NATIONALER WASSERSTOFFRAT

STATEMENT

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Hydrogen in aviation in Germany

1 INTRODUCTION

The path towards climate-neutral aviation requires not only evolutionary improvements but also radical steps in technologies in many areas as well as corresponding infrastructures. In addition to revolutionary aircraft and propulsion concepts, sustainable energy sources (synthetic fuels, hydrogen, etc.), modified flight routes and modal shifts also play an important role.

Especially in view of the global growth in air traffic, a significant reduction in the ecological footprint of aviation is a central task for research, industry and society. Aviation today is responsible for about 2.5% of global manmade CO_2 emissions. If the effects of non-CO_2 emissions such as water vapour and nitrogen oxide are added, the influence of aviation on global warming increases to around 3.5%[1]. According to emission reporting under the Framework Convention on Climate Change, in 2019 Germany emitted approximately two million tonnes of CO_2 from national aviation and approximately 30 million tonnes of CO_2 from international aviation.

A study by Eurocontrol from October 2020[2] provides important information on the distribution of flights as well as corresponding CO_2 emissions: Flights over 1,500 km account for just under 25% of all flights in the Eurocontrol area, but are responsible for over three quarters of all CO_2 emissions; the number of flights under 500–600 km, on the other hand, is over 30%, but these represent only 4.3% of CO_2 emissions. Flights covering the distances in between are thus responsible for approximately 20% of total air traffic emissions. This makes it clear that a differentiated view of the various flight segments is also very important with regard to technologies and fuel concepts.

The vision for the future of aviation is the zero-emission aircraft – an aircraft that emits no pollutants during both flight and ground operations. This ambitious goal requires substantial research and long-term developments in sustainable energy sources, disruptive aircraft concepts and components, and alternative propulsion concepts.

The evolutionary further development of engines in combination with sustainable biofuels and synthetic fuels* (Sustainable Aviation Fuels = SAFs) will already enable significantly emission-reduced air transport in the short term. For example, existing aircraft could increasingly use biogenic aviation fuels based on waste and residual materials in the short term and electricity-based synthetic kerosene in the long term. Drop-in fuels require no modifications to the engine and can already reduce CO_2 emissions by more than 50%. In addition, 50–70% of soot and particulate emissions can be avoided using advanced fuels. The effects of drop-in fuels can be maximised with blending rates above 50%. Barriers to large-

* The production processes of synthetic fuels are not explained further here, as these are the subject of further work within the German National Hydrogen Council.

scale introduction are currently production capacity and manufacturing costs. Near-drop-in fuels[3] can reduce CO_2 emissions by up to 80% (net emissions), soot. particulate emissions by up to 90% and NOX emissions by almost 100% through co-optimisation of fuel and burners.

Further significant improvements are possible through the use of climate-neutral hydrogen, as this can reduce emissions of CO_2, soot and aerosol precursors to zero. The effects of emitted water vapour on the climate, including at different flight altitudes, have yet to be sufficiently researched.

In addition to these advantages with regard to emissions, hydrogen can play an important role alongside SAFs because of its potential cost advantages compared to synthetic fuels (one less conversion stage and no need for climate-neutral CO_2). However, specific challenges with respect to using hydrogen in aviation, including due to its lower energy density, will mean that SAFs will have to be used to a greater extent, especially on longer medium-haul and long-haul routes. In the short term, a significant reduction in emissions can also be achieved with SAFs in this route range and on medium-haul routes up to 1,500 km; in the medium and long term, the climate and economic advantages and disadvantages of hydrogen and SAFs must be carefully weighed up.

