Obstacles and challenges to the market ramp-up of SAF

Contact us

InnoFuels project, Innovation Cluster “Application in Aviation”

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1 Introduction

Making aviation more climate-friendly requires a rapid, efficient and significant reduction in climate-damaging emissions. Promising measures in this regard include the increased use of Sustainable Aviation Fuels (SAF), which is already to be promoted through corresponding legally binding national and EU-wide blending obligations. However, the availability of SAF to make a significant contribution to reducing emissions and fulfilling the quotas requires a rapid market ramp-up of the more climate-friendly fuel. From an economic perspective, a market ramp-up is achieved when the product in question is in broad demand and is produced in correspondingly large quantities. This in turn requires the necessary production capacities to ensure availability. In the case of SAF, this step has not yet been taken.

This report examines and analyses the obstacles and challenges currently facing the market ramp-up of SAF in Germany as part of the BMDV-funded InnoFuels project in the focus area “Application in Aviation”. The obstacles were identified at two stakeholder workshops in September 2023 and February 2024 and supplemented by literature research and expert interviews.

The aspects identified as obstacles to the market ramp-up of SAF subsequently formed the basis of a stakeholder survey. The aim of this survey was to assess the importance and urgency of resolving the market barriers from an aviation perspective. This should ensure that the subsequent development of solutions for the market ramp-up of SAF initially focuses on the obstacles with the highest priority.

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2 Identification and prioritisation of barriers to market ramp-up

Stakeholder workshops

As part of the InnoFuels project, two comprehensive stakeholder workshops were held to **identify and analyse** the **obstacles to the market ramp-up of SAF**. These workshops took place in September 2023 and February 2024 and aimed to systematically work out the challenges for the market ramp-up of SAF. The events were attended by representatives of various stakeholder groups, including research institutions, airlines, fuel producers, airport operators, financing institutions, sustainability organisations (NGOs), regulatory authorities, companies along the supply chain and original equipment manufacturers (OEMs).

The **first workshop** focussed on the general regulatory aspects and framework conditions in connection with the introduction of SAF. The participants discussed the current legal requirements and political framework conditions that influence the use of SAF. The results of this workshop were then analysed and expanded upon through literature research and expert interviews.

In the **second workshop**, the previously identified obstacles were further analysed and discussed in groups. The group work focussed on three main areas: technical challenges, the use of SAF as a business case and socio-economic challenges. This resulted in a comprehensive list of obstacles that affect the aviation industry to varying degrees and are also partially addressed to other interest groups.

Carrying out the stakeholder survey

The results of the workshops formed the basis for a subsequent stakeholder survey. The aim of the survey was to **assess the identified barriers** to the market ramp-up of SAF according to their relevance for the aviation industry. The respondents' task was to assess for each market obstacle whether the resolution of the respective obstacle is considered important and/or urgent from an aviation perspective.

The options shown in Figure 1 in the sense of an Eisenhower matrix were available for evaluating the factors of *importance* and *urgency*.

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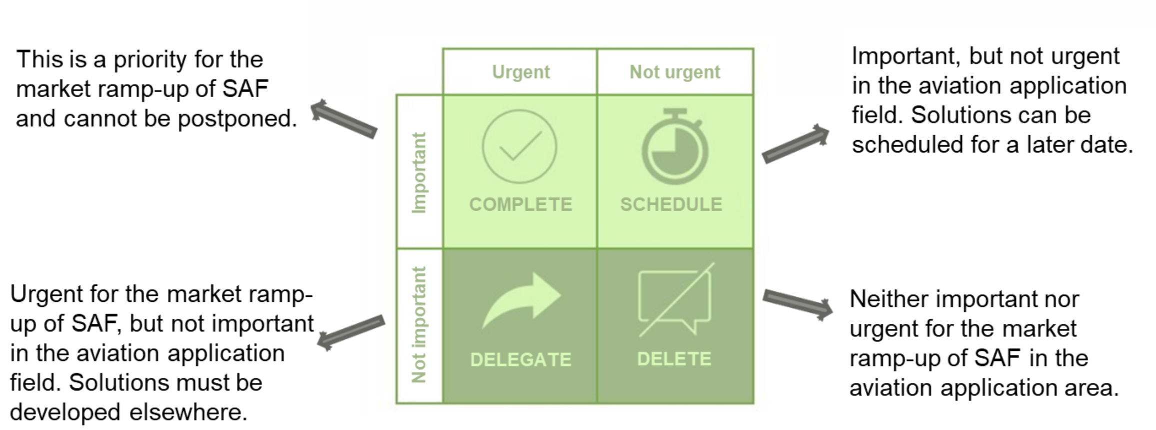

Figure 1: Eisenhower matrix from [1] with evaluation options for prioritising market barriers

The survey period ran from 30 April to 20 May 2024, with the survey link being distributed both via the project's internal stakeholder mailing list and via the social media network LinkedIn. There were 37 participants in total, which can be broken down into different stakeholder groups as shown in Figure 2. It is clearly recognisable that although the majority of participants (15 parties) come from the research sector, at least one stakeholder from each group is represented.

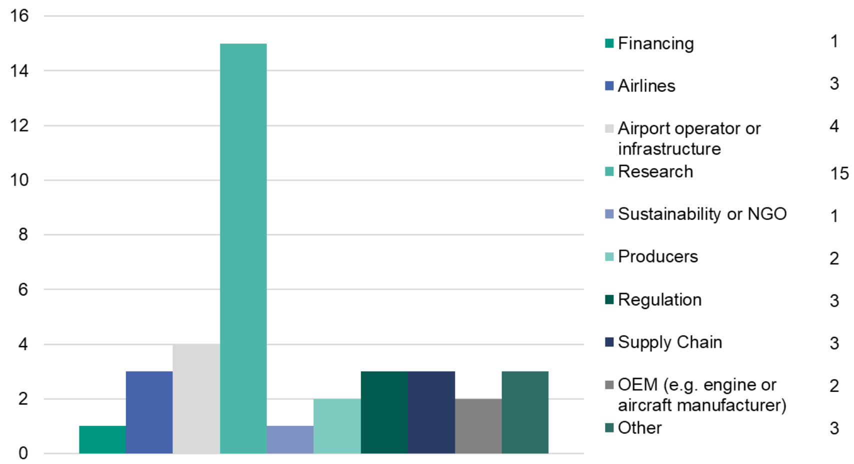

Figure 2: Structure of survey participants by stakeholder group

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Evaluation of the stakeholder survey

In the course of analysing the survey, the key areas of action were divided into four **thematic areas: "Investments", "Production", "Aviation users" and "Sustainability"**. The relationship between these four areas is shown below in Figure 3.

