A White Paper on the Integration of Electric Aircraft Systems

Jossue Sarango

New Jersey Institute of Technology

12 April 2025

Executive Summary

Electric aircraft propose the opportunity for reduced environmental damage while expanding the reach of local communities. This white paper analyzes the feasibility of their implementation and identifies challenges with integrating hybrid technology.

In response to the beginning production of small electric aircraft, traveling short distances with minimal passengers, airline corporations have begun searching for opportunities to commercialize this technology. Approximately 170 different electric aircraft are already underway internationally, a growth of over 50% compared to previous years (Selkirk 2020). The introduction of new technology creates room for growth in a very competitive and profitable market. Driving forces to adopt this technology include:

Lower Costs: Electric planes promise savings in the areas of fuel and maintenance, lowering the overall price of travel for companies and their passengers.

Cleaner Flight: Electric planes reduce nitrogen oxide emissions by 95% (Chu 2021). Electric motors also produce significantly less noise than traditional combustion engines and reduce noise pollution.

Regional Travel: Electrified air travel introduces a new method of urban transportation that reduces congestion and connects regional airports.

This paper examines the potential benefits of adopting this technology, how it functions, and weighs the challenges that limit the expansion of electric aircraft commercially.

Introduction

Aviation, representing one of the world's leading forms of transportation, both for leisure and for business, is simultaneously one of the most carbon-intensive forms of travel. The United States alone accounts for 200 million tons of the global CO2 total, approximately 23%. (Overton 2022). Combined, aircraft are responsible for 5% of the world's global warming, gradually increasing the Earth's surface temperature, threatening food security, human health, and ecosystems. The demand for air travel is now higher than ever; in 2023 alone, approximately 4.4 billion passengers traveled via airlines, an estimated 1.8 billion were international travelers and 2.6 billion were domestic (Hyde 2024). Though the release of toxic gases into the atmosphere has remained the same for decades, airline companies have begun making attempts to reduce their carbon footprint in response to media backlash. Modern strategies to achieve carbon neutrality by 2050, have driven companies to strive for operational efficiency: increasing seating capacity per aircraft and fitting as many passengers as possible without exceeding capacity (Ingram 2023) Though these efforts point in the right direction, their opportunity for growth and improvement is extremely limited, especially in the plummeting regional travel market. The notion of dumping millions of toxic fumes into the atmosphere for a distance that could similarly be traveled through land rails makes near-travel flights futile. This inefficiency combined with the cost per passenger, fuel, maintenance, and staff, steer airlines from hosting regional flights. The introduction of aircraft electrification, rather, aligns with reduced cost promises, environmental benefits, and introduces near-distance flights as a viable option for travelers. Historically, in the face of financial burdens, airlines have customarily retired less efficient planes to replace them with more viable aircraft that maximize efficiency. This shift creates the opportunity to explore different propulsion technologies, such as hybrid-electric aircraft that integrate electric motors to reduce carbon footprint and noise pollution. Though small electric planes are beginning to make breakthroughs and integrate with regional travel, to achieve this nationally, there must be improvements to how airports and power grids adapt.

