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Roadmap for the Development and Introduction of Sustainable Aviation Fuels

1. Background

Sustainable Aviation Fuels (SAF) have great potential to become the main driver for the reduction of greenhouse gas emissions in the aviation sector - both for current and future fleets. This requires great efforts to develop appropriate regulations and promotional measures to support the development of commercial production facilities as well as suitable conditions of use for SAF, thus ensuring SAF's economic competitiveness.

While SAF from biogenic raw materials (e.g., vegetable oils, waste oils and fats, organic municipal/industrial waste and other residual materials) are currently only available in small quantities - approximately 100,000 tons compared to the global fossil fuel market of approximately 280 million tons - SAF's production capacity from biogenic sources is expected to increase to more than 10 million tons over the next 10 years. Forecasts from the USA and Asia suggest that capacity could even increase to 30 to 40 million tons by 2030. This substantial increase in production is accompanied by the expectation that the price of SAF will level off at a factor of 2 compared to fossil kerosene - depending on the development of fossil crude oil prices - while it is still significantly higher today. The ecological advantages of biogenic SAF are significant: up to 80 % less CO_2 emissions and up to 70 % less particulate emissions (demonstrated in detail by DLR and NASA) can be achieved. Airlines in the USA are already using the low available SAF quantities regularly on their flights (not least because of a favourable regulation to reduce the high prices). In contrast, European airlines are reluctant to use SAFs due to a lack of regulatory incentives and are waiting for larger production volumes and thus for competitive costs and a targeted regulatory framework for the use of SAFs.

If German (and European) aviation wants to make a significant contribution to the global climate protection goals, the use of sustainable aviation fuels is essential. To this end, corresponding production capacities for SAF must be established in Germany as well and suitable regulatory framework conditions must be created. Since the use of biogenic SAF will be limited in the medium and long term due to limited biomass potential, production processes that can be used to manufacture non-biogenic SAF (i.e. based on electricity from renewable energy sources, water and CO_2) must also be promoted today. This technology is currently only available at an early stage of development and must be developed into an industrially available technology for corresponding large-scale plants in parallel to the market launch of biogenic SAFs.

The **roadmap** developed by the aireg members and presented below shows a possible development path for this, taking into account technological, ecological, economic and regulatory conditions and requirements. To this end, the aireg members offer cooperation to politicians at the federal and state level as well as other stakeholders from industry, business and science in order to accelerate the urgently needed market launch and production ramp-up of SAF.

2. Aim of the Roadmap

The aireg Roadmap presents measures and incentives to achieve a significant share of sustainable fuels in aviation. This includes measures in the field of research and development (R&D) of corresponding manufacturing technologies, milestones for technological development and implementation as well as regulatory and other supporting measures. The time horizon for the introduction of such sustainable fuels within the framework of this roadmap includes concrete proposals for implementation up to the year 2030 as well as recommendations that go beyond 2030 and potentially have an effect until 2050. All in all, the roadmap serves as a set of objectives to advance the use of sustainable aviation fuels strategically, systematically and holistically. With a view to introducing sustainable aviation fuels to the market, it is intended to support all the players involved and to avoid favouring/discriminating against individual market players.

3. Measurements

The diagram shows the entirety of the package of measures required. The respective individual measures are divided into research/development-related, technical, regulatory and support activities. They are also assigned on a timeline with regard to their possible time reference points. In the following, the individual measures are explained in more detail with regard to their content, objectives and mechanisms of action.

3.1 Research and Development (R & D)

Establishment of a PtL Demonstration and Research Centre in Germany

Establishment of a research and demonstration centre (in the sense of a pilot plant) for PtL fuels under the umbrella of an existing (federal) research organisation with the aim of scaling-up / market preparation of PtL fuels. In addition, a networking and bundling of the existing competences from research and industry in Germany is to be realised, i.e. close cooperation with research and industry. This research and demonstration centre should include the construction of a semi-industrial production plant with an annual production of approximately 10,000 tonnes of sustainable synthetic kerosene. While initially only the Fischer-Tropsch technology could be used for this purpose (only this technology route has been formally approved for aviation to date), other technology routes are to be tested for their industrial suitability or transferred to them in the course of the project. In this respect, this centre can also play a coordinating and integrative role for activities at other locations in Germany.