The obstacles from the stakeholder survey were categorised according to the topic areas, presented graphically together with the survey results and are attached to this report as illustrations (Appendix: Figures 4-8). The core statements from the survey are summarised below. The focus is on the obstacles that were categorised as particularly relevant (important and urgent) for the aviation industry.

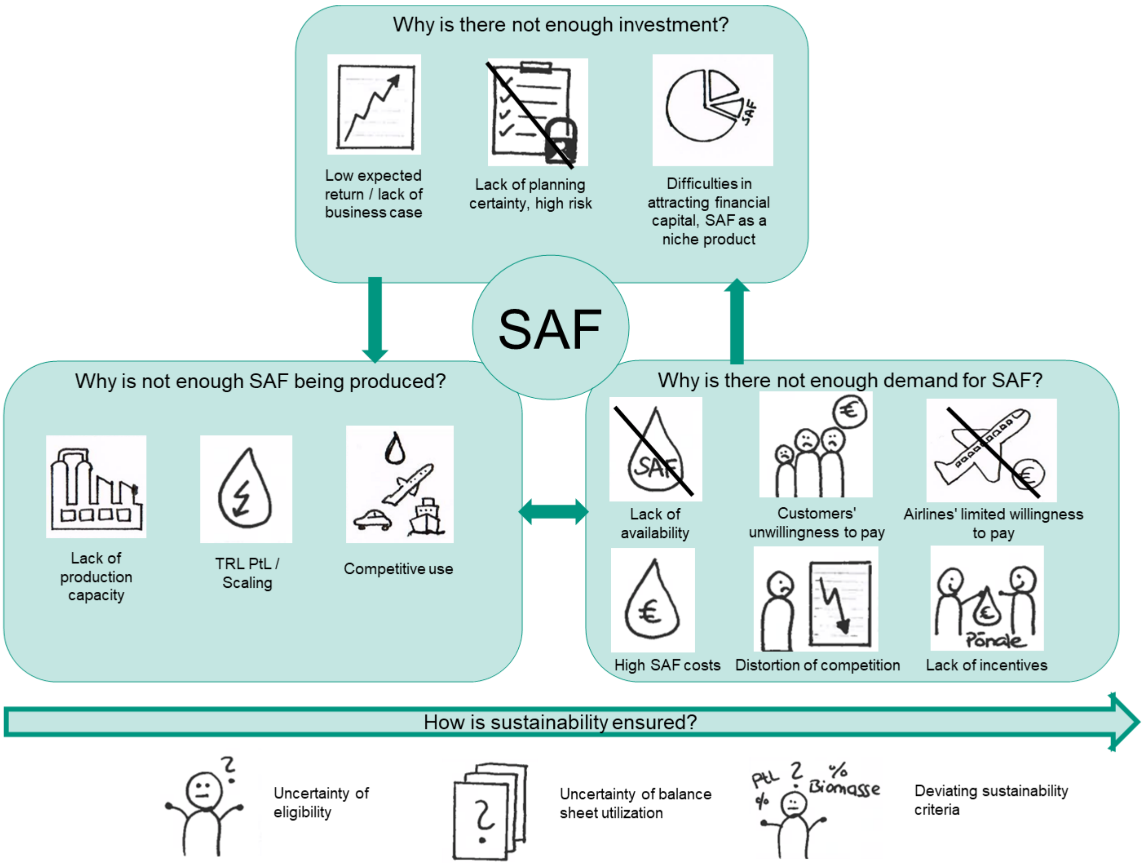

Figure 3: Key issues and barriers to the market ramp-up of sustainable aviation fuels [own illustration]

In the area of **investment**, the lack of investment for SAF systems proved to be particularly problematic, as 89 % of respondents considered this obstacle to be highly relevant. Insufficient planning and investment security due to regulatory framework conditions also represented a critical hurdle for of participants. Due to the high proportion of votes compared to

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the obstacles in the other areas, these two obstacles should be prioritised when developing solutions.

In the area of **production**, 84 % of respondents identified SAF's low production capacities as a particular obstacle to the market ramp-up. This was followed by the lack of upscaling of the PtL process chain, the actual feasibility of which was also seen as important and urgent by 59 %. The time-consuming and cost-intensive approval processes for SAF production processes and fuels by the responsible standardisation organisation ASTM were rated as important by a total of 78 % of participants, 46 % of whom also rated the removal of this obstacle as urgent.

In the field of **aviation applications**, 65 % of respondents rated uncertainty regarding additional costs and a lack of economic incentives as the most important and urgent obstacle to be resolved, as the costs for SAF are higher than for fossil kerosene. The lack of availability of SAF at airports was also given high priority.

In the area of **sustainability**, the majority of participants (51 %) rated the strict regulation of the CO_2 source in the SAF production process in accordance with RED II/III as the most significant obstacle. The elimination of the limited availability of sustainable biomass was also rated as important by 76 % of the respondents, but only half of them felt it was urgent. Compared to the other topic areas, the urgency of eliminating the obstacles to sustainability was also rated as lower overall.

Socio-economic aspects were considered to be less important overall and are therefore not considered in more detail below. The limited availability of renewable energies and the lack of electrolysis capacity for hydrogen are also not considered in more detail. Although these are important and urgent general challenges, they are not only inhibiting the market ramp-up of SAF, but are also global barriers to the supply of renewable energies and green hydrogen. Therefore, these issues need to be addressed not only from an aviation perspective, but also from a broader perspective.

