



The
Federal Government

PtL roadmap

Sustainable aviation fuel from renewable energy
sources for aviation in Germany



The target

On the path towards carbon-neutral aviation, the actors involved in the roadmap are working jointly to set up and expand the production of sustainably generated PtL kerosene in future years. They consider the use of a minimum of 200,000 tonnes of PtL kerosene in German aviation by 2030 realistic. This target is linked to Germany's National Hydrogen Strategy.

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The target and how to achieve it

Air transport connects people across the globe and enables the urgent transport goods of value. This is essential in a free and globalised world. Air transport accounts for 2.8¹ per cent of global anthropogenic CO₂ emissions. Aviation is responsible for 3.5 per cent of anthropogenic warming since the beginning of industrialisation², most recently (before the Covid 19 pandemic) the annual contribution was about 5.5 per cent. Prior to the Coronavirus crisis, global air transport grew by about six per cent each year over the past five years. The pandemic caused a decline in passenger air travel by up to two-thirds compared to 2019. The global demand for air transport is anticipated to gradually increase again. It is currently not possible to provide a solid estimate for when passenger air travel will be back to 2019 levels due to the changes in the air transport market as a consequence of the Coronavirus crisis.

Ambitious climate targets have been established with the Paris Agreement, the European Union's Green Deal, Germany's Climate Action Programme 2030, the Climate Action Act and the Federal Government's hydrogen strategy. In the Climate Action Act, the Federal Government aims to reduce the CO₂ emissions from the entire transport sector by 42 per cent by 2030 compared to 1992 levels and to become greenhouse gas-neutral by 2050. Aviation also needs to contribute to achieving these targets.

There are a number of levers to be employed in order to achieve these targets, such as:

- + Purchasing more efficient aircrafts
- + Optimising processes both in the air and on the ground
- + Shifting flights, for example by providing improved rail connections
- + Avoiding flights, for example by increasing the use of video conferencing
- + Developing newer, more efficient technologies and aircraft types
- + Carbon pricing instruments, for example EU-ETS and CORSIA

To make flying carbon-neutral and sustainable, however, it is essential to substitute fossil kerosene with kerosene made from sustainably produced, renewable energy sources and raw materials. In this context, electricity-based (PtL, power-to-liquid) kerosene from renewable energy sources in particular play a key role. The use of such fuels can reduce the emissions of the aviation fleet, provided that a correspondingly low amount of carbon or no CO₂ is emitted during the production of these fuels, for example by using renewable energy sources. On the basis of current knowledge, an electrification of air transport – especially for medium-range and long-distance flights – will hardly be possible, meaning that aviation will continue to depend on drop-in fuels³ also in the long run. Numerous airlines have conducted trials using bio aviation fuels and these fuels have since been employed by some airlines. The amount of sustainable biomass available is, however, constricted

1 IEA | 2018

2 https://www.dlr.de/content/en/articles/news/2020/03/20200903_global-air-transport-contributes-3-5-percent-to-global-warming.html

3 PtL kerosene is drop-in capable, i.e. it can be blended with fossil kerosene and used without changing the aircraft fleet or existing infrastructure.

and much sought-after by other applications and sectors as well. This is why this roadmap deals exclusively with electricity-based kerosene from green hydrogen. At the moment, electricity-based fuels are not yet produced in marketable quantities. Some production pathways for PtL kerosene have already been approved for use in planes. Further measures need to be taken to incentivise the production

and use of sustainable PtL kerosene, in order to lower the price of electricity-based aviation fuels from renewable energy sources, which is still high, to marketable levels. Germany now has the opportunity to develop and expand crucial industry know-how and technological leadership in producing and using sustainably generated PtL kerosene. Global alliances are a promising future path in this context.

On the path towards carbon-neutral aviation, the actors involved in the roadmap are working jointly to set up and expand the production of sustainably generated PtL kerosene in future years. They consider the use of a minimum of 200,000 tonnes of PtL kerosene in German aviation by 2030 realistic⁴. This target is linked to Germany's National Hydrogen Strategy.⁵

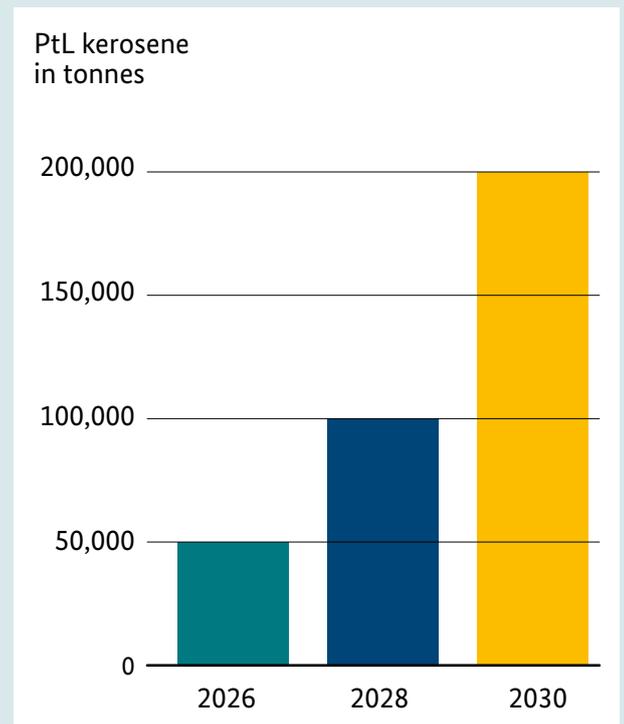


Figure 1: PtL kerosene market ramp-up

4 Corresponds to 2 per cent of the kerosene sales in Germany in 2019.

5 <https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.html>

On the one hand, there must be a supply of the product in order to establish a market for PtL kerosene. To begin with, only a low level of supply is available until additional sources for renewable energy are created and large-scale plants implemented and process engineering established, as well as the associated additional field trials of different technology pathways are conducted and economies of scale are viable. On the other hand, a purchase obligation must ensure that demand be created, because without it a market will not evolve because of the higher costs involved. Political decisions can support both sides by providing funds as well as setting requirements. The comparatively high production costs at the moment

