Hydrogen as a Sustainable Fuel for Aviation

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Abstract

Electric aircraft are the next step in electrification of transportation in the fight against climate change. The aviation industry produced 2% of the world's carbon emissions. With the implementation of hydrogen fuel cells, both private and commercial sectors of the aviation industry can be transformed into low-carbon or zero-carbon sectors. In this literature review, hydrogen has been explored and evaluated as an alternative fuel for the next generation of the commercial aviation transportation industry. Hydrogen has already proven itself to be useful, NASA has been using it for years to fuel their Space Shuttle missions and Toyota was one of the first manufactures to develop and make commercially available, a hydrogen-powered vehicle. The use of hydrogen fuel cells in commercial aircraft provides many benefits but not without some challenges that need to be addressed. This research analyzed the benefits of hydrogen fuel cells and its implementation into the commercial aviation industry. Hydrogen is an answer to the climate crisis that faces us, but that does not mean it is perfect. However, companies like Boeing, Rolls Royce, and Airbus, and researchers from across the country are addressing the issues that hydrogen faces. That is the purpose of this study: evaluate the extent hydrogen technologies can be used for sustainable aviation to reverse the climate crisis.

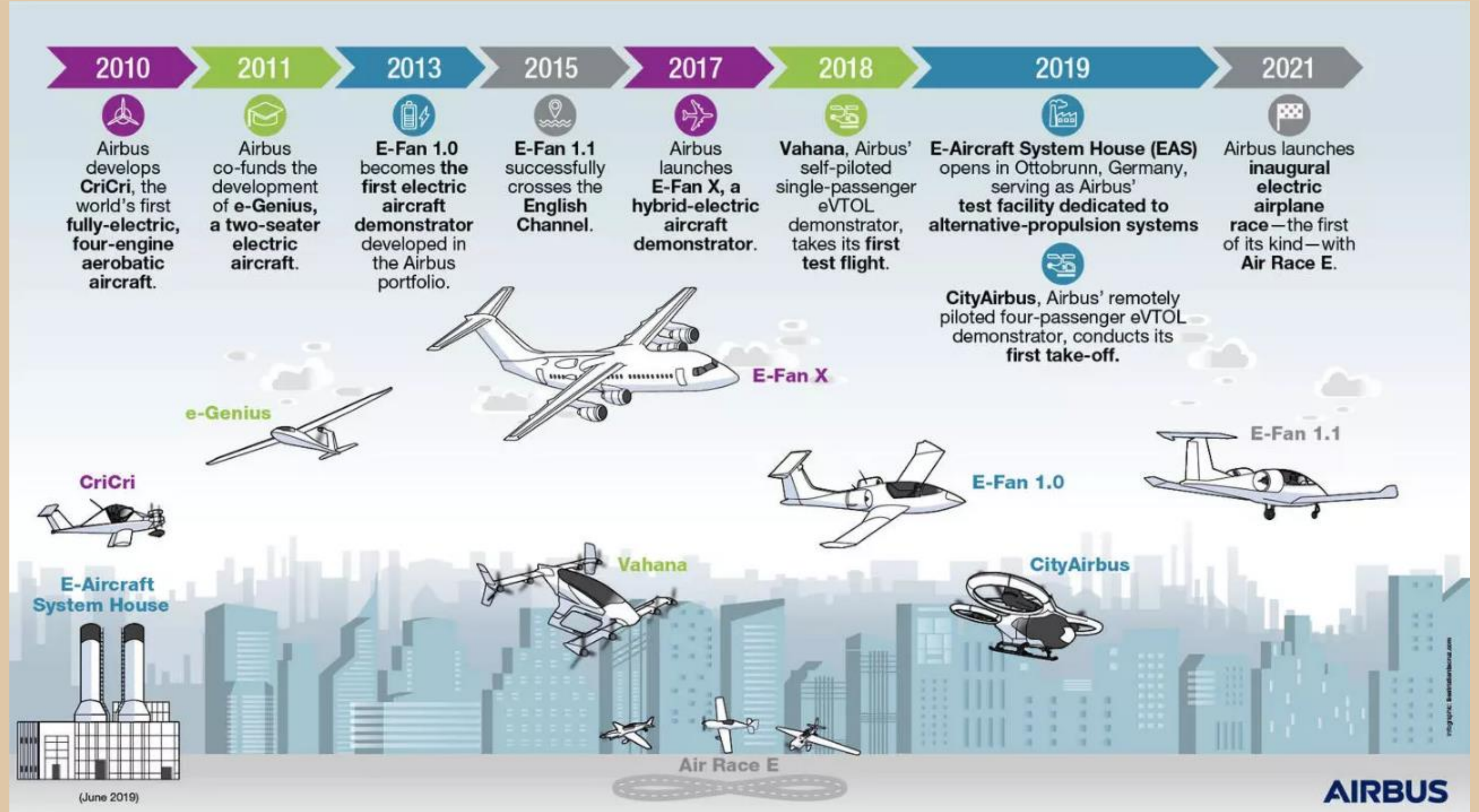
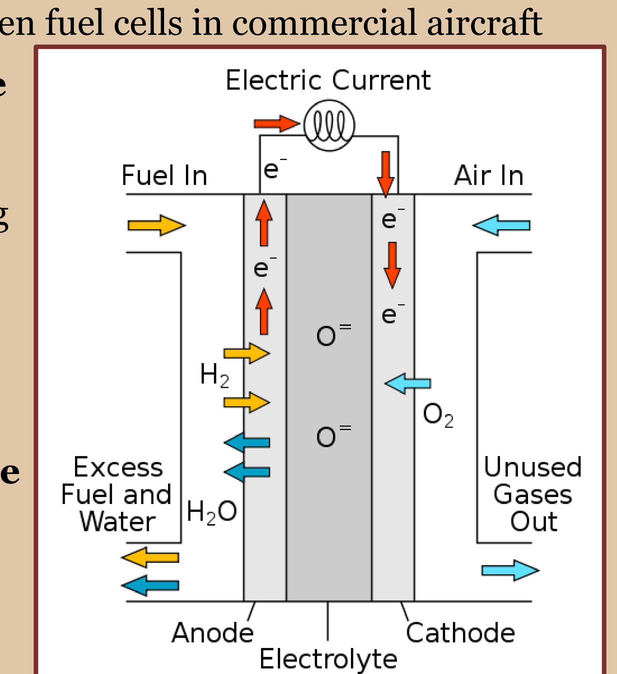