The prioritisation of the survey results underlines the **need for focused development of solutions**, particularly in the **areas of investment and production**, in order to effectively drive the market ramp-up of SAF. The development of solutions is analysed in a separate report. The obstacles and their underlying reasons are explained below.

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3 Why is there not enough investment in SAF?

The market ramp-up of sustainable aviation fuels is hindered by various factors, making investments in this area unattractive. There are many reasons why producers and financial investors are unwilling to invest in production facilities for sustainable aviation fuels (SAF), and these relate to all aspects of the economic, technical and regulatory framework.

From an investor's perspective, three obstacle clusters can be defined:

1. Low return expectation
2. High risk of failure
3. Difficulties in attracting financial capital

Low expected return

The **low expected return** on investments in plants for the production of SAF results on the one hand from high production costs. The investments are associated with high costs for the synthesis plant, possibly for CO_2 extraction by means of direct air capture (DAC) or separation, for the generation of renewable electricity and for electrolysis capacities. Furthermore, the costs of actual production depend to a large extent on the costs of the energy required and the sustainable raw materials (biomass, CO_2, water). Depending on the location and the selected process, energy costs can account for up to 50 % of the production costs [2].

On the other hand, despite the introduction of the national PtL quota (BImSchG) from 2026, which differs from the ReFuelEU Aviation Regulation, there has so far been **no substantial demand** for PtL kerosene in Germany (see chapter 5). On the one hand, this situation is due to the fact that the payment of the penalty stipulated in the BImSchG [3] together with the costs for fossil kerosene and CO_2 certificates is more favourable than the costs (and thus the prices) for PtL kerosene from the first pioneer plants. In addition, diverging national laws in various countries create uncertainty for potential investors with regard to regulatory requirements. Airlines are faced with the challenge of passing on the high additional costs for the use of SAF to their customers. This problem affects private travellers in particular. In the business customer segment, there is a certain willingness to accept higher prices, provided that the CO_2 savings from SAF are certified and can be offset. However, this is not yet the case for all planned SAF production paths. The market's reluctance to accept higher prices and the uncertainty regarding creditability **are preventing a demand-side stimulus**.

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High risk of failure

Another barrier to market ramp-up is the complexity and associated risks involved in building a PtL plant. Apart from the classic HEFA process, many newer production processes are not yet available on an industrial production scale (see chapter 4). This means that investments are still associated with a technological risk. In particular, the processes for the production of electricity-based fuels using the Fischer-Tropsch process or the Methanol-to-Jet route still have a relatively low level of maturity as an overall system with the production of synthesis gas. This is accompanied by the **technological risk** that commissioning may be delayed, fail entirely, or that the process itself may not work, leading to the failure of the entire project.

The construction of a plant requires long planning periods of more than two years and therefore involves **significant planning risks**. Uncertain assumptions regarding the costs of constructing the plants and the development of production costs, lengthy authorisation procedures and relatively high upfront costs in the planning phase make planning difficult and uncertain. In addition, there are complex dependencies on planned infrastructures (H_2 grid, electricity grid expansion, CO_2 supply) or necessary investments in the entire supply chain (RE generation, H_2 generation, CO_2 supply, synthesis plants, processing plants). This means that complex consortia and partnerships have to be coordinated and managed, which entails an **organisational risk**.

The mandatory use of SAF, and therefore its production, is subject to a whole range of legal regulations, which can result in significant **regulatory risks**. For example, regulations on the usability of biomass in the production of SAF determine the material basis for production and, depending on the availability of the materials, indirectly also their prices. In some cases, these regulations also determine the production processes. And they determine the creditability of the end product and thus its marketability. Specific regulations on the conditions for the purchase of renewable energy define the regional and temporal supply range of electricity for the production of hydrogen and thus also for PtL fuels.

The EU ReFuelEU Aviation Regulation has been in force since 2024 and is therefore directly and immediately effective. As part of ReFuelEU Aviation, the EU legislators have defined a review clause in which the effectiveness of the introduced and planned regulations will be reviewed by 2027. This means that rules and requirements currently in place, such as SAF quotas and penalties, could be changed again, which further reduces planning certainty.

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Difficulties in attracting financial capital

Finally, the investor also has to bear a **systemic risk**. With the construction of a plant, he has made an investment with a long-life cycle on the production side of 20-30 years, in which his options to change the costs are limited. On the customer side, however, the airline has a short purchase cycle of 6-12 months. As cost reductions in production can generally only be realised with next-generation systems, the investor runs the risk of being stuck with the costs of the old system.

The limited return and the high investment risks ultimately lead to an unfavourable risk-return ratio and therefore no reliable business case. This risk-return ratio means that **little capital is available for investment**. **There is a lack of "bankability**" – i.e. the certainty for the investor that funds from the private sector and banks will be made available. This is exacerbated by the complexity of the matter, which is often difficult for private investors to understand and assess.

Another reason for the shortage of funding is the **extensive discontinuation of** federal **subsidies** in 2024. In addition, there is no return flow from tax levies (air traffic tax, EU ETS certificates) to finance the transformation process through the ramp-up of SAF, as provided for in the coalition agreement.

It is also striking that the major oil companies are reluctant to invest in SAF, particularly in PtL. One of the reasons for this is that kerosene, and therefore also SAF, is a niche product compared to petrol and diesel. Investments are practically only focussed on biogenic SAF with a focus on HEFA, as existing plants can be converted for this purpose.

4 Why is not enough SAF being produced?

The obstacles to the market ramp-up of SAF production can be found in several areas. On the one hand, there is hardly any upscaling of production capacities and the manufacturing processes themselves. A distinction must be made between bio-based and electricity-based manufacturing processes. The high costs are also a factor that affects both the provision of the raw materials and the production of the fuel itself. Another issue is the lack of availability of the source materials, which also applies to both electricity-based and biogenic fuels. Due to their importance for sustainability, the feedstocks are addressed in chapter 6.

