How Do We Permanently Decarbonize Air Travel?

A look at three technologies that may lead the aviation industry to a post carbon future.

Every year, the 198 parties to the United Nations Framework Convention on Climate Change (UNFCCC) meet to measure progress and negotiate multilateral responses to climate change. The latest - 28th Conference of Parties (COP 28) - was held in Dubai in the United Arab Emirates from November 30 to December 12, 2023. It yielded a call to "[*Transition] away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science."* This was heralded by the United Nations (UN) as the beginning of the end of the fossil fuel era.(1) However, ironically, the meeting itself will likely set a record for carbon emissions, due to the number of participants, and the fossil fuel emissions from air travel to the Middle Eastern state!(2)

This raises two questions for me – the first of which I'll try to answer in this article and the second, I'll leave for you to ponder:

1. If we are to meet the UN's goals, what will the future of air travel look like, and

2. What example is COP 28 setting relative to the monster it is trying to slay? Anyone who has attempted complex negotiations will tell you there is value in "getting the people into the room," but **were the thousands of local government electeds, their staff, and private companies in attendance at COP28 really needed there and what value did they add?**

To answer question 1, **let's start by looking at the impacts of aviation on global climate.** The US Department of Energy estimates that worldwide, aviation accounts for 2% of all human-caused carbon dioxide (CO_2) emissions and 12% of all transportation CO_2 emissions.(3) This impact comes from the use of approximately 6.2 million barrels (260 million gallons) of fossil-jet fuel across the world daily. That usage is set to increase by approximately 30% by 2028, as the aviation industry recovers fully from the impacts of the global pandemic.(4) To combat this impact, the UN's International Civil Aviation Organization (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) caps net CO_2 aviation emissions at 2020 levels through 2035. And, the International Aviation Transportation Association (IATA) has set an aspirational goal to reach net zero carbon by 2050,(5) through the use of sustainable aviation fuel (SAF).

SAF is produced from plants that absorb carbon emitted to the atmosphere, offsetting the emissions from burning the fuels they produce. This is what is commonly known as the carbon cycle. In the United States, the Department of Energy (DOE), the Department of Transportation (DOT), the Department of Agriculture (USDA), and other federal government agencies are working together to develop a comprehensive strategy for scaling up new technologies to produce SAF on a commercial scale. Their goal is to achieve a minimum of a 50% reduction in life-cycle-greenhouse gas emissions compared to fossil fuel by 2030, and to supply sufficient SAF to meet 100% of aviation fuel demand by 2050.[6]

To check out how the work to produce this fuel is coming, **I visited the Phillips 66 San Francisco Refinery in Rodeo, California in November 2023.** This facility is currently in the final stages of a revolutionary switch from fossil to renewable feedstocks. Despite court challenges from environmental groups, and a very complicated construction project, the "Rodeo Renewed" project remains on track to produce 67,000 barrels of renewable fuels per day - over 2.8 million gallons daily - sometime in 2024.[7] The feedstocks for these fuels will be soybean oil, corn oil, rapeseed oil, and other vegetable oils; tallow and other animal fats; used cooking oil; fats, oils and greases; and other waste oil products.

The scale of the engineering feat to accomplish this switch should not be underestimated. A significant portion of the existing fossil-fuel refining facility will be idled, the adjacent carbon plant closed, a linked refinery in Santa Maria, California, closed, and the over 200-mile pipeline between the two facilities purged of its oil products. On top of this, a new multimillion dollar filtration and processing unit is in the final stages of installation in Rodeo. The latter emphasizes the immense monetary gamble Phillips 66 is taking on the commercialization of renewable fuels which have been, until now, small players in the California transportation market.

The fuels produced in Rodeo will include renewable diesel and SAF, "drop in" products that reduce carbon emissions from trucks[8] and jets[3] according to the DOE and the California Air Resources Board's low-carbon-fuel standard.[9] If emission reduction projections bear out - and there are some who believe they won't[10] - what results is a very valuable bridge fuel that gives us time to get to a full zero-carbon emissions aviation future.

But wait, if this is a carbon neutral fuel, why isn't it the future? The answer to this question is a little trickier. Ultimately, jets using SAF still emit carbon and many of the same harmful pollutants as jets using fossil fuels, including small particulate matter. Setting aside the debate regarding the carbon neutrality of SAF, and that its other emissions appear to be lower than fossil fuels,[11] these emissions are still harmful to the climate and human health. Additionally, there is a significant question regarding the world's capacity to produce the amounts of SAF needed to meet global demand. For example, if 100% of the Phillip 66 Rodeo facility's capacity was used to produce SAF, it would supply only 1% of the world's current demand for the fuel. So, while environmental practicality dictates that we must use SAF in some part at least through 2050 to offset aviation emissions, it cannot be the ultimate solution.

