SOLUTIONS

for the accelerated market ramp-up of sustainable aviation fuel

CENA HESSEN

DLR

condor

est. 1956

Project InnoFuels, Innovation Focus “Application in Aviation”

Authors Sandra Richter, Deandra Drewke, Franziskus Hellwig
Deutsches Zentrum für Luft- und Raumfahrt e.V.
Léonie Lauer, Bernhard Dietrich, Melanie Grohs
CENA Hessen
Sina Rathgeber, Sophia Dunning
Condor Flugdienst GmbH

Contents

FUNDING PROGRAMME RENEWABLE FUELS

With funding from the Federal Ministry of Transport by decision of the German Bundestag

Coordinated by NOW NOW-GMBH.DE

Project management agency VDI|VDE|IT FNR

1 Introduction

The transition towards more climate-friendly aviation calls for the use of sustainable aviation fuel (SAF). Based on current knowledge, this is the most promising solution for reducing climate-damaging emissions from air traffic and reduces not only CO_2 emissions but also non-CO_2 effects that impact the climate. As the key to a successful fuel transition in aviation, particularly for long-haul flights, the move to more sustainable aviation fuel is therefore promoted by corresponding, legally mandated national and EU-wide admixture requirements. Despite this, SAF is currently only available in small quantities around the world and is also significantly more expensive than fossil kerosene [1]. A rapid and competitively neutral market ramp-up is essential in order to meet the statutory quotas and make a significant contribution to reducing emissions.

The market ramp-up of SAF faces numerous obstacles, which can be broken down into four areas [2]. The key question is how the **sustainability** of SAF can be ensured given that investment decisions by plant operators are being postponed indefinitely or large-scale construction projects are being cancelled, particularly in light of the current lack of clarity or uniformity of sustainability criteria. The insufficient current **investment** is due to the absence of a business case and severe limitations in planning certainty for investors. This can be attributed to the aforementioned lack of – or international differences in – sustainability criteria, as well as the complexity of the projects, in conjunction with considerable risks for first movers.

Moreover, there is a lack of **incentivisation of demand** on the part of airlines. This is partly due to a distortion of competition, as the high cost of SAF relative to fossil kerosene can only be passed on to customers to a limited extent in the highly competition-oriented, global aviation market. On the other hand, airlines' willingness to pay has decreased due to ongoing uncertainty regarding the eligibility and book & claim use of SAF, as well as a lack of additional government funding that could effectively stimulate market ramp-up.

In turn, the fact that the **production capacities** for SAF potentially cannot be increased fast enough or on a sufficient scale is due to factors including the lack of investment decisions (see above), the limited availability of raw materials (e.g. biomass and hydrogen) and the

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

low technology readiness level on the industrial scale in the case of power-to-liquid (PtL) systems.[1]

Sustainability must therefore be ensured through corresponding regulation in order to boost planning certainty for investors and demand from airlines. In turn, this will increase willingness to invest and allow an expansion of production capacities. Figure 1 presents an overview of possible solutions to these obstacles.

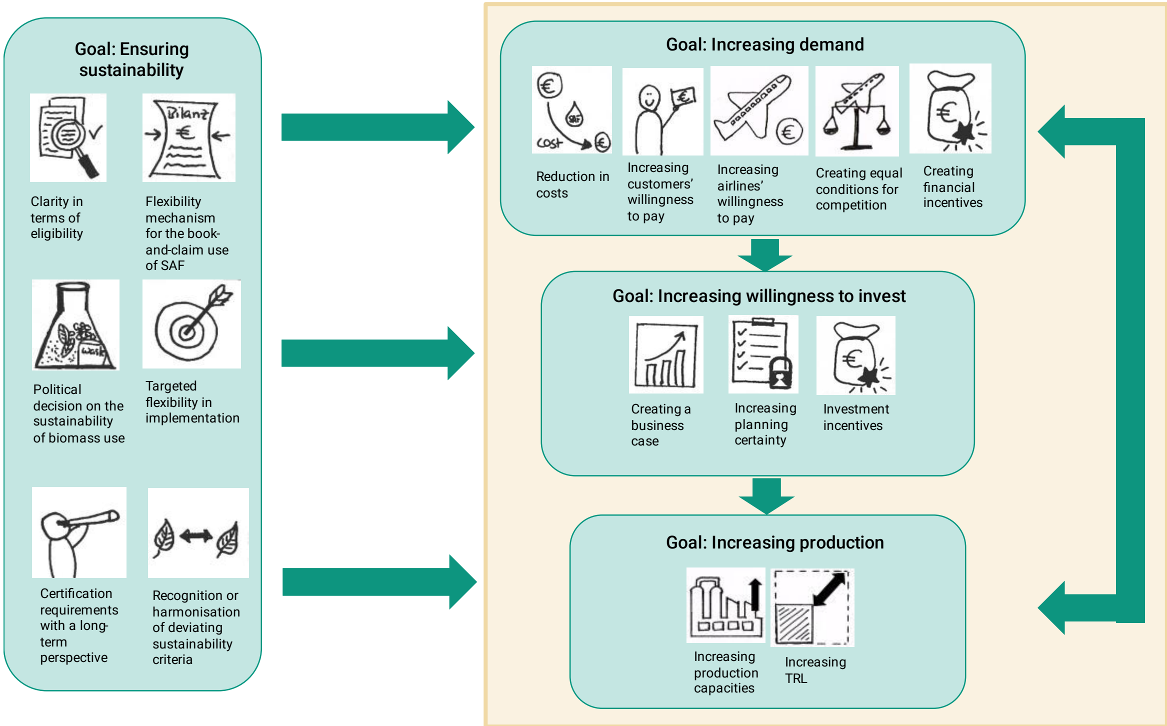


Figure 1: Overview of possible solutions for breaking down obstacles to SAF market ramp-up [own image]

For these four areas, we will now set out solutions that have been developed in the innovation focus "Application in Aviation" as part of the InnoFuels project, which is supported by the Federal Ministry for Digital and Transport (BMDV). These solutions are based on a stakeholder workshop that was carried out in June 2024. The workshop included a discussion of existing solutions that were derived partly in the run-up to the action paper of the SAF working group (AG) of the federal government's Working Group on Climate-Neutral Avi-

[1] For an overview of the different production pathways, see [6].

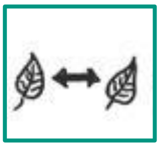
FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

ation (AKKL) [3], as well as new potential solutions. These solutions were then further developed in conjunction with the relevant InnoFuels innovation focuses and supplemented with literature research and expert interviews.

2 Ensuring sustainability

The sustainability of alternative fuels is the key factor in order for such fuels to contribute to more climate-friendly aviation. This encompasses not only the input materials but also the production process. Within the framework of the obstacle analysis,[2] numerous uncertainties were identified in relation to the sustainability of SAF. These obstacles are largely due not only to unclear sustainability criteria (e.g. national differences in permitted biogenic raw materials or eligible sources of CO_2) but also to a lack of clarity regarding the eligibility and book & claim use of SAF. This affects not only biogenic but also power-based SAF. The discussed solutions are therefore aimed primarily at transparent regulation that ensures sustainable production of the fuel but also includes certain scope for flexibility – particularly in the market ramp-up phase.

2.1 Recognition or harmonisation of deviating sustainability criteria



In a global industry, **unified international standards are essential** in order to achieve transparency in terms of sustainability. This relates not only to the end product but also to the input materials because, if these materials are imported, for example, they must meet the sustainability standards of the importing country. However, the criteria according to which SAF is considered sustainable vary from one country and one region to the next. Although uniformly defined sustainability criteria theoretically already exist with the Renewable Energy Directive (RED II and RED III Directives) and ReFuelEU Aviation, some of these criteria lack clarity (particularly because the legal texts are often difficult to read and the calculation of greenhouse gas emissions is complex) and transparency when it comes to their application (above all due to a lack of control mechanisms). Moreover, the **guidelines and definitions outside the EU** deviate strongly

[2] The obstacles to the market ramp-up of SAF were analysed by the innovation focus "Application in Aviation" in a previous report as part of InnoFuels.

Funding Programme Renewable Fuels
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

from these criteria. Action is needed when it comes to working towards uniform international standards, for example with regard to uniform global rules for the use of carbon dioxide (CO_2), particularly in relation to the use of industrial sources [3].

Since aviation is a global market, the aim should be to achieve worldwide **homogenisation of sustainability criteria**, although this is seen as a particularly challenging proposition. In view of national legislation and differences between countries, there is a risk that the homogenisation of sustainability criteria could cause the criteria to be reduced to the lowest common denominator, which could in turn jeopardise the achievement of sustainability goals. Initially, however, the existing standards for the larger markets, such as the EU, the USA and China, must be analysed in order to identify differences in sustainability criteria. Likewise, the International Civil Aviation Organization (ICAO) has already defined sustainability criteria for SAF within the framework of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[3] [4]. A first step towards the recognition or harmonisation of deviating sustainability criteria could therefore be for official bodies to **create a guideline** that explores the objectives, differences in regional regulations, and options for harmonisation.

2.2 Targeted flexibility in implementation

Strict sustainability criteria are fundamental so as not to jeopardise the overarching goal of climate neutrality. In addition, there are strict certification processes (see ASTM D4054 [5]) that must be adhered to in aviation. Nevertheless, it is important to explore whether the market ramp-up of SAF could be accelerated as part of a pragmatic approach if **interim solutions** were also possible or greater use could be made of them, such as the **use of CO_2 from point sources that are difficult or impossible to avoid** or production via **co-processing** (in relation to co-processing, see [6]). Here, in the

[3] See the report "Overview of relevant laws and industry standards for the market ramp-up of sustainable aviation fuels" from the innovation focus "Application in Aviation" as part of the InnoFuels project. [6]

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

interest of sustainability, it is important to ask whether there is not already a way of achieving added value with an interim solution that is, for example, 80% sustainable, instead of waiting for a 100% solution.[4]

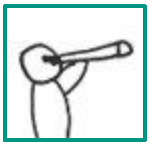
This also raises the question of the sensible long-term use of investment capital. Indeed, **temporary or interim solutions** are not currently envisaged by the EU or regulations in the area of PtL production, as the aim is not to incentivise solutions that are only (relatively) short-term. The aim is to prevent such approaches from becoming a permanent solution, which could jeopardise sustainability in the long term from the perspective of political decision-makers and is the reason for this critical stance. On the other hand, temporary solutions could contribute to the expansion of production capacities.

Apart from regulatory requirements, it is also important to **build acceptance** among air passengers and in society, e.g. in the form of information on the avoidance effect that can actually be achieved in relation to climate-damaging emissions, as well as explanations of why production is more expensive than fossil kerosene and other background information on SAF. In addition to the aforementioned temporary solutions for the extraction of CO_2 and SAF production, this can be demonstrated using the example of hydrogen (H_2) production. Obtaining hydrogen using nuclear power could significantly reduce public acceptance, even though the EU considers nuclear power to be a sustainable source of power under certain conditions. Namely, certain natural-gas and nuclear-power operations are classified as transitional activities that are intended to contribute to climate protection according to the EU taxonomy for sustainable economic activities. These activities are subject to certain prerequisites and are time-limited. For example, new nuclear power plant projects for energy production are recognised as climate-friendly if planning permission is granted before 2045 [7, 8]. Accordingly, the implementation of interim solutions is not fundamentally ruled out, and the example of hydrogen production could serve as an example for the production of PtL products or SAF in the specific application.