are a key challenge. Creating a self-sustaining market for PtL kerosene will require all sides to act: a balanced mixture of state action is as necessary as the willingness of the individual actors (e.g. petroleum industry, plant manufacturers, air carriers, airline passengers) to contribute their share to the incremental costs of PtL kerosene. One tool in this context is the introduction of a compulsory minimum energy quota for aviation fuel sold in Germany. This requirement must be met by those placing the product on the market, i.e., the petroleum industry companies. At the same time, it is important to avoid competitive disadvantages for the German aviation industry.

It is intended to achieve the goal of using a minimum of 200,000 tonnes of PtL kerosene in German aviation by 2030 by means of the following activities:

⊕ Technological development

- + Proving that the plants and components that are needed for PtL production, which are already technologically advanced enough in their own right, are compatible with each other in terms of overall technical integration even when used at an industrial scale.
- + Research and development to increase the technical readiness of individual components such as capturing carbon directly from the air.

⊕ Sustainability criteria

- + Establishing uniform, binding and reliable ecological and social sustainability standards, first at the European and then as soon as possible at the international levels.

⊕ Supporting the market ramp-up

- + Defining binding targets for the use and sale of renewable PtL kerosene including intermediate phases, starting at the German level, followed by the European and international levels.
- + Creating the regulatory framework conditions for a self-sustaining PtL kerosene market, while taking care not to distort competition.
- + State funding not linked to a specific technology to support the market ramp-up of PtL kerosene production from green hydrogen aiming to build production plants which in turn will successfully introduce into the market energy- and cost-efficient solutions that comply with climate targets. This is supplemented by a commitment on the part of the aviation industry to purchasing relevant quantities of PtL kerosene in the future.

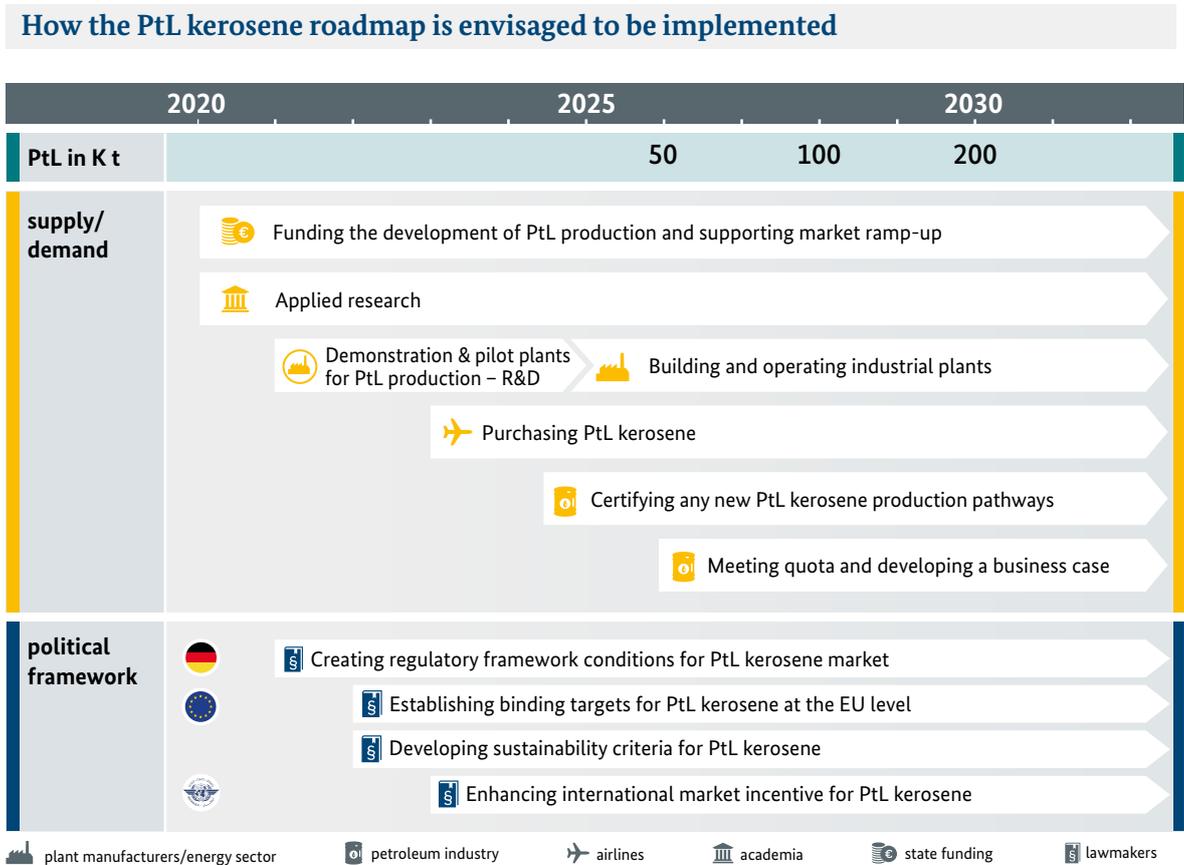


Figure 2: Implementation of PtL kerosene roadmap for aviation

For Europe’s aviation sector to contribute to achieving climate targets and to be carbon-neutral by 2050 at the latest, it will be necessary to massively expand the use of renewable energy sources within the EU and beyond. This needs to be done especially urgently against the backdrop that in other sectors as well there will be a soaring demand for renewable energy and sustainably produced hydrogen. Wherever possible, biogenic carbon sources, for example a biogas plant, should be developed for PtL kerosene production.

