

# Exploring the Technology Needed to Build Electric Passenger Planes

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## ABSTRACT

Environmental scientists have found that airplanes account for 2.6% of all global CO<sub>2</sub> emissions. Hence, in order to reduce CO<sub>2</sub> emissions, it would be helpful to build electric-powered passenger planes for air travel. Therefore, electric passenger planes are the focus of this research. Our methodology included reviewing, analyzing, and summarizing primary sources from peer-reviewed journals and conference publications. We examine and discuss the small-scale electric planes that can currently fly short distances along with the challenges of flying large-scale electric passenger planes for long distances.

## Introduction

### Fossil Fuel Planes Are Harmful to The Environment

Humans' continuous use of fossil fuels has emitted many GreenHouse Gases (GHG), in particular, CO<sub>2</sub> is one of the very abundant types of GHG. This affects the global average temperature negatively and creates numerous problems. These consequences include melting ice, rising sea levels, water stress, declining agricultural yields, heat waves, and biodiversity loss (Stocker et al. 2013). The severity of these dilemmas depends on the level of temperature anomalies.

In 2019, aviation was responsible for 2.6% of the world's entire CO<sub>2</sub> emission. Additionally, according to Oko-Institut, because of the rapid growth of the sector and the difficulty of easily implementing technological solutions to reduce GHG emissions from aircraft, the aviation industry could account for up to 22% of global impacts on climate change by 2050 (Cames et al. 2015). These values involve several uncertainties, and a study is already in progress to seek the results (Linke et al. 2020). Overall, these results show that the aviation sector is responsible for many different current effects on the climate, and change is highly emphasized.

In the past 150 years, roughly 3 billion passengers are in the air each year, which resulted in the rise of carbon dioxide levels by nearly 53%.

### Electric Passenger Planes Have Several Environmental Benefits Along with Many Others

By developing electric passenger planes, the aircraft industry can reduce greenhouse gasses, noise pollution, and congestion in addition to realizing economic benefits. Each of these advantages is further explored below.

### *Electric Planes Help Reduce Greenhouse Gas Emissions*

The United States can achieve an 80% reduction of greenhouse gases and petroleum use by 2050 if we choose to adapt to hybrids and differently powered vehicles (Medicine 2019). More specifically, if there is an adaptation to biofuel vehicles, fuel cell vehicles, compressed natural gas vehicles, and electric vehicles, there will be an 80% reduction of greenhouse gases.

### *Noise Reduction Is a Benefit of Electric Planes*

Because of their electric motors and steep rise and descent profiles, regional electric aircraft have the potential to produce less noise. In fact, they can reduce noise by as much as 85% (White 2020). Conversely, noise levels are significant for fossil fuel aircraft, especially when taking off and landing. Inside the cabin, it can reach up to 105 decibels (dB), although during cruising altitudes noise drops to about 85 dB (Moshvitch 2014). For reference, 105 decibels is approximately as loud as a hair dryer, a lawn mower, a blender, or a subway train.

### *Electric Aircraft Can Increase Accessibility and Reduce Congestion*

Encouragement of a transportation mode shift away from ground transportation for regional destinations could minimize congestion and the need for automobile parking at airport hubs for those accessing larger markets. In addition, it would cut emissions by switching air travel to clean electric power for local destinations. Electric aircraft may offer a reasonable, environmentally friendly alternative while cutting down on prices and travel time for people going to and from remote locations.

Cities all around the nation are expanding and changing. As a result, there are problems including traffic jams, inefficiency, pollution, and price rises (Andrew Beebe 2018). The public transportation system, which is now expensive and inflexible due to urban expansion, has to be more flexible (Andrew Beebe, 2018). Bringing air taxis to major cities is one idea for promoting city growth. Rooftop additions on existing structures are necessary for a long-term infrastructure design (Andrew Beebe, 2018). Multibillion-dollar businesses will be able to jump from building to building in cities thanks to this architecture (Andrew Beebe, 2018).