4 In addition to the InnoFuels innovation focus “Sustainability”, this topic is also examined in greater detail in the innovation clusters “Market & Regulation” and “Supply Chain”.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

2.3 Certification requirements with a long-term perspective



Stakeholders see the creation of a long-term perspective as a very important, or even the most important, approach to a solution. Without a long-term perspective, investments in PtL facilities carry considerable risk, as it takes a long time to build a new facility (several years, depending on the size). In other words, the framework conditions must be reliable and must offer **grandfathering of current sustainability criteria** in order to safeguard investments. In the learning phase of the market ramp-up, it is possible to modify and further develop (technical) requirements for PtL SAF production, for example in relation to the sourcing of renewable energies or CO_2. This is similarly true of the procurement of the raw gases CO_2 and H_2 on a balance basis. It is currently possible to procure the feed gases on a balance basis via a common feed line. However, this is associated with narrow framework conditions, e.g. due to the fact that the accounting period is limited to three months or a quarter. There is also no certainty that the procurement criteria will not be adjusted again in the coming years. With regard to eligible raw materials, there are still contradictions between the RED II revision and the ReFuelEU Aviation regulation [9]. In order to drive forward investments, grandfathering rights could be considered for initial projects, as many private investors are currently unwilling to bear the risk of financing installations and projects due to the lack of safeguards (see section 4.3) [3].

It is important to note that this is not about watering down existing laws or framework conditions, but rather about creating **rules that can be relied on in the long term**. One example for this is the introduction of E10 petrol in 2010. E10 was introduced in Germany in order to meet the requirements of the EU directive on the reduction of greenhouse gas emissions from fuels [10]. From that point onwards, there was initially a binding requirement that petrol with up to 10 vol% bioethanol had to be offered at petrol stations. Since 2015, however, distributors have only been required to demonstrate the reduction in greenhouse gases [11], i.e. the proportion of biofuels can be lower accordingly. Given that the fuel is offered at a cheaper price than normal (premium) petrol, there is a secure market despite considerable criticism at the time of its introduction.

Funding programme Renewable Fuels
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

2.4 Political decision on the sustainability of biomass use

There is a need not only now but also in the future to **use biomass** to meet the demand for SAF, together with PtL kerosene [1]. In order to expand production capacities and scale up the PtL process chain (see section 5), there is a need for sufficient quantities of H_2 and CO_2 or biomass. The supply of the corresponding quantities of H_2 is tied to the expansion of electrolysis capacity and renewable energies. In terms of biomass, the proportion of raw materials from Germany used for the production of biofuels was 15% in 2023 [12]. This raises the question of where further **sustainable biomass potential** is available that could be used for SAF production. In the EU, decisions regarding the use of sustainable biomass are made based on RED II or its revised version (RED III). However, the list of permitted biomass contained in the directive should be understood in a dynamic sense because there is a continuous need for adjustment to keep up with constant advances in research. Discussions around new, specific and sustainable approaches to the use of biomass revolve, on the one hand, around the further development of existing approaches and, on the other, around new options.

When it comes to the use of biomass or biogenic raw materials, it is important not to disregard the **balancing** of sustainable development goals with social and economic factors. Moreover, strategic decisions on direction can only be taken and consistently implemented at the political level [3]. Uncertainties exist primarily in relation to the sustainability and certification of biogenic SAF as well as the criteria for production, which limit the choice of biogenic starting materials.

Currently available biomass potential

Based on the biomass use defined by RED II, appropriate importance is attached to the **strategic further development of existing approaches**, i.e. specifically to the use of biogenic residues and waste materials from agriculture and forestry. The exploitation of this biomass is also generally associated with the greatest potential in Europe in terms of availability and biomass use. This also applies to Germany, where new sources can still be tapped into (in an economically viable manner). With this in mind, approaches such as innovative conversion processes or synergistic techniques, which are used for the efficient processing or recycling of residues and waste materials, should be further developed to the point of market maturity.[5]

With regard to **new options** or sources of biomass, new possibilities are frequently raised, such as the potential of algae or the use of genetically modified and therefore higher-yield plants for biomass (which is, above all, a topic of research in the USA [13]). In the case of algae, however, despite their considerable potential (algae bind CO_2 from the atmosphere efficiently and contain a high proportion of fatty oils) [14], there are significant challenges when it comes to the production of algae fuels. So far, it has not been possible to achieve large-scale and economically viable production, with one key problem being the high production costs [15, 16]. For these reasons, many companies – including large corporations such as Shell and ExxonMobil – have discontinued their algae fuel projects [17]. One promising solution for improving the profitability of algae production could be the "biorefinery" concept. In addition to biofuels, this would also derive sustainable alternatives for dietary supplements and plastics production – such as omega-3 fatty acids, vitamins, proteins or bioplastics – from algae. This parallel production of multiple products could tap into additional revenue sources, thereby bringing down the cost of production. Here too, however, there remains the challenge of designing efficient and cost-effective processes [15].

Further potential resources result from the use of industrial waste gases or urban waste. Corresponding techniques have been developed primarily in the USA by companies such as LanzaTech/LanzaJet [18, 19, 20].

Moreover, **geographical expansion** could also be considered in order to exploit further biomass by exploring the potential in neighbouring countries, as well as countries beyond the European continent. This is of considerable relevance to Germany, as a highly industrialised country, with a view to potentially importing and processing biomass and re-exporting part of the end products. Corresponding supply chains could be built up. To this end, there is a need to ensure compliance with the sustainability criteria, to include factors such as long transport routes, the associated costs and possible risk factors such as industrial policy and investment security in the corresponding countries, and to sufficiently weigh up the corresponding advantages and disadvantages in terms of an import strategy.

[5] SAF working group, Measure 9

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

Additionally available biomass potential

Lastly, it is also important to consider whether **redistribution** could be used to tap into biomass potential for SAF in the long term, for example by substituting existing production in different sectors with other sources on a long-term basis. One example would be the use of biomass for the production of bioethanol for admixture to E10. In the long term, increasing electrification in the passenger car industry may result in less fuel consumption, thereby releasing biomass potential. This could open up an additional source for the **production of biogenic SAF**, e.g. Alcohol-to-Jet (AtJ) conversion.

Figure 2 shows the energy supply from biomass in Germany in 2021 by biomass category, energy source and sectoral use. In total, the biomass used in that year came to 1,713 petajoules (PJ), covering 10% of German energy demand [21, 22].

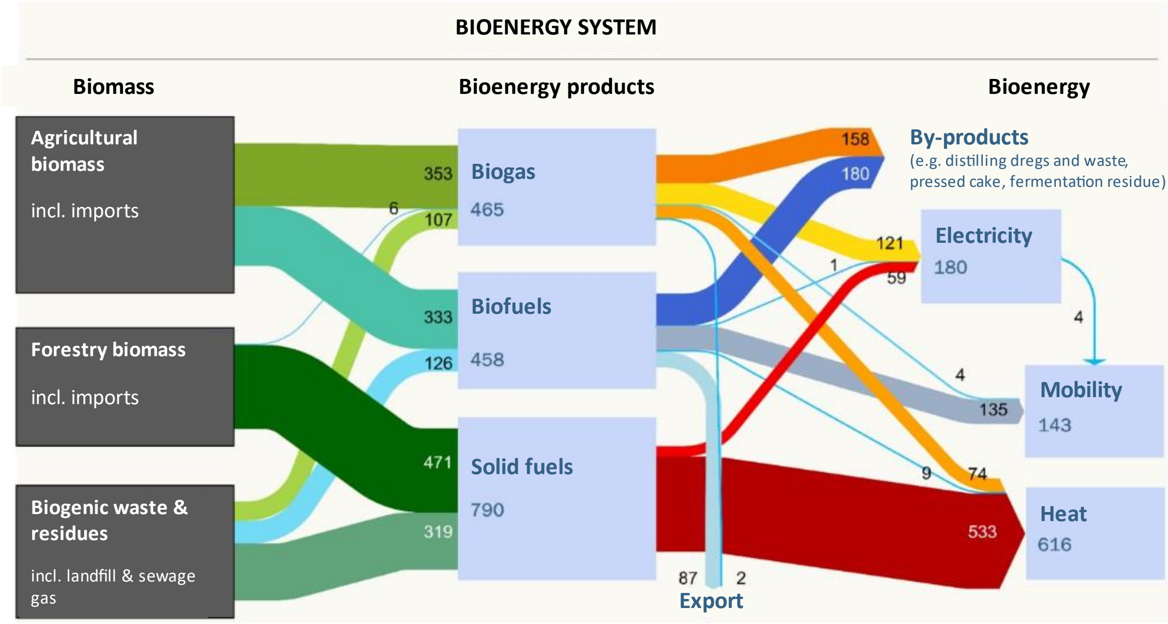


Figure 2: Biomass use for energy in Germany for the year 2021 in petajoules (PJ) [21]

Mobility is the sector with the lowest biomass use and is similar in magnitude to electricity derived from biomass (see Fig. 2). With that in mind, it is also worth considering a shift in the use of biomass not only within the transport sector. The diversion of biomass used in the electricity and heating sector is also conceivable and would be a sensible prospect in the medium to long term. For example, the expiry of support for waste wood under the German Renewable Energy Sources Act (EEG) could potentially make significant quantities available for other energetic or material uses.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

2.5 Clarity in terms of eligibility

Only if there are clear rules on the **eligibility of SAF** for crediting against greenhouse gas reduction targets – and these rules create an incentive for use – will airlines be motivated to use more sustainable fuel and therefore to have a positive impact on the climate footprint. The actual environmental benefits of SAF in the form of CO_2 reduction and, as the case may be, reductions in non-CO_2 effects must be comprehensible and capable of being recorded in full.[6] Verification of SAF use is achieved using "chain of custody" (CoC) systems or tracking tools [23]. Besides the options for complete physical separation of SAF thanks to a separate supply chain or the mass balance system (a shared infrastructure used by various suppliers and customers), the most intensively discussed approach to the creditability of SAF in the aviation sector is currently the "book & claim" system.

Book & claim

A book & claim system can be seen as a **refinement** of the **SAF flexibility mechanism** defined by the European Commission in the ReFuelEU Aviation regulation. With a view to **ensuring the supply of SAF** until production and supply capacities are expanded over the next 10 years, this allows the share of SAF to be distributed flexibly to EU airports. In the interim period, some airports can therefore be supplied with a higher share of SAF, while no or only a small share of the more sustainable fuel is used at other airports [24]. Details of the specific mode of operation and possible implementation of such a mechanism are yet to be provided by the European Commission.[7]

In the case of book & claim, the **crediting of SAF is decoupled from the physical use of the fuel**. Producers, which would also be required to provide evidence of sustainability, would issue certificates in the amount of their production volume, which could then be freely traded. An airline could therefore declare the more sustainable fuel on a book & claim basis if it is not available at the airport or not refuelled directly. Objectives and framework conditions for the development of specific models are already being defined by various initiatives

---

[6] Within the framework of InnoFuels, certification and crediting systems are dealt with primarily in the innovation focus "Sustainability".

[7] 1 July 2024 has been announced as the target date for defining the details.

and institutions [25]. The development of such a mechanism must ensure that Scope 1 and Scope 3[8] are not decoupled from one another when it comes to providing evidence to the regulator. Otherwise, the airline – as the SAF user – would have no way of crediting the emissions reduction.

A pragmatic and flexible book & claim mechanism could support market ramp-up of SAF, as **all users would have access to SAF regardless of their location** and in a logistically efficient manner without the need for additional infrastructure or corresponding transport routes. In turn, this would expand the market potential for producers. However, there are challenges when it comes to designing a broadly applicable model and implementing it in an unbureaucratic manner accordingly. In turn, if various different systems were used, this would increase complexity for the user due to potential regional overlaps.

Smart use of SAF

The decoupling of SAF use through the purchase of certificates from physical use in the aircraft could, in the long term, also pave the way for the concept of the "smart use of SAF". Here, the more sustainable fuel is specifically used on flight routes where an additional reduction of climate impact is to be expected due to the avoidance of non-CO_2 effects [26]. When it comes to launching a book & claim mechanism, however, any new system should not be too complex in design in order to promote general acceptance of its use. Moreover, it would be sensible to adopt a uniform design of such a mechanism across the EU and ideally worldwide.

