy.ec.europa.eu/publications/delegated-regulation-union-methodology-rfnbos_en

24 https://energy.ec.europa.eu/publications/delegated-regulation-minimum-threshold-ghg-savings-recycled-carbon-fuels-and-annex_en

25 https://www.iea-amf.org/app/webroot/files/file/Workshop_Task63/IEA%20AMF%20Talk%20Robert%20Malina%20Dec%201%202022.pdf

26 https://www.icao.int/environmental-protection/pages/SAF_LifeCycle.aspx

27 https://www.icao.int/environmental-protection/Documents/SAF/Guidance%20on%20SAF%20policies%20-%20Version%201.pdf

long-term and stable policies for the deployment of sustainable aviation fuels and listed three main policy mechanisms: the first one aimed at supporting the growth of the SAF supply targeted to increase feedstock and fuel production capacities, the second one at creating SAF demand and the third one at enabling the SAF marketplace. For each of these mechanisms, the authors described several policy types, all summarized in a table at the end of the document. Focusing on the first one, which the International Air Transport Association (IATA) urges governments to set up incentives for[28] as production is the step in the value chain which needs the most stimulation, ICAO pinpoints four types of policies. The first type refers to governmental funding for research, development, demonstration and deployment of SAF. The second is meant to enlarge the infrastructure of SAF supply. Thirdly, ICAO indicates targeted incentives to assist the facility operation of SAF, and last but not least, a fourth type of policy needs to recognize and value the environmental benefits of SAF.

Conclusions

There is no doubt that aviation will continue growing, and being one of the most hard-to-abate sectors, emissions from aviation are also expected to increase. In order to reach the net-zero aviation goals in 2050, it is imperative to apply immediate solutions to reduce emissions already now. **SAF is the key solution in the short to mid-term**. The aviation industry is aware of this challenge and is eager to reduce its emissions. However, SAF availability on the market is very limited, and the prices are still too high.

Sustainable aviation fuels will play a key role in decarbonizing aviation. To increase their production and use, the following R&I actions are needed:

- Development of new and improved sustainable feedstock production methods to increase the available feedstock base
- Improvement of energy-efficient processes to enhance cost-competitive SAF production routes
- Formulation of standardized methods for feedstock traceability
- Exploration of how science can contribute to a policy framework enabling European SAF production

ReFuelEU is a remarkable step forward to accelerate the production and use of SAF, and with it, contribute to stabilising the market. **Most of the production technologies are still not commercially available. Demonstration and deployment of viable SAF production routes are urgently needed.** Therefore, **significant research efforts are required**, particularly to **diversify feedstock, increase process efficiency and reduce production costs**. These research efforts will depend on the type and maturity of the technology. On the other hand, **it is expected that both feedstock and SAF will be imported** to fulfil ReFuelEU's obligation due to the limitations of feedstock availability and production facilities in Europe. **To produce SAF sustainably**, which is crucial for success, **not only standardized methods for feedstock traceability but also stronger policy support for European SAF production must be developed**.

[28] https://www.iata.org/en/pressroom/2022-releases/2022-06-21-02/

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