In the medium term, using unavoidable carbon from industrial processes may be an option for

a successful market ramp-up due to its availability and low procurement costs. Fundamentally, however, the selection of the source of renewable energy and CO₂ need to harmonise with the overarching goals of a cross-industry greenhouse gas reduction, the promotion of renewable energy and sustainability criteria that are necessary for environmental protection. In view of the goal of greenhouse gas-neutrality by 2050, carbon capture from the air is vital and needs to be prepared and gradually used in the market ramp-up. The European Commission needs to clarify in follow-up projects to what extent and how carbon from biogenic sources or from industrial processes may be credited.

In addition, at the international and European levels in particular, regulatory preconditions must be defined to ensure that the climate targets agreed upon are complied with and to ensure fair competition. Airlines from third countries that do not follow the preconditions necessary to comply with climate targets should not have competitive advantages on these grounds. Aviation agreements with third countries ensure that airlines from these countries are required to comply with the respectively applicable national and European environmental requirements when flying into the Federal Republic of Germany.

In view of the state support necessary to achieve the climate targets, especially when it comes to producing green hydrogen, a regulatory framework is needed at the EU level in order to ensure investment certainty. Otherwise, a market ramp-up cannot succeed without leading to severe disadvantages for the European aviation industry. Additionally, it would be helpful if procedures were simplified and criteria in European state aid legislation were adjusted for the effects of the pandem-

ic on air transport. Given the ambitious time frame, the industry needs to take investment decisions by 2021 at the latest to establish the first PtL production plants. For this to happen, relevant regulatory issues need to be clarified to give the investors legal certainty. This includes, for example, clear criteria for sourcing renewable electricity for electrolysis and clear accounting and crediting rules when both PtL crude and fossil crude oils are used in the production of kerosene and other products in refineries. The European Commission needs to present a proposal on this in the course of 2021. It is important to have clarity about these framework conditions as quickly as possible to provide investment and legal certainty for the first plants.

A continuous monitoring is in place for implementing this roadmap. Its signatory actors are discussing the progress towards achieving the objectives at regular meetings. Projects initiated by the actors involved in promoting PtL kerosene are documented and made accessible to a broader public. The implementation status will also be published.

Technological development

Power-to-Liquid (PtL) is the term used for the production of liquid fuels from electricity, water and CO₂. For this reason, PtL fuels are also called electricity-based fuels. Their potential to contribute to reducing greenhouse gas emissions is determined by the use of additional sources of renewable energy. Two possible production pathways are outlined below. More information on the production can be found in a study by the German Environment Agency on PtL kerosene.⁶

Production pathways

Currently, there are two methods to produce PtL kerosene: Fischer Tropsch synthesis and alcohol synthesis with the alcohol subsequently converted to kerosene. The processes for alcohol synthesis currently used in Germany are methanol-to-olefins and olefins-to-distillate conversions; internationally, there are also, however, alternative processes based on other types of alcohol.

Both production pathways require electricity to produce hydrogen and CO₂ as carbon source in the synthesis process. Even when the plants

are retrofitted in their design and operation for PtL production, there will be by-products such as synthetic diesel or gasoline as well as synthetic base materials that can be used in other transport sectors or the chemical industry. The market should also enable the sale of these by-products. In that way, operators could optimise their plants' business model and they will avoid having to pass on the costs of the plant to only one product, kerosene in this case. At the same time, this increases the plant operators' resilience when they do not depend on marketing solely one product.

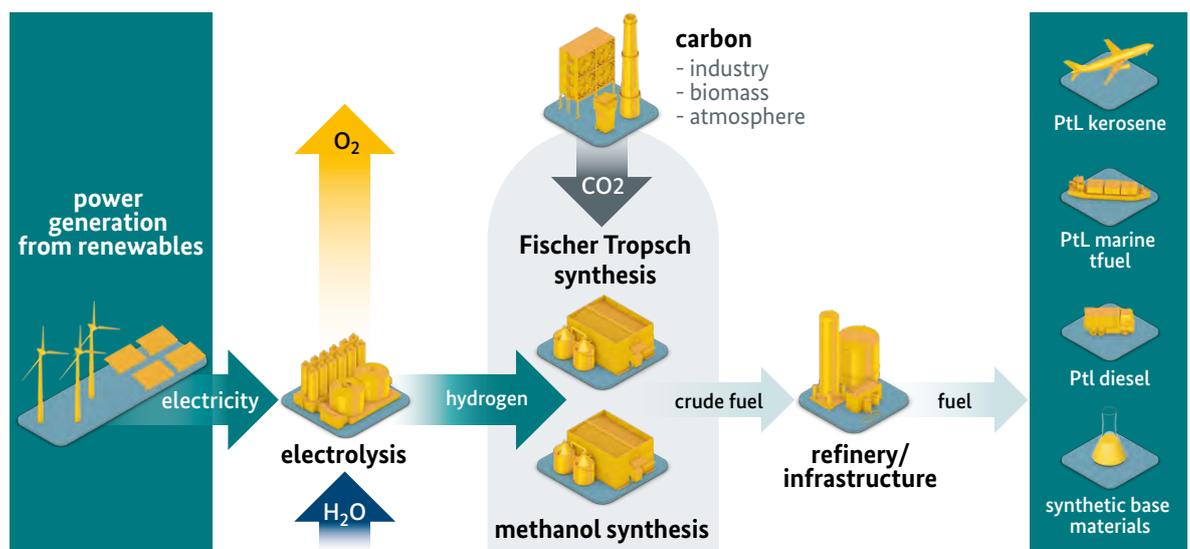


Figure 3: Simplified illustration of PtL production pathways (source: NOW GmbH)

6 https://www.umweltbundesamt.de/sites/default/files/medien/377/publikationen/161005_uba_hintergrund_ptl_barrierefrei.pdf

As yet, there is no proof confirming for either process that the individual components of the plants work well in an overall integrated system at an industrial scale. The production of synthetic gas as input material for the Fischer Tropsch reactor is a key challenge in the Fischer Tropsch process, especially when the power needed is supplied by power plants using fluctuating renewable energy. This issue is being addressed by the market actors with varying, innovative approaches. Another factor to be taken into account is that specific requirements concerning flexible operations may be

imposed in the course of drafting the delegated act on power purchasing criteria, which the European Commission is going to present by the end of 2021. One major challenge for the methanol route is the conversion of green methanol into kerosene. Some technical solutions require an uninterrupted synthesis process and cannot react flexibly to fluctuating power generation.