Figure 1: The developmental steps Airbus has taken to innovate hydrogen fuel cells in commercial aircraft

Left (Figure 2): Photo of Blended Wing Body design.

Right (Figure 3): Fuel cell operation.



Introduction

Hydrogen's biggest attraction is its abundance in the universe. Hydrogen is the most abundant fuel on the planet, outnumbering the next element, helium, by three-fold. Meaning that if its use were to become widespread, there would not be a risk of a depletion of material as it is impossible to run out of hydrogen. Even with its abundance, hydrogen is more energy dense than gasoline. Hydrogen has 120 mega-joules per kilogram while gasoline has 44 mega-joules per kilogram. To put into context, 2.2 pounds of hydrogen (1 kg) is equivalent to 6.2 pounds (2.81 kg) of gasoline. However, the problem with hydrogen is that it faces challenges when it comes to its storage while being used as an energy source. Even though hydrogen is more energy dense, it has a lower volumetric energy density than gasoline, meaning hydrogen is less dense than gasoline so more volume is needed to store. Liquid hydrogen, however, occupies 75% less space than gaseous hydrogen and 10,000 psi pressure tanks are not necessary with liquid hydrogen. The caveat is that liquid hydrogen needs to be kept at -423 degrees Fahrenheit (-253 degrees Celsius). With that said, hydrogen is significantly more efficient as a fuel source compared to gasoline. In hydrogen vehicles, its energy efficiency is 50-65% while gasoline vehicles have 20-40%. So, the potential is there for hydrogen, its benefits outweigh its challenges, especially since the only biproducts of hydrogen fuel cells is water.