3 Boosting demand

According to current studies, there will continue to be a large price difference between SAF and conventional kerosene for the foreseeable future. One basic prerequisite for faster market ramp-up and therefore for an effective boosting of demand for SAF – potentially beyond statutory quotas – is the **equal treatment** of domestic EU airlines and non-European competitors **in terms of competition**. So far, the fact that SAF and, in particular, power-based

[8] In accordance with the definition in the Greenhouse Gas Protocol, Scope 1 encompasses a user's direct greenhouse gas emissions (combustion emissions of the fuel in the aircraft), whereas Scope 3 also includes all indirect emissions across the entire value chain.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

PtL fuels will be available neither in sufficient quantities nor at competitively neutral prices for the foreseeable future has often been ignored in regulatory considerations. There is no tangible cost degression in sight. Only through a **holistic strategy** that systematically stimulates SAF ramp-up through competitively neutral measures and that substantially reduces the price of SAF can there be a transition to carbon neutrality in aviation.

In order to effectively boost demand for SAF, targeted measures must be adopted with a view to increasing the availability of SAF at competitive prices. The following examples are intended to clarify how a holistic strategy could be incentivised for a competitively neutral market ramp-up of SAF and what regulatory prerequisites must be established to that end. The examples demonstrate how **regulatory and economic incentives could be effectively combined** in order to sustainably promote the acceptance and use of SAF.

3.1 Creating equal conditions for competition

Differences in international and national SAF quotas can lead to unequal conditions for competition between users. Appropriate measures that are designed to avoid distortions of competition should be adopted to avoid disadvantages for airlines operating in regions of the world and countries with high SAF quotas.

3.1.1 Climate club model

From an economic perspective, a club is a voluntary association of participants who share the costs of production of a common good in order to make shared use of it. The benefits of the club must be sufficiently large, and the members must pay contributions and adhere to the rules of the club. For example, a model for accelerating the market ramp-up of SAF and therefore the design of market regulations for aviation could be designed based on William D. Nordhaus's climate model [27]. Thanks to international cooperation and unified standards, an "aviation climate club" for the SAF market ramp-up could help to minimise competitive disadvantages in European and global aviation, which arise due to different regulatory prerequisites for the use of SAF depending on the world region in question. A model of this kind should aim for carbon-neutral air transport in compliance with the Paris

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

Agreement, operate according to corresponding sustainability criteria, ensure fair conditions for competition, and allow for technological openness in implementation. [9]

Coordinated measures for the promotion of SAF, as well as targeted economic incentives, could accelerate market penetration and effectively support the transition to carbon neutrality in air transport. The use of SAF could be harmonised and scaled up worldwide if the climate club were to focus on technological innovation and protecting competition. The transformation could also become independent through self-financing of the industry, e.g. by dedicated use of funding from the EU ETS for aviation. A corresponding model approach is being developed in the InnoFuels project as part of a separate study.

3.1.2 End goal-oriented climate levy

Another lever for effectively driving the scaling and use of sustainable aviation fuels and therefore for achieving the target of carbon neutrality in air transport by mid-century would be the introduction of an EU climate protection levy. This passenger and final destination-based levy would be applied equally to all airlines, and the revenue would be earmarked for the SAF market ramp-up. The prerequisite for this kind of **cost-neutral solution to creating a self-supporting market** for SAF and a global level playing field would be that all existing national aviation levies in EU air transport were brought together within a single levy. The end goal-oriented climate levy would be based on the emissions for the specific flight destinations and would therefore effectively contribute to the reduction of CO_2 emissions and, at the same time, to increased demand for SAF [28].

By analogy to the German aviation tax, the amount of the levy could be based on the distance to the destination airport (competitively neutral) and would be defined on an annual basis such that the total revenue covered the procurement of the SAF that was required from a regulatory perspective. Ultimately, the SAF procured in this way could be put into circulation in the EU at the price of conventional aviation fuel, which would effectively boost demand for SAF – potentially beyond the statutory requirements.

Given that a climate protection levy serves a specific fiscal purpose, its introduction would be permissible under European law in accordance with Art. 100(2) of the Treaty on the

[9] In the InnoFuels innovation focus “Application in Aviation”, a model of this kind is being developed within the framework of a separately commissioned study.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

Functioning of the European Union (TFEU) and possible in the event of unanimity in the European Council.

3.1.3 Binding environmental and climate protection standards in air transport agreements

Another targeted measure to boost demand for sustainable aviation fuels is the implementation of unified, binding environmental and climate protection standards in bilateral and multilateral air transport agreements (see section 2.1). If Germany and the European Union were to ensure compliance with European SAF requirements (ReFuelEU Aviation quotas) both in the revision of existing and the negotiation of future air transport agreements, this would not only create a global level playing field but also, above all, significantly bolster demand for and production of SAF at the international level. For example, with a view to increasing SAF use, Singapore is planning to introduce mandatory refuelling of 1% SAF for departing flights from 2026, and this is to be increased to 3–5% by 2030 [29, 30]. These quotas are, however, below the European levels.

3.2 Creating financial incentives

With a view to promoting the use of SAF, targeted financial incentives should be created in order to cushion the additional costs for the more climate-friendly fuel. This could be achieved via tax advantages or fee reductions or through the expansion of SAF allowances/Fuels Eligible for ETS Support (FEETS).

3.2.1 Tax advantages

Until the introduction of a Europe-wide, harmonised, competitively neutral levy system for the effective scaling of SAF in Europe, **existing fiscal levers** – particularly at the national level – could be used and targeted at the production and use of SAF. In Germany, this relates primarily to the national aviation tax, which was introduced by the German Aviation Tax Act (LuftVStG) on 1 January 2011 and, until 2024, runs to between €15.53 and €70.83 per flight depending on the distance to the destination airport [31, 32, 33].

The principle of the efficient use of funds for the decarbonisation of air transport is also expressly recognised by the legislature: the federal government's coalition agreement for 2021–2025 [34] set out plans to use the revenue from the aviation tax to promote carbon-neutral, power-based aviation fuels. The redesignation of this tax revenue was intended to

Funding Programme Renewable Fuels
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

support the market ramp-up of SAF by investing the revenue in R&D projects for the production and use of sustainable aviation fuels. This was with a view to making the production of SAF more attractive – particularly in the critical phase of market ramp-up – and to accelerate scaling, thereby boosting availability and cost-efficiency on a long-term basis. Despite the express commitment in the coalition agreement, an unplanned increase in aviation tax deprived the airlines of further capital, which could have been used for investment in fleet replacement and sustainable fuels. If the tax revenue raised by the industry could be used for scaling SAF as planned, this would represent an important contribution to achieving the climate goals in air transport.

A look at the USA shows that it could lead the way with its funding policy for alternative aviation fuels. The Biden government has introduced **tax credits** in order to promote the development and use of these fuels. These credits start at USD 1.25 per gallon of SAF that achieves a 50% reduction in greenhouse gas emissions relative to fossil kerosene. For each additional reduction by 1 percentage point, an additional cent is paid – albeit up to a maximum of USD 1.75 per gallon. This measure, which is part of the Inflation Reduction Act (IRA), is aimed at annual production of 3 billion gallons of SAF by 2030 and a 20% reduction of CO_2 emissions from air transport [35]. It is currently impossible to assess whether these rules will be abolished again by the new American administration, as announced before the election, or will endure.

3.2.2 Advantages in terms of fees and charges

The creation of financial incentives for sustainable aviation fuel by means of fee reductions or the fanning out of charges is a key method for promoting the introduction of SAF. Airports and governments can introduce special programmes that subsidise the use of SAF and therefore reduce the economic hurdles for airlines. One example of such initiatives is the SAF Incentive Programme at Heathrow Airport (London), which covers up to 50% of the additional costs of SAF. Heathrow is seeking to triple the share of SAF at the airport. Other airports such as Schiphol (Amsterdam) and Arlanda (Stockholm) offer similar incentives. For example, Schiphol provides subsidies of €500 per tonne for bio-based SAF and €1,000 per tonne for PtL SAF, so that synthetic fuel is available and the costs for airlines are reduced [36].

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

A holistic approach to defining an SAF strategy should not only take account of these initiatives of individual airports but also emphasise the need to establish coordinated and regulatory objectives. Unilateral airport initiatives have the disadvantage of distorting competition in Europe. On the other hand, binding regulatory objectives developed in collaboration with airlines, such as harmonised EU-wide implementation of ReFuelEU Aviation and supporting efficiency measures, such as a book & claim system, could reduce logistics costs and emissions and simplify the provision of evidence [37].

A combination of airport and government incentives, as well as a coordinated regulatory strategy, could decisively spur on the market ramp-up of SAF.

3.2.3 Expansion of FEETS/SAF allowances

"FEETS" – that is Fuels Eligible for ETS Support (formerly known as SAF allowances) – offer financial incentives to airlines to increase the use of SAF by compensating for the price difference relative to conventional kerosene, partly through the purchase of free certificates. This mechanism, which is enshrined in the 2023 revision of the EU ETS Directive [38], varies depending on the type of SAF used and the refuelling location. For example, the compensation levels range from 50% for non-fossil kerosene, 70% for advanced biofuels and 95% for PtL to up to 100% for the purchase of SAF on islands. The European Aviation Safety Agency (EASA) is currently tasked with determining and defining the price difference between conventional kerosene and SAF [39, 40].

At a market price of approximately €2,800 per tonne (t) for biogenic SAF (production costs: €1,800/t [39]) and an assumed future price of €4,500 per tonne for PtL kerosene, the additional costs relative to fossil kerosene, which is around €820/t [39], are significantly reduced, as shown in Figure 3.

In terms of the price of PtL kerosene, it is currently only possible to make theoretical forecasts based on production costs. These costs vary depending on the literature source or scenario due to the chosen allocation methods, the technologies, and the raw material and staffing costs, which differ from one location or production country to another. According to EASA, the production costs for PtL kerosene in 2023 ran to €6,600–8,700/t [39]. The study by Andreas Meurer et al. [41] estimates the current costs in the baseline scenario as being slightly lower at €4,000–7,700/t.

However, long-term forecasts point to more favourable developments: Stefan Bube et al. [42] assume that the production costs for synthetic kerosene could be around €3,500–

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

5,500/t in the coming years. At the same time, the lowest costs can be achieved if account is also taken of the sale of by-products such as diesel and naphtha. The estimates of Andreas Meurer et al. [41] are even more optimistic, with expected production costs of €1,900–3,500/t for the year 2050. Although upscaling of production is likely, it is not currently foreseeable that this will cause the price to reach or even fall below the €3,500/t threshold in the near future. This results in the above assumption of a price of €4,500/t for PtL kerosene.

An extension of FEETS beyond 2030, as well as an increase in the available quantity, would be key levers for supporting air transport with the transition to carbon neutrality by 2050. The targeted promotion of SAF through financial incentives seems indispensable in order to mobilise the necessary investments in the production and use of SAF and to sustainably reduce emissions in air transport.