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Obstacles to the production of electricity-based SAF (PtL fuels)

In addition to the **lack of electricity generation plants for the provision of renewable energies** for the production of green hydrogen, **the lack of production capacities** is currently the greatest obstacle to the market launch of electricity-based SAF.

The **provision of sufficient quantities of H_2** is currently primarily a cost issue, as the green electricity required is still very expensive and electrolysers with sufficient capacity and high efficiency must first be built. Depending on the design, the efficiency ranges from 50 % to 90 % on average, whereby plants with a very high efficiency (i.e. > 75-80 %) are still predominantly research plants [4-6]. Although the technology of electrolysers is already mature, the continuous production of the necessary quantities of H_2 still requires development work, particularly with regard to improving efficiency and balancing load fluctuations in the electricity grid.

A lack of production capacity is mainly due to the fact that the entire process chain along the PtL production chain **has not yet been sufficiently scaled up.** Overcoming this challenge requires considerable efforts, especially financial ones, in terms of research and development work and further demonstration of the technology.

Due to the lack of upscaling, the **production costs for existing demonstration plants** are **extremely high**, which makes investments for the industry (from potential customers as well as producers) risky. In addition, purchaser must be found for all co-products and by-products if they cannot be fed back into the process. This is countered by restrained or inadequate political support. However, this is needed as long as PtL products are not yet commercially available.

In terms of production itself, the **provision of CO_2 via direct air capture (DAC)** is currently another challenge that needs to be solved, as this process is not yet available for the provision of large quantities of CO_2. The CO_2 in the air accounts for 0.04 % by volume and therefore needs to be highly concentrated. In principle, the construction of a DAC plant is possible anywhere, but only makes sense where renewable electricity is available and with a direct connection to the PtL synthesis. As the efficiency is currently still very low, the DAC technology still lacks the necessary scaling to be considered for commercial use, which makes the DAC process very expensive. On the other hand, different DAC technologies are being developed, some of which are competing with each other for funding (at the same

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time, of course, the technology should remain open). In point sources and biogenic sources, CO_2 is already present in a clearly concentrated form.

Obstacles to the production of biogenic SAF

In contrast to PtL fuels, the development of bio-based fuels is already much further advanced. HEFA and AtJ kerosene are already commercially available. The restrained expansion of production capacities is mainly due to the foreseeable **lack of availability and the sometimes complex processing of the raw materials.** In the production of biogenic SAF, competition with the food and animal feed industry must be ruled out. This applies not only to the plant-based raw material itself, but also to the cultivation areas. Therefore, only residues from agriculture and forestry and the recycling of used edible oils and fats can be of interest here. This considerably restricts the selection and availability of suitable biogenic material.

This restriction requires complex **processing and preparation of the biogenic material**. Basically, these processes are now available and state of the art. However, they increase production costs compared to the availability of an already pure starting material.

Further obstacles in the production of SAF

In addition to the obstacles described above that directly affect production, there are other challenges that are closely linked to the production of SAF and have an impact on the market ramp-up.

Firstly, there is the **time-consuming and cost-intensive approval process** in accordance with ASTM D4054, which is a basic prerequisite for a new fuel to be launched on the market at all. Not only the fuel or the SAF itself is certified, but also the entire production process. This is why ASTM D7655 currently contains eight different SAF fuels, even though they are very similar in most cases from a purely chemical point of view.

The production of SAF is still a very new process in some cases, which, in addition to ASTM certification for the product itself, also requires certification as proof of sustainability. The **shortage of skilled labour and any necessary (new) infrastructure**, particularly with regard to the supply of RED II-compliant hydrogen and carbon dioxide, therefore poses a further challenge.

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Co-processing is another option for increasing the quantity of synthetic fuels proportionately. Currently, the permitted blending quotas are very low, so it is hardly worthwhile for manufacturers to invest in this or to utilise this option at all.

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5 Why is there not enough demand for SAF?

Another obstacle to the market ramp-up of sustainable aviation fuels is the current low demand from airlines. Various factors contribute to this reluctance and make the spread of SAF more difficult.

High costs of SAF

One key aspect is the **high cost of SAF compared** to conventional Jet A-1 fuel. The price difference is considerable, which limits the airlines' ability and willingness to pay. Many airlines operate on tight margins and are therefore unable to bear the higher cost of SAF without passing it on to customers. In a globally competitive market, however, this is difficult or sometimes impossible. Indeed, the agreed quotas for blending and placing on the market according to ReFuelEU Aviation, in combination with the considerably higher production costs for alternative aviation fuels compared to fossil kerosene, lead to unavoidable **price increases for flight tickets** due to increased fuel costs as a significant cost block for airlines. It should be noted that the various target groups (cargo, business, tourism) are confronted with different price elasticities and, in some cases, seasonality [7].

Distortion of competition and lack of financial incentives

Competitiveness is also impaired by different quota regulations for distributors at national and EU level. There is also a lack of a standardised, binding definition of the term "distributor". In Germany, this is defined as a "tank farm enforcer", which is why airlines as end customers can often only act as price takers on the market. While some countries have ambitious targets and quotas for the use of SAF, others are less strict. Although there are EU-wide quotas, it is not yet clear whether this invalidates national quotas. These differences lead to an **uneven playing field** within the EU. Airlines operating as distributors in countries with high SAF quotas are at a disadvantage compared to airlines from EU countries and **third countries** with lower or no quotas, as they have to bear higher fuel costs.

There is also **uncertainty regarding differing penalties** (fines) between national and EU requirements. It is often unclear when and under what conditions which quota applies and which penalty is to be paid accordingly. This uncertainty relates in particular to the question of which regulations take precedence and how compliance with the various quotas and directives is monitored and penalised. The lack of clarity about what penalties are to be

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expected in the event of non-compliance and how these will be enforced leads to uncertainty among airlines and distributors instead of creating an additional incentive for the use of SAF [8].

Another obstacle to demand is the **lack of financial incentives for the use of SAF**. As long as the costs for SAF are significantly higher than for conventional kerosene and there are no clear economic benefits or targeted government support measures, the willingness of airlines to switch to SAF will remain low. It is precisely at this point that a **lack of government support** for the SAF market ramp-up or the cancellation of these funds is a major obstacle.

