Prediction of environmental benefits introducing hybrid-electric propulsion on regional aircraft

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Despite an average yearly increase of aircraft efficiency of 1.3% between 1960 and 2014, aviation accounts for about 2% of man-made greenhouse emissions and up to 12% of transport-related emissions, as the efficiency gain has been offset by a steady traffic growth. For this reason, it is crucial that all aeronautical stakeholders undertake actions to make aircraft operations more sustainable. For what concerns commuter (19 seats) and regional aircraft (up to 70 seats), traditionally powered by turbopropellers, various solutions are possible:

- Serial hybrid-electric: Electric motors, connected to the propellers, are fed by batteries and/or electric energy coming from a Power Generation System (PGS). The PGS can either be a thermal engine or a hydrogen fuel cell system.
- Parallel hybrid-electric: Both the electric motors and the PGS are mechanically connected to the propellers. In the typical sizing, batteries provide a power boost during high-demand flight phases.
- Full electric: Electric motors, connected to the propellers, are fed by batteries only.

An extended study of the preliminary sizing of aircraft adopting the proposed propulsive configurations shows that the serial hybrid-electric configuration with fuel cells, fueled by liquid hydrogen, is by far the most convenient in terms of environmental impact. However, an assessment of the TRL of fuel cell and hydrogen tank components, together with the complexity of the new certification framework to be established, suggests that such a technology might be further down the road when compared to hybrid-electric solutions in which the PGS is comprised of thermal engines coupled with electric generators. For this reason, the serial hybrid-electric system with a thermal PGS (thermal hybrid-electric, THE) is assessed. Particularly, two scenarios based on the expected technological development of batteries and motors expected in 2035 and 2050 are considered.

The innovation introduced with the hybridization of the propulsion system reduces the environmental impact of aircraft operations, but comes with a compromise on the design point performance (payload and range of the aircraft). The work presented here aims at pointing to a suitable tradeoff, relying on the networks of existing European airlines. Turboprop regional aircraft are currently heavily used only in inter-island services in Greece and the Canaries, for which a design range of 600 km and 370 km respectively is enough, excluding the diversion range. Targeting these design ranges, it is possible to obtain a retrofit of the ATR72, that despite the reduction of payload, reduces the fuel per passenger on every flight part of the network. This is clearly more marked for shorter flights, which present a higher energy hybridization factor, and for the 2050 scenario, for which the technology will be more favorable. This allows to reduce the yearly fuel budget by 49% and 68% in 2035 and 2050 respectively, achieving emission-free operations below 1,400 ft.

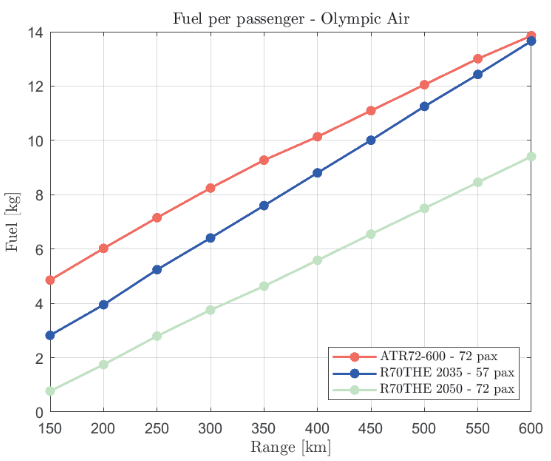

Figure 1: Fuel per passenger for THE regional aircraft (red: current ATR72-600; blue: retrofit with 2035 technology; green: retrofit with 2050 technology).