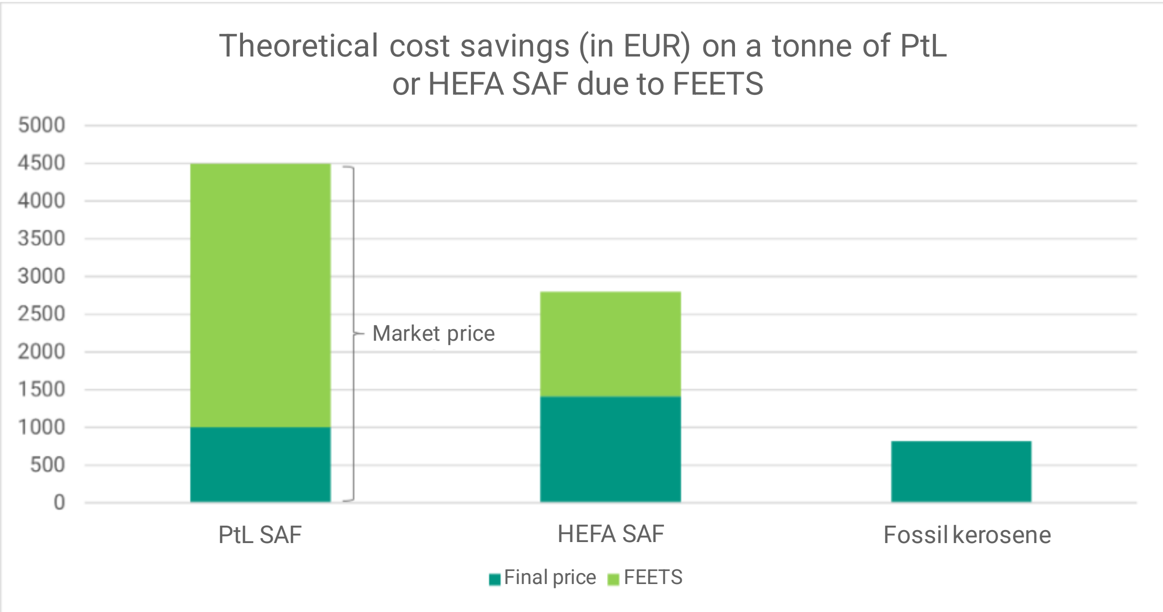


Figure 3: Cost savings (in EUR) on a tonne of PtL or HEFA SAF (advanced biofuels) due to the possible receipt of FEETS (formerly SAF allowances); total bars indicate the respective market price, incl. SAF allowances in light green and the final price in dark green [own graph]

The national implementation of the EU ETS 1 through the amendment of the Greenhouse Gas Emissions Trading Act (TEHG) envisages the provision of FEETS only in the reduced scope ("intra-EU"). This applies to all flights with both their origin and destination in the European Economic Area (EEA), as well as flights from the EEA to Switzerland and the UK based on existing agreements. The application for FEETS is made via the emissions report

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

from the reporting year 2024 onwards. The International Air Transport Association (IATA) emphasises the significance of such measures. Through greater support and an improved incentive system, Germany could lead the way on the introduction of SAF in air transport and make a key contribution to achieving the climate goals [43, 44].

3.3 Increasing customers' willingness to pay

At the end of the value chain, significantly higher fuel costs due to the use of SAF will also impact ticket prices for passengers or transport costs in airfreight. Here, depending on the customer segment, there is the possibility of adopting targeted measures in order to boost customers' willingness to pay for the resulting additional costs. Individual incentives can be particularly effective in the case of passengers, while regulatory requirements are particularly relevant to corporate customers (business travel, airfreight). In relation to private aircraft, regulatory measures could also be particularly effective in promoting the use of SAF.

3.3.1 Commitment to carbon-neutral business travel

Companies that make their business travel carbon-neutral rely on either sustainable technologies or offsetting. By giving preference to SAF or integrating it into their travel guidelines, companies create demand for more environmentally friendly fuel. The World Economic Forum emphasises that although the establishment of a successful SAF market requires bulk buyers such as airlines, the demand for SAF can also be boosted by business travellers from companies [45].

One key driver of the increased use of SAF in the corporate context is the Corporate Sustainability Reporting Directive (CSRD), which obliges companies to portray their greenhouse gas emissions transparently and to actively reduce them across the entire value chain. Here, the focus is particularly on the indirect Scope 3 emissions, which include business travel by plane [46].

This approach is complemented by offsetting, with compensation for the remaining CO_2 emissions through investments in climate protection projects. The combination of SAF and offsetting can further boost demand for SAF if companies use SAF as a key element of their emission reduction strategy for air travel. The Gold Standard organisation emphasises that this commitment contributes to the offsetting of emissions and the use of SAF to promote market development and availability of sustainable fuels [47]. Through travel guidelines that favour environmentally friendly tariffs, companies strengthen this effect by creating financial incentives for the aviation industry to invest more in SAF [48].

3.3.2 Use of SAF in airfreight

The use of SAF is also becoming increasingly important in airfreight. As with business travel, airfreight transport also falls into the category of companies' indirect emissions (Scope 3), which must be disclosed and reduced within the framework of the CSRD [46]. As airfreight makes a significant contribution to these emissions in many sectors, the use of SAF here represents an opportunity to reduce emissions and document them transparently in sustainability reporting.

Accordingly, logistics providers and airlines now offer SAF-based transport solutions specifically for their freight customers, for example in the form of SAF surcharges. Customers that book these sustainable options then receive corresponding certificates that can be used within the framework of CSRD reporting for Scope 3 emissions [49, 50]. In airfreight, SAF therefore represents a concrete option for meeting the increasing requirements for sustainable and verifiable emissions reporting.

The willingness to pay for SAF in airfreight is therefore shaped less by individual conviction and rather, primarily, by regulatory necessities and corporate sustainability strategies.

3.3.3 Regulatory requirements for business jets/private jets

The discussion around the obligatory exclusive use of SAF for business jets highlights important regulatory and environmental questions. Business jets have a higher environmental impact per passenger but are currently exempted from, among other things, environmental levies such as the EU ETS 1 and are not taken into account in relation to SAF from a regulatory perspective. However, this segment of air transport could also become considerably more environmentally friendly due to SAF, which produces significantly lower CO_2 emissions than conventional kerosene, and could promote market ramp-up through corresponding demand. The European umbrella organisation of NGOs in the transport sector, Transport & Environment (T&E), emphasises that additional funds could be generated through the corresponding measures, which are aimed at affluent passengers using private jets. In turn, these funds could be invested in the promotion of PtL SAF in order to promote

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

SAF in aviation. For example, this could be achieved through a levy on private jets per flight [51].

3.3.4 Sales incentives for customers

In sectors such as the food or fashion industry, too, the more sustainable purchase option generally comes at a higher price. The section of consumers that attach value to sustainable products are prepared to pay this price because, for them, the end product promises benefits in terms of sustainability. In air transport, too, this raises the question of what incentives could be offered to passengers so that as many of them as possible make a contribution to sustainable aviation through their buying decision. This topic was explored by Frankfurt University of Applied Sciences as part of the “CompIncent” project [52][10] with a view to developing innovative incentive measures aimed at motivating air passengers to voluntarily bear the additional costs of SAF. According to a survey carried out with 1,208 participants as part of the project, it emerged that 51.2% of participants would not be prepared to pay a voluntary surcharge for a flight that demonstrably gave rise to less or no CO_2. In response to whether certain incentives could, on the other hand, motivate them to pay a surcharge, 45% of respondents answered in the affirmative. Most commonly, participants could be motivated to pay a surcharge on the flight ticket by add-ons such as a free change, the use of a “green lounge” or priority check-in. According to the results of the CompIncent project, other incentive mechanisms may lie in the areas of appreciation (e.g. gift on the plane, free coffee at the airport), information policy with respect to the end customer (CO_2 emissions, possibilities for CO_2 reduction) and visibility (green boarding pass, recognition at the airport and on board).

The design of an incentive system and the associated ticket prices should take account of the corresponding customer segment. A passenger in business class or first class generates higher CO_2 emissions per capita than a passenger in economy due to the greater space requirements. Accounting for this relationship in the additional costs for SAF as part of the air fare would allow the burden to be distributed more equitably.

[10] The project is funded by the State of Hesse and the House of Logistics and Mobility (HOLM) as part of the “Innovation in Logistics and Mobility” measure of the Hessian Ministry of Economics, Energy, Transport and Housing.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

3.4 Increasing airlines' willingness to pay

In addition to measures to boost willingness to pay in the different customer segments, it is also important to consider such measures with respect to airlines. For example, this could take the form of corresponding financial management – or, from a technical perspective, the marketing of the additional advantages of using SAF.

3.4.1 Financial management

Effective financial management is vital in order to boost demand for SAF. One option here are wholesale cooperatives that bundle demand from multiple airlines and negotiate with SAF producers as a single block. This bundling improves pricing conditions and stabilises deliveries, contributing to a market ramp-up of SAF [53]. Equally important are specialised procurement organisations that focus on long-term contracts and the logistics infrastructure to ensure a reliable supply of SAF.

However, these measures must be reviewed from a legal point of view, particularly in relation to anti-trust law. Wholesale cooperatives and procurement organisations could potentially influence competition, and careful planning is therefore needed in order to minimise legal risks and ensure compliance with competition rules. A procurement organisation of this kind could, for example, also be part of an aviation climate club (see section 3.1.1).

The SAF working group's catalogue of measures, which was developed within the framework of the federal government's Working Group on Climate-Neutral Aviation, underlines the need for initiatives of this kind in order to support the market ramp-up of SAF. The measures set out in this catalogue support the creation of efficient procurement structures and the pooling of demand as a central lever for boosting SAF demand and scaling up the market [3].

3.4.2 Marketing of additional advantages/benefits of SAF

The additional advantages of using SAF can be leveraged in successful marketing. To avoid concerns around greenwashing and to promote acceptance, this communication should clarify the environmental impact on a factual basis. In addition to the reduction in net CO_2 emissions, the use of SAF also reduces "non-CO_2 effects", which include all emissions that

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

also contribute to global warming. Particularly worthy of mention here is the particle-induced formation of vapour trails [54, 55].

Due to the altered composition of, above all, aromatic-free SAF in comparison with fossil kerosene, the jet exhaust trail contains significantly less – or hardly any – soot particles. Accordingly, this not only reduces the non-CO_2 effects, but also allows for more complete – and therefore cleaner – combustion overall, resulting in less wear in the engines and greater combustion efficiency.

These advantages are greater the higher the proportion of SAF used in refuelling. Based on the existing logistics and pipeline infrastructure at the airports, refuelling is only possible with separate refuelling logistics – even in the case of an already approved 50% mixture. In general, SAF is fed in via the existing infrastructure, e.g. NATO's Central Europe Pipeline System, where it is mixed with pure fossil kerosene. The effort involved in refuelling with 100% SAF would be much greater if this could only be used in aircraft approved by the manufacturers.

4 Increasing willingness to invest

The insufficient willingness to invest in production facilities for sustainable aviation fuels can be attributed to, in particular, the low expected return, the high risk of not achieving production and sale of the certified product, and difficulties in acquiring financial capital. To boost willingness to invest, there is therefore a need for a stable business class, planning certainty and, among other things, government investment incentives. This section sets out how these aspects can boost the attractiveness of investments in SAF facilities.

4.1 Business case for investment in SAF facilities

A business case encompasses all relevant factors that lead to a decision on implementing a project. An investment is only made if the sum of all relevant factors and their impacts is positive. As part of this process, opportunities and risks are weighed up against one another and evaluated. This is a good way of assessing the effectiveness of measures and solutions. It is important to create or boost opportunities and to minimise or rule out risks as far as possible.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

4.1.1 Creating a market and a marketable product

Most of the measures aimed at creating new opportunities are market-oriented. The market for SAF is made up of air transport with its various market segments. SAF is currently a cost-intensive product that offers little or no direct added value relative to conventional kerosene. The essential added value lies in the significant reduction of fossil greenhouse gases and their effects. So far, however, barely any – almost negligible – account has been taken of these effects when calculating the costs of using fossil kerosene. Worldwide, there is still no established mechanism for the consideration of these effects.

For example, at an EU ETS CO_2 price of €70[11] per tonne of CO_2, the additional costs per tonne of kerosene are around €220.[12] At a price of around €820 per tonne of fossil kerosene, the total costs are around €1,040 per tonne and therefore still far below the price of SAF, which is significantly higher at around €2,800 in the case of HEFA SAF and at an assumed future price of approx. €4,500 in the case of PtL SAF (in relation to the market price of SAF, and particularly the derivation of the PtL price, see section 3.2.3). For offsetting under CORSIA,[13] the additional cost would instead only be around €60 per tonne of fuel, i.e. the costs for fossil kerosene would then be €880 [36]. In the event of failure to meet the ReFuelEU SAF quota, on the other hand, the assumed prices result in penalties of at least €3,960 or €7,360 per tonne (see Figure 4) for distributors, which are calculated as follows [56]:

2 x (price/t of SAF – price/t of fossil kerosene) x SAF shortfall = penalty

2 x (€2,800/t – €820/t) x SAF shortfall = €3,960/t minimum penalty for HEFA SAF

2 x (€4,500/t – €820/t) x SAF shortfall = €7,360/t minimum penalty for PtL SAF

For airlines, the penalty should be at least double the average market price of kerosene. Airports are also subject to other penalties, which are to be defined by the Member States [56]. However, the penalties only apply to the very small part initially covered by the quotas (EU admixture quota from 2025 onwards: 2% SAF).

