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POWER-TO-LIQUIDS (PTL): SUSTAINABLE FUELS FOR AVIATION

(Presented by Germany)

EXECUTIVE SUMMARY

The ICAO basket of CO_2 mitigation measures includes aircraft technology, operational improvements, sustainable aviation fuels and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), in order to achieve ICAO's global aspirational goals with regard to environmental protection and climate change for international aviation. Sustainable fuels have the potential to become a major element for achieving absolute emissions reductions in aviation. Also, the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change requires massive reductions of climate relevant emissions in all sectors by mid-century to pave the way for a global temperature rise limitation in the second half of this century.

This Information Paper provides a current overview of the concept of producing sustainable jet fuel using additional renewable electricity, so-called Power-to-Liquids (PtL). Production pathways and jet fuel drop-in capability are explained. Compared to biofuels, PtL do not raise the demand for arable land and require lower water input. Produced from renewable electricity, PtL have the potential to become almost CO_2-neutral in the longer-term. PtL can make a major contribution to a climate friendly air transport sector.

Strategic Objectives:	This working paper relates to Strategic Objective E – Environmental Protection.
Financial implications:	
References:	

1. INTRODUCTION

1.1 The ICAO basket of CO_2 mitigation measures includes aircraft technology, operational improvements, sustainable aviation fuels and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), in order to achieve ICAO's global aspirational goals with regard to environmental protection and climate change for international aviation. Sustainable fuels have the potential to become a major element for achieving absolute emissions reductions in aviation. Also, in the Paris Agreement under the United Nations Framework Convention on Climate Change of 2015, the signatories declared to keep the global temperature rise well below 2 °C, and to drive efforts to limit the temperature increase even further to 1.5 °C above pre-industrial levels. This agreement requires a substantial reduction of all climate relevant emissions and efforts from all sectors and fields of application - including air transport - to achieve temperature neutrality in the second half of this century. ICAO's long-term traffic forecasts of 2018, which cover the coming two decades, expect global aviation to grow by 4.1 % on average annually. Efficiency measures in the air transport sector are essential and must be significantly reinforced. However, in the past, annual efficiency improvements did not exceed 2 %, leading to a net increase of climate relevant emissions. One essential option to achieve ambitious emissions reductions are sustainable fuels which allow a minimization of climate relevant emissions and which are based on renewable energies, thus avoiding depletion of natural resources. The ICAO Basket of Measures highlights the importance of reductions of climate relevant emissions by the use of sustainable aviation fuels as an important pillar. Accordingly, CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation), adopted by the ICAO Member States in October 2016, and the ICAO Vision on Sustainable Aviation Alternative Fuels should comprise PtL as a measure to substantially reduce climate relevant emissions from aviation. Earlier input on PtL was presented by Germany at the CAEP Steering Group meeting 2016 and by Germany's technical experts at the ICAO 'Conference on Aviation and Alternative Fuels', which took place in October 2017 in Mexico City.

2. WHAT ARE "POWER-TO-LIQUIDS"?

2.1 PtL stands for "Power-to-Liquids" comprising synthetically produced liquid hydrocarbon fuels for combustion engines in aviation - and possibly for other transport modes like shipping and heavy duty haulage. The main energy source and feedstocks for the production of Power-to-Liquids are renewable electricity, water and carbon dioxide (CO_2).

2.2 Typically, PtL production comprises three main steps:

1) Hydrogen production from renewable electricity using the electrolysis of water;

2) Provision of climate neutral CO_2[1] and conversion; and

3) Synthesis to liquid hydrocarbons with subsequent upgrading/conversion to refined fuels.

2.3 Different synthesis methods to produce renewable PtL jet fuel are available, e.g. the Fischer-Tropsch (FT) synthesis, or the methanol (MeOH) synthesis. The Fischer-Tropsch synthesis process produces a mixture of various long-chain hydrocarbons which must undergo further processing to get jet fuel, gasoline, diesel, and other basic chemicals. According to current jet fuel standards, blending with conventional kerosene is possible up to 50 %. Methanol synthesis results in products of very high purity, subsequently processed to long-chain hydrocarbons.

2.4 Other production technologies for renewable liquid fuels of non-biogenic origin are currently under research and development. The "Sun to Liquid" process funded by the EU's H2020 research program is one current example for current R&D activities to push PtL production processes.[2]

[1] Non-fossil CO_2 can be extracted from the air or derived from biogenic sources of existing installations.