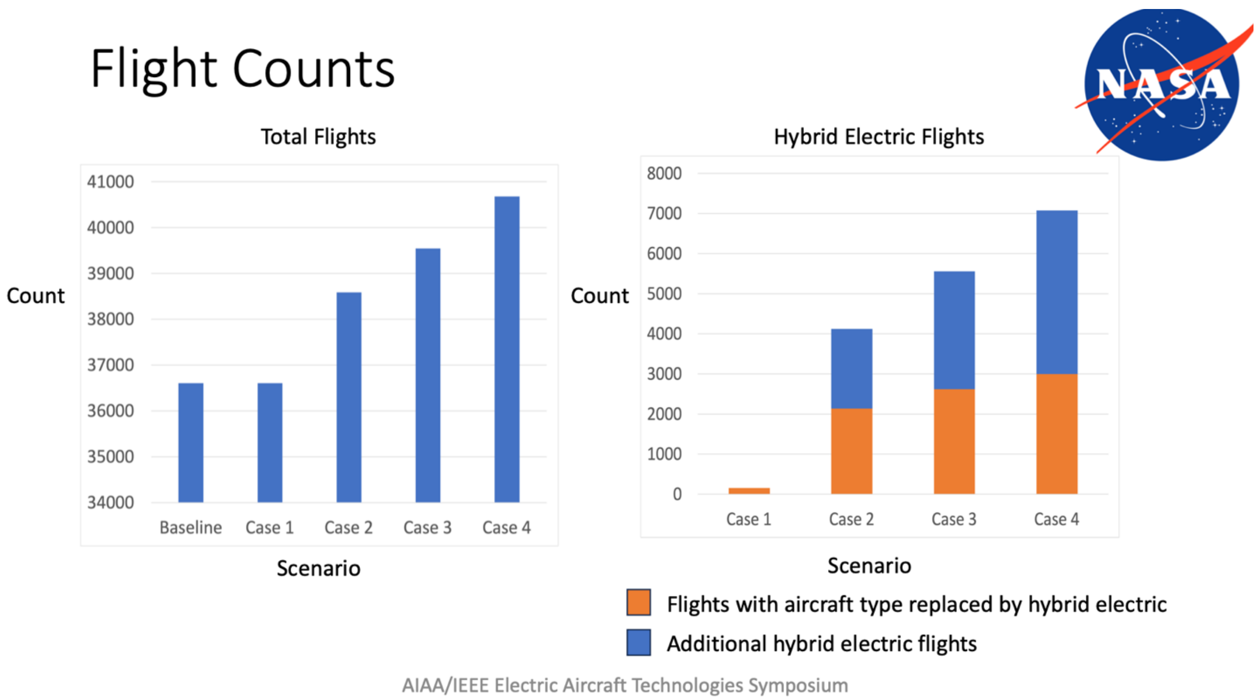

Figure 1. Operating Hybrid Electric Aircrafts in the National Airspace System

Source: NASA Technical Reports Server 2024

The Range of Electrified Aviation

Beyond commercial use, aircraft remain a vital resource for multiple departments for efficient operations. The most recognized is the role aviation plays in military systems, specifically in the Air Force, facilitating aerial inspections, delivering cargo, medical organs, and being used for training. For civilians, aircraft impact their every day, delivering packages, responding to disasters, and connecting lands to facilitate global transparency. Nevertheless, the integration of electric systems within aircraft also differs in severity and operation tactics.

As an introduction to electrification, electric power is guided towards powering all non-essential aircraft systems. These systems can include and are not limited to cabin systems, electricity, and communication radios. Within flight operations, this would represent less strain on the primary combustion engines, requiring them solely for propulsion rather than cabin power. On the tarmac, electric vehicles will replace gas-powered tugs to maneuver aircraft while contributing to the greener earth objective. These changes directly reduce the consumption of fossil fuels, operating on green power and limiting the release of toxic gases into the atmosphere.

Hybrid-electric is a term used for stronger electrification which introduces the integration of electric motors to produce synergistic interactions between all electric elements within an aircraft. These can be understood as electric motors operating alongside internal combustion engines for augmented power and regenerative capabilities that create a self-dependent system that charges the same power it uses. This integration can be directly translated to quieter travel for in-flight passengers as electric motors are responsible for maintaining cruising speeds rather than louder combustion engines.

The most efficient form of aircraft is referred to as truly electric or full electric. These aircraft rely solely on electric power and represent the cleanest form of aviation travel. The feasibility of these planes is a feat many engineers are approaching today, specifically identifying solutions to the battery carrying limitations due to their size and weight.