---

11 The average price for emissions allowances in the EU ETS was €65 in 2024 and €83.66 in 2023 [66].

12 Combustion of a tonne of kerosene releases approx. 3.16 tonnes of CO_2. As of reporting year 2024, the German Emissions Trading Authority (DEHSt) considers this value to be the emission factor for Jet A and Jet A1 jet kerosene [66].

13 For an overview of CORSIA, see [6].

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

In addition, it should be noted that, with regard to the national PtL quota in Germany (BImSchG), which is to be abolished in favour of the EU quotas in any case, the penalty of some €3,000 per tonne envisaged in this context cannot have a steering effect in light of the previously assumed production costs of €4,500. In that case, the abatement costs would be less than the production costs.

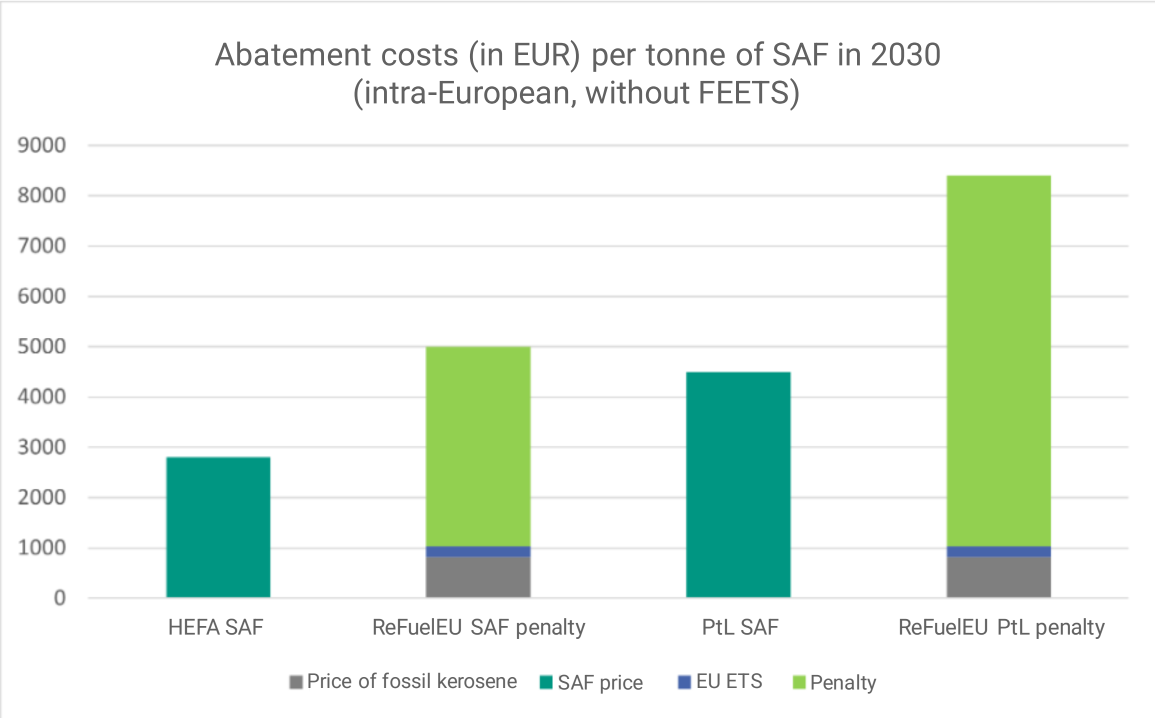


Figure 4: Abatement costs per tonne of SAF in the EU without taking account of FEETS (formerly SAF allowances); note: the price of PtL SAF, at €4,500, is an assumed future market price based on various studies (see section 3.2.3) [own graph]

As the share covered by the quotas and therefore the penalties is initially very small, no market for SAF will develop due to the penalisation instrument alone. It is therefore necessary to actively create this market via an appropriate framework.

The first and most important measure to increase market opportunities is the **definition of an attractive market with critical mass and growth potential for SAF**, steady customers, high stability and predictable rules of the game. The critical mass and growth potential already exist. Indeed, the market for fossil kerosene is large and is likely to keep growing: in 2019, approx. 48 million tonnes of fossil kerosene were used for refuelling in Europe [57]. At a price of approx. €620 per tonne in 2019 [58], this corresponded to a fossil market volume of around €30 billion. Even with stagnating consumption, this market will continue to

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

grow due to the higher prices for SAF. However, steady customers, high stability and predictable rules of the game are not present in the market.

Moreover, for investors, rising demand and a marketable product are indispensable. Given that demand does not arise automatically, in light of the high prices for SAF, it must first be created. In principle, this can be achieved directly by means of quotas, with sanctions in the event of failure to comply. Alternatively, it could also be achieved indirectly via a defined withdrawal from fossil kerosene. The marketable product is also defined externally: it must meet technical requirements for use in aviation (e.g. Jet A1 quality) as well as sustainability criteria stipulated by policymakers. Here, opportunities can be created and can serve as a framework for applying less stringent criteria to initial products and their production (e.g. playgrounds, regulatory sandboxes) than at a later stage. Moreover, the product must be recognised as SAF in order to be identified as such in the carbon pricing systems.

4.1.2 Competitive production

Companies or financial backers invest in a (future) state-of-the-art solution such as PtL in the hope that it will bring them competitive advantages or a good return. However, the investment costs are extremely high for SAF, at over €6,500 per tonne of production capacity [59]. In order to finance these investments, it is vital to ensure **access to affordable capital**. This is where **venture capital** comes in. Assuming that an investment in an SAF facility were risk-free, the expected profit from the aforementioned investments would be approx. €150 per tonne. At an average dividend rate, it would be over €600, and in the case of high-risk investments, it would be over €1,000.[14]

There is also a need for **favourable location costs and favourable factor costs** for the raw/input materials (deionised water or H_2, CO_2, renewable energy). The production of a tonne of PtL requires approx. 25,000 kWh of power and approx. 3.5 tonnes of CO_2.[15] Another key factor for investors is how soon the project can be implemented. Here, in terms of timing, it is particularly important to consider factors such as licensing procedures, procurement processes, preparation of contracts and delivery times with technology providers, as

[14] Risk-free investment in German government securities: 2.5%; average MSCI World returns: 9.2%; returns on risky investments: 20%

[15] Energy content of 1 tonne of kerosene: approx. 12,500 kWh; stoichiometric CO_2 effect: 3.15

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

well as construction site preparation. With faster processes, investors can hope for better sales potential and generate revenue faster.

The complexity of a business plan and the influence of the individual elements highlight the **need to develop an exemplary business case** together with industry stakeholders and to use this as a basis for deriving effective measures and their leverage effects. The next section sets out the key measures that are relevant from an investor's point of view in order to boost the attractiveness and solidity of an investment in an SAF production facility.

4.2 Potential-boosting measures as investment incentives

With regard to sales, there are various options that increase both sales security and the lucrativeness of the price. An indirect increase in the costs of the competing product fossil kerosene could be achieved through tax differentiation or successive increases in the price of airline-specific certificates in the EU ETS. Another option would be to apply a **swap model in order to reduce the prices of SAF, initially to a reference price**, and therefore to increase the sales potential of the first production runs. This could be done in the context of calls for tenders or via a contract for difference (CfD).

To boost the sales potential in relation to corporate customers, one option would be to **incorporate the business flyer segment within general aviation in the EU ETS** or to make **flights without SAF no longer tax-deductible**. In addition, government bodies (e.g. business travel of members of federal government institutions, official air fleet of the Federal Armed Forces) could lead the way and purchase SAF for their own use. Here, pricing could be based on cost price.

In order to improve returns on investment on the cost side, incentive measures are conceivable in the area of CAPEX (investment grants) or OPEX (price and usage guarantees for renewable energy, CO_2 and feedstock). In the style of the Inflation Reduction Act (IRA) in the USA, **tax credits** could be granted, **e.g. with respect to aviation tax, for achieving CO_2 reductions with SAF** relative to fossil kerosene (see section 3.2). These credits could be applied both to the producer and to the purchasing airline.

Besides the direct financial measures, however, there are other supporting elements. For example, the acquisition of funding sources can be facilitated through "**investor conferences**" – events that offer banks and venture capital providers the opportunity to enter into dialogue with potential producers and political representatives and to discuss projects, as

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

well as their implementation. The advantage of such conferences is that they support the partners when it comes to representing the complexity of SAF production and marketing in a comprehensible manner.

The implementation of the auctioning procedure and the application of a swap model, as well as the implementation of subsidies or hedging (see below), among other things, would require the **establishment of a transformation financing system (TFS)**. This system defines and coordinates how capital inflows, for example from state sources or levies, interact with capital outflows in subsidies, investments or price mechanisms (CfD, swap, price guarantees).

Another key factor is the **acceleration of planning and licensing procedures**. The construction of liquid gas terminals in 2022 has shown that even large-scale projects can be approved very quickly. This has an immediate positive impact on revenue generation and therefore on the profitability of the investment.

4.3 Risk-mitigation measures for greater planning certainty

Reducing risks in the business case leads to an increase in a facility's bankability. Technological risks can be minimised through a diversified portfolio strategy based on investment in different technologies. However, the **greatest risks for investors are of a regulatory nature**, as the rules of the game can be changed in this regard. In particular, investment decisions are hampered by the fear of potential regulatory changes following an FID or during the operating phase of at least 10–15 years with high OPEX. This particularly affects areas that directly impact production costs or the marketability of products until the facility is amortised, e.g. changes in permitted raw materials, framework conditions for the sourcing of green energy, quotas, penalties, CO_2 reduction targets, etc. These **affect the entire portfolio** and therefore increase the risk for investments in SAF as a whole. Whereas, depending on its implementation, the force majeure clause of ReFuelEU Aviation [60] can reduce the risk of penalties for airlines and distributors, it increases the risk for investors. Likewise, although the requirement that the "review" clause of ReFuelEU Aviation be used to reduce competitive disadvantages addresses key issues in the aviation industry, this clause simultaneously increases the investment risks for SAF production facilities for as long as it remains unclear whether and in what form the requirements of ReFuelEU Aviation will be implemented. This can mean that investments are abstained from or delayed, which stakeholders have identified as a key obstacle.

Stability in regulation is therefore the key factor for success. This stability could be facilitated through **grandfathering rights**, although that would require amendments to European legislation. A purely national solution would not be compatible with EU law. Moreover, the instrument can only cover such regulatory risks as arise due to changes in sustainability criteria or the nature of fuels. For example, it would be stipulated that projects realised within a certain period of time could engage in production in accordance with the applicable rules at the time of their approval until the end of their technical life (20–30 years) and market the products as SAF.

If the regulation were changed, e.g. by postponing the admixture quotas, this would result in revenue and cost risks for producers. Other instruments are needed to mitigate these risks. In relation to financing, one option is to **mitigate risk through price guarantees on sales** of SAF or the procurement of raw materials and energy. These measures could be financed from government resources or from a transformation fund as part of the aforementioned TFS. Particularly in the case of "first-of-its-kind" facilities, **risks can be mitigated through subordinated loans or state guarantees**. These measures also facilitate access to private capital, so that the financing could be secured.

Moreover, the clear presentation of regulations could help to alleviate risks in planning and execution. Simple options include the creation of a handbook or toolbox or the establishment of advisory bodies, for which projects like InnoFuels could act as an initiator or provide start-up assistance. Furthermore, an integrated and coordinated approach by the participating licensing authorities could significantly accelerate the procedure when it comes to building corresponding facilities.