3. WHY PTL FUELS?

3.1 As long-haul aviation will very likely be depending on liquid fuels in the coming decades, it is necessary to encourage the production and use of climate-neutral liquid fuels to contribute to the global climate goals.

3.2 In comparison to biofuels, PtL achieves higher area-related yields when energy is derived from renewable energy sources such as photovoltaic and wind energy. The water requirement for PtL production is also significantly lower compared to the production of biofuels. Therefore, PtL can be seen as a key technology to enable a fully regenerative, sustainable, post-fossil fuel supply of aviation in the longer run, while avoiding the potential risks and adverse side effects through the energetic use of cultivated biomass and in land-use.

3.3 In the medium-term, it is essential to bring forward synthetic fuels like PtL. As the synthesis of PtL requires large amounts of renewable energy, their use should be focused on sectors in which electricity cannot be used directly, such as existing aircraft and engine technologies. This comprises pilot and demonstration projects for the production of PtL, which aim to reduce production costs by economies of scale, enable market launch and contribute to ensure sufficient capacity of this technology in the long-term.

3.4 Like biofuels, PtL is a hydrocarbon which means that non-CO_2 effects of emissions at high altitude (e.g. coming from change of natural cloudiness resp. nitrogen oxides, sulphur oxides, water vapour, and aerosols like soot and partially NO_x) would remain. Through the 'design' of PtL, these effects may be downscaled but cannot be avoided entirely. Unless a technological breakthrough towards electrical propulsion on long-haul flight can be achieved, such effects on high altitudes can only be addressed by significant efficiency improvements, climate friendly routing, traffic reduction and finally offsetting by negative emissions elsewhere.

4. CRITERIA FOR SUSTAINABLE POWER-TO-LIQUIDS

4.1 To ensure that PtL contributes to global GHG reduction and does not harm sustainable development, three general criteria must be fulfilled:

1) Production from additional renewable energy,

2) Use of required CO2 from non-fossil sources, and

3) Production regions provide for sustainable, socially and environmentally responsible production, e.g. water and territory for renewable electricity generation must not be scarce or already at their limits.

4.2 Provided that PtL is derived from additional renewable electricity and non-fossil CO_2, it could reduce aviation's CO_2 emissions significantly. However, to achieve this, PtL production plants

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[2] See WP by EU on European Views and Support for the Development and Use of Sustainable Alternative Aviation Fuels [CAAF2/17-WP/14]: Horizon 2020 project SUN-to-LIQUID and http://www.sun-to-liquid.eu/.

would have to obtain their power only from additional renewable energy sources and must not cause additional fossil electricity generation, since otherwise global CO_2 emissions could even increase.[3]

5. TECHNOLOGY READINESS LEVEL

5.1 PtL can be produced from concentrated renewable CO_2 sources using established industrial processes with relatively high technology readiness levels.[4] While individual processes have been applied on a large-scale, PtL full system integration is recently progressing due to demonstration plants in Iceland, Finland, Germany, Spain[5], Switzerland[6] and Norway. A demonstration plant for PtL jet fuel will be built in Stade (Germany) by 2021/2022.[7] Improved processes for carbon capture from air and high-temperature electrolysis, which are at industrial scale demonstration level in Canada and Norway currently, could increase the production potential and efficiency, respectively.[8]

5.2 PtL jet fuel is drop-in capable. The ASTM jet fuel standard allows for a 50% blend of Fischer-Tropsch synthetic fuel. A further increase of the blending quota is technologically possible. PtL via the methanol pathway is not yet approved.

6. ECONOMICS AND SCALABILITY

6.1 A crucial aspect for a large scale use of PtL is the economic feasibility. The main constraints for the short-term deployment of PtL synthesis and use are production costs compared to conventional jet fuel. Under current conditions, costs for PTL jet fuel are expected to be 3 to 5 times higher than costs for conventional fuel[9]. However, significant cost reductions can be achieved through decreasing renewable electricity costs (wind, solar), increasing efficiencies through improved PtL production processes (e.g. high-temperature electrolysis, CO2 extraction, etc.), learning effects through increased deployment, and economies of scale. Learning curves can be quite steep under favourable conditions as the development of wind power and photovoltaics cost has shown in the past.