The methanol route, in contrast to the Fischer Tropsch method, has not yet been approved for kerosene use.

 Both the Fischer Tropsch synthesis and alcohol-based conversion routes can contribute to PtL kerosene production. This is why the actors involved in the roadmap are advocating for further developing the technologies of different production pathways and for designing the framework conditions as to enable additional production pathways without favouring a specific technology.

Power purchase

Only by using power generated from additional renewable sources can climate change emissions be avoided in the production itself. The costs for purchasing power are the main cost factor in the production of PtL kerosene. The additionality of renewable energy sources is of key significance as this is the only way to ensure that the fuels benefit the climate and – as stipulated by the National Hydrogen Strategy – their production does not cause additional greenhouse gas emissions. One possibility to ensure power supply from renewable energy sources is to connect the production plants directly to additional power plants. A transparent, traceable purchase of green power from the commercial grid, for example by means of a Power Purchase Agreement (PPA) and guarantees of origin, must be enabled in the future to ensure that the plants can run at full capacity and that there is energy supply even at locations where a direct power supply

is not possible. By the end of 2021, the European Commission will establish under what conditions the requirements for a green power purchase are met in a delegated act on the basis of the Renewable Energy Directive EU 2018/2001 (RED II). This will include requirements for a temporal and spatial connection between power purchase and kerosene production, the impact on the power grid (particularly concerning possible bottleneck situations in the grid) and the additionality of deploying renewable energy sources (see chapter on sustainability). It is especially relevant here that the kerosene production method is, to the extent possible, beneficial to the grid and the system in place. Partner countries need to fulfil the corresponding requirements and provide the proof necessary if they wish to sell their products in the European market. For the German electricity grid, this entails that no relevant bottleneck situations are caused or

exacerbated. Against this backdrop, the priority should be building production plants at an industrial scale in regions with an above-average potential for renewable energy sources.

The EU’s delegated act will then also apply to sustainably produced PtL kerosene. The legal act’s framing should not turn out to be a hurdle in the market ramp-up of the technologies.

📌 The actors involved in the roadmap support revising the system of state-initiated components in the price for electricity as outlined in the National Hydrogen Strategy and support the envisaged exemption from the surcharge imposed by Germany’s Renewable Energy Act (EEG) on green hydrogen production.

CO₂ sources

The selected source of CO₂ co-determines the ecological value of PtL kerosene. PtL kerosene can only become carbon-neutral when the CO₂ source enables a CO₂-atmosphere cycle, meaning that the CO₂ has previously been captured from the air. CO₂ from the following sources enable a CO₂-atmosphere cycle (see table 1):

Biogenic sources	Direct Air Capture ⁷
+ Biogas plants	+ Absorption
+ Bio ethanol plants	+ Adsorption
+ Biomass CHP	

Table 1: Potential CO₂ sources (source: ifeu)

Additionally, unavoidable process emissions (for example the process emissions from a cement plant) can be potential CO₂ sources, provided that the utilisation of this CO₂ does not slow down the necessary reduction of carbon emissions from the industrial plants.

Capturing CO₂ from flue gas, biogas, chemical process gases or the air requires energy, the amount of which depends, among other factors, on the CO₂ concentration of the respective medium and on the capturing technology. Air, for example, contains 0.04 per cent

of CO₂ by volume, biogas 20-45 per cent and process gases from cement plants 14-33 per cent. More information can be found in the ifeu study⁸ titled „CO₂ sources for PtX production in Germany - technologies, environmental impact, availability“ which was conducted as part of the Copernicus Programme. In the future, there may also be the possibility to introduce the carbon necessary for synthesis directly in the form of sustainable bio mass.

From the climate perspective, CO₂ from sustainable, biogenic sources and CO₂ from the atmosphere are the preferred sources and need to be the ones used in the medium and long term. Besides lowering the relatively high costs of capturing CO₂ from the atmosphere, it is also necessary to improve and scale the technology. The decentralised nature of biogenic processes is a challenge when biogenic CO₂ sources are used that would complicate large-scale use. The increased use of sustainable biomass at point sources could serve as an approach to make CO₂ from biogenic sources available more easily in the future for the production of PtL kerosene. In the short term, the use of unavoidable CO₂ emissions from industrial point sources seems to be necessary in ramping up PtL kerosene production. For

⁷ Direct Air Capture is a process for extracting carbon dioxide from ambient air.

⁸ https://www.ifeu.de/wp-content/uploads/ifeu_paper_03_2019_CO2-Quellen-f%C3%BCr-PtX.pdf (in German)

this purpose, it can be reasonable to use unavoidable emissions from industrial processes such as the production of cement, as long as

this does not impede the transition to renewable base material and alternative processes.

📌 The objective is to use CO₂/carbon from sustainable, biogenic sources and from the atmosphere. It may, however, be reasonable to start with using unavoidable CO₂ emissions from industrial processes for a successful market ramp-up due to their availability and low procurement costs. This should not, however, become an impediment for exploring and using CO₂ from biogenic industrial processes or the atmosphere.