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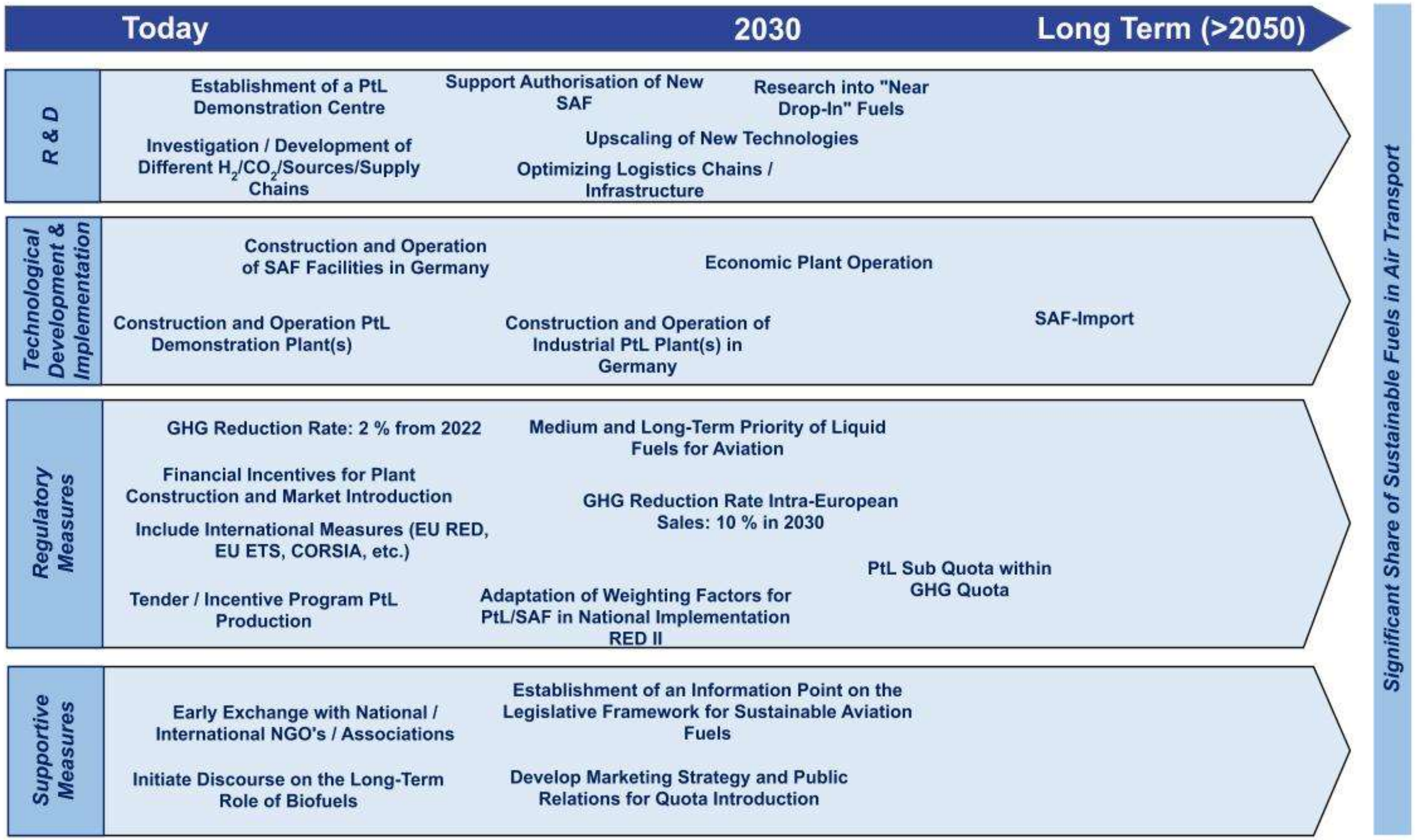

Investigation / Development of Different H_2/CO_2 Sources/Supply Chains

A major challenge for the large-scale production of synthetic, electricity-based fuels is a secure, efficient and sustainable supply of the starting materials hydrogen (H_2) and (sustainable) carbon dioxide (CO_2). Therefore, both the potentials of hydrogen supply by water electrolysis and the availability and development of sustainable CO_2 sources have to be analysed.

