The H_2 Takeoff: The Dawn of Hydrogen-Powered Aircraft

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Abstract

The use of fossil fuels supported the human progress over recent centuries: powering engines, generating electricity, and creating new materials. Fossil fuels have paved the road to our modern globalized world. Despite these numerous advances, the increasing link between their byproducts, greenhouse gases (GHG), such as carbon dioxide, and anthropogenic climate change are clear, prompting many industries to investigate alternative fuel sources for electricity generation and transportation. The aviation industry seeks alternative fuels, as global air travel contributes 7% of total GHG emissions. The most promising option for airline decarbonization is green hydrogen, which has an energy density of 120 MJ/kg, compared to diesel and gasoline (45.5 and 45.8 MJ/kg, respectively). Green hydrogen, as opposed to grey and blue hydrogen, is produced entirely through renewable sources, including solar, nuclear, and wind power through water electrolysis. The environmental benefits of hydrogen led many companies to design hydrogen-fueled aircraft, like ZeroAvia's ZA600 zero-emission engine for 9-19 seat regional turboprops, and Airbus's ZEROe project. NASA has been working on developing the large liquid hydrogen-fueled turbo-electric aircraft, N3X. The research and developments promise a green future for aircraft innovation and the reversing the damaging effects of global warming.

Background Info

According to the Adler and Martins 2023 article from the journal *Progress in Aerospace Sciences*, aviation drove "$2.7 trillion in economic activity" and "supported 65.5 million jobs" in 2016. Altogether, this made up "3.6% of the global GDP". Despite the importance of aviation sector, its greenhouse gas (GHG) emissions contribute 3.5% of climate warming. This alarming trend has prompted numerous scientific studies into sustainable, alternative energy options, with hydrogen being one of the most promising. For transportation, hydrogen shows excellent potential as an aircraft fuel, replacing conventional fossil fuel-based energy sources such as kerosene. The transition to alternative green fuels represents a significant step in making the airline/aerospace industry more sustainable overall.

Although most GHG emissions come from large, long-haul aircraft, regional airlines also share increased pressure to adopt hydrogen. The developments within hydrogen-powered small aircraft are exciting, as several established companies and start-ups have taken up the goal of hydrogen adoption. Among these is ZeroAvia, an aerospace company that's developing zero-emission engines for commercial aircraft. Their ZA600 engine, comprised of a fuel cell (FC) SuperStack Module, a 400 kW continuous power inverter (which converts DC electrical power into AC), and a 660 kW max power motor, has powered this transition, being first implemented into the Cessna Grand Caravan as part of the company's timeline to deliver zero-emission flight to "thousands of 9-19 seat regional turboprops" (ZeroAvia, Executive Summary).

Figure 1: Description of ZeroAvia's ZA600 FC powertrains.

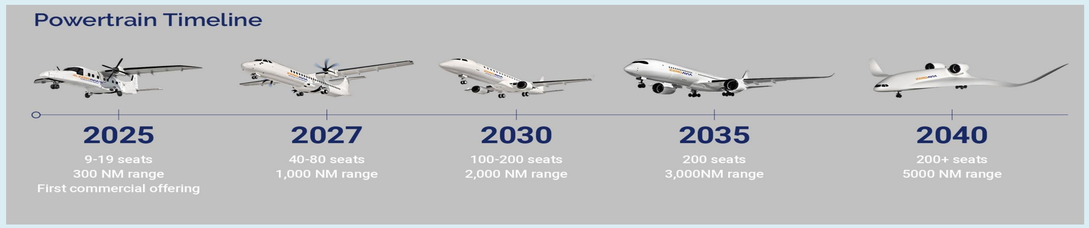

Figure 2 (Above) : ZeroAvia's timeline for plane development.

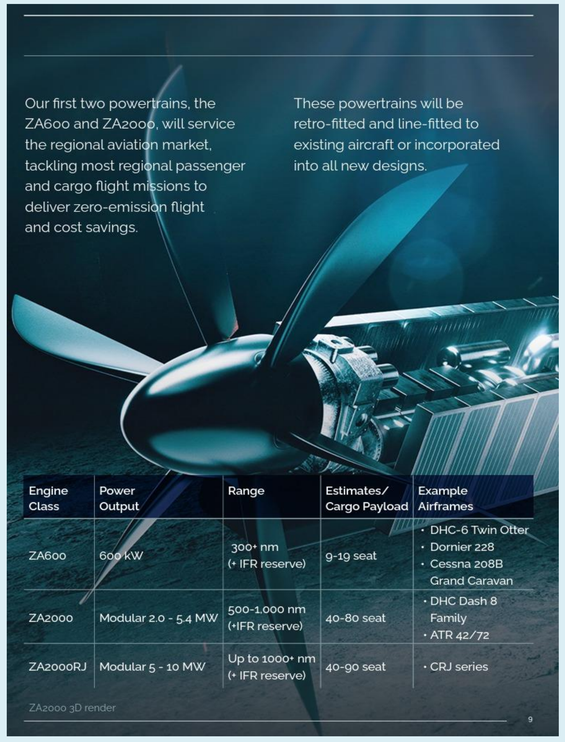

Figure 3: ZeroAvia's comparison of their ZA600 and ZA2000.

Results

According to Mukhopadhaya and Rutherfords' analysis in The International Council on Clean Transportation, LH2-powered aircraft will play an important role in aviation decarbonization. Despite this promising outlook, LH2-combustion aircraft will still not be at same performance level by 2035 as current Jet A kerosene counterparts. Due to the low volumetric energy density of hydrogen and the high volume of fuel storage, their payload and range is limited compared to current Jet A planes. Despite these technical issues, current private developments, namely ZeroAvia's ZA600 and ZA2000 fuel cell powertrains, allow for retro-fitting to existing aircraft, which will service the regional aircraft market and enable decarbonization. While the physical limitations of hydrogen will not assure aviation's projected transition by 2035, the future of hydrogen-powered aircraft is promising and will reverse the effects of global warming.

Conclusion

- Hydrogen is a promising alternative to conventional, kerosene-based aircraft fuels, with a comparatively high energy density.
- Hydrogen's drawbacks stem from its physical conditions, namely its low density, required large volume for fuel storage, and low temperatures to preserve it in its liquid state.
- Despite these physical limitations, many private companies, especially ZeroAvia and Airbus are projected to develop potentially commercial models within the upcoming decade.
- The ZA600 and ZA2000 powertrains successfully combine emerging fuel cell and electric motor technologies.

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