5 Increasing production

The increase in the production capacity of PtL facilities is one of the most important levers when it comes to supplying more SAF and thereby accelerating market ramp-up. To this end, several prerequisites must be met:

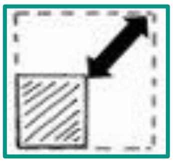
- increase in technology readiness level (TRL)

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

- safeguarding of financing
- clear regulations for production and use
- location-specific factors
- supply of the necessary raw materials

The biggest obstacles are currently seen as being the lack of investment security or safeguarding of financing, as well as the uncertain availability of starting materials (H_2, CO_2, biomass), which is primarily due to regulatory requirements that lack clarity in some regards. Resolving these obstacles could result in a significant ramp-up in production capacities. The above conditions are explained in greater detail below. For the availability of raw materials, please refer to section 2.

5.1 Increasing technology readiness level (TRL)



One key prerequisite for the build-up and expansion of production capacities for SAF is the full development, demonstration and establishment of corresponding technologies. Whereas biogenic SAF based on vegetable oils and carbohydrates (e.g. sugar, starch and lignocellulose) is already well developed (e.g. AtJ or HEFA SPK), the technology readiness level for the production of synthetic SAF via Fischer–Tropsch or methanol/dimethyl ester synthesis is not yet sufficient for commercial implementation. It should be noted that the use of renewable aviation fuel has so far focused primarily on admixture. The long-term aim is to develop pure (100%) SAF, which must fully meet the requirements in terms of infrastructure, engine technology, etc.

One challenge when it comes to evaluating development stages is that similar **developments** are (or can be) assessed **with different TRLs**, as these usually stem from an individual assessment by the developers themselves or are carried out by others according to different criteria. The definitions for the TRL scale, originally developed by the National Aeronautics and Space Administration (NASA) [61], have been applied analogously to the assessment of the development of other processes, including, for example, by the EU as part of their support measures, within the federal government’s current Energy Research Framework Programme, or by project sponsors [62]. A classification for the development of process routes for fuel production can be found in DBFZ Report 44 [63], although there is no common definition. To this end, the InnoFuels innovation focus “Production” aims to develop **uniform criteria** that can be used to assess the TRL for a specific development. In addition, process chains for the production of renewable aviation fuels generally comprise a whole series of individual processes with different development stages. The overall stage of development is then generally derived in different ways. With that in mind, a recommendation is also being developed for the TRL assessment of composite process chains.

Research and development to increase TRL

One approach to increasing the TRL of technologies is to **pool research and development** (R&D) in this area, for example by building test and pilot facilities (TRL 5–7) in consortia with an appropriate composition. Particularly in the precompetitive phase of process development, the coordinated intensification of collaboration is desirable in order to map processes across the entire value chain and to promote interdisciplinary collaboration, as well as the resulting synergies. This could be supported by corresponding **promotion of research and development**, on which research is always dependent, particularly in the case of work aimed at increasing the TRL. The suspension or complete cessation of funding, as occurred at the end of 2023, is diametrically opposed to the desire for timely implementation. Experience in recent years shows that R&D funding cannot be limited solely to the cost of building test facilities. Particularly in the case of semi-technical and pilot facilities of TRL 5 or above, experience shows that, following initial commissioning, it takes a long time for the functioning, operation and product quality to meet expectations. This also calls for well-trained staff for a period of more than three years, which must be **funded beyond the construction phase**.

Like industry, research is also dependent on derisking. For example, this could involve projects or pilot facilities receiving funding over a period ranging from several years (> 3) to decades. It would also be possible to create a business case via **lighthouse projects**. This would provide industry partners with greater certainty to invest in research as well. In addition to a long-term perspective for a business model in the respective market segment, there is a need for measures to compensate for the relatively high production costs at this stage of development with a view to incentivising investment. If this is done for sufficiently long periods of time, industry partners are given additional impetus to commit and invest more intensively in the research phase. Here, it is important not only to focus on the production of PtL SAF but also to take account of further PtL products during development, particularly with regard to the FT route. For technical reasons, the FT product spectrum includes not only SAF but also PtL naphtha and/or diesel as unavoidable by-products (coproducts). When it comes to investments in research by industry, this should therefore

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

also be made attractive to other stakeholder groups (e.g. the chemical industry as a possible buyer of naphtha or shipping as a possible buyer of diesel). After all, it is also clear that targeted research is essential in order to support the raising of the TRL and therefore the upscaling of production capacities.

In terms of development time and the necessary effort or expenditure (including financially, in terms of staffing, and methodologically), it makes a difference

- whether a process development to increase the TRL follows the classical approach of **scaling up via various sizes of facility** (semi-technical → pilot → demo → production), each with a greater production capacity, or
- whether the same production capacity, spatially distributed according to demand, is achieved with a greater number of small-scale modular facilities that can be brought to commercial maturity within a shorter development time (**numbering up**).

Each case requires the development of corresponding production capacity for their manufacturing and the associated feedstock and product logistics, which is at least partly available for large-scale facilities on sites that have already experienced industrial use ("brownfield sites").

Further development of production routes

Research and development should focus not only on further developing and optimising those technologies that are currently the most promising – in addition to the Fischer–Tropsch process, the methanol-to-jet process is also of interest for SAF production – but also on further promoting the **testing and development of new processes**. On the one hand, new processes have the potential to make previously unused resources suitable for SAF production. On the other, it has been shown that new processes also pave the way for producing fuels with a different composition, which can in turn influence the fuel's emissions and properties. Given the potential change in composition, new fuels must also undergo an elaborate, time- and cost-intensive approval process in accordance with the standard ASTM D4054 [5]. This process can also be supported by research, e.g. with **prescreening** by the DLR [64], which can yield considerable time and cost savings for the approval process. Here, all relevant fuel parameters are determined and validated in advance of the actual approval

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

process, significantly boosting the chances of successful direct approval without individual steps having to be repeated.[16]

In particular, processes that are relevant to PtL process chains exhibit not only fundamental (economic) challenges but also relatively low technical readiness and are still some way from commercial use. On the one hand, these are the technologies for harnessing carbon dioxide in chemical synthesis, e.g. the reverse water–gas shift reaction and high-temperature co-electrolysis for the production of syngas or new catalysts for direct synthesis. On the other hand, it is particularly important to increase the TRL for **the supply of CO_2 using direct air capture (DAC) technology**. As long as the DAC process is not yet sufficiently developed, there will be a need for other carbon sources, which are currently based primarily on biomass and to a limited extent also on concentrated CO_2 sources (point sources). However, biomass is a limited resource, and statutory requirements mean that not every biogenic carbon source is also a potential carbon source for the production of eligible SAF. The use of CO_2 from point sources is subject to strict regulatory limits, including in order to avoid the use of CO_2 with lower greenhouse-gas reduction becoming a permanent solution. Even assuming complete defossilisation, however, it is foreseeable that there will be unavoidable CO_2 emissions from industrial processes (e.g. cement production, chemical industry) in the future (2040+). There will therefore be a need for DAC technology in the long term to reduce CO_2 emissions. The testing of PtL SAF production processes on the pilot and demonstration scale offers an opportunity to further develop this technology in parallel.

5.2 Safeguarding financing

First of all, please refer to section 4 of this report for a purely economic perspective on ensuring willingness to invest. The possible solutions from a production perspective are outlined below.

Given the low current production capacities and lack of support for industry, companies would at present need to invest considerable **equity capital** (depending on the size of the facility, this amount can be assumed to be at least in the mid-hundreds of millions), which

[16] At present, a further development of the prescreening process is continually carried out as part of projects funded nationally or by the EU, e.g. in the Federal Ministry of Digital and Transport (BMDV) project "Refineries for Future".

With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR
FUNDING PROGRAMME RENEWABLE FUELS

carries a high level of risk in an unclear regulatory environment. As long as **long-term certainty** is not provided via regulatory measures, one possible solution is to create guidelines in order to assist affected companies with implementation and reduce the risk associated with the necessary investments (at least to some extent) [3].

When it comes to **creating a guideline**, it is important to consider the target audience – with producers, distributors and users, there are at least three groups with different requirements. For example, relevant aspects for producers include specifications for the starting materials or information on permitted feedstock materials and quantities for co-processing, as well as, where applicable, best practices and economic framework conditions relating to production processes [6]. If necessary, reference can also be made to other guidelines, e.g. the approval process for the introduction of a new SAF (ASTM D4054) [5], which is also relevant to the use of a new production process. For distributors and producers (which are often one and the same), guidelines on fuel handling and logistics – and particularly on sustainability certification – are important. Users, e.g. airlines, must in turn rely on producers to meet all sustainability criteria. For users, the only relevant questions are under what conditions, where and how they can credit the use of SAF (see e.g. CORSIA, EU ETS, book & claim).

5.3 Clear regulations for production and use

Regulations can specify the entire life cycle of the SAF, from the raw materials to production and use. The regulatory framework regarding the raw material sources and for production is primarily conditioned by the need to ensure sustainability and has already been described in section 2. The aim is to create a market with the help of regulations that are as clear and reliable as possible. For producers, predictability that this market and the associated (clear) rules will be in place in the long term is essential in order to develop corresponding business models/business cases and thus to service the market.

For the use of SAF and the promotion of its market ramp-up, four fundamental **industrial policy instruments** were identified as part of the stakeholder workshop (see section 1), whose implementation into a regulatory framework is thought to be potentially useful:

(I) the introduction of binding quotas for the use of SAF

(II) the imposition of penalties for non-compliance with quotas

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

(III) subsidies for the procurement of SAF

(IV) taxation of fossil kerosene

Quotas and penalties have already been introduced through ReFuelEU Aviation. It is becoming apparent, however, that they are not enough alone to initiate market ramp-up [1]. The extent to which the existing quotas can be implemented given the current shortage of SAF remains in question. The innovation focus “Market & Regulation” addresses the degree to which **subsidies** for SAF and/or **taxation of fossil kerosene** create an incentive or, conversely, have a counterproductive effect.

At this point, it is important to emphasise that **government** cannot be solely responsible for the expansion of production capacities and the market ramp-up of SAF, as it does not build any facilities or place fuels on the market itself. However, it must create a **secure framework for industry and business** through corresponding instruments (see e.g. points I–IV) and clear regulations. In turn, based on the specifications or political framework conditions, these stakeholders are responsible for implementation with a view to expanding production capacities and market ramp-up of SAF.

5.4 Location-specific factors

In addition to the fundamental challenges described above, there are also always **location-specific factors** that can act both as obstacles and as drivers. These are factors that are determined by local conditions, such as existing or planned infrastructure, logistics and the supply of resources such as energy, raw materials and skilled workers. However, local political, economic, social and regulatory framework conditions also play an important role. For example, there are currently only a few possible locations in Europe and particularly in Germany that meet the **requirements in terms of electricity** with regard to grid infrastructure and the share of renewable energies for the production of PtL fuels. There is also a need to compensate for the fluctuating production of renewable electricity, particularly in the event of a “Dunkelflaute” (i.e. a period when neither solar nor wind energy is available). This results in load variations during electrolysis, leading to uneven or even discontinuous production of hydrogen. Ideally, however, PtL production facilities should always operate continuously and at the highest possible degree of utilization. This requires a steady supply of the feed gases H_2 and CO_2. Accordingly, suitable locations must be either identified and

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

upgraded or created, e.g. by supplying existing industrial parks with sufficient quantities of regenerative energies and reserving storage facilities for H_2, as well as for CO_2.[17]

Another location-specific issue is the availability of skilled workers. On the one hand, in industrialised countries, classical refineries will ultimately have to convert their operations in any case. On the other hand, conventional refineries will operate in parallel with facilities for the production of biogenic and power-based SAF, as well as other PtL products, for many years. The fact that the two sectors are reliant on the same limited pool of skilled workers points to a need not only for continuous training of new skilled workers but also for some way of coordinating the transfer of such workers between the sectors. Furthermore, the necessary certifications to ensure the sustainability criteria call for specially **trained personnel**. The question is therefore whether this problem ought to be regulated through industrial policy.