6.2 The development of PtL could take advantage of the high renewable power generation potentials in regions where the potential exceeds domestic energy demand. PtL thus entails increased energy safety, locally added value, and a sustainable business perspective for regions with abundant renewable energy potential.

6.3 PtL is not merely a technology for aviation's fuel demand. PtL production via the Fischer-Tropsch synthesis pathway gives rise to a multitude of hydrocarbons as intermediate products. Hence, to further facilitate the deployment of the technology up to market maturity, the sectors should

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[3] Öko-Institut (2019): Kein Selbstläufer: Klimaschutz und Nachhaltigkeit durch PtX. https://www.oeko.de/fileadmin/oeko_doc/Impulspapier-soz-oek-Kriterien-e-fuels.pdf

[4] While this approach does not result in a closed loop recycling of CO_2 emissions, carbon could at least being used twice – first for the industrial process and second as a component of the synthetic fuel. As long as the capture of carbon from the air is too costly, this could be a viable way for the development of the synthetic fuel industry.

[5] https://www.dlr.de/dlr/desktopdefault.aspx/tabid-10081/151_read-35119/#/gallery/35513

[6] https://www.iwr.de/news.php?id=36104

[7] https://www.airliners.de/synthetische-treibstoffe-retter-luftfahrt-klimabilanz/50510

[8] See 'The Carbon Capture & Storage Association (CCSA)' (2019) International CCS projects, http://www.ccsassociation.org/why-ccs/ccs-projects/international-projects/.

[9] See Albrecht, F. G. Maier, S.; Dietrich, R.-U. (2017): Power-to-X for the future fuels supply, Techno economic evaluation and system analysis, presentation held 18 Oct 2017, https://elib.dlr.de/116674/ and Schmidt, P. et al. (2018), Power-to-Liquids as Renewable Fuel Option for Aviation: A Review, Chemie Ingenieur Technik, Vol. 90, No 1-2, pp 127-140, https://onlinelibrary.wiley.com/doi/abs/10.1002/cite.201700129.

cooperate in a common effort to achieve synergies, e.g. with long-haul international shipping and the chemical industry.

7. PTL SUPPORTING ACTIVITIES IN GERMANY AND EUROPE

7.1 The further development of PtL especially for aviation is being actively supported in Germany and Europe. For instance, the Aviation Initiative for Renewable Energy in Germany 'aireg' is committed to the increased production and use of regenerative aviation fuels in Germany (www.aireg.de). In 2011, aireg was founded by airlines, airports, research institutes, companies of the aviation industry and companies in the provision and processing of raw materials. At the National Aviation Conference on August, 21st 2019, the Federal Ministry of Economics and Energy, the Federal Ministry of Transport and Digital Infrastructure, the Federal States, Trade Unions and the Aviation Industry jointly signed a statement of their goals for a national aviation strategy. One goal is to strengthen research and development for PtL in order to make air traffic more climate-friendly in the medium-term. The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the German Environment Agency are funding a research project for developing a roadmap for climate protection in aviation and maritime transport focussing on synthetic fuels from renewable energy as one important mitigation option. This research project is conducted by Oeko-Institut, DLR and CE Delft. The EU funded SUN-to-LIQUID project started in 2016 and will design, fabricate, and experimentally validate a large-scale, complete solar fuel production plant. The field validation will integrate for the first time the whole production chain from sunlight, H_2O and CO_2 to liquid hydrocarbon fuels.[10] Furthermore, the German Federal Ministry of Transport and Digital Infrastructure (BMVI) has implemented a comprehensive international research and demonstration project regarding the use of renewable jet fuel at airport Leipzig/Halle (DEMO-SPK). The main objective of the DEMO-SPK project is to examine the behaviour of different multi-blends of fossil and renewable jet fuels under realistic conditions within the general fuel supply infrastructure of an airport. Impacts on the reliable and safe operation of the airport infrastructure as well as determination of necessary technical adjustments are of great interest. Various renewable jet fuels are used and tested from different manufacturing processes. Results of the project will be presented by the end of 2019.[11]

7.2 All these activities are very important for triggering the learning processes which are essential to further develop PtL production and deployment in the medium and long-term.

— END —

[10] http://www.sun-to-liquid.eu/.
[11] https://www.bmvi.de/SharedDocs/DE/Artikel/G/MKS/demo-spk.html.