Support Authorisation of New SAF

In aviation, there are high demands on fuel properties, which are defined in various specifications and standards (e.g. ASTM D1655, ASTM D7566, DEF STAN 91-91). The certification of new, sustainable aviation fuels within the scope of these specifications, but also the use of 100% SAF is time and cost-intensive. Future certification procedures should, therefore, be supported by appropriate measures. For example, the use of previous experience with already approved synthetic fuels and the incorporation of more recent internationally acquired research results can usefully supplement the optimisation efforts of ASTM.

Upscaling of New Technologies

In order to be able to use new technologies along the entire PtL production chain (e.g. new electrolysis processes, new synthesis reactors) in an economically viable way, an upscaling of today's plant standards is absolutely necessary. To this end, the upscaling of these technologies from laboratory or experimental scale to industrial scale must be supported; this includes integration into existing industrial production structures.

Optimizing Logistics Chains and Infrastructure

Even if a large part of the already existing (fuel-side) infrastructure for the fossil kerosene used today can also be used almost without restriction for sustainable aviation fuels, both the upstream logistics chains (e.g. H_2/CO_2 transport, fuel transport from decentralised plants) and parts of the processing infrastructure (e.g. existing refinery plants) must be adapted and optimised to meet the requirements for the large-scale use of SAF.

Research into "Near Drop-In" Fuels

In addition to the further development of drop-in fuels, so-called near drop-in fuels should also be further developed and promoted. Drop-in fuels are fully compatible with the existing fuel infrastructure and existing aircraft and engine technologies. The compatibility extends from older aircraft types and engine types to modern aircraft types and engine technologies. However, drop-in fuels today can only be blended with conventional aircraft fuels up to a maximum of 50 %, which reduces the achievable emission reductions, for example. In contrast, renewable aircraft fuels (e.g. ASTM D7566 compliant HEFA-SPK or FT-SPK) can be used up to 100 % in modern engine technologies, which among other things significantly increases the achievable emission reductions compared to drop-in fuels, but can also reduce pollutant emissions and maintenance costs. Against this background, ASTM qualification and the use of near drop-in fuels must be promoted.

3.2 Technological Development and Implementation

Production of Biogenic SAF in Germany

Existing plant capacities for the production of sustainable, biogenic fuels can only provide SAF for aviation to a limited extent. Moreover, they are almost exclusively located outside of Germany. In order to maintain corresponding know-how in Germany and to build up corresponding plant capacities for a national supply of biogenic SAF (bio-raw materials and waste), consideration should be given to upgrading existing biofuel plants for the supply of SAF. This would (i) achieve further market availability of corresponding synthetic kerosene, (ii) gain additional experience with industrial plant operation also in Germany, which could then be transferred to other projects if necessary, and (iii) provide significant SAF quantities for German and European air traffic.

Construction and Operation of SAF Demonstration Facilities

PtL fuels and hybrid processes based on feedstock combinations have the potential to make a decisive contribution to environmentally friendly and climate-neutral air traffic. However, apart from a few laboratory or micro-plants, i.e. production output quantities on a litre or kilogram scale, no larger plants are currently under construction or in operation. These are, however, absolutely necessary in order to go through the learning curve in the production of such fuels and thus realise cost reductions in fuel production, which is absolutely essential for the (timely) market entry of sustainable aviation fuels. The construction and operation of one or more PtL demonstration plant(s) for the production of PtL fuel quantities on an industrial (demonstration) scale (at least 10,000 to 15,000 tonnes per year), each of which will involve costs of approx. 150 to 200 million euros, will make it possible to establish a pioneering technological role in Germany that is important in terms of industrial policy and will form the basis for a sustainable source of added value through the relevant technologies.

Construction and Operation of Industrial SAF Facility(s) in Germany

After a successful demo operation, the technology has to be transferred to a (large) industrial scale in order to (i) achieve an upscaling of the technology, (ii) gain experience with an industrial plant operation in order to be able to transfer it to further projects, and (iii) to realize first significant offers of use for German and European air traffic.