📌 In order to increase the optimisation and efficiency potential of the corresponding technologies, the funding guidelines of the Federal Transport Ministry on the development of renewable fuels also addresses individual components such as Direct Air Capture.

Design and approval of fuels

The American Society for the Testing of Materials (ASTM) is the most important body for the approval of synthetic aviation fuels. It coordinates its work with the European standardisation organisation DefStan. The first approval of this kind took nine years and required the production of several thousand tonnes of aviation fuel for testing purposes. The approval procedures were further developed, however, and can now be completed within few years. The quantities needed for testing are now be no more than some to a few hundred tonnes, depending on how similar the synthetic fuel is to others that have already been approved.

The design of the chemical composition of synthetic fuels has the advantage over petroleum-based aviation fuel that the aromatics and sulfur content can be reduced and even eliminated. Pollutants such as NO_x, SO₂ and unburnt hydrocarbon, generated in the combustion of fossil aviation fuel, and soot parti-

cles forming plane contrails can in this way be greatly reduced. As early as 2014, the German Aerospace Centre (DLR) proved that adding 50 per cent of sustainable aviation fuel – this is the blending ratio currently applicable – reduces the in-flight emissions of soot particles from an aircraft engine by 50 to 70 per cent compared to the emissions from the combustion of pure aviation fuel. The number and size of the ice crystals at the time of contrail formation depend, inter alia, on the emissions of soot particles from aircraft engines. If these are reduced, the number of ice crystals in newly formed contrails is lowered, thus reducing the climate effect of high-altitude clouds formed in the process. But it is likely, nonetheless, that additional climate effects will be the result of using PtL aviation fuel due to changes in the natural formation of clouds. The reduction of soot emissions as such is, however, an important step towards reducing the impact on climate change⁹.

⁹ https://www.dlr.de/content/en/articles/news/2019/02/20190627_climate-impact-of-clouds-formed-from-aircraft-condensation-trail.html

📌 If more than the currently permissible amount of 50 per cent of sustainable aviation fuel is to be added, the impact on the propulsion system (engine, tank, power distribution, sealings, calibration of the sensor technology) and the refuelling infrastructure need to be investigated scientifically and be subjected to technical trials, which may result in modifying the propulsion system as well as other aircraft components and the refuelling infrastructure. It is important that research not limit itself to the latest aircraft generations but also includes existing fleets, because the concerns expressed by ASTM primarily refer to the compatibility with older patterns. At the same time, existing findings about the climate impact of PtL aviation fuels should be enlarged upon. These research issues should be pursued with the aim of increasing the blending ratio with technology.

Applied research

The Fischer Tropsch method has been used for decades. Nonetheless, there are still technical issues about the large-scale production of electricity-based aviation fuels that need to be discussed scientifically and resolved. The same is true for the scaling of the alcohol-based technology and other potential technologies in the future. Additional scientific questions will arise about how to design the fuels to further reduce their impact on the environment. Besides other projects and testing facilities, the existing need for research and development will be addressed by creating a platform for the development, testing and demonstra-

tion of different production processes for PtL fuels (PtL platform). The Federal Ministry of Transport and Digital Infrastructure (BMVI) is planning the implementation of such a platform and is currently developing concepts. The Federal Ministry for Economic Affairs and Energy (BMWi) supports research and development in the field of electricity-based fuels in the context of the 7th Energy Research Programme, for example with its „energy transition in the transport sector: sector coupling through the use of electricity-based fuels“ research initiative and with real-world laboratories on energy transition.

📌 The Federal Ministry of Transport and Digital Infrastructure aims to establish a PtL platform close to the market as a connecting link between development projects and the market ramp-up.

Transport logistics

Electricity-based fuels must fulfil the criteria of a so-called drop-in fuel¹⁰. This fuel blend can then be used in the existing infrastructure all the way from the manufacturers and refuelling warehouses at airports to the plane itself. Pipe lines, trucks or rail transport are used for delivering to airports. The Central Europe-

an Pipeline System (CEPS) for alternative fuels cannot be used yet as it requires approval from all NATO member states. Germany's approval is still outstanding. According to the Defence Ministry, the approval procedures necessary are currently being clarified.

 The actors involved in the roadmap are advocating for the use of the Central European Pipeline System (CEPS) for sustainable aviation fuels.

Sustainability criteria

In contrast to base material used for the production of biofuels, electricity-based fuels are not subject to quantity restrictions such as result from limited crop areas or competing use by other sectors. It is crucial to define criteria for the renewable energy used in the production of PtX fuels. There is significant potential available globally for the generation of power from renewable energy sources which can be used for PtL kerosene production. In the long term, however, this potential – that needs to be tapped in a commercial, ecological, and socially sustainable manner – will also underlie a certain limit. Among other factors, the availability of fresh water, land use and raw materials for the production of the plants need to be considered.

Various requirements need to be fulfilled for the sustainable production of PtL kerosene. These focus is on supplying the production plants with additional renewable power, carbon from sustainable sources, water and land use, for example, for the generation of renewable energy and carbon capture from the air. In view of the expected future PtL aviation fuel production at international locations, additional sustainability aspects also need to be considered. In an integrated approach, these aspects include avoiding adverse ecological effects on ecosystems and natural resources

such as water availability, ensuring local energy supply, the costs for this supply, and the social impact of large-scale infrastructure projects on the population in neighbouring zones.

There are not yet uniform sustainability standards and accounting and certification systems for PtL kerosene. A comprehensive process is therefore necessary to introduce sustainability criteria for all relevant aspects that, to the extent possible, apply across regions. Corresponding standards and systems need to be

¹⁰ PtL kerosene has drop-in capabilities, i.e., it can be blended with fossil aviation fuel and used without changes in the aviation fleet and existing infrastructure.

established for a global market ramp-up of PtL kerosene. Only this will enable those who sell and use it to understand transparently, efficiently and reliably, how sustainable this fuel is, which in turn will create acceptance and

ensure the benefits for the environment and the climate. The experience from similar systems for biofuels and power from renewable energy sources can be used when developing global certification and accounting systems.

