International Civil Aviation Organization

WORKING PAPER

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CONFERENCE ON AVIATION AND ALTERNATIVE FUELS

Mexico City, Mexico, 11 to 13 October 2017

Agenda Item 4: Defining the ICAO vision on aviation alternative fuels and future objectives

POWER-TO-LIQUIDS (PTL): SUSTAINABLE ALTERNATIVE FUELS PRODUCED FROM RENEWABLE ELECTRICITY

(Presented by Germany)

SUMMARY

The 2015 Paris Agreement under the United Nations Framework Convention on Climate Change requires massive greenhouse gas emission reductions in all sectors by mid-century to pave the way for a global greenhouse gas neutrality in the second half of this century. Renewable fuels are a major building block in achieving absolute emission reductions in aviation. This Working Paper gives an introduction into the concept of producing sustainable jet fuel using renewable electricity, so-called Power-to-Liquids (PtL). Production pathways and jet fuel drop-in capability are explained. Compared to biofuels PtL has no demand for arable land and a significantly lower demand for water. Produced from renewable electricity PtL has the potential to become almost CO_2-neutral in the longer term. It can make a major contribution of the air transport sector to the global climate goals.

Action by the Conference is in paragraph 7.

1. INTRODUCTION

1.1 In the Paris Agreement under the United Nations Framework Convention on Climate Change of 2015, the community of States 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 in greenhouse gas emissions from all sectors and fields of application - including air transport – to achieve greenhouse gas neutrality in the second half of this century. In fact, ICAO's long-term traffic forecasts, which cover the coming two decades, expect global aviation to grow by 4.5 % annually. Efficiency measures in the air transport sector are essential and must be significantly reinforced. However, merely improving efficiency efforts will not be enough. Hence ambitious emission reductions require fuels which allow to minimize greenhouse gas emissions and are based on renewable energies while avoiding depletion of natural resources. The ICAO Basket of Measures highlights the importance of GHG emission reductions through 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 GHG emissions from aviation. Earlier input on PtL was presented by Germany at the CAEP Steering Group meeting 2016 and by Germany's contractors at the ICAO Seminar on Alternative Fuels, which took place in February 2017[1].

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 other transport modes. The main energy source and feedstocks for the production of Power-to-Liquids are renewable electricity, water and carbon dioxide (CO_2).

2.2 Several pathways are possible. Typically PtL production comprises three main steps[2]:

1) hydrogen production from renewable electricity using the electrolysis of water;
2) provision of renewable CO_2[3] and conversion; and
3) synthesis to liquid hydrocarbons with subsequent upgrading/conversion to refined fuels.

2.3 Various synthesis methods to produce renewable PtL jet fuel are available, e.g. the Fischer-Tropsch (FT) synthesis, or the methanol (MeOH) synthesis.

2.4 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. The product mix can be shifted towards at least a 50 % share of jet fuel components by energy content. Methanol synthesis results in products of very high purity, subsequently processed to long-chain hydrocarbons.

2.5 Other production technologies for renewable liquid fuels of non-biogenic origin are currently under research and development, such as the "Sun to Liquid"[4] process under the EU's Horizon 2020 program.

3. WHY PTL FUELS?

3.1 As aviation is supposed to continue to depend on liquid fuels in the medium and long term, it is necessary to develop the production and use of greenhouse gas-neutral liquid fuels to contribute to the global climate goals.

3.2 PtL fuels have the potential to be used almost without additional greenhouse gas emissions, provided they are derived from renewable electricity and renewable CO_2. PtL production

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[1] https://www.icao.int/Meetings/altfuels17/Documents/20170208_ROTH_V1-0_submitted.pdf
[2] Another pathway, the CO-electrolysis, converts water and CO_2 simultaneously, followed by step 3.
[3] Such as CO_2 from biogenic sources or CO_2 extracted from air.
[4] 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 (EUR 4.5 Million contribution). Recently the first ever production of solar jet fuel has been experimentally demonstrated and efforts are continuing to complete an integrated fuel production chain that will be validated at pre-commercial state.

plants should obtain their power only from additional renewable energy sources and should not cause additional fossil electricity generation, since otherwise no positive climate effect will occur[5].

