BATTERY AND FUEL CELL AIRCRAFT

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INTRODUCTION

The future of flying electric taxis will revolutionize transportation while transforming urban mobility into a greener, zero-emissions world. If renewable energy and nuclear sources of electricity are adopted, such aircraft CO_2 emissions would be concentrated at the source power stations.

ELECTRIC VERTICAL TAKE-OFF AND LANDING eVTOL AIRCRAFT

The Hexa is an electric vertical-takeoff-and-landing (eVTOL) wingless multicopter. It is developed by LIFT Aircraft, a Texas-based company. The USA Air Force is testing the “flying car” that was designed for the commercial market to be used in military missions, including rescuing troops, delivering cargo and conducting security checks over an airfield. eVTOL platforms with quiet electric engines and simple sustainment footprints could become key to the Air Force as it figures out how to operate away from large airfields, a concept known as Agile Combat Employment, ACE.

The aircraft does not need a runway, has room for one person and can fly for about 10-15 minutes and cover a range of 10-15 miles, depending on the payload. A person can learn to fly Hexa quickly because many of the flight systems are automated, but Lift plans to develop a fully automated version. It does not require a pilot’s license for operation.

Figure 1. HEXA electric eVTOL aircraft, “flying car”.

Archer, a leading Urban Air Mobility startup and developer of all-electric vertical take-off and landing (eVTOL) aircraft, has entered into a purchase and collaboration agreement with United Airlines for its battery-powered aircraft. The reason they have many rotors is because it is quieter than having one big rotor. They are worried about noise.

Figure 2. All-electric vertical take-off and landing eVTOL aircraft.

Figure 3. Technical Specifications of electric eVTOL aircraft. The operational cost is expected to be $3.30 per mile travelled. It has a 60 mile range, can fly at 150 mph and can carry 4 passengers with 1 pilot. The plane will have a take-off weight of less than 7,000 pounds.

United Airlines placed a $1 billion order for Archer's eVTOL aircraft with an option for an additional $500 million of aircraft. United, along with Mesa Airlines, are preparing to transport customers with Archer's eVTOL zero-emission aircraft. United CEO Scott Kirby embraces the new aircraft as a way to "decarbonize air travel." "By working with Archer, United shows the aviation industry that now is the time to embrace a cleaner, more efficient modes of transportation. With the right technology, we can curb the impact aircraft have on the planet, but we have to identify the next generation of companies who will make this a reality early and find ways to help them get off the ground," "Archer's eVTOL design, manufacturing model and engineering expertise has the clear potential to change how people commute within major metropolitan cities all over the world."

Archer is scheduled to unveil the eVTOL aircraft this year as it's slated for series production in 2023. Looking ahead, the eVTOL aircraft could fly customers between Hollywood and LAX Los Angeles International Airport, significantly reducing CO_2 emissions by up to 50% per passenger.

Morgan Stanley Research told clients last month that the eVTOL aircraft industry, transporting people around metro areas, could be a $1.5 trillion market by 2040. "The intersection of many technologies, such as ultra-efficient batteries, autonomous systems, and advanced manufacturing processes are spawning a flurry of activity in this space," wrote Adam Jonas, Head of Morgan Stanley's Global Auto and Shared Mobility research team.

German-based company, Lilium, signed a deal with the city of Orlando, Florida, in November 2020 to build the country's first flying taxi hub with flight operations beginning in 2025.

By the midpart of the decade, some of us will be zipping around in zero-emissions air taxis, bouncing from city to city in minutes, while others will be stuck on the ground in traffic.

FUEL CELL HYDROGEN ELECTRIC AIRCRAFT

An aircraft introduced by the Boeing Company was powered by a hydrogen fuel cell and successfully completed a flight in Spain.

Figure 4. Hydrogen Fuel cell Aircraft designed by the Boeing Company Research And Technology (BRAT) division; formerly Phantom Works was first flown in Spain. Source: Boeing.

Touting the potential that solid oxide fuel cells have for small aircraft, the Boeing Company is not considering them as the primary source of power for passenger planes. Its strategy for saving fuel on the commercial aircraft is to use carbon composite materials that bring down the overall weight such as in the Dreamliner Boeing 787 plane..

DESIGN FEATURES

As the present time, the hydrogen fuel cell plane needs an extra boost from a lithium-ion battery to climb up to its cruising height. It then relied solely on a single Proton Exchange Membrane fuel cell to cruise for 20 minutes at a maintained speed. The plane was developed at the Boeing's Phantom Works with a team of companies and universities from the UK, Austria, Germany, Spain and France over a five-year effort.

The outcome is a two-seat plane, adapted from a Dimona motorized glider. The Dimona is a lightweight airplane with a 53.5-ft. wingspan that reached 62 mph during a test cruise.