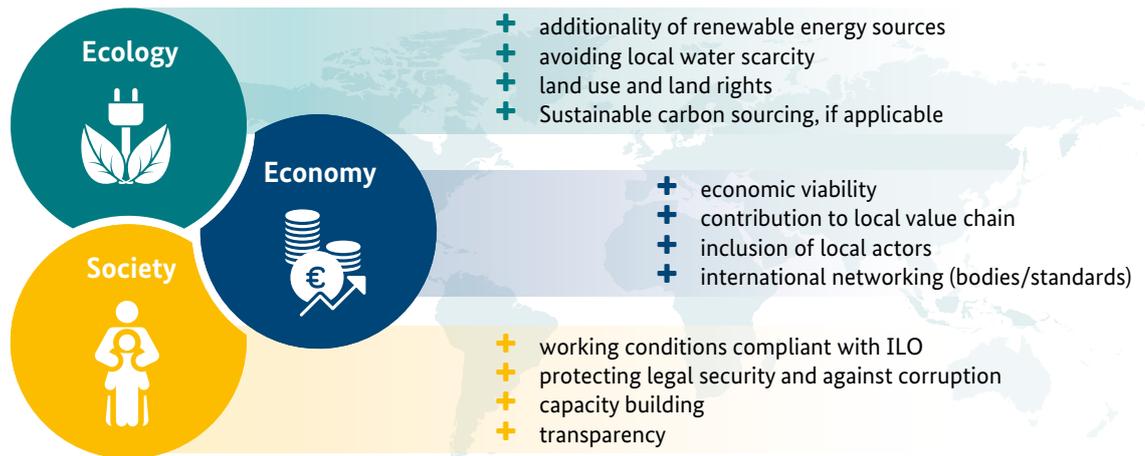


Figure 4: Potential sustainability principles for PtL (source: NOW GmbH)

International Civil Aviation Organisation

The ICAO’s Committee on Aviation Environmental Protection (CAEP) in its Fuels Task Group (FTG) has worked on developing procedures and methods to include sustainable aviation fuels in the context of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)¹¹. PtL fuels have not yet, however, been specifically included, and the sustainability criteria for sustainable aviation fuels are still insufficient. But a life cycle assessment has been conducted, looking at changes as a consequence of both direct and indirect land use. In CORSIA’s pilot phase,

the ICAO agreed on two binding sustainability criteria: sustainable aviation fuels need to achieve a minimum of 10 per cent reduction in greenhouse gas emissions and they cannot be produced from biomass grown on land with a high carbon stock (primary forests), wetlands and peatlands. Compliance with the criteria is intended to contribute to local, social and economic development while avoiding competing with food and feed crops and water. It is intended to approve additional criteria by the end of CPORSIA’s pilot phase (2023), thereby making them binding.

11 <https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx>

European Union

The Renewable Energy Directive (RED II) stipulates for Europe and thus also for Germany that sustainability criteria be met concerning biomass and power purchase in PtX production and also for the reduction of greenhouse gases in the case of renewable fuels used in the transport sector. For this to happen, the European Commission needs to present a delegated act. Irrespective of this, Germany needs to

transpose RED II into German legislation by 30 June 2021. Pursuant to RED II the GHG reduction from electricity-based fuels in transport must, 1 January 2021, amount to at least 70 per cent compared to fossil equivalents. Provisions of how to treat commercial power when determining the GHG value will be defined at the end of 2021 in a delegated act from the Commission.

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- 📌 Sustainable, electricity-based kerosene can only be produced by using additional renewable energy and needs to show a certain GHG reduction effect. The criteria for purchasing power from renewable energy sources from the commercial grid will be regulated in a legal act by the European Commission. One crucial factor is how beneficial the production of electricity-based kerosene is to the grid and system in place. The actors involved in the roadmap are accompanying the development of the legal act.
 - 📌 In the further development of the sustainability criteria for PtL kerosene, the actors involved in the roadmap will advocate that a uniform, legally binding standard be developed at the European and international levels.
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Supporting the market ramp-up

PtL kerosene production is neither well-established on the market nor competitive under the current framework conditions. The Federal Government and the Länder are funding the development and production of PtL kerosene, in order to improve the situation on the supply side. Creating a regulatory framework is a key complement for the purchase side to support the market ramp-up of PtL kerosene. On the demand side, the market ramp-up should be supported by voluntary commitments from the aviation and logistics industries to purchase PtL kerosene.

Regulatory framework for market initiatives

The requirements to commit to long-term, binding targets, and the incentives and obligations to support the market actors in achieving the targets are employed to create investment certainty. The interplay among the international, European and national levels is of great significance for the aviation industry in order to avoid distortions of competition. Regulatory measures should be designed in such a way

as to be efficacious but at the same time not affect competition. Furthermore, they should be timed in such a way that a first ramp-up of electricity-based PtL fuels can take place by the mid-2020s. It would therefore be reasonable to start at the regional level, and to then aim to gradually establish comparable regulations at the European and international levels.

International Civil Aviation Organisation ICAO

At the ICAO assembly meeting in 2013, global targets were defined for the international aviation sector: improving annual fuel efficiency by 2 per cent and stabilising global CO₂ emissions at 2020 levels (carbon-neutral growth as of 2020). To achieve these global targets, ICAO is pursuing a bundle of measures, including improvements in aircraft technology, improved operative processes, the use of sustainable fuels, and market-based measures. ICAO's environmental committee is currently drafting a long-term climate target for international aviation, which will be presented at the next assembly meeting in 2022.