Companies/ Electric Aircraft Models	People/ Passengers	Range (miles)	Autonomous	Vertical Landing And Takeoff	Hybrid
Airbus E-Fan X	1	50	No	No	Yes
Ampaire Electric	6	750	No	No	Yes
Amp. TailWind E	9	350	No	No	No
Amp. TailWind H	9	750	No	No	Yes
Astro ELROY	2	18	No	Yes	No
Bell NeXt	4	150	No	Yes	Yes
Boeing Pav	2	50	Yes	Yes	No
City Airbus 2.2	4	60	No	Yes	No
DeLorean DR7	2	120	No	Yes	No
Dubai Air Taxi	2	31	Yes	Yes	No
Elevation Alice	9	650	No	No	No
Kitty Hawk Cora	2	110	No	Yes	No
Kitty Hawk Flyer	1	20	No	Yes	Yes
Lilium jet	5	186	No	Yes	No
Pipistrel Alpha El.	2	80	No	No	No
SureFly	2	70	No	Yes	Yes
UberAir	5	43.3	No	Yes	No
Wright Electric	150	335	No	No	No

Table 1. Companies Manufacturing Electric Aircraft Prototypes

Source: International Conference on Transportation and Development 2020

Propulsion and Operations

To achieve flight, aircraft energy consumption assimilates an inverse parabolic behavior where the most energy required is during departure and arrival. These high consumption periods release tons of toxic fumes as a by-product of burning fossil fuel within the internal combustion engine. Though at a smaller rate, aircraft continue to release these destructive gases throughout the entire flight. Traditionally, jets operate using turbofan engines which require large quantities of fuel to operate. Shifting towards hybrid technologies allows for the integration of electric motors, a homogenous process that enables them to work alongside turbofan engines rather than replace them. This advanced technology is a step closer to achieving future fully electric aircraft and displays efforts to reduce carbon footprint.

The concept is as follows: during takeoff when the aircraft requires the most power, electric engines will provide a boost to the turbofan engine to reduce strain and operate with less fuel consumption. While the carrier is in flight, the turbofan engine will operate at its most optimal strength, allowing the aircraft to maintain altitude, while the electric motors are responsible for supplementary loads such as battery cooling, lights, and power steering (Electrification 2024). The result of this hybrid technology is minimized fuel expenses and lower maintenance costs as engines operate with less strain and more efficiency. A study conducted at the Massachusetts Institute of Technology discovered the proposed design successfully reduces nitrogen oxide emissions by 95%, a released chemical that results in approximately 16,000 premature deaths every year (Chu 2021).