HYDROGEN ZERO CARBON FUEL CELL AIRCRAFT

A six-seater Piper M-Class had been fitted out at a research and development hub at Cranfield airport in the UK to run on hydrogen, and on this maiden flight in the late summer of 2020. With that flight, ZeroAvia, the California-based start-up that had developed the aircraft with partners in Britain and elsewhere, was ready to move to the next stage in the journey towards zero carbon aviation [1].

Figure 5. HyFlyer six-seater hydrogen airplane. Its successor is planned to seat up to 20 passengers. Source: ZeroAvia.

> "A catchphrase for the transition to a low or zero carbon economy is "electrify everything" – that is, create a world in which most human activities, from manufacturing and construction to transport and tourism, run on electricity generated from low or zero carbon sources such as wind,

solar and perhaps nuclear power. But there is a problem: some sectors look to be hard if not impossible to electrify in the near and medium term, and aviation is, perhaps, foremost among them.

Before the pandemic grounded most flights, commercial aviation accounted for about 2.5% of global emissions of carbon dioxide. It sounds like a small proportion of the whole, but it is more than those of Germany (2.2%), and this is not the whole story. Carbon dioxide accounts for about half of aviation's contribution to what is known as its effective radiative forcing – that is, its total contribution to the factors that actually drive a rise in global average temperature. Contrails – water vapour trails from aircraft – are aviation's largest other factor.

Importantly in the context of flight, hydrogen packs a lot of energy per unit of mass

The good news is that commercial aviation has an excellent track record in improving efficiency. Carbon dioxide emissions per passenger flight have fallen more than 50% since 1990 thanks to improved engines and operations. The bad news is that these gains have been overwhelmed by rising volumes of air traffic. This has increased by at least a fifth over the past five years, and is predicted to reach 10 billion passengers a year by 2050.

At first glance, hydrogen looks to be a good solution to the challenge of flying without wrecking the climate. Whether hydrogen is used to power a fuel cell to generate electricity or directly combusted for motive power, the only waste product is clean water. Importantly in the context of flight, hydrogen packs a lot of energy per unit of mass – three times more than conventional jet fuel, and more than a hundred times that of lithium-ion batteries.

Governments and companies are investing in this potential. ZeroAvia's 2020 hydrogen-powered flight, known as HyFlyer I, was supported by the UK Government, whose Jet Zero Council promises "a laser focus on UK production facilities for sustainable aviation fuels and the acceleration of the design, manufacture and commercial operation of zero-emission aircraft."

The UK government, together with private investors and commercial partners are supporting ZeroAvia in the development of an aircraft with a hydrogen-electric (fuel cell) powertrain capable of carrying up to 20 passengers about 350 nautical miles (648km). ZeroAvia's founder and chief executive Val Miftakhov, says the company expects to offer commercial flights using such a plane as early as 2023, and that by 2026 it will be able to realise flights over a range of 500 nautical miles (926km) in aircraft with up to 80 seats. For 2030, Miftakhov has even bigger plans: "We will have single-aisle jets, 100-seat category," he says.

AIRBUS CONCEPT AIRCRAFT [1]

There is ambition in mainland Europe too. Hydrogen "is one of the most promising technology vectors to allow mobility to continue fulfilling the basic human need for mobility in better harmony with our environment", says Grazia Vitaldini, chief technology officer at Airbus, the world's largest aircraft manufacturer. In September 2020, Airbus announced that hydrogen-fueled propulsion systems would be at the heart of a new generation of zero-emissions commercial aircraft. The project, named ZeroE, is a flagship of the European Union's multibillion-euro stimulus package, aimed at greening the bloc's economy.

Airbus has presented three concept planes which it says could be ready for deployment by 2035. The first is a turboprop (propeller) driven aircraft capable of carrying around 100 passengers about 1,000 nautical miles (1,850km). The second, a turbofan (jet), could carry 200 passengers twice as far. Both look similar to already existing planes, but ZeroE's third concept is a futuristic-looking blended-wing design that is a striking departure from commercial models today. Airbus says this third design could be capable of carrying more passengers over longer distances than the other two, but has not released more detail at this stage. All three designs are envisaged as hydrogen hybrids, which means they would be powered by gas-turbine engines that burn liquid hydrogen as fuel, and also generate electricity via hydrogen fuel cells.

Figure 6. Airbus hydrogen-fueled aircraft. Airbus is aiming to have its three concept hydrogen aircraft in operation by 2035. Source: Airbus.