So, if SAF is the bridge, what is the destination? Here is where we need to take larger technological leaps of faith – something I hate doing - but seeing as it's the beginning of 2024, I will ask for your indulgence! Where these leaps lead us is to a bunch of start-up and traditional aerospace companies whose technology offerings are in various stages of development. For convenience, I will group these efforts into three categories based on their core technologies – electric, hydrogen and "lighter than air" (LTA) aircraft.

In a May 2023 article I wrote about new battery technologies in the US and China with significantly improved energy densities, enough energy density to power aircraft. However, what I didn't mention was that, even in the absence of those advancements, **there are a plethora of electric planes on drawing boards across the world.** Traditional manufacturers such as Airbus, Boeing and Embraer are competing with startups such as Beta, Joby Aviation, Evation and Heart Aerospace to get the first generation of electric planes and personal electric aircraft to market.(12) Electric aircraft have zero direct emissions, lower total carbon emission, and better overall efficiency than their piston fossil-fuel competitors.(13) However, electric batteries currently can't compete with fossil fuels or SAF for range or energy storage efficiency. So electric planes are currently no competition for jet aircraft and are unlikely to rival them long into the future.(14) This doesn't mean that there won't be a large market for them.

The companies that I mention above are working on small passenger planes, short-and-medium range regional planes, and exciting air taxis and personal air vehicles that have the potential to revolutionize transportation. Examples of short-range passenger planes include the Evation Alice, a twin propellor fully-electric plane with an expected 250 nautical-mile range and 2,500 pound capacity, targeting the executive, commercial and cargo markets,(15) and the Heart Aerospace ES-30, an all-electric or hybrid 30-seater, four propellor plane with ranges up to 400 nautical miles, slated to go into passenger service for Scandinavian Airlines in 2028.(16) Examples of the much-hyped air taxis or personal air vehicles include the Joby eVTOL which was delivered for testing to the US Air Force in September 2023(17) - and flew a test route from New York's downtown heliport in November 2023(18) - and Boeing's Wisk which is currently testing in Los Angeles.(19) Meet George Jetson, maybe. And while these personal mobility options will be exciting, they will likely only offset a small fraction of the emissions from overall air travel.(13)

On top of the limited emissions reductions achieved by electrifying this air transportation segment, substantial fast-charging-and-electric infrastructure will need to be installed at airports, homes, and other landing locations to support these aircraft. Also, the electricity supplied to these aircraft needs to be renewable to achieve carbon emissions reduction benefits. The challenges here are not insubstantial but there may be other emissions benefits to electrification that are not instantly obvious. For example: sufficiently deployed personal/taxi electric aircraft may reduce wear and tear on roads, reduce urban congestion emissions, and reduce tire particulate matter emissions into the air and water.

Similarly, hydrogen aircraft will only offset a fraction of the emissions from overall air travel at least initially.(20) Companies like Airbus and startups like ZeroAvia, Universal Hydrogen and H2Fly are working on a variety of aircraft configurations that use liquid or gaseous hydrogen and fuel cells as their propulsion mechanisms. Airbus has set the goal of having zero carbon emissions aircraft deployed in passenger service by 2035, and is currently testing propulsion systems in its A380 MSN1 test aircraft.(21) Universal Hydrogen has entered the aviation marketplace with a hydrogen conversion kit for the regional ATR 72 and the De Havilland Canada Dash-8 aircraft. The kit consists of a fuel-cell electric powertrain that replaces the existing turboprop engines and hydrogen capsules stored in the rear of the converted plane's fuselage.(22) The company recently exceeded 250 orders for these conversions.(23) However, more significant to the future of aviation are the efforts of H2Fly, who recently conducted a test flight using liquid hydrogen.[24]

Currently, liquid hydrogen has perhaps the largest potential to be the zero-carbon aviation fuel of the future because it can be burned directly in jet engines.[25] In addition, because of its energy density, liquid hydrogen is the closest to fossil fuels and SAF in terms of its ability to power long-range flight. I say closest, but it's not that close. To provide the same range as fossil fuels or SAF, liquid hydrogen needs approximately four times as much space in an aircraft to accommodate its fueling and cooling systems.[26] This is certainly not ideal, but this technology is in its infancy and will benefit from aircraft redesign, economies of scale and technology evolution. IATA believes the use of this fuel would produce no carbon emissions and *"with regards to local air quality, hydrogen combustion produces up to 90% less nitrogen oxides than kerosene fuel, and it eliminates the formation of particulate matter."*