2 PROSPECTS AND CHALLENGES OF USING HYDROGEN AS AN ENERGY SOURCE

Hydrogen propulsion can significantly reduce the impact on the climate. Hydrogen eliminates CO_2 emissions in flight and can be produced carbon-free. Also taking into account non-CO_2 emissions and the uncertainties in these effects, recent estimates show that direct hydrogen combustion could reduce in-flight climate impacts by 50–75%[4] and fuel cell propulsion coupled with the turbines provides further efficiency gains. For the widespread use of hydrogen-powered aircraft, several technological and economic problems must be solved:

- overall efficiency must be increased with lighter tanks and high-performance fuel cell systems,
- liquid hydrogen (LH_2) must be stored and distributed in the aircraft,
- engines must be able to burn hydrogen with low NOx emissions, and
- efficient refuelling technologies must be developed comparable to those for kerosene,
- liquid hydrogen infrastructure must be developed and constructed at airports,
- efficient ground, maintenance and repair processes must be developed in parallel with the development of the aircraft and the new components,
- the supply of hydrogen must be systematically integrated into the energy infrastructure of the respective world regions (Europe),
- hydrogen-powered aircraft must be approved as well as hydrogen as an aviation fuel.

3 USES FOR HYDROGEN-POWERED AIRCRAFT

Assuming that these challenges can be successfully overcome, hydrogen engines will be best suited for regional, short-haul and possibly medium-haul aircraft. As things stand today, it cannot be conclusively determined which type of hydrogen engine will be best suited for which length of flight. This depends not only on the engine, but also on the supply of LH_2 in the aircraft (tank and tank integration, fuel supply, etc.) and thus also has an impact on aircraft design and layout.

Even if H_2 is technically feasible as an energy source for air transport, it seems less suitable for long-distance evolutionary aircraft from an economic point of view. In particular, the size of the hydrogen tanks, the associated larger aircraft architecture and the resulting higher energy demand would lead to significantly higher costs per passenger. However, new aircraft designs (e.g., blended wing body) could open up completely new options, but we are probably still two to three decades away from such an aircraft entering service.

4 FEASIBILITY AND ADVANTAGES

Feasibility studies and economic analyses show that hydrogen can be an essential component of future aviation technology. If H_2-powered aircraft are deployed in segments where they are the most cost-effective means of decarbonisation, they could reach an optimistic market potential of 35–40% by 2050.4 If Sustainable Aviation Fuels (SAFs) power the other 65–60% of aircraft, the climate impact of aviation would drop enormously, bringing the CO_2 reduction targets set by the EU and ATAG within reach. From the scientific point of view, concrete estimates of the climate impacts with regard to water vapour emissions will be possible in four to five years at the earliest.

5 PRODUCTION, INFRASTRUCTURE AND SUPPLY

However, the supply and refuelling infrastructure requires considerable investment and coordination, including the construction of liquid hydrogen capacity and local supply at airports. In the market potential mentioned above, by 2040 the global aviation demand for liquid hydrogen (LH_2) would amount to approx. 10 million tonnes (>330 TWh) per year4, in Europe some 100,000 tonnes (>>3 TWh).

Due to the different properties of LH_2 in aviation compared to conventional kerosene, the safety regulations for handling and use must be re-evaluated and revised. In addition, H_2 producers, logistics companies, airports, aircraft manufacturers and airlines need to work closely together to ensure that production, logistics, and infrastructure and supply development, as well as aircraft roll-out, occur simultaneously.

If H_2 aircraft were successfully introduced to the market from around 2035, H_2 aircraft with a medium-haul range would probably also be introduced by 2050, leading to even higher aviation demand for LH_2, which would be appreciably beyond the 10 million tonnes per year mentioned above. This would entail considerable additional investment for hydrogen supply in aviation, but also for the airport refuelling infrastructure. Even though these changes are significant for all stakeholders, especially for airports, possible technical limitations have to be taken into account during implementation.

6 RECOMMENDATIONS OF THE GERMAN NATIONAL HYDROGEN COUNCIL

Bold steps are needed from research, industry and politics to initiate a path to decarbonisation and defossilisation through hydrogen in aviation. The industry needs to embark on the path of commercialisation today, because aircraft development and certification takes more than ten years and substantial fleet renewal at least another ten years. In order to switch to a new propulsion technology, an ambitious sector roadmap for research and innovation (R&D) is needed, with associated activities being sustainably promoted by politics (hydrogen strategy and federal funding programmes), accompanied by long-term stable political framework conditions.

