MAHEPA GROUND INFRASTRUCTURE INVESTMENT PLAN PAVES A WAY FOR COMMERCIAL HYBRID AIRCRAFT

The MAHEPA ground infrastructure investment plan provides an operational, financial and regulatory aspects of hybrid aircraft operations at airports. It presents a very first serious attempt for economic assessment of relatively novel investments needed in ground infrastructure to enable charging and refuelling of hybrid aircraft.

In the upcoming years a wide range of hybrid-electric aircraft from single-seater ultralights, micro-feeder aircraft to regional airliners will be produced and will enter existing markets, as well as create new markets for commercial flights. Due to rather new hybrid propulsion technologies, they are not yet widely used in commercial sense, therefore the ground infrastructure at airports would have to be adapted or newly developed to enable operation of ICE-hybrid and fuel-cell hybrid aircraft. The MAHEPA ground infrastructure investment plan presents a very first serious attempt for economic assessment of relatively novel investments needed in ground infrastructure to enable charging and refuelling of hybrid aircraft, while also considering financial and regulatory aspects.

For ICE-hybrid aircraft charging, ground infrastructure will require battery charging stations and optionally a battery swapping equipment. A hybrid-electric 19-seater with battery capacity of 50-100 kWh and 70-seater aircraft with battery capacity of 180-360 kWh would require a single three-phase station with charging power of 43 kW. Such station would cover all needs for charging a 70-seater aircraft in 66 % of airports.

Considering the number of flights with 19-seater and 70-seater per airport (for Europe in 2017), most airports would need only one charging station to charge a 19-seater and 70-seater ICE-hybrid aircraft. Airports with larger number of flights would require from 4 to 8 charging stations with 120 kW power output to provide enough electricity for their hybrid-electric fleet. For the majority of airports investment cost would vary between 15 000 EUR and 50 000 EUR, while for the airports, which operate the most frequent number of flights, the infrastructure cost might raise up to approx. 200 000 EUR.

The main disadvantage of battery charging is slow charging times of batteries. Therefore, a battery swapping mechanism sounds as a very intriguing alternative, but due to many obstacles, such as stocking of different battery types, responsibility in case of accidents, this is still less feasible option. Regardless of the chosen methods, the concern that remains is the need to standardize charging equipment and procedures in aviation industry.

In the case of charging fuel-cell hybrid electric aircraft, the most feasible solution of ground infrastructure at small airports at the time being would be to purchase liquid hydrogen from producers and deliver it to the airport with cryogenic trucks. If fuel-cell aircraft becomes widely spread, a feasible option would also be to build a hydrogen production plant in the vicinity of an airport, as it only requires a refuelling hose, a refuelling connector, and safety monitoring equipment.

A 19-seater aircraft would require approx. 200 kg of hydrogen for a 500 km range flight, resulting in production and truck delivery cost of around 2 500 EUR, while a 70-seater aircraft,
would require approx. 700 kg of hydrogen for the same range, resulting in an approximate cost of 8 500 EUR.

Considering the number of flights with 19-seaters and 70-seaters per airport (for Europe in 2017), 80% of airports operating with 19-seater aircraft and 50% of airports operating with 70-seater aircraft would require less than 1 ton of hydrogen daily (daily cost around 12 000 EUR). If all conventional aircraft would be replaced with fuel cell hybrid electric aircraft, 90% of airports would consume around 10 tons of hydrogen daily for fuelling, which would result in an approximate cost of 120 000 EUR.

Considering the delivery scenario and the necessary amounts of hydrogen, the cost of hydrogen and its delivery would vary between 2 500 EUR to up to 500 000 EUR, largely dependent on the size of the aircraft, travelled distance and the flight frequency.

**SMALL COMMERCIAL AIRCRAFT WITH HYBRID PROPULSION TECHNOLOGIES WILL BE ON MARKET FROM 2025 ON**

Understanding future potential markets requires a thorough analysis of air passengers travels while also considering the technological improvements on the aircraft, such as development of new hybrid-electric propulsion systems. Hybrid-electric propulsion technologies are appealing for a new paradigm of transport services and business models with their many advantages, such as low or almost zero emissions, reduced noise and low operating costs. The possibility to commercialize the use of pure-electric 8-seater and hybrid-electric 19-seater and 70-seater is very intriguing. From technical point of view, pure electric battery driven aircraft will be feasible only for light aircraft (1-8-seater) and short ranges up to approx. 200 km, unless batteries will significantly improve in upcoming years. According to market studies, such aircraft cannot be successfully used for on-demand flights, as in 70% of the cases aircraft in this segment connects city pairs with a range from 300 km on. As such, pure electric battery driven aircraft will present a very appealing option for pilot training, sport or hobby use, for touristic flights, especially in vacation areas due to zero gas pollution and low noise during entire flight. It is expected that the 8-seater pure electric aircraft will enter the market around the year 2025.

ICE-hybrid aircraft will be technically feasible for all sizes of aircraft and economically justifiable, especially if considering favorable taxing and subsidy policies regarding the positive affect on environment. With zero gas emissions and low noise during takeoff, an ICE-hybrid aircraft can achieve same ranges as conventional aircraft and has more environmental advantages on crowded airports and airports near large cities. This type of aircraft would be most preferably used in Scandinavia, Great Britain and on airports that charge penalties for gas emissions. It is expected that the 8-, 19- and 70-seater ICE-hybrid aircraft will enter the market around the year 2035.

ICE-hybrid aircraft will be mainly used in the transition period towards implementation of fuel-cell hybrid aircraft, which will present the most feasible long-term solution given the production prices of hydrogen. The prices of hydrogen will play a major role in the market implementation. They are expected to drop on the level competitive to kerosene after 2037 (allowing price of hydrogen to be 5 times higher as kerosene). Considering this timeline it is expected that the 8-, 19- and 70-seater fuel-cell hybrid aircraft will enter the market around the year 2040.