While all of this sounds positive, as with electric aircraft, the use of liquid hydrogen would need significant new infrastructure at airports. Also, because of its size, hydrogen is notoriously hard to store and compress. This raises both significant efficiency and safety concerns.[26] Lastly, to meet its full emissions reduction potential, the hydrogen itself would need to be produced from zero-carbon or carbon mitigating sources, likely adding substantial cost to the fuel itself. Bottom line - a lot of development needs to happen to make this fuel's potential a reality.

In terms of a full zero-carbon future, the technology we have reviewed so far either looks very far away or incapable of doing the required duty cycle. But **rather than trying to replicate our current air transportation model, our approach to air travel may need to change along with our technology.** Perhaps taking inspiration from Greta Thunberg's sailing ship journey to the United Nations in 2019,[27] a few start-up companies are embracing lighter than air (LTA) aircraft to go back to the future. Flying Whales' LCA60T is a concept helium cargo airship that is expected to go into service in 2027.[28] Its propulsion motors will be powered by batteries, and it is expected to have a 60-tonne cargo carrying capacity. LTA Research's Pathfinder 1 received Federal Aviation Authority (FAA) permission to begin flight testing in California in October, 2023.[29] This titanium and carbon-fiber framed helium aircraft will initially be powered by both diesel and electric engines but could be powered by hydrogen fuel cells in the future. Similar to the Flying Whales aircraft, LTA Research's ultimate goal is cargo delivery to remote areas in times of humanitarian crisis. Hybrid Air Vehicles' A10 is a combustion engine powered helium aircraft with a reported 4,000 nautical mile range and 10 tonne carrying capacity.[30] The manufacturer is scheduled to deliver 20 of these aircraft for passenger service in 2027.[31] Later evolutions of this aircraft are slated to work using battery propulsion only, and a larger version of the vessel, the A50, is also on the drawing board.

These airships offer the distinct advantages of long-range flight, heavy-cargo-carrying capacity and the ability to land practically anywhere. This means that they would not need airports or significant specialized infrastructure built at airports. For example, rather than having to run miles of electrical to an airport for these craft, they could dock at grid points where power is abundant. Also, by being able to dock in practically any area, vessel manufacturers believe they could essentially bring the airport to you, offering total travel times comparable to current regional jets.[32] Additionally, these aircraft could reduce emissions from air travel[33] and cargo transportation[34] by up to 90%, based on hybrid air vehicles and IATA projections respectively. Lastly, the technology for these craft – electrical, hydrogen and solar power systems, air frames and outer skins, are all readily available today.

So, what's the catch? What is not so readily available is the helium that these ships depend on for buoyancy. Helium replaced hydrogen in aircraft because of the perception of the latter's flammability,[35] but is a finite resource here on earth. This finite supply has led to several helium price shocks over the years and scarcities related to reserves, mining and supply chain issues.[36] Also, to supply the totality of the need for an airship-based travel system would likely exhaust all known reserves of helium. Therefore, the future of airships may again be hydrogen, which would likely slow their development, as new safety and FAA regulations would be needed to deploy that gas for lifting applications.[35]

But perhaps the largest barrier to the adoption of this mode of transportation is speed. Researchers recently estimated that a transatlantic trip in one these vessels using solar power to assist on board batteries may take as many as three days[37] – inconceivable in our modern world! Obviously, speed is less of an issue for cargo and, dependent on the onboard experience during such travel lengths, this may not be as big an issue for the environmentally conscious. Again, a lot of work is needed to take these craft from concept to reality, but the technology in this case appears to be available and able to meet the duty cycle, if not our temporal expectations.

Conclusions

So, there we have it, a look at the possible future of full-zero emission flight. Not a very clear picture at this point, but what is clear is that aviation has and always will attract the innovators and adventurers. With that in mind, I envision a mix of the technologies discussed above, as well as a long-term reliance on SAF for the future. I also expect as carbon pricing becomes more and more of a reality in our lives, these solutions will sort themselves out via competition, cost and pricing. This will likely lead to a more crowded, exciting and varied aviation fleet in our skies in the latter half of this century.

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