3.3 PtL achieves higher area-related yields when energy is derived from renewable energy sources such as photovoltaic and wind energy[6]. 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, while avoiding the potential risks and adverse side effects through the energetic use of cultivated biomass (see 2.1)[7].

3.4 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. 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[8].

4. ADVANTAGES OVER BIOFUELS

4.1 The use of biofuels (especially crop-based biofuels) may result in a number of problems including increasing competition for arable land, indirect land use changes and the socio-economically problematic linkage to food prices and land rights.

4.2 Furthermore area-related energy yields of biofuels are significantly lower compared to other renewable energy sources.

4.3 Biofuels produced from biogenic waste and residues are less problematic with respect to the sustainable use of natural resources, but they are partially already used in other sectors[9].

5. TECHNOLOGY READINESS LEVEL

5.1 PtL can be produced from concentrated renewable CO_2 sources using established industrial processes with technology readiness levels (TRL) between 8 and 9 (out of 9). 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, and soon in Norway[10]. Improved processes for CO_2

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[5] Renewable power, which replaces power from fossil sources, has a high greenhouse gas substitution potential. In case of converting renewable power into PtL, the potential is considerably smaller. German Environment Agency/ Umweltbundesamt – UBA: „Integration of Power to Gas/ Power to Liquids into the ongoing Transformation Process“. Position Paper, June 2016. https://www.umweltbundesamt.de/en/publikationen/integration-of-power-to-gas-power-to-liquids-into

[6] See figure 3.12, page 82 in https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/Studien/studie-langfristszenarien.pdf;jsessionid=CE4153CFA38BCBF287D242AD39BA2635?__blob=publicationFile&v=4 (“Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global”, March 2012, only in German. Study for the German Ministry for Environment.

[7] German Environment Agency/ Umweltbundesamt – UBA: „Power-to-Liquids - Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel“. Background Paper, September 2016. https://www.umweltbundesamt.de/publikationen/power-to-liquids-potentials-perspectives-for-the

[8] “Renewable Energy Sources and Climate Change Mitigation”. Special Report of the Intergovernmental Panel on Climate Change (IPCC). Published 2012. http://www.ipcc.ch/report/srren/

[9] German Environment Agency/ Umweltbundesamt – UBA: “Sustainable Use of Global Land and Biomass Resources”. Position Paper, June 2013. https://www.umweltbundesamt.de/publikationen/sustainable-use-of-global-land-biomass-resources

[10] http://carbonrecycling.is/comercial-scale/;http://soletair.fi/news/finnish-demo-plant-produces-renewable-fuels/; http://www.sunfire.de/en/company/press/detail/sunfire-produces-sustainable-crude-oil-alternative; http://www.sunfire.de/en/company/press/detail/first-commercial-plant-for-the-production-of-blue-crude-planned-in-norway

extraction from air and high-temperature electrolysis, which are at present technology demonstration/ development level, increase the production potential and efficiency, respectively.

5.2 Renewable electricity costs have dropped significantly in recent years and are expected to decline further due to technical improvements.

5.3 PtL jet fuel is drop-in capable. The ASTM jet fuel standard already allows for a 50% blend of Fischer-Tropsch synthetic fuel. 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. Cost reductions can be achieved through decreasing renewable electricity costs (wind, solar), increasing efficiencies through improved PtL production processes (e.g. high-temperature electrolysis, CO_2 extraction, etc.), and economies of scale.

6.2 The development of PtL would take advantage of the high renewable power generation potentials in certain regions that are exceeding global energy demand. PtL thus entails increased energy security, 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 cooperate in a common effort to achieve synergies, e.g. with the chemical industry.

7. ACTION BY THE CAAF/2

7.1 The CAAF/2 is invited to:

a) emphasize within the ICAO Vision on Aviation Alternative Fuels the urgent need to assess the impact of launching alternative fuels produced from renewable electricity based on non-biogenic energy sources;

b) encourage within the ICAO Vision on Aviation Alternative Fuels the development of a market launch strategy for alternative fuels produced from renewable electricity based on non-biogenic energy sources; and

c) consider within the ICAO Vision on Aviation Alternative Fuels the use of PtL as a contribution to ICAO's Basket of Measures.

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