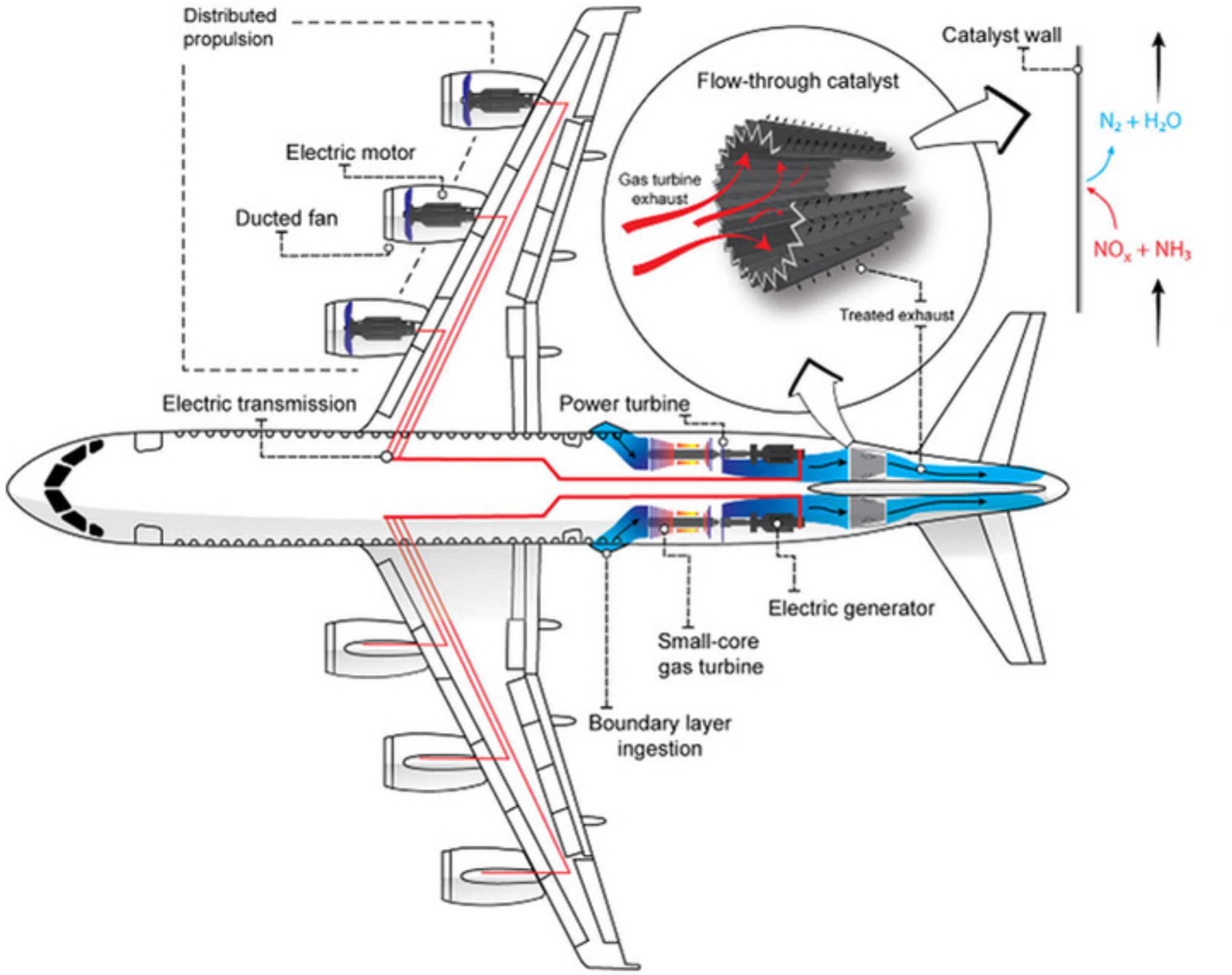

Figure 2: Proposed Hybrid-Electric Design to Reduce Global Nitrogen Oxide by 95%

Source: MIT Researchers 2021

Driving Forces

The electric aircraft market was estimated to be $8.8 billion in 2022 and is expected to reach $37.2 billion by 2030 (Mehra n.d.). The growing interest in aircraft electrification is primarily driven by economic, environmental, and societal factors. In a report to congressional committees, key stakeholders such as airports, aircraft manufacturers, electrical utilities and air traffic management organizations voiced their interest in transitioning toward electrified air travel (USGAO 2022). Together they identified implementation barriers to better understand the challenges carried by this emerging industry. In NASA's most recent Regional Air Mobility report they identified the lack of recognition and attention to regional airports, highlighting how a breakthrough in electric propulsion systems would revolutionize local airports (Antcliff 2021). The concept builds on the idea that electrified aircraft will be able to travel with more efficiency and a smaller carbon footprint while still maintaining profitable margins for airlines. These shifts will allow for the relocation of funds towards underutilized local airports to meet infrastructure requirements and better expand goals of renewable energy generation. Thus, the factors driving the electrification of aircraft are the following:

- Reduced Emissions: Emission reductions are one of the primary driving forces persuading airlines to shift towards cleaner travel. A report analyzing aircraft pollution concluded that the adaptation of hybrid-powered vehicles will allow the United States to achieve an 80% reduction of greenhouse gases and petroleum use by 2050 (Zhang 2024). The proposed integration of hybrid-electric aircraft success prevails largely in short-distance flights, previously regarded as the most energy inefficient, by allowing for cleaner and self-sufficient travel through regenerative braking.