### *Economic Development Is an Additional Benefit of Electric Planes*

According to a Washington State study (WSDOT 2020), airports and public organizations are mainly interested in the potential for electric aviation to promote economic development by providing services to presently underserved areas, opening markets that have been shut down, repurposing general aviation airports to offset operational costs, and improving pilot training operations for nearby trade schools. Additionally, there is a lot of interest in promoting new innovations and technologies.

### *Electric Planes Have Reduced Operating and Pilot Training Costs When Compared to Fossil Fuel Planes*

According to Collins Aerospace (White 2020), the Internal United Technologies Corporation conducted a study that suggests commercial hybrid-electric and electric propulsion aircraft could lower airline operating and maintenance costs by 20% (electric and hybrid) as well as increase fuel efficiency by 40%.

Other advantages of electrified aviation include the capacity to perform vital community services like medevac services, organ delivery, and crucial cargo delivery, as well as a reduction in the cost of pilot training (a significant element in managing pilot shortages).

## **Methods**

Primary sources from peer-reviewed journals and conference publications were read, analyzed, and summarized to finish the information gathering process. We chose articles that looked at the operations and performance

metrics of electric passenger jets as well as prospective advantages and difficulties. Presented in this research study are the analysis and findings derived from these articles.

## Results

Currently, there are not many electric planes on the market, as battery technology is not sufficiently developed; however, a few electric aircraft are currently available, and table 1 below summarizes our findings.

**Table 1.** Companies that Manufacture All-Electric and Hybrid Aircraft Prototypes (Moua et. al 2020)

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

Zunum	12	700	No	No	Yes
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Within Table 1, range refers to the distance the plane can travel. Autonomous refers to the ability to fly without a pilot. Vertical landing and takeoff refers to the ability to land and take off vertically like a helicopter, which would allow for landing on buildings. Hybrid refers to using both electric and gasoline as an energy source.

One electric aircraft manufacturer of note is Pipistrel. This company currently manufactures and sells 8 electric planes which can carry a few passengers and haul a decent amount of weight. Although there are not many passengers to be flown, it is a good start and outlook into the future.



**Figure 1.** Photographs of Pipistrel electric planes

Figure 1 above shows the Pipistrel electric planes. The Panthera (left) and the Alpha Trainer (right) are both current models on the market.

## Discussion

Although electric aircraft have multiple environmental and economic benefits, they are not standard vehicles for air travel because of the manufacturing challenges. The prominent challenge in electrical aviation is improving battery capacity due to the weight, volume, cost, and reliability of power converters and their associated systems (Radek Jurecka 2012). In addition, batteries will need to have a rechargeable feature to the fuel-cell technology so they can store enough energy for long-range flights (Radek Jurecka 2012). Nonetheless, storage is critical to making electric flight successful.

According to NASA experts, the battery technology must advance at an 8% rate to provide 250 Whr/kg of electricity for a nine-passenger airplane (Carmel 2017). The carbon intensity of power produced by all-electric aircraft batteries will be equal to the global average of 500g of CO<sub>2</sub> per kWh due to the warming influence, which can result in warming intensities of 2-10% (Andreas W. Schäfer 2019). As a result, while holding the same weight, jet fuel has 43 times the energy of a battery (Hawkings 2018).

## Reasons Companies Are Investing in The Development of Electric Planes

In addition to the environmental benefits, our research also revealed many economic benefits that incite companies to invest in developing electric planes. These benefits include reduced operating costs, expanded market potential, and greater environmental justice.

### *Reduced Operating Costs*

The main drivers for airplane operators and manufacturers to electrify aircraft are anticipated operational cost savings and decreased long-term cost advantages. For instance, Ampaire estimates that a 15-passenger aircraft would experience a 90% reduction in fuel expenses and a 50% reduction in maintenance costs. Such more affordable cost structures might present a chance to revive service on less profitable routes. Additionally, electric airplanes offer less maintenance, quieter takeoffs and landings, and lower emissions of carbon and other pollutants. Ampaire, for instance, proposes 60% quieter takeoffs and landings while removing tailpipe emissions (excluding emissions from energy generation), which are significant in places with dense populations.