Lack of availability of SAF

Another key factor is the **lack of availability of SAF**. The availability of fuel is currently inadequate both in general ("chicken and egg problem") and at the locations where it is used. As refuelling at airports is usually done via pipeline systems, it is not possible to supply an airline or an aircraft with a specific batch of fuel. The delivered fuel is mixed ("blended") in refuelling depots and then distributed further. The targeted refuelling of an individual aircraft with SAF is therefore not possible and would require the establishment of a parallel infrastructure. The same would apply to 100 % aromatics-free SAF in the event of partial authorisation. This would mean a considerable or even unaffordable effort for distributors and airports if airlines want or have to use SAF directly, especially if no balance sheet utilisation (see chapter 6) is possible.

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6 Uncertainties regarding the sustainability of SAF

Uncertainties regarding the sustainability of electricity-based SAF (PtL fuels)

Hydrogen (H_2) and carbon dioxide (CO_2) are required as starting materials for electricity-based fuels. Both H_2 and CO_2 must comply with the provisions of RED II, whereby in the case of the provision of H_2 it is the electricity procurement criteria that must be observed.

Sufficient renewable electricity that fulfils the criteria of RED II must be available for the operation of the electrolysers, as well as clean and desalinated water as the actual raw material. As numerous forecasts predict that the potential of possible sources of renewable electricity in Germany and Central Europe will not be sufficient to cover the electricity requirements of all private households, industrial consumers and additionally the necessary electrolysis capacity, either the electricity itself, the hydrogen (in pure form or as a derivative) or the PtL product will have to be imported. Many regions of the world in which a significant surplus of renewable electricity can potentially be expected, primarily from wind and solar energy, and which are therefore suitable for the operation of large electrolysis plants, often have a **shortage of clean (drinking) water.**

The **sources of CO_2** can be roughly divided into three cases:

- CO_2 from the air
- CO_2 from biomass
- CO_2 from point sources (industrial waste gases)

There are also special cases such as geological deposits (e.g. in rocks or as a result of volcanic activity), however these do not play a role in the industrial extraction of CO_2. From a regulatory perspective, the extraction of **CO_2 from the air** (DAC – Direct Air Capture) is the least critical. From a technical point of view, however, this is the least mature process (see chapter 4) and is therefore not yet available for the supply of large quantities of CO_2.

The extraction of **CO_2 from point sources** is technically mature, as the purification of flue and exhaust gases is already state of the art for environmental reasons. Only the storage of CO_2 is an additional step, but this can also be regarded as state of the art. Therefore, the usage of point sources is particularly from a regulatory perspective an obstacle as a guaranteed CO_2 saving potential must be demonstrated and, depending on the origin, utilisation is only permitted until 2036 or 2041 [9].

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Different sources can also be distinguished for the utilisation of **CO_2 from biomass**:

- Combustion of biomass for energy supply / heat generation (combustion must not serve the sole purpose of CO_2 recovery)
- Separation of CO_2 from biogas
- CO_2 from biotechnological processes such as fermentation for the production of alcohols or biological wastewater treatment

Similar to the extraction from point sources, the separation of CO_2 from the above-mentioned sources is also technically mature. The main challenge here is to install a flexible processing system, as the composition of the resulting product or waste gases depends on the composition of the biological material, which is subject to natural fluctuations. This may reduce the efficiency of CO_2 capture or increase the cost of installation. In principle, the cost issue (apart from the development of DAC) is certainly far less critical for CO_2 supply than for H_2 supply. However, the utilisation of CO_2 from biomass is also subject to the regulations of RED II. In addition, there is the question of the creditability of the CO_2 savings.

Uncertainties regarding the sustainability of biogenic SAFs

In contrast to PtL SAFs, the production of biogenic SAFs involves the more or less direct conversion of organic source materials into kerosene. In the production of biogenic SAFs, **competition with the food and animal feed industry must be excluded**. This applies not only to the plant-based raw material itself, but also to the cultivation areas. Therefore, only residues from agriculture and forestry and the recycling of used edible oils and fats can be of interest here. This considerably restricts the selection and availability of suitable biogenic material.

This restriction requires complex **processing or preparation of the biogenic material**. Basically, these processes are now available and are state of the art. However, they increase production costs compared to the availability of an already pure source material.

To process used edible oils and fats, they must be purified from other food residues, inorganic components (common salt) and water. From a biochemical perspective, residues from forestry and agriculture are primarily lignocellulose, whose main components are lignin, cellulose and hemicellulose. Various types of sugar molecules can be obtained from cellulose and hemicellulose using suitable digestion processes, which can be biotechno-

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logically converted to alcohols and/or directly to hydrocarbons. The catalytic and/or (hydro)thermal conversion of sugar molecules and lignocellulose (or their components) to hydrocarbons or kerosene is also possible or under development.

Further uncertainties regarding the sustainability of SAF

Another major factor hindering the market ramp-up of sustainable aviation fuels are the existing uncertainties regarding the sustainability of SAF. These uncertainties affect several areas and make it difficult for SAF to be widely accepted and used. For example, **different sustainability criteria** lead to confusion and uncertainty. Various regions and countries have different standards and requirements for the sustainability of SAF. These different criteria make it difficult for producers to obtain standardised and generally recognised sustainability certificates. The lack of harmonisation of criteria means that investors and airlines are unsure whether the funds invested and the use of SAF are actually recognised as sustainable.

There is also uncertainty about the **eligibility of SAF**. The extent to which SAFs can be counted towards the reduction targets for greenhouse gas emissions is often unclear. Different crediting models and calculation methods can lead to the actual environmental benefits of SAFs not being fully recorded or recognised. Depending on the production process, the CO_2 reduction can vary greatly from one to 90 % [10]. The question therefore arises as to how much CO_2 reduction is to be recognised and how the source is tracked.

