As the aviation industry moves toward electrification, one of its greatest challenges remains the limited range of electric aircraft due to the low energy density of current batteries. Martin Hepperle, Group Research Lead of the German Aerospace Center, explains,

> "In order to power larger aircraft a dramatic improvement in battery technology would be required. …the mass specific energy density would have to be increased at least by a factor of 5 to become useful. More realistic this factor would have to be in the order of 10 to attract commercial interest for larger (regional) aircraft" (Hepperle, 2012).

This technological limitation underscores a critical barrier in making electric flight competitive with conventional aviation. This slow pace of improvement has intensified the search for alternative energy solutions capable of extending flight ranges without sacrificing performance. Simultaneously, Karie Riley and colleagues from the U.S. Environmental Protection Agency found that "UFP concentrations are elevated downwind of commercial airports, and… proximity to an airport also increases particle number concentrations within residences" (Riley et al., 2021). Such findings demonstrate how traditional turbine-engine aircraft significantly contribute to ultrafine particulate pollution, which is linked to respiratory inflammation and long-term health risks. The dual challenges of energy inefficiency and environmental degradation establish a pressing need for sustainable transformation within aviation. Advancing electric aircraft, therefore, is not merely a technological pursuit, it represents an environmental and public health necessity.

Works Cited (Including lit review Sources):

Akagi, R. (n.d.-b). RAM Air-Turbine of minimum drag. DigitalCommons@CalPoly. https://doi.org/10.15368/theses.2021.11

Barzegar-Kalashani, M., Seyedmahmoudian, M., Mekhilef, S., Stojcevski, A., & Horan, B. (2023). Small-scale wind turbine control in high-speed wind conditions: A review. Sustainable Energy Technologies and Assessments, 60, 103577. https://doi.org/10.1016/j.seta.2023.103577

Bolaños-Vera, M. A., Ortiz-Pérez, A., Durazo-Romero, E., Pérez-Mota, J., González-Uribe, L., & Pérez-Reyes, I. (2024). Numerical analysis of aerodynamic performance of the Ram Air Turbine in an aircraft. *Heliyon*, *10*(11), e32039. https://doi.org/10.1016/j.heliyon.2024.e32039

Clarke, M. A., Erhard, R. M., Smart, J. T., & Alonso, J. (2021). Aerodynamic optimization of Wing-Mounted propeller configurations for distributed electric propulsion architectures. AIAA Aviation 2019 Forum. https://doi.org/10.2514/6.2021-2471

Deere, K. A., Viken, J. K., Viken, S. A., Carter, M. B., NASA Langley Research Center, Wiese, M. R., Norma Farr, & Craig Technologies. (2017). Computational analysis of a wing designed for the X-57 distributed electric propulsion aircraft. AIAA Aviation Forum, 1–2. https://ntrs.nasa.gov/api/citations/20170005883/downloads/20170005883.pdf

Dowling, M., & Costello, M. (2018b). Feasibility Study of embedded wind energy