- Noise Reduction: A large factor limiting the expansion of airports throughout the country is noise pollution caused by aircraft during takeoff and landing. Modern combustion engines pollute the air with toxic fumes and loud exhaust notes that bother both civilian homes surrounding airports and passengers within the aircraft. A study on noise emissions compared the interior cabin noise of a traditional fossil fuel aircraft to carry the same decibel weight as a lawn mower (Zhang 2024). It is estimated that the transition to fully electric propulsion could reduce aircraft noise by roughly 85% (White 2020).
- Lower Costs: From an economic standpoint, incorporating electricity into aircraft represents a profitable investment with a guaranteed return. Amapire, an American aircraft manufacturer startup claims its hybrid-electric propulsion technology lowers fuel consumption by 90%, aircraft maintenance by 50%, and noise pollution by 60% (Ampaire 2025). The regenerative capabilities of electric motors allow for aircraft to fly more frequently without prolonged charging periods. Digitizing aircraft systems also facilitate the identification of issues the carrier might experience and allows for scheduled maintenance service to keep the aircraft functional.
- Increased Accessibility: The development of hybrid-electric aircraft introduces air travel as a clean method of transportation that is environmentally conscious and feasible for short distances. As urban cities expand and human population numbers reach an all-time high, current transportation infrastructures become inflexible and stationary; the result is rising city congestion and traffic jams (Beebe 2018). The solution to this inevitability is the introduction of air taxis that operate on clean energy. The switch will promote local travel and allow for urban architecture to adjust to a more efficient form of transportation.

- Economic Development: A Washington State study supports the shift to hybrid-electric aircraft by emphasizing the opportunity to repurpose neglected local airports and re-open shops that were previously vacated due to a lack of consumers (WSDOT 2020). The shift also introduces the opportunity for innovation, contradicting traditional forms of travel and taking steps toward a hybrid future.

Hybrid-Electric Adoption

To effectively introduce hybrid technology as a reliable replacement to traditional combustion engines, mock trials, and aircraft efficiency must be appropriately measured. To do so, electric aircraft will be introduced into private sectors such as pilot training and private aviation. This controlled environment enables researchers to test hybrid behavior against traditional earth elements to appropriately determine it as a viable option for commercial travel. Modern attempts to test this technology have begun incorporating it into an existing fleet of over 200 thousand aircraft (Schwab 2021). The Pipistrel's Alpha Electro is a perfect example of a market-ready aircraft that has received the European Union Aviation Safety Agency certification. Operating with a 60-kW motor and a 21-kWh battery, the Alpha Electro can effectively travel for nearly 160 kilometers or roughly an hour of flight time (Walków 2019). The near-term goal of adopting this technology is to be able to seamlessly introduce it into current air travel. This would recommend that aircraft travel shorter distances and carry smaller passenger amounts to minimize risks and ensure reliability.

Following this adoption, a transition will be made toward implementing an air taxi system that departs vertically rather than horizontally. This concept proposes fast travel time for short distances with disregard to road congestion. UberAir and Dubai Taxi (see Table 1) are some of the few competitors actively taking steps towards reliably integrating this technology. United Airlines has taken a similar approach, pushing for electrified air freight carriers that allow for enhanced mobility through densely populated areas (United 2021). The goal of this is to enhance production efficiency and utilize electric aircraft as a tool to promote their services.

Conclusion

Electrified air travel will revolutionize transportation and will have everlasting impacts on how humans move. Nevertheless, prolonged research and development are undoubtedly still necessary to address the current barriers hindering the implementation of hybrid technology. High-capacity batteries for starters are a largely complex aspect that are fundamental for electric transportation yet carry multiple intricacies by design. Weight and density are a main concern; aircraft engineers must properly identify carrying capacities to reduce gravitational forces pulling on the aircraft, directly making the aircraft heavier and requiring more power. The technologies required to charge these systems must also be explored as different applications require different power ratings and speeds; a move that pushes for innovating updated charging methods within international airports. Electrical wiring must be designed and carefully positioned to minimize interference with critical systems. New methods of maintenance must be taught and practiced to respond to wear and tear properly. Though universal standards are yet to be decided, it is well understood that their role in future implementations will be vital. The technology is now available, and it is only through its utilization that it can be explored further to soon achieve fully electric skies

References

Antcliff, K. (2021). *Regional Air Mobility – SACD*. NASA. https://sacd.larc.nasa.gov/ram/

Beebe, A. J. B. (2018). “Electric Flight Will Transform Our Cities for the Better, and It Will Happen Sooner Than You Think.”