### *Expanded Market Potential*

Regional aviation is anticipated to experience the fastest growth in regions where travel is fewer than 500 km (310 miles). This is due to the existing technology's constrained battery capacity and the new economic viability of operating these routes. Many of these routes only use a limited number of airports, underutilizing numerous minor airports. Only 30 (0.6%) of the 5,050 U.S. airports that are open to the public, according to the NASA Regional Air Mobility report (Antcliff et al. 2021), support 70% of domestic air travel. Electric aircraft may be used to successfully serve an extra 5,000–8,000 public and private usage airports that are now unprofitable regional destinations (Howell Hanano, n.d.). It will be easier to get on planes and take less time to go to the airport if there is more traffic at these airports. Only 60% of Americans live within the same distance of a commercial airport, whereas 90% of Americans live within a 30-minute drive of a regional airport, according to McKinsey. Reduced air access costs for underserved communities are also encouraged by the cost of federal subsidies to keep vital air service to small villages operating. Currently, the federal government provides subsidies for unprofitable legacy service routes in order to retain scheduled air service and the related economic advantages of connected mobility.

### *Improved Environmental Justice*

Environmental justice is the fair treatment of all people regardless of race in regard to the development, implementation, and enforcement of environmental laws, regulations, or policies.

Environmental injustice impacts individual colored communities in several negative ways. Over the years, the discriminatory policies and practices that constitute environmental injustice have burdened communities of color more frequently, especially Black Americans, American Indians/Alaska Natives, Asian Americans and Pacific Islanders, and Hispanic populations. More times than not, these communities are located next to pollution sources such as major roadways, toxic waste sites, landfills, and chemical plants. These disadvantaged populations also were concentrated in substandard housing, where hazardous exposures are much more likely. Often communities of color face cumulative health impacts from multiple co-occurring exposures.

Interest in this topic is also sparked by environmental justice issues. The most likely significant environmental justice issues at and around airports are noise and air quality, which are also the most likely environmental issues (FAA 2018). Environmental justice concerns are brought on by effects on human health or the environment, including related social and economic effects with displacement (e.g., of people and businesses), which are the most likely significant environmental justice issues at and around airports.

Commercial aircrafts' turbine engines in particular emit large amounts of UFP (ultrafine particulate matter). The UFP attribution to aircraft emissions has been associated with lung inflammation in individuals with asthma (Habre et al. 2018).

Airport air pollution can also effectively impact sensitive subpopulations. Henry et al. studied the impacts of several California airports on surrounding schools and found that over 65,000 students spend 1 to 6 hours a day during the academic year being exposed to airport pollution, and the percentage of impacted students was higher for those who weren't the most economically advantaged. Rissman et al (Henry et al. 2019). Rissman et al. studied PM<sub>2.5</sub> at the Hartsfield-Jackson Atlanta International Airport and found that the relationship between minority population percentages and aircraft-derived particulate matter was found to grow stronger as concentrations increased(Rissman et al. 2013).

Electric aircraft can help alleviate environmental injustice. By definition, electric aircraft will not require turbine engines, so therefore the UFP will be significantly less in colored communities. This then would also help improve conditions for students who would usually spend 1 to 6 hours a day during a school year exposed to airport pollution. Furthermore, this would help individuals in general with certain lung conditions with reduced UFP in the environment. In addition, electric airplanes also produce way less noise than normal commercial aircraft, therefore it would be beneficial to have in everyday life for the economically challenged communities.

## Conclusions

This research has demonstrated that hybrid/electric vehicles would benefit the environment in ways that would be positive for all living species. Everything from less congestion to lower noise levels so that we can preserve our environment and help each other. However, there will exist many struggles nonetheless as we will still need to develop stronger and reliable batteries and how to successfully remodel airports. But looking at the current efforts, progress will be made. Thus, hopefully in a few decades, we will have a system of aircraft that benefits both the environment and us.