ICAO countries adopted a global carbon compensation system in 2016: the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The aim is to achieve carbon-neutral growth by having the airlines finance carbon-reducing climate projects around the world. The projects' size is determined by the amount of aviation emissions to be offset. In the scope of CORSIA, sustainable fuels fulfilling certain criteria (see sustainability criteria/ICAO) can be credited towards reducing an airline's CO₂ emissions. Until now, PtL fuels have not been specifically included, only biofuels.

In 2017, ICAO's Vision 2050¹² for sustainable aviation fuels was launched, calling for states, industry and other stakeholders to aim for a „significant“ share of sustainable aviation fuel

consumption by 2050. The ICAO Vision does not specify how much the share should be. Germany advocated for PtL kerosene to be included in ICAO's Vision 2050.

📌 The actors involved in the roadmap continue to support a stronger emphasis on PtL kerosene at the ICAO level. In so doing, ambitious sustainability criteria need to be developed, adopted and implemented for electricity-based fuels as well that should not fall behind the ones at the European level.

📌 The German ministries participating in the roadmap will examine to what extent the use of PtL kerosene can be boosted in framing international measures.

European Union

Renewable Energy Directive (RED II)¹³

RED II specifies national renewable energy targets for each Member State by 2030, taking into account the country's starting position and overall potential for renewable energy. RED II also includes a sub-target and corresponding provisions for the transport sector. Member States must require fuel suppliers to supply a minimum of 14 per cent of the energy consumed in the transport sector as renewable energy by 2030. These EU requirements will be transposed into German legislation by means of a greenhouse gas quota in the Federal Immission Control Act (BImSchG) and separate statutory instruments based on it. The greenhouse gas quota stipulates a GHG reduction percentage rate by which suppliers need to reduce the GHG emissions arising from the use of gasoline and diesel fuels. RED II needs to be transposed into national law by 30 June 2021. But the proportionate costs for electricity-based fuels are far higher, at least in the first plants, than the costs of alternative

options to meet the GHG quota, such as advanced biofuels or the use of electricity certificates from e-vehicles. Multiple credits for by-products from the production of PtL kerosene may be reasonable as a supporting option to lower costs, as envisaged for the use of green hydrogen in the refinery process.

As a crucial incentive in the ramp-up and market launch of liquid, electricity-based fuels, it is intended to introduce a PtL sub-quota based on energy content for the aviation sector in the course of transposing RED II. The quota will oblige those placing kerosene on the market to ensure that the fuel available in Germany is blended with a specific share of PtL kerosene. The share should increase gradually, starting with 0.5 per cent in 2026 (corresponds to about 50,000 tonnes) to 2 per cent by 2030 (corresponds to about 200,000 tonnes). This approach will ensure the market introduction of PtL fuels in that part the

¹² <https://www.icao.int/environmental-protection/pages/SAF.aspx>

¹³ Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources; available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN>

transport sector, which does not have alternative propulsion systems (e.g. electric aviation). By-products from the refinery can nonethe-

less be used for other modes of transport and counted towards the GHG quota.

RefuelEU Aviation initiative¹⁴

The RefuelEU Aviation initiative, stemming from the Green Deal, aims to boost the supply and demand for sustainable aviation fuels in the EU and in this way contribute to achieving the EU's climate targets. An initial public consultation on the initiative took place in June 2020. The European Commission also conducted a survey on an impact assessment. Several meetings were held at the same time with Member States. The results from the consultations and the survey of stakeholders

will be summarised in a study. The study will also contain proposals for legislative action deriving from the above. The Commission expects to present a first proposal in the first quarter of 2021 at the latest. Besides funding sustainable kerosene production and voluntary commitments, the discussion focuses in particular on a quota for renewable kerosene at the European level, including a sub-quota for PtL kerosene.

📌 The actors involved in the roadmap advocate for swiftly creating the framework conditions for a self-sustaining PtL kerosene market at the European level and support the introduction of a sub-quota for aviation from 2026 on, starting in Germany. In case of a mandatory quota that could result from a revision of RED II and/or the RefuelEU Aviation initiative, it is important to avoid competitive disadvantages for the European aviation industry.

European Emissions Trading System (EU-ETS)

The European Union has been using emissions trading as an instrument for climate change policy since 2005. Aviation has also been included since January 2012. Every airline conducting inner-European flights needs to buy a number of allowances corresponding to how much CO₂ is emitted. Biogenic aviation fuels can be used in the offsetting scheme. The emission factor of these aviation fuels is zero. The

Emission Trading Directive is planned to be amended to accommodate for the incorporation of CORSIA into European legislation and the announcement of the Green Deal to reduce the free allocation of allowances. State revenues from the auctioning of allowances will flow into the Energy and Climate Fund. Money from this fund will be used, inter alia, to support the market ramp-up of PtL fuels.

14 <https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12303-ReFuelEU-Aviation-Sustainable-Aviation-Fuels>

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- 📌 The German ministries participating in the roadmap are examining if and how the revenues from the EU-ETS can continue to be used to fund PtL kerosene.
 - 📌 The German ministries participating in the roadmap are examining if and how multiple credits can be attributed to PtL kerosene in the scope of the EU-ETS, if airlines buy it beyond what the quota requires of suppliers.
 - 📌 As PtL fuels will initially not be available everywhere right, the actors involved in the roadmap are examining the possibility of establishing reliable accounting rules to enable airlines to purchase PtL kerosene independently of their route network and to use it to offset emissions in the context of appropriate accounting systems. In the European accounting system for the Paris Agreements, GHG reduction credits can only be used once. It is also important to review in this context, how a potential double counting of emission reduction certificates within CORSIA can be precluded.
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State funding

Federal Government

The Federal Government is funding the development and production of PtX products and technologies in a great number of projects and initiatives at the national and international levels, in order to support a self-sustaining market. Examples of selected funding measures are described below. More information can be found on the websites of the individual ministries.