HYDROGEN AS A SUSTAINABLE AVIATION FUEL, SAF, BIOFUELS AND E-FUELS [1]

Hydrogen has higher energy by mass than jet fuel, but it has lower energy by volume. This lower energy density is because it is a gas at typical atmospheric pressure and temperature. The gas needs to be compressed or turned into a liquid by cooling it to extremely low temperatures (-253C) if it is to be stored in sufficient quantities. "Storage tanks for the compressed gas or liquid are complex and heavy," says Finlay Asher, a former aircraft engine designer at Rolls-Royce and founder of Green Sky Thinking, a platform exploring sustainable aviation.

And there are other challenges. The energy density of liquid hydrogen is only about a quarter of that of jet fuel. This means that for the same amount of energy it needs a storage tank four times the size. As a consequence, aircraft may either have to carry fewer passengers to make space for the storage tanks, or become significantly larger. The first option, which applies to Airbus's first two concept planes, would mean a reduction in ticket revenue, other things being equal. The second option, embodied in Airbus's third concept, requires a bigger airframe, which is subject to more drag. Further, an entire new infrastructure would need to be put in place to transport and store hydrogen at airports [1].

In addition, there is the question of whether hydrogen can be produced at scale and at a competitive price without itself having a large carbon footprint. The great majority of hydrogen used in industry today is created using fossil fuel methane, releasing carbon dioxide as a waste product. Hydrogen can be produced from water through a process called electrolysis, driven by renewable power, but this process is currently expensive and requires large amounts of energy. Only about 1% of hydrogen is produced this way at present.

Aviation passenger numbers are projected to double by 2037, meaning many more greenhouse gas emissions unless sustainable alternatives are found. As things stand, liquid hydrogen is more than four times as expensive as conventional jet fuel. Over the coming decades the price is expected to drop as infrastructure is scaled up and becomes more efficient. But according to Britain's Royal Society and the management consulting group McKinsey, it is likely to remain at least twice as expensive as fossil fuels for the next few decades.

In September 2020, the Air Transport Action Group, a Geneva-based body that speaks on behalf the global aviation industry, published a set of scenarios which suggest that, even as the volume of air traffic increases, it will be possible for global aviation to reach zero emissions of carbon dioxide – but only a decade or so later than 2050. According to these scenarios, the direct use of hydrogen will play only a marginal role, but the game-changer will be what are termed "sustainable aviation fuels", or SAFs.

The advocates of SAFs argue they have a number of clear advantages over pure hydrogen. Because they are chemically identical to existing jet fuel, they can in principle be "dropped in" to existing systems with little or no redesign, without delay, and without the substantial ancillary investments required for hydrogen-powered airframes and their supporting infrastructure. Paul Stein, chief technology officer at the engine makers Rolls Royce, argues they are the key to a more sustainable future. "If SAF production can be scaled up – and aviation needs 500 million tonnes a year by 2050 – we can make a huge contribution for our planet," he says.

SAFs can be divided into two categories. The first are biofuels made through the chemical or thermal treatment of biomass such as agricultural residues and other wastes. A second category is electro fuels, or "E fuels". Through these fuels, which are also known as "power to liquid", hydrogen could end up playing a key role in aviation after all.

E fuels are made by reacting hydrogen with carbon dioxide to make "syngas". This is then converted through what is known as Fischer-Tropsch process into "e-crude" – a crude oil substitute that can be refined to jet fuel and other fuels. If the large amount of energy required at each stage of manufacture is sourced from zero carbon sources, then the whole process can be carbon neutral, with no more carbon dioxide in the atmosphere after the flight than before the fuel was made.

DISCUSSION

The integration of fuel cells into aircraft could invigorate the Boeing Company into the Unmanned Aerial Vehicle (UAV) and small recreational airplane markets.

Along the effort of testing cheaper aircraft fuels, the Virgin Atlantic Company conducted a biofuel test of a Boeing 747. Small airplane owners are being squeezed by rising fuel costs and may be willing to pay more for an environmentally friendly aircraft.

In the small UAVs market a UAV called Pterosaur made a 78 miles flight powered only by a hydrogen fuel cell developed by Horizon Fuel Cell Technologies of Singapore.

Using direct air capture technology developed by the Swiss company Climeworks to source CO_2, and hydrogen produced from water with renewable energy, the Oslo-based company Norsk e-Fuel aims to open what may be the world's first E fuel industrial plant Herøya, Norway, in 2023, producing 10 million liters of fuel per year for the Norwegian and European markets. The next step in 2026 would be a plant capable of 100 million litres a year. A full-sized plant could provide half the fuel for the top five most frequently serviced flight routes within Norway, cutting their emissions by half, says Karl Hauptmeier, Norsk e-Fuel's managing director [1].

There is a need to improve the range or load capacity of electrical aircraft. This will be the case for all electric aircraft until the kilowatt density to weight factors are drastically improved. Current battery tech does not cut it. There is greater hope for the cryogenic hydrogen in conjunction with fuel cells approach.

REFERENCE

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