Downing, S. (2019) 6 Electric Aviation Companies to Watch. https://www.greenbiz.com/article/6-electric-aviation-companies-watch

Electrification, C. (2024). *Comparing Electric, hybrid, and hydrogen-powered flight*. Carpenter Electrification. https://www.carpenterelectrification.com/blog/comparing-electric-hybrid-hydrogen#:~:text=The%20combustion%20engine%20provides%20primary,power%20during%20takeoff%20and%20climbing.

Hyde, D. (2024). Aviation: Benefits beyond borders global report. https://aviationbenefits.org/downloads/aviation-benefits-beyond-borders-2020/

Ingram, J. (2023). *How the airline industry is Tackling Climate Change*. Defiance ETF. https://www.defianceetfs.com/how-the-airline-industry-is-tackling-climate-change/

Krause, H. (2022). *GAO-22-105020 Highlights, Advanced Air Mobility*. Stakeholders Identified Issues to Address for ’Advanced Air Mobility. https://www.gao.gov/assets/gao-22-105020-highlights.pdf

Mehra, A. (n.d.). *Electric Aircraft Industry*. Market Research Firm. https://www.marketsandmarkets.com/PressReleases/electric-aircraft.asp

Moua, L. (2020) Critical Review of Advancements and Challenges of All-Electric Aviation doi:10.1061/9780784483138.005

Overton, J. (2022). *Issue brief: The growth in greenhouse gas emissions from Commercial Aviation* EESI. https://www.eesi.org/papers/view/fact-sheet-the-growth-in-greenhouse-gas-emissions-from-commercial-aviation

Schwab, A. (2021). *Electrification of Aircraft: Challenges, Barriers, and Potential Impacts*. National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy22osti/80220.pdf

Selkirk, D. (2020). "Is This the Start of an Aviation Revolution? BBC. February 11, 2020. https://www.bbc.com/future/article/20200211-the-electric-plane-leading-a-revolution

United. (2021). "United Adding Supersonic Speeds with New Agreement to Buy Aircraft from Boom Supersonic." United. June 3, 2021. https://hub.united.com/2021-06-03-united-adding-supersonic-speeds-with-new-agreement-to-buy-aircraft-from-boom-supersonic-2653216403.html

Walków, Marcin, and Qayyah Moynihan. (2019). "This Electric Plane Takes Just One Hour to Charge and Can Travel 160 Kilometers for Just $5." Business Insider (June 19, 2019). https://www.businessinsider.com/electric-plane-charges-in-hour-can-cover-160km-2019-6/.

White, T. (2020). *Hybrid-electric propulsion--a great start to reducing aviation's carbon footprint*. Collins Aerospace. https://www.collinsaerospace.com/news/stories/2020/03/white-hybrid-electric-propulsion-great-start-reducing-aviation-carbon-footprint

Windhorst, R. (2024). *NASA Technical Reports Server (NTRS)*. NASA. https://ntrs.nasa.gov/

Andrew Beebe, J. B. (2018). "Electric Flight Will Transform Our Cities for the Better, and It Will Happen Sooner Than You Think."

WSDOT. (2019). Electric Aircraft Working Group Report. June 2019. WSDOT Aviation Division. https://wsdot.wa.gov/sites/default/files/2019/07/15/ElectricAircraftWorkingGroupReport-June2019.pdf

Zhang, Hans & Harris, Joy. (2024). Exploring the Technology Needed to Build Electric Passenger Planes. Journal of Student Research. 13. 10.47611/jsrhs.v13i1.6196.