Another key example of the influence of location-specific factors is the production of sustainable fuels or their precursors, such as Fischer–Tropsch products or methanol, in upstream process chains at "favourable locations", generally outside Europe. These locations generally offer considerable potential for the production of renewable energy, but there are sometimes challenges in terms of infrastructure, the supply of raw materials (especially drinking water), or the political and social framework. For example, if it is first necessary to install facilities for the production of renewable electricity, to build infrastructure or to fundamentally train or bring in skilled workers, this obviously provides opportunities to support the corresponding regions in terms of their economic and social development on the one hand, but also leads to additional costs, effort and time requirements on the other. Unclear regulations or uncoordinated certification systems, as well as political uncertainty, can even rule out concepts of this kind.

The above examples are intended to illustrate that location-specific factors can play an important role but also, above all, an ambivalent one. They must be taken into account in the development of production concepts or concepts for value chains and, of course, when selecting suitable locations. At the same time, driving factors must be weighed up against hindering factors. As discussed in general terms in the previous sections, this could be

[17] The BMDV funding project "Real-time Power Supply for e-fuels" (RePoSe) examines how the flexible operation of a PtL facility works in practice with fluctuating availability of electricity.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

achieved by pooling research and other activities – for example in relation to resource potentials, industry and infrastructure, as well as social factors – and made available in guidelines. In addition, clear and reliable regulation and certification could be developed with the corresponding partner countries.

6 Outlook

This report sets out a series of possible solutions as a contribution to the discussion around accelerating the market ramp-up of SAF. It examines ways of ensuring sustainability, boosting demand and increasing willingness to invest, and therefore for expanding production.

To ensure sustainability, there is a need for clarity in terms of eligibility, a flexibility mechanism for the book & claim use of SAF, a political decision on the sustainability of biomass use, certification requirements with a long-term perspective, targeted flexibility in implementation, and a recognition or harmonisation of deviating sustainability criteria, among other things. In order to boost demand, it is important to reduce the cost of SAF, increase the willingness to pay on the part of airlines and their customers, and to create equal conditions for competition and financial incentives. To increase the willingness to invest in SAF facilities, there is a need not only for investment incentives but also, above all, for a solid business case and planning certainty. Lastly, in terms of production, capacities must be expanded and the TRL must be increased.

In particular, the creation of a business case and the systemic approach of a market model have proven essential, as many obstacles can then be addressed at the same time. Another focus is the (ongoing) lack of upscaling in terms of production facilities. As the project proceeds, there are plans to examine selected solutions in greater depth. In the innovation focus “Application in Aviation”, this will include the creation of an example business case and an overarching market model (“aviation climate club”) that discusses questions around the organisation of the financing and procurement system. Moreover, further selected solutions will be developed by InnoFuels both in “Application in Aviation” and in the other areas.

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

List of abbreviations

Abbreviation	Meaning
TFEU	Treaty on the Functioning of the European Union
AG	Working group (Arbeitsgemeinschaft)
AKKL	Working Group on Climate-Neutral Aviation
ASTM	American Society for Testing and Materials
AtJ (SPK)	Alcohol-to-Jet (synthetic paraffinic kerosene)
BMDV	German Federal Ministry for Digital and Transport (formerly the BMVI)
BMWK	German Federal Ministry of Economic Affairs and Climate Action (formerly the BMWi)
CAPEX	Capital expenditure (investment expenditure)
CfD	Contract for difference
CO_2	Carbon dioxide
CoC	Chain of custody
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CSRD	Corporate Sustainability Reporting Directive
DAC	Direct air capture
DLR	German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e.V.)
EASA	European Union Aviation Safety Agency
EU	European Union

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

EU ETS	EU Emissions Trading System
EEA	European Economic Area
E10	Petrol containing 5% to 10% bioethanol
FEETS	Fuels Eligible for ETS Support
FMS	Forms management system
R&D	Research and development
H_2	Hydrogen
HEFA (SPK)	Hydroprocessed esters and fatty acids (synthetic paraffinic kerosene)
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IRA	Inflation Reduction Act
Jet A1	Jet fuel, kerosene
LuftVStG	German Aviation Tax Act
NASA	National Aeronautics and Space Administration
OPEX	Operational expenditure
PtL	Power to liquid
RED	Renewable Energy Directive
SAF	Sustainable aviation fuel
TEHG	Greenhouse Gas Emissions Trading Act
TFS	Transformation financing system
GHG	Greenhouse gas

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

TRL	Technology readiness level
UK	United Kingdom
USD	US dollars
USA	United States of America

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

Bibliography

[1] CENA Hessen, “CENA SAF-Outlook 2024-2030 / Eine Analyse von Mengen, Technologien und Produktionsstandorten für nachhaltige Flugtreibstoffe,” CENA Hessen – Kompetenzzentrum für Klima- und Lärmschutz im Luftverkehr, Frankfurt am Main, 2023.

[2] DLR, CENA Hessen, Condor, “Hemmnisse und Herausforderungen zum Markthochlauf von SAF,” 2024.

[3] Arbeitsgruppe SAF (AG SAF), “10 Maßnahmen zur Beschleunigung des Markthochlaufs von Sustainable Aviation Fuel (SAF),” AG SAF as part of the Working Group on Climate-Neutral Aviation (AKKL)", 2024. [Online]. Available: https://aireg.de/wp-content/uploads/2024/09/Massnahmenkatalog_SAF-Hochlauf.pdf. [Accessed 21 October 2024].

[4] ICAO, “An Overview of CORSIA Eligible Fuels (CEF),” 2019. [Online]. Available: https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg228-231.pdf. [Accessed 21 October 2024].

[5] ASTM International, “Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives,” 16 May 2023. [Online]. Available: https://www.astm.org/d4054-22.html. [Accessed 21 October 2024].

[6] DLR, CENA Hessen, Condor, “Übersicht zu relevanten Gesetzen und Industriestandards beim Markthochlauf von Sustainable Aviation Fuels,” 2024.

[7] European Parliament, “Taxonomie: Keine Einwände gegen Einstufung von Gas und Atomkraft als nachhaltig,” 6 July 2022. [Online]. Available: https://www.europarl.europa.eu/news/de/press-room/20220701IPR34365/taxonomie-keine-einwande-gegen-einstufung-von-gas-und-atomkraft-als-nachhaltig. [Accessed 23 October 2024].

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

[8] European Commission, "Questions and Answers on the EU Taxonomy Complementary Climate Delegated Act covering certain nuclear and gas activities," 2 February 2022. [Online]. Available: https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_712. [Accessed 27 February 2025].

[9] K. Meisel, "Neuerungen der RED-II-Revision für fortschrittliche Kraftstoffe," 28 May 2024. [Online]. Available: https://www.dbfz.de/fileadmin/user_upload/Fachgespraeche/Biokraftstoff-Fachgespraeche/Vortraege/01_BKFG_Meisel_Neuerungen_RED_II_revision_1_.pdf. [Accessed 16 April 2025].

[10] Deutscher Bundestag, "Aktueller Begriff - Der neue Kraftstoff E10," [Online]. Available: https://www.bundestag.de/resource/blob/191732/2f4ab6390b65f6a72e9623fcc2a36957/e10-data.pdf. [Accessed 23 October 2024].

[11] Shell, "Gibt es eine Beimischungspflicht für Biokraftstoffe?," 2024. [Online]. Available: https://support.shell.de/hc/de/articles/360010714317-Gibt-es-eine-Beimischungspflicht-f%C3%BCr-Biokraftstoffe. [Accessed 9 January 2025].

[12] K. Naumann, K.-F. Cyffka and F. Müller-Langer, "Hintergrundpapier zur THG-Quote und der Quotenerfüllung 2023," 19 December 2024. [Online]. Available: https://www.dbfz.de/fileadmin/user_upload/Referenzen/Statements/Hintergrundpapier_Quote_2023.pdf. [Accessed 27 February 2025].

[13] Spiegel Wissenschaft, "Forscher züchten die Super-Pflanze," 4 January 2019. [Online]. Available: https://www.spiegel.de/wissenschaft/technik/gentechnik-40-prozent-mehr-biomasse-forscher-zuechten-super-pflanze-a-1246385.html. [Accessed 23 October 2014].

[14] A. Kaiser, "Fliegen mit Algen - ist das die Lösung?," Das Wirtschaftsportal von manager magazin & Havard Business Manager, 1 November 2019. [Online]. Available: https://www.manager-magazin.de/unternehmen/energie/biosprit-

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

kerosin-aus-algen-noch-lange-nicht-wirtschaftlich-a-1294185.html. [Accessed 23 October 2014].

[15] C. Ridley, “Why is algae fuel in decline?,” World Economic Forum, 20 May 2016. [Online]. Available: https://www.weforum.org/agenda/2016/05/why-are-algal-biofuels-in-decline/. [Accessed 23 October 2024].

[16] G. N. F. M. Taofeeq D. Moshood, “Microalgae biofuels production: A systematic review on socioeconomic prospects of microalgae biofuels and policy implications,” *Environmental Challenges,* 2021.

[17] E. Wesoff, “Hard Lessons From the Great Algae Biofuel Bubble,” 17 April 2017. [Online]. Available: https://www.greentechmedia.com/articles/read/lessons-from-the-great-algae-biofuel-bubble. [Accessed 23 October 2024].

[18] LanzaTech, “Biorefining - Operating at Commercial Scale since 2018,” [Online]. Available: https://lanzatech.com/biorefining/. [Accessed 23 October 2024].

[19] LanzaTech, “The Circular Carbon Economy starts with recycled carbon, found above ground.,” [Online]. Available: https://lanzatech.com/putting-recycled-carbon-to-use/. [Accessed 23 October 2024].

[20] Lanzajet, „Forging a new pathway to sustainable fuels.,“ [Online]. Available: https://www.lanzajet.com/circulair. [Accessed 23 October 2024].

[21] D. Thrän, M. Borchers, M. Jordan, V. Lenz, T. Markus, N. Matzner, K. Oehmichen, D. Otto, K. S. Radtke, N. Reshef, M. Sadr, D. Siedschlag and R. Wollnik, “BECCS – ein nachhaltiger Beitrag zur dauerhaften CO2-Entnahme in Deutschland? Diskussionspapier,” November 2024. [Online]. Available: https://www.ufz.de/export/data/2/296151_29966.pdf. [Accessed 27 February 2025].

[22] BMWK, “Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland,” September 2023. [Online]. Available: https://www.bmwk.de/Redaktion/DE/Downloads/Energie/zeitreihen-zur-

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2022.pdf?__blob=publicationFile&v=2. [Accessed 27 February 2025].

[23] ICAO, “SAF accounting and Book & Claim systems,” [Online]. Available: https://www.icao.int/environmental-protection/Documents/ACT-SAF/ACT%20SAF%20Series%206%20-%20SAF%20accounting%20and%20book%20and%20claim%20systems.pdf. [Accessed 18 November 2024].

[24] European Union, “Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation) (Text with EEA relevance),” 31 October 2023. [Online]. Available: https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=OJ:L_202302405. [Accessed 23 October 2024].

[25] ICAO, “SAF accounting and Book & Claim systems,” 2023. [Online]. Available: https://www.icao.int/environmental-protection/Documents/ACT-SAF/ACT%20SAF%20Series%206%20-%20SAF%20accounting%20and%20book%20and%20claim%20systems.pdf. [Accessed 9 January 2025].

[26] R. Tech, U. Schumann, C. Voigt, T. Schripp, M. Shapiro, Z. Engberg, J. Molloy, G. Koudis and M. E. Stettler, “Targeted Use of Sustainable Aviation Fuel to Maximize Climate Benefits,” *Envorinmental Science & Technology,* 17 November 2022.