Economic Plant Operation

Partly due to the lack of a regulatory framework, it is not yet clear how the nationwide market launch and market ramp-up of electricity-generated synthetic kerosene can succeed. On the one hand, electricity-based fuels are complex to produce and will, therefore, remain more expensive than fossil aviation fuels for the foreseeable future. On the other hand, the learning curve in the production of such fuels must first be run through in order to enter the market. From a certain point on, however, economical plant operation must be possible - under the given conditions.

SAF Import

In the long term, the production potential for sustainable and cost-efficient aviation fuels in Germany or the EU is limited compared to German or EU demand. In order to produce large quantities of sustainable aviation fuels, the import of biogenic or electricity-based raw materials and fuels from regions with a high occurrence of renewable energies should, therefore, be aimed at. The import of large quantities of biogenic and electricity-based raw materials and fuels requires transparent verification of compliance with sustainability criteria in the countries of origin. Here, an early exchange with national and international NGOs and associations, as discussed in Section 3.4, can play an important role.

3.3 Regulatory Measures

Financial Incentives for Plant Construction and Market Launch of SAF

As no (larger) plants for the production of SAF kerosene have been built or are in operation in Germany to date, it has not yet been possible to run through the necessary learning and experience curves to reduce production costs. Accordingly, such SAFs are currently not competitive with fossil fuels. In order to realize an urgently needed market ramp-up, the government must, therefore, create appropriate financial support measures that will encourage and ideally ensure a fundamental build-up of SAF production capacities.

Include International Measures (EU RED, EU ETS, CORSIA, etc.)

Air transport is an internationally oriented industry; therefore, in addition to individual national control measures, international and transnational measures or agreements to reduce air transport emissions should be sought. In order to implement the measures proposed in this roadmap, it is urgently necessary to review their regulatory compatibility with regard to existing measures, such as the EU ETS or CORSIA, or to interpret them in a way that is compatible with the regulations.

Tender / Incentive Program SAF Production

In order to implement a market ramp-up for advanced SAFs, the international tendering of production capacities, in combination with a corresponding subsidy - comparable to the expansion of renewable energies via the EEG levy - appears to be a promising instrument after a demonstration phase. Within the framework of such a tendering model, necessary PtL production capacities should be put out to tender in several rounds, for which producers (consortia) can apply. Producers will then receive a fixed additional remuneration for a fixed period of time to ensure competitiveness with conventional fossil fuels.

Medium and Long-Term Priority of Liquid Fuels for Aviation

Since only limited quantities of sustainable liquid fuels will be available in the longer term, it is important to use the feedstocks and products in sectors or transport areas where no alternatives to broad-based emission reductions (e.g. through direct electrification or the direct use of hydrogen) are realistic in the medium to long term. This applies in particular to aviation and (ocean) shipping and, to some extent, to heavy goods transport.

Adjustment of Weighting Factors for PtL/SAF in National Implementation RED II

According to the current EU Renewable Energy Directive (EU RED II), alternative fuels in aviation can be credited with a factor of 1.2 towards the target share of renewable energies in the transport sector to be achieved in accordance with Article 25, as long as they are not fuels from food and feedstuffs. This small multiplier cannot serve as a significant driving force for the use of sustainable fuels in aviation. However, it can be increased when RED II is implemented in national law, provided that a reasonable compromise between a higher credit factor and unrealised GHG savings is possible and acceptable.

GHG Reduction Rate Intra-European Sales

The GHG reduction rate is an effective means of reducing greenhouse gas emissions from aviation in a timely and predictable manner. By introducing a corresponding quota, it can be ensured that a significant use of sustainable fuels - and thus a corresponding climate protection effect - is achieved by 2030. In order to produce as large quantities of sustainable aviation fuels as possible and thus make the most effective use of cost degression through economies of scale, while avoiding distortions of competition as far as possible, such a GHG reduction quota should be implemented on a transnational scale. This would be appropriate for intra-European (EU-27) air transport[1] ; it would then also be compatible with the current balance area of the EU ETS. A quota model should be as close as possible to RED II. This applies in particular to sustainability criteria that renewable aviation fuels must meet in order to count towards quota targets. A quota should be implemented as quickly as possible (2 % from 2022) and should be gradually increased to a greenhouse gas reduction of 10 %[2] by 2030. At national level, an amendment to the existing Biofuel Quota Act and an extension to include a sub quota for air transport would be effective and easy to implement. Furthermore, such a quota can also be implemented as part of the national implementation of RED II in German law.