There are also uncertainties regarding the **accounting utilisation of SAF**. This uncertainty concerns the question of how the use of SAF is included in the overall balance of greenhouse gas emissions. Accounting use means that airlines can buy SAFs and count their use towards their emissions balance, even if SAFs are not physically used in their aircraft (principle of book & claim). This requires a reliable and transparent system for tracking and certifying the SAF used. Uncertainties arise from possible changes to the regulations, the manner of certification and tracking as well as the acceptance of these practices by the various regulatory authorities.

The **social acceptance of SAF** is also an issue. The perceived uncertainty about the additional costs incurred in relation to the environmental benefits has a negative impact [11]. This scepticism can lead to the general public being less willing to accept higher air fares resulting from the use of SAF. In addition, the social participation of less affluent population

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groups in travelling is impaired by the increase in flight prices, meaning that lower-income households can afford to travel less.

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7 Conclusion and outlook

The market ramp-up of Sustainable Aviation Fuels is being delayed by obstacles in four areas. Essentially, the problem lies in the fact that it is unclear how the sustainability of SAF is to be ensured, as this has an impact on all other areas. Unclear or inconsistent sustainability criteria therefore mean that there is insufficient investment, production and demand.

There is insufficient investment because, among other things, there is no business case due to the lack of sustainability criteria or different sustainability criteria internationally, the complexity of the projects and the high risks, and planning certainty is severely limited. There is also a lack of demand incentive on the part of the airlines due to the distortion of competition caused by the high costs of SAF, which can only be passed on to customers to a limited extent in a highly competitive market. Added to this is the lack of state subsidies to efficiently stimulate the market ramp-up. It is also unclear how these can be recognised and how they can be used in the balance sheet, which further reduces the willingness to pay. In addition, only small quantities of biogenic SAF and no PtL SAF (only on a laboratory scale) have been produced worldwide to date. Production capacities cannot be increased sufficiently and quickly enough, as there is a lack of investment and raw materials and the technology maturity level for PtL is not yet high enough.

Sustainability must therefore be ensured in order to increase demand and planning certainty, so that the willingness to invest increases and production can be expanded. Further project work in the focus area “Application in Aviation” of InnoFuels will focus on working out which solutions can be considered to remove the identified obstacles and accelerate the market ramp-up of sustainable aviation fuels.

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List of abbreviations

Abbreviation	Meaning
ASTM	American Society for Testing and Materials
AtJ	Alcohol-to-Jet
BImSchG	Federal Immission Control Act (Bundes-Immissionsschutzgesetz)
BMDV	Federal Ministry for Digital and Transport Affairs (Bundesministerium für Digitales und Verkehr)
CO_2	Carbon dioxide
DAC	Direct Air Capture
EU	European Union
EU ETS	European Emissions Trading System
H_2	Hydrogen
HEFA	Hydroprocessed Esters and Fatty Acids
NGO	Non-Governmental Organisation
OEM	Original Equipment Manufacturers
PtL	Power-to-Liquid
RED	Renewable Energy Directive
SAF	Sustainable Aviation Fuels