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## References

- [1] T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P. M. Midgley, et al., *Climate change 2013: The physical science basis, Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change 1535*.
- [2] M. Cames, J. Graichen, A. Siemons, V. Cook, 2015, *Emission reduction targets for international aviation and shipping*, Directorate General for Internal Policies; European Parliament—Policy Department A; Economic and Scientific Policy: Bruxelles, Belgium.
- [3] F. Linke, K. Radhakrishnan, V. Grewe, R. Vos, M. Niklaß, B. Lühns, F. Yin, I. Dedoussi, 2020, *Glowopt—a new approach towards global-warming-optimized aircraft design*, in: 1st Aerospace Europe Conference (AEC).

[4] Medicine, T. N. A. o. S. E. (2019). "Fossil Fuels ". From National Academies of Science, Engineering, and Medicine (<http://needtoknow.nas.edu/energy/energy-sources/fossil-fuels/>).

[5]White, Tim. 2020. "Hybrid-Electric Propulsion: A Great Start to Reducing Aviation's Carbon Footprint." Originally published in Regional International/ERA magazine, March 2020. <https://www.collinsaerospace.com/en/newsroom/Stories/2020/03/White-Hybrid-Electric-Propulsion-Great-Start-Reducing-Aviation-Carbon-Footprint>.

[6] Moshvitch, K. (2014). "How to cut noise in a plane cabin." from BBC([www.bbc.com/future/story/20140226-tricks-for-a-peaceful-flight](http://www.bbc.com/future/story/20140226-tricks-for-a-peaceful-flight)).

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

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

[9]Jurecka, R., & Bencalik, K. (2012). Airplanes with an electric motor. *Aviation*, 16(3), 63-68. <https://doi.org/10.3846/16487788.2012.732304>.

[10]Carmel, J. (2017). "The Quiet Revolution: Aviation Prepares to Go From Jet Age to Electric Era of Flight." "

[11]Andreas W. Schäfer, S. R. H. B., Khan Doyme, Lynnette M. Dray, Albert R. Gnadt, Rod Self, Aidan O'Sullivan, Athanasios P. Synodinos & Antonio J. Torija (2019). "Technological, economic and environmental prospects of all-electric aircraft." *Nature Energy* 4: 160–166.

[12]Hawkings, A. J. (2018). "Electric Flight is Coming, but The Batteries Aren't Ready." ". from <https://www.theverge.com/2018/8/14/17686706/electric-airplane-flying-car-battery-weight-green-energy-travel>.

[13]Antcliff, Kevin, Nicholas Borer, Sky Sartorius, Pasha Saleh, Robert Rose, Maxime Gariel, Joseph Oldham, et al. 2021. Regional Air Mobility: Leveraging Our National Investments to Energize the American Travel Experience. NASA. April 2021. <https://sacd.larc.nasa.gov/sacd/wp-content/uploads/sites/102/2021/04/2021-04-20-RAM.pdf>.

[14]Howell Hanano, Elizabeth J. n.d. "Green for Take Off: Inside the Electric Airplane Industry." Toptal. <https://www.toptal.com/finance/market-research-analysts/electric-airplanes>.

[15] Habre R, Zhou H, Eckel S, Enebish T, Fruin S, Bastain T, et al. 2018.05.031. Short-term effects of airport-associated ultrafine particle exposure on lung function and inflammation in adults with asthma. *Environ. Int.* 2018;118:48–59. <https://doi.org/10.1016/j.envint>.

[16] Henry RC, Mohan S, Yazdani S. 2019, Estimating potential air quality impact of airports on children attending the surrounding schools. *Atmos Environ* 2019;212:128–35. <https://doi.org/10.1016/j.atmosenv.2019.05.046>.

[17] Rissman J, Arunachalam S, BenDor T, West JJ., 2013.07.010., Equity and health impacts of aircraft emissions at the Hartfield-Jackson Atlanta International Airport. Landsc Urban Plan 2013;120:234–47. <https://doi.org/10.1016/J.landurbplan>.