Hydrogen fuel cells have also started to gain attention from private companies and government officials, securing millions of dollars in grants and investments to develop the technology and produce large commercial aircraft. United Airlines has invested $115 million in a company called ZeroAvia (a hydrogen-electric aircraft engine company) with the goal of reducing greenhouse gas emissions by 100% by 2050. A company called Universal Hydrogen secured funding from Airbus, General Electric, American Airlines, JetBlue, and Toyota to develop hydrogen fuel cell engines for zero-emission flights. Airbus has been one of the revolutionary players for the industry, exploring both hydrogen-combustion and fuel-cell propulsion technologies. Airbus recently had a successful flight in their ZEROe project which will have in-flight testing in 2026 and has the objective to produce a hydrogen-powered commercial plane by 2036. The Biden-Harris Administration announced $750 million to reduce the cost of the production of clean hydrogen (green hydrogen is achievable by using renewable power sources to perform electrolysis and split hydrogen and oxygen from water), and the U.S Department of Energy has issued another $750 million to lower the cost of hydrogen technologies in delivery and storage.

References

Results

With specific analysis into the ZEROe project by Airbus, four components have been developed. The Turbofan, the Turboprop, the Blended-Wing Body, and the Fully Electrical (which is fully powered by hydrogen fuel cells). The Turbofan, Turboprop, and the Blended-Wing Body are all currently powered by two hybrid-hydrogen turbofan engines. Except for the Turboprop, which is powered by two hybrid-hydrogen turboprop engines driving 8 bladed propellers. The hybrid-hydrogen turbofan engine is something that Airbus is experimenting with, and it allows for the use of both liquid hydrogen and jet fuel, just like a hybrid car and alternate between using electricity or a combustion engine. These engines improve the overall effectiveness of jet fuel, filling in the gaps of efficiency drops, when necessary, but struggle with combustion control as ensuring stable and efficient combustion with hydrogen requires precise control. The hybrid-hydrogen turbofan engine combines the benefits of hydrogen technology and its climate friendliness with existing jet propulsion technologies that, for now, acts as a good steppingstone for the industry to begin utilizing. However, Airbus still maintains its mission to develop a fully electric aircraft, and their current prototype has a range of 1,000 nautical miles and can hold less than 100 passengers. The Fully Electrical Prototype did achieve zero emissions during its test flight and its propulsion method is quite and efficient.

A new aircraft type that is being experimented with is the Blended Wing Body (BWB) design concept. Unlike the traditional tube-and-wing aircraft, the BWB integrates the wing seamlessly into the fuselage, causing the entire aircraft to generate lift instead of just the wings. The BWB allows for ample room for cylindrical hydrogen fuel tanks, which were a challenge to implement in the traditional tube-and-wing design. Since the entire aircraft generates lift, it reduces fuel consumption by 30-40% and the elimination of the empennage (tail section) and/or top-mounted engines reduce the noise decibels by 15 or more. The BWB design also benefits military applications, improving survivability by lowering radar and infrared signatures. The Pentagon has already allocated $235 million to an aviation startup by the name of JetZero. JetZero specializes in the development of Blended Wing Body aircraft in general, not necessarily hydrogen fueled, but they are still important in pioneering the BWB so it may have great use for hydrogen-based fuel source implementation. JetZero is also partners and receiving funding from the United States Airforce, the National Aeronautics and Space Administration (NASA), and the Federal Aviation Administration (FAA).

Conclusion

- Hydrogen presents itself as a contender for the fuel source for the next generation as it offers zero-emission energy and contributes to a cleaner environment. Its versatility and high energy density make it a clear choice for the replacement of jet fuel in the commercial aviation industry.
- Hydrogen does pose limitations, including the difficulties of storing liquid hydrogen within the aircraft due to having to it at 20 K and the need to support extensive infrastructure development to support hydrogen production, distribution, and refueling.
- Hydrogen fueled commercial aircraft are expected to the market in the next decade, with prototypes and demonstrations making successful test flights presently. The industry as a whole has a mission to integrate hydrogen technology by 2030 (the latest estimate being by 2050) for eco-friendly air transportation.

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