The **Federal Ministry of Transport and Digital Infrastructure (BMVI)** has a total of 1.3 billion euros at its disposal from the Energy and Climate Fund for the production and ramp-up as well as the development of renewable fuels from electricity and advanced biomass. Corresponding funding guidelines are currently being drafted by the BMVI with the support of the National Organisation Hydrogen and Fuel Cell Technology (NOW). Funding guidelines for the development of renewable fuels are scheduled to be published in the first quarter of 2021. The publication of another set of funding guidelines, also addressing PtL kerosene, is intended for the third quarter of 2021. As this is a case of extensive funding, it requires a state-aid approval from the European Commission. On average, three to

four years are envisaged for drafting and building a PtL plant. PtL production from funded plants is thus expected at the earliest from 2025.

The **Federal Ministry for Economic Affairs and Energy (BMWi)** is supporting research projects for the production and use of alternative, electricity-based fuels with about 87 million euros as part of its „energy transition in the transport sector: sector coupling through the use of electricity-based fuels“ research initiative. In line with its motto „one-stop funding“, the BMWi has combined its programmes on energy research, on research and development of transport technologies and on maritime technologies, and used synergies. Based on the research findings, a roadmap will be developed under the chairmanship of the German Aerospace Centre by 2022, which will issue recommendations for the development, production and market launch of sustainable fuels. Furthermore, sector coupling and hydrogen technologies are a particular focus among the 20 winners of the first „real-life laboratories on energy transition“ competition. Some of these consortia are planning to make hydrogen and derived products

(e.g. methanol) available for use in the mobility sector. Funding guidelines which will be notified soon were coordinated with the European Commission to in particular fund the operating costs of the real-life laboratory projects and to enable a funding period of up to 10 years. In 2020, Westküste 100¹⁵ started as the first hydrogen real-life laboratory.

The **Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)** has been funding projects on PtL kerosene at the international level (e.g. in Brazil) since 2015 as part of the International Climate Initiative. In addition, the International PtX-Hub Berlin¹⁶ was established in 2019, which is drafting a concept for sustainability requirements for PtX fuels, for example, and supporting the ramp-up of PtL kerosene at the global level. The BMU is also setting up a PtX competence centre in Cottbus, including a plant to produce

PtL kerosene. On the basis of BMU funding guidelines, additional funds will be made available for the production and use of electricity-based fuels for aviation.

The Kopernikus-P2X project¹⁷ funded by the **Federal Ministry of Education and Research (BMBF)** is performing the basic research to optimise hydrogen production and processing. It does not focus on fuel production, but the project provides important advances in technical insight that can also be used in PtL kerosene production.

The **Federal Ministry for Economic Cooperation and Development (BMZ)** entered into an „Alliance to Develop the Power to X Sector“ with Morocco¹⁸ in the context of the National Hydrogen Strategy, which is planning a reference plant. A potential kerosene production is currently being discussed.

15 <https://www.westkueste100.de/en/>

16 <https://ptx-hub.org/>

17 <https://www.kopernikus-projekte.de/projekte/p2x>

18 <https://www.bmz.de/en/development-policy/green-hydrogen>

The Länder

The Länder play a crucial role in implementing the market ramp-up as specific demonstration projects are planned to produce PtL, competence centres are established and a dedicated research environment is created.

In spring 2020, during the Conference of the Länder Ministers of Transport (VMK), the Länder introduced for the first time an agenda item on supporting the market ramp-up for alternative propulsion technologies and fuels in aviation. The aviation working committee as a sub-group of the Joint Conference of the Heads of Roads and Transport Departments agreed that Hesse as the lead state heading the aviation working committee will organise an exchange of information among the Länder and coordi-

nate the consultations with the Federal Government. Already now, a number of Länder are actively initiating and supporting project consortia together with partners from the private sector and research organisations. They aim to further explore various technical options and to test them for practical application, in order to support the market ramp-up and co-shape it. Funding for plants using different technology pathways to produce electricity-based fuels in aviation that is initiated and planned by the Federal Government is important to test and gradually implement demonstration-scale plants in Germany and abroad at various locations, based on their specific local conditions. An overview of the individual initiatives can be found in the attachment.

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- 📌 The German ministries involved are reviewing to what extent the Federal Government can also become active on the demand side.
 - 📌 The donors will actively exchange information about the PtL kerosene projects they are funding, in order to use the findings for the market ramp-up. The exchange between the Federal Government and the Länder will be conducted via the aviation working group of the Conference of the Länder Ministers of Transport.
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Contribution from the private sector actors involved

The market ramp-up of PtL kerosene requires projects which aim to build production plants. Joint activities by all actors involved are required to implement the market ramp-up, from demonstration plants to pilot plants to industrial-scale production.

Besides paying compensation for flight emissions with which climate projects will be financed, airlines can enable passengers and companies to reduce the CO₂ emissions of their flights by buying sustainable aviation fuel (e.g. Lufthansa with its COMPENSAID¹⁹ programme).

¹⁹ <https://compensaid.com/>

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- 📌 The members of the signatory associations commit themselves to contributing their know-how, particularly in state-funded pilot projects, and to enter into purchase obligations.
 - 📌 The German Aviation Association supports a European quota for PtL kerosene, as discussed in the RefuelEUAviation initiative, provided it can be implemented without distorting competition.
 - 📌 The airlines participating in the roadmap will offer their passengers the possibility to use PtL to offset emissions as soon as it is available on the market.
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Best Practices for PtL kerosene production and use

To monitor compliance with the targets, PtL kerosene projects of the actors involved in the roadmap will be documented in a publicly accessible database that will be updated as the projects progress.

The project database will also be the basis for regular meetings, at which the actors involved with the roadmap can exchange information about their progress in achieving the targets.

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