[27] W. Nordhaus, “Climate Clubs - Overcoming Free-riding in International Climate Policy,” *American Economic Review,* vol. 105, no. 4, pp. 1339-70, April 2015.

[28] BDL Bundesverband der Deutschen Luftverkehrswirtschaft, “Klimaschutz,” [Online]. Available: https://www.bdl.aero/themen/klima-und-umweltschutz/klimaschutz/. [Accessed 14 November 2024].

[29] CAAS, “Singapore Sustainable Air Hub Blueprint,” 2024. [Online]. Available: https://www.caas.gov.sg/docs/default-source/docs---so/singapore-sustainable-air-hub-blueprint.pdf. [Accessed 27 February 2025].

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport
by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

[30] L. Barrington and B. Goh, “Singapore to require departing flights to use sustainable fuel from 2026,” Reuters, 19 February 2024. [Online]. Available: https://www.reuters.com/sustainability/singapore-require-departing-flights-use-sustainable-fuel-2026-2024-02-19/. [Accessed 27 February 2025].

[31] Generalzolldirektion, “Luftverkehrsteuer,” [Online]. Available: https://www.zoll.de/DE/Fachthemen/Steuern/Verkehrsteuern/Luftverkehrsteuer/luftverkehrsteuer_node.html. [Accessed 23 October 2024].

[32] Forschungsinformationssystem, “Luftverkehrssteuer in Deutschland,” 18 July 2023. [Online]. Available: https://www.forschungsinformationssystem.de/servlet/is/478884/?clsId0=276646&clsId1=276653&clsId2=0. [Accessed 23 November 2024].

[33] Generalzolldirektion, “Steuersätze,” [Online]. Available: https://www.zoll.de/DE/Fachthemen/Steuern/Verkehrsteuern/Luftverkehrsteuer/Grundsaetze-Besteuerung/Steuersaetze/steuersaetze_node.html. [Accessed 14 November 2024].

[34] SPD, Bündnis 90 / Die Grünen, FDP, “Mehr Fortschritt wagen - Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit,” 7 December 2021. [Online]. Available: https://www.spd.de/fileadmin/Dokumente/Koalitionsvertrag/Koalitionsvertrag_2021-2025.pdf. [Accessed 23 October 2024].

[35] Klimaschutzportal, “USA fördern alternative Flugkraftstoffe,” 29 November 2022. [Online]. Available: https://www.klimaschutz-portal.aero/meldung/usa-foerdern-alternative-flugkraftstoffe/. [Accessed 23 October 2024].

[36] To70, “Airports as Catalysts: Driving SAF Adoption Through Incentive Funds,” 10 October 2023. [Online]. Available: https://to70.com/airports-as-catalysts-driving-saf-adoption-through-incentive-funds/. [Accessed 23 October 2024].

With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

[37] IATA, “Airports & Sustainable Aviation Fuel (SAF),” [Online]. Available: https://www.iata.org/contentassets/fa95ede4dee24322939d396382f2f82d/iata-saf---position-paper.pdf. [Accessed 14 November 2024].

[38] European Union, “Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC,” 13 October 2003. [Online]. Available: https://eur-lex.europa.eu/eli/dir/2003/87/oj/deu. [Accessed 23 October 2024].

[39] EASA, “EASA 2024 REPORT - State of the EU SAF market in 2023,” 2024. [Online]. Available: https://www.easa.europa.eu/en/document-library/general-publications/state-eu-saf-market-2023#group-easa-downloads. [Accessed 9 January 2025].

[40] European Commission, “Initiative: Aviation fuels & emissions trading – calculating the price difference between eligible fuels and kerosene (detailed rules),” 6 January 2025. [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14020-Aviation-fuels-emissions-trading-calculating-the-price-difference-between-eligible-fuels-and-kerosene-detailed-rules-_en. [Accessed 23 January 2025].

[41] A. Meurer, P. Jochem and J. Kern, “Decentralised production of e-fuels for aviation: implications and trade-offs of a targeted small scale production of sustainable aviation fuel based on Fischer–Tropsch synthesis,” *Sustainable Energy Fuels,* p. 752–765, 15 January 2024.

[42] S. B. Bube, S. Voß, G. Quante and M. Kaltschmitt, “Cost analysis of kerosene production from power-based syngas via the Fischer-Tropsch and methanol pathway,” *Fuel 384,* p. 133901, 4 December 2024.

[43] IATA, “SAF Deployment,” [Online]. Available: https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-policy-2023.pdf. [Accessed 18 November 2024].

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

[44] IATA, "Developing Sustainable Aviation Fuel (SAF)," [Online]. Available: https://www.iata.org/en/programs/sustainability/sustainable-aviation-fuels/. [Accessed 18 November 2024].

[45] World Economic Forum, "Aviation must make these changes to meet long-term emissions goals," 30 November 2023. [Online]. Available: https://www.weforum.org/stories/2023/11/aviation-changes-needed-meet-long-term-emissions-goals/. [Accessed 9 January 2025].

[46] N. Emig, "Scope 3 Emissionen und ihre Bedeutung in der CSRD," Envalor, 28 February 2025. [Online]. Available: https://envalor.com/de/blog/scope-3-emissionen/. [Accessed 16 April 2025].

[47] Gold Standard, "How Do You Solve a Problem Like Scope 3?," 3 July 2024. [Online]. Available: How Do You Solve a Problem. [Accessed 9 January 2025].

[48] AirPlus, "Nachhaltige Geschäftsreisen," 21 October 2019. [Online]. Available: https://comms.airplus.com/de/blog/nachhaltige-geschaeftsreisen. [Accessed 9 January 2025].

[49] DHL, "GoGreen Plus," 2025. [Online]. Available: https://www.dhl.de/de/geschaeftskunden/paket/leistungen-und-services/services/service-loesungen/gogreen-plus.html. [Accessed 16 April 2025].

[50] Lufthansa Cargo, "Sustainable Choice," 2025. [Online]. Available: https://www.lufthansa-cargo.com/de/add-on-services/sustainable-choice. [Accessed 16 April 2025].

[51] Transport & Environment, "Wer könnte die E-Kerosin-Produktion in Deutschland finanzieren?," 29 May 2024. [Online]. Available: https://www.transportenvironment.org/te-deutschland/articles/wer-koennte-die-e-kerosin-produktion-in-deutschland-finanzieren. [Accessed 9 January 2025].

[52] Frankfurt University of Applied Sciences, "CompIncent - Anreize zur CO2 Kompensation im Luftverkehr," 2023. [Online]. Available: https://www.frankfurt-

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

university.de/de/hochschule/fachbereich-3-wirtschaft-und-recht/forschung-am-fachbereich-3-wirtschaft-und-recht/aktuelle-forschungsprojekte-am-fb-3/compincent/. [Accessed 9 January 2025].

[53] ATAG Air Transport Action Group, "Sustainable aviation fuel," [Online]. Available: https://www.atag.org/industry-topics/sustainable-aviation-fuel/. [Accessed 18 November 2024].

[54] Lee, Fahey, Skowron, Allen, Burkhardt, Chen, Doherty, Freeman, Forster, Fuglestvedt, Gettelman, D. Léon, Lim, Lund, Millar, Owen, Penner, Pitari, Prather, Sausen and Wilcox, "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018," *Atmospheric Environment,* 1 January 2021.

[55] R. S. Märkl, C. Voigt, D. Sauer, R. K. Dischl, S. Kaufmann, T. Harlaß, V. Hahn, A. Roiger, C. Weiß-Rehm, U. Burkhardt, U. Schumann, A. Marsing, M. Scheibe, A. Dörnbrack, C. Renard, M. Gauthier, P. Swann, P. Madden, D. Luff, ... and P. Le Clercq, "Powering aircraft with 100 % sustainable aviation fuel reduces ice crystals in contrails," *Atmospheric Chemistry and Physics,* vol. 24, no. 6, p. 3813–3837, 27 March 2024.

[56] NOW GmbH, "NOW-Factsheet ReFuelEU-Aviation-Regulation," May 2025. [Online]. Available: https://www.now-gmbh.de/wp-content/uploads/2023/11/NOW-Factsheet_ReFuelEU-Aviation-Regulation.pdf. [Accessed 16 April 2025].

[57] FuelsEurope, "Statistical Report 2024," 2024. [Online]. Available: https://www.fuelseurope.eu/uploads/files/modules/documents/file/1720682523_b0kO2xvpBcF1zMAkf2g2kLpgAjlUsRdNymMKmajT.pdf. [Accessed 27 February 2025].

[58] R. Bocksch, "Kerosinpreis weiterhin deutlich über Vor-Pandemie-Niveau," statista, 24 July 2024. [Online]. Available: https://de.statista.com/infografik/32682/entwicklung-des-preises-fuer-kerosin/. [Accessed 23 January 2025].

[59] P. Smeets, "Sustainable Aviation Fuel: Herausforderung Markthochlauf," 6 September 2024. [Online]. Available: https://background.tagesspiegel.de/verkehr-

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

und-smart-mobility/briefing/sustainable-aviation-fuel-herausforderung-markthochlauf. [Accessed 21 October 2024].

[60] European Parliament, “ReFuelEU Aviation initiative - Summary of the Commission proposal and the Parliament's draft committee report,” May 2022. [Online]. Available: https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/729457/EPRS_BRI(2022)729457_EN.pdf. [Accessed 27 February 2025].

[61] NASA, “Definition Of Technology Readiness Levels,” [Online]. Available: https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/#:~:text=Technology%20Readiness%20Levels%20(TRL)%20are,level%20of%20a%20particular%20technology.. [Accessed 14 November 2024].

[62] Projektträger Jülich, “Definition des Technologischen Reifegrades (in Anlehnung an die TRL Definition der NASA),” [Online]. Available: https://www.ptj.de/lw_resource/datapool/systemfiles/cbox/2373/live/lw_file/definition_des_technologischen_reifegrades.pdf. [Accessed 21 October 2024].

[63] J. Schröder, K. Naumann, N. Dögnitz, G. Costa de Paiva, S. Hauschild, K. Meisel, H. Etzold, S. Nieß, J. Köchermann, K. Görsch, K.-F. Cyffka, F. Müller-Langer, E. Remmele and K. Thuneke, “DBFZ Report Nr. 44 - Monitoring erneuerbarer Energien im Verkehr,” 2023. [Online]. Available: https://www.dbfz.de/pressemediathek/publikationsreihen-des-dbfz/dbfz-reports/dbfz-report-nr-44. [Accessed 27 February 2025].

[64] DLR Institut für Verbrennungstechnik, “Prescreening neuer Treibstoff-Kandidaten,” 2024. [Online]. Available: https://www.dlr.de/de/vt/forschung-transfer/forschungsdienstleistungen/prescreening-neuer-treibstoff-kandidaten. [Accessed 21 October 2024].

[65] Deutsche Emissionshandelsstelle (DEHSt), “Einnahmen aus dem Emissionshandel erneut auf Rekordniveau,” 7 January 2025. [Online]. Available:

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

https://www.dehst.de/SharedDocs/Pressemitteilungen/DE/2025-001-jahresabschluss-2024-euets-nehs.html. [Accessed 23 January 2025].

[66] Deutsche Emissionshandelsstelle (DEHSt), "Emissionsfaktor für Jetkerosin Jet A und Jet A1," 2024. [Online]. Available: https://www.dehst.de/SharedDocs/Newsletter/DE/2024/2024-01-30-luftverkehr-fms-vertraulichkeit-emissionsfaktor-02-emissionsfaktor.html. [Accessed 23 January 2025].

FUNDING PROGRAMME RENEWABLE FUELS
With funding from the Federal Ministry of Transport by decision of the German Bundestag
Coordinated by NOW NOW-GMBH.DE
Project management agency VDI|VDE|IT FNR

FUNDING PROGRAMME
RENEWABLE
FUELS

With funding from the

Federal Ministry
of Transport

by decision of the
German Bundestag

Coordinated by

NOW
NOW-GMBH.DE

Project management agency

VDI|VDE|IT

FNR