PtL Sub Quota within GHG Quota

Due to the limited raw material potential for the production of biofuels, the predicted strong market growth in air traffic means that, for climate protection reasons, electricity-based fuels will have to supplement biofuels in the medium term and possibly replace them in the long term. Since the hurdles for the production of PtL fuels are comparatively high, a minimum share of these fuels in the overall fuel mix should be ensured by means of a sub quota. A corresponding market ramp-up can then be controlled by a continuously increasing sub quota for electricity-based fuels. This makes it possible to run through learning curves and thus reduce the costs of PtL fuels in the long term. A PtL sub quota in relation to domestic air traffic in Germany could be introduced from 2025 at 1 % and increased by 1 percentage point per year until 2030.

[1] Until such a regulation takes effect throughout the EU, Germany - similar to the Scandinavian countries or the Netherlands - should play a pioneering role with regard to domestic German air traffic.

[2] According to Article 25(1) of RED II, the share of renewable energy in the final energy consumption of the transport sector of each Member State must be at least 14 % by 2030. In addition, liquid fuels of non-biogenic origin must, according to Article 25(2), have a minimum greenhouse gas saving of 70%. Thus, the 14% in terms of energy content corresponds to a GHG reduction rate of approximately 10%.

3.4 Supporting Measures

Early Exchange with National and International NGOs and Associations

The measures presented here and their intended effect as well as their impact on the environment and the population must be communicated as early and transparently as possible in order to eliminate possible misunderstandings or take counter-arguments into account. For this reason, national NGOs should be involved in the communication as early as possible. In addition, national or transnational measures can only be a first step towards effective international action to achieve a significant reduction in emissions from international aviation through the use of sustainable fuels. It is therefore equally important to communicate planned measures to international NGOs as well as IATA and ICAO at an early stage.

Initiate a Discourse on the Long-Term Role of Biofuels

From an economic point of view and taking into account existing technologies and raw materials, biogenic fuels are urgently needed for a timely market launch of renewable aviation fuels. Due to their limited potential, however, biogenic fuels cannot serve as the only renewable fuel option in aviation and must be supplemented by PtL fuels in the medium term. Within the framework of a holistic strategy, it is necessary to assess the role of biogenic fuels, i.e. to discuss whether, when and how a specific biofuel option/technology should be pursued and promoted in future alongside the promotion of PtL; this applies, for example, to the raw material option of municipal waste. A short-term expansion or establishment of higher biofuel production capacities, which would potentially become obsolete with the construction of future PtL plants, should be avoided from the outset. To this end, a targeted debate is required on whether and which biofuel options should and must be promoted and made available, and to what extent, from when and until when.

Establishment of an Information Point on the Legislative Framework for Sustainable Aviation Fuels

For start-ups and medium-sized companies it is hardly affordable to understand and permanently follow the constantly changing legislation, especially regarding RED II, CORSIA and national standards, with sufficient accuracy. This creates a high degree of uncertainty as to whether (innovative) manufacturing processes will be recognised. Also, the paths to recognition are often unclear. A body should therefore be established (e.g. at a subordinate authority, university institution, etc.) to provide information in a secure and bundled manner and to provide clarity as to whether a fuel can be counted towards certain quotas if innovation is to take place in the sector.

Develop Marketing Strategy and Public Relations for Quota Introduction

In order to inform both the public and affected stakeholders about the planned measures and their effects in advance of a quota introduction, a marketing strategy must be developed to prevent communication errors of the past - which have occurred in particular with the introduction of biogenic fuel in road traffic, but also with E10 - in advance. In this context, the introduction of the GHG reduction quota for air traffic presented here must also be integrated into the public relations work of the affected stakeholders, NGOs and the responsible authorities as a matter of urgency in order to ensure broad acceptance in all areas.