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Appendix

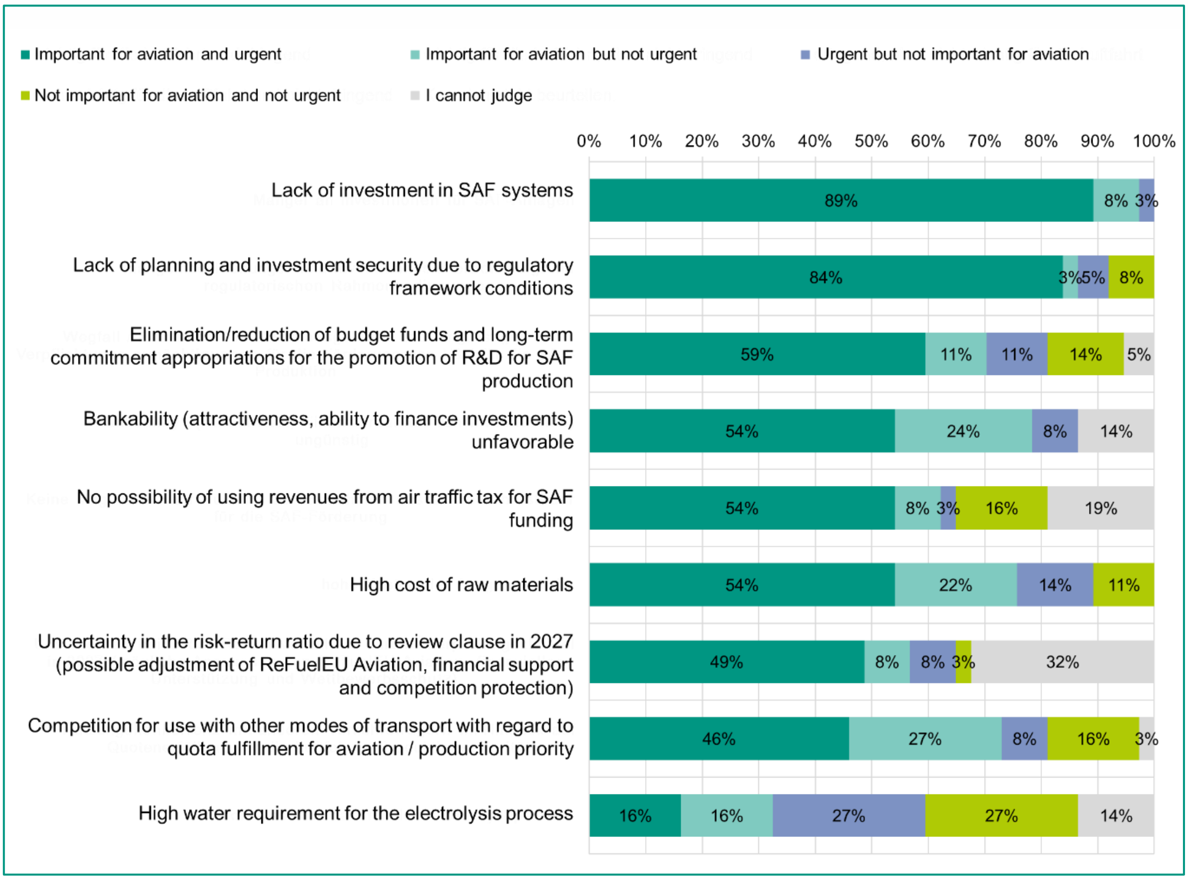

Figure 4: Survey results for the topic of investments

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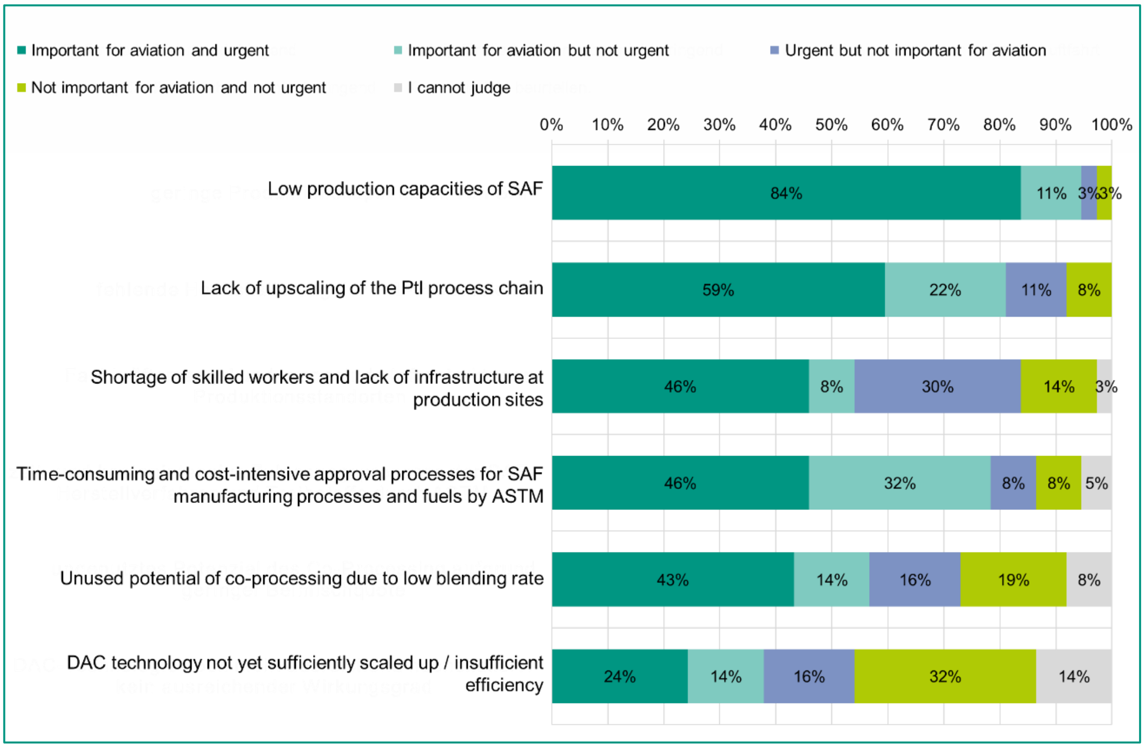

Figure 5: Survey results for the topic of production

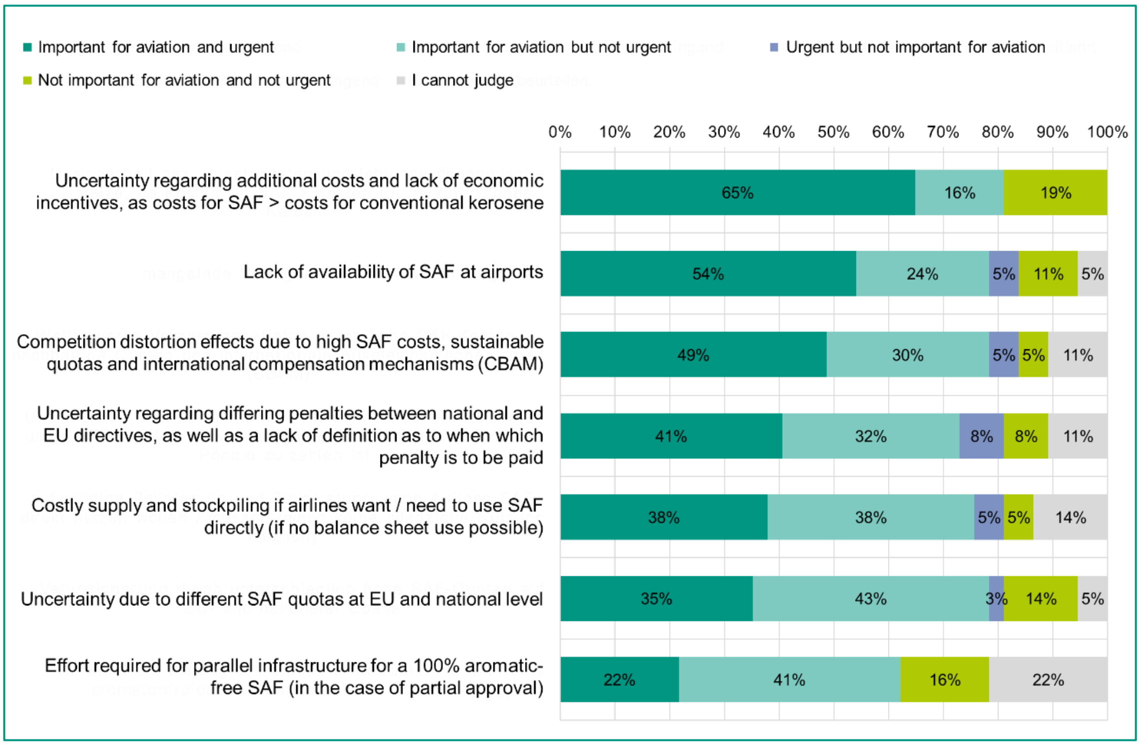

Figure 6: Survey results for the subject area of aviation applications

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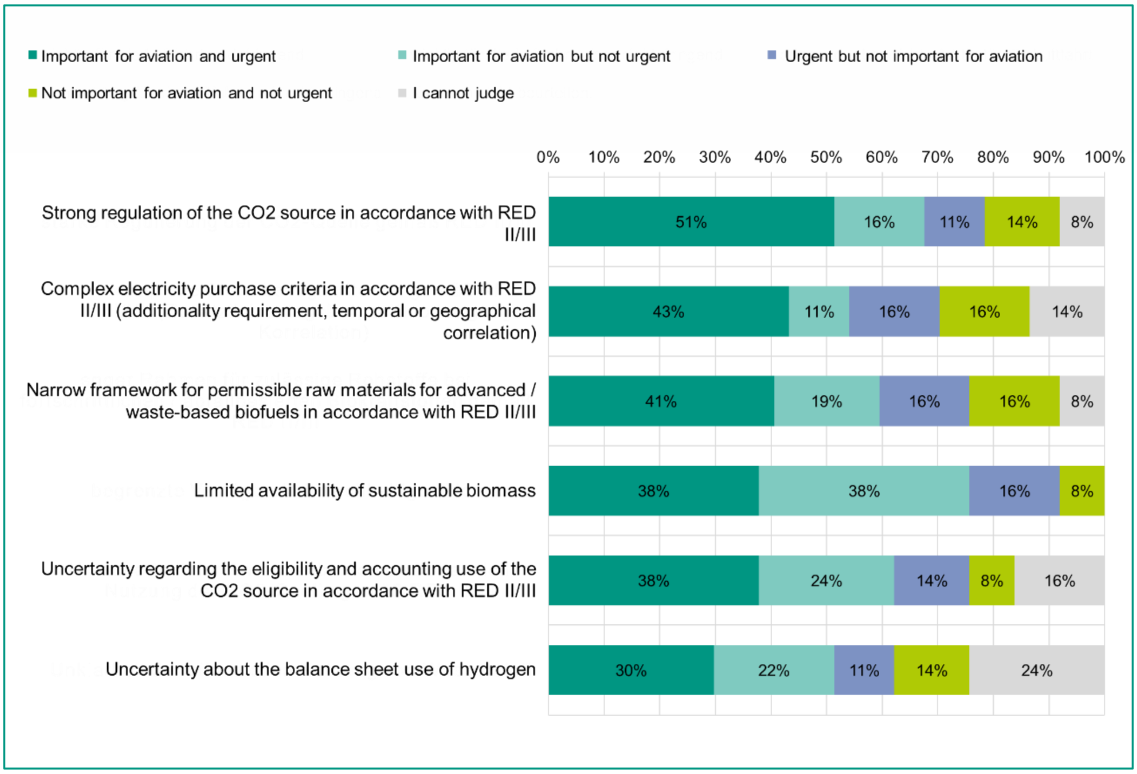

Figure 7: **Survey results for the topic of sustainability**

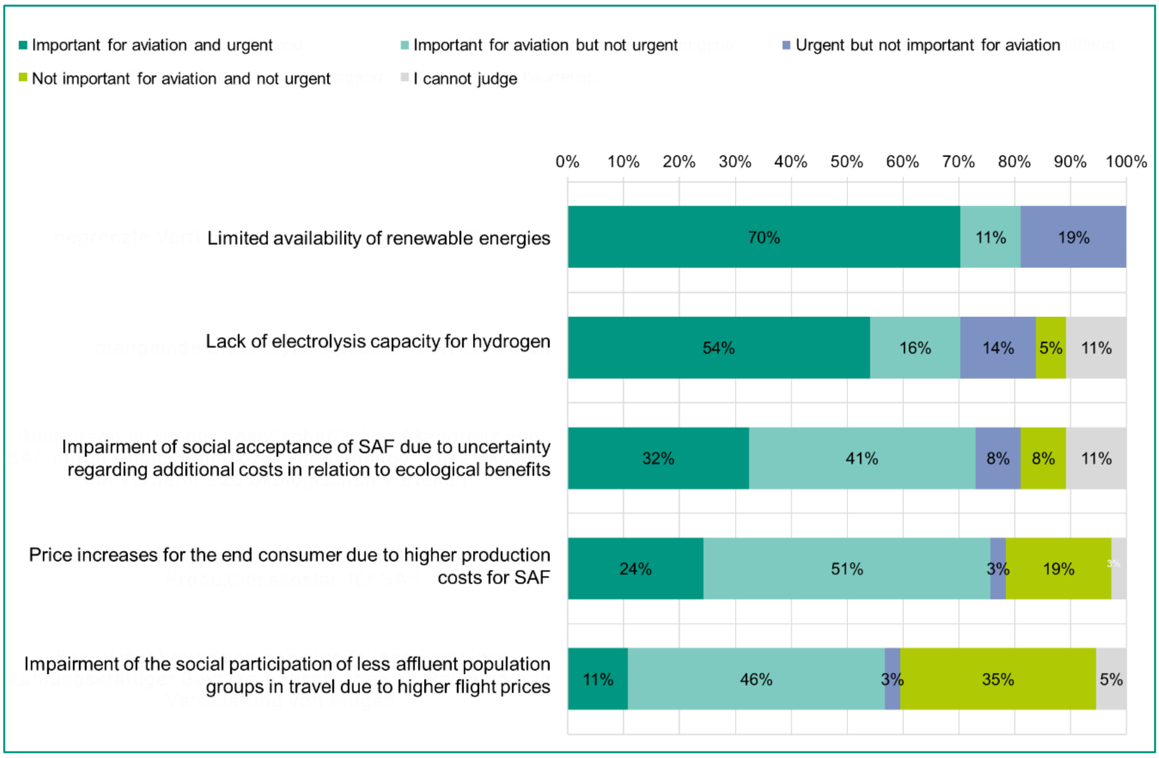

Figure 8: **Survey results for other topics outside the innovation cluster "Application in Aviation"**

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