The German National Hydrogen Council therefore recommends the following:

- Development of a long-term, politically secure Europe-wide plan for decarbonisation of the sector that reflects the potential of hydrogen and SAFs and at the same time takes into account the complexity of aviation, its international interdependencies, the economic implications and the exceptionally high safety requirements.
- Within the framework of the revision of the RED II (Directive EC 2018/2001), measures leading to increased direct use of hydrogen in aviation must be adequately considered. Attention must be paid to the long lead time of this disruptive technology.
- At the same time, the RED II should be further developed to set an ambitious level for the decarbonisation of the energy sources used in both national and European aviation for the period up to 2040 with interim targets for 2030 and 2035. Modal shifts and the need for cost-effective emission reduction must be taken into account.
- Research, especially in the area of engine/combustion chamber development and materials research in the field of cryogenic hydrogen, must be significantly intensified. For example, structural materials that resist cryogenic hydrogen and their insulations are just as important as the interaction of gaseous hydrogen with metallic and polymeric materials.
- In addition, research into the climate impact of emitted water vapour must be intensified. The state of knowledge on both modelling and the effect in the upper atmosphere needs to be improved.
- Ground processes and efficient maintenance and repair technologies are to be developed and expanded, as is the necessary infrastructure, and a connection to the German H_2 network is to be provided for airports.
- New safety standards and processes for aircraft with LH_2 onboard storage are to be defined and the development of logistics, infrastructure and supply is to be coordinated. R&D activities and funding should focus on the following key areas:
  - development for commercial use of the required aircraft components including LH_2 fuel storage and supply on board aircraft,
  - LH_2-suitable aircraft systems first for short- and medium-haul, subsequently after intensive technical testing possibly also for long-haul,
  - establishment and expansion of production, infrastructure and supply of liquid hydrogen,
  - creation of a legal framework for the entire system (aircraft, infrastructure, etc.), analysis on the optimisation of hydrogen hubs with subsequent construction,
  - support for and preparation for the approval of hydrogen-powered aircraft as well as the approval of hydrogen as an aviation fuel in the international bodies responsible for this.

These measures should feed into the promotion of a demonstrator programme to be adopted as early as possible and into the implementation of a pilot project, both financed from the EC Fund. A suitable programme for the provision of SAFs and the additional hydrogen required for this must be developed together with the petrochemical industry.

SOURCES USED:

1 D.S. Lee et al.: The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018, Atmospheric Environment 244 (2021) 117834, Elsevier, 2020.
2 Eurocontrol – Aviation Intelligence Unit: Think Paper No. 7, October 2020.
3 Near-drop-in fuels are fuels that can be used up to 100%, if necessary with minor adjustments in the aircraft fuel system and in the engines (DLR, 2018).
4 McKinsey: Hydrogen-powered aviation: A fact-based study of hydrogen technology, economics, and climate impact by 2050 (May 2020).

H2 NATIONALER WASSERSTOFFRAT

THE GERMAN NATIONAL HYDROGEN COUNCIL

On 10 June 2020, the German Federal Government adopted the National Hydrogen Strategy and appointed the German National Hydrogen Council. The Council consists of 26 high-ranking experts in the fields of economy, science and civil society. These experts are not part of public administration. The members of the National Hydrogen Council are experts in the fields of production, research and innovation, industrial decarbonisation, transportation and buildings/heating, infrastructure, international partnerships as well as climate and sustainability. The National Hydrogen Council is chaired by former Parliamentary State Secretary Katherina Reiche.

The task of the National Hydrogen Council is to advise and support the State Secretary's Committee for Hydrogen with proposals and recommendations for action in the implementation and further development of Germany's National Hydrogen Strategy.

Contact: info@leitstelle-nws.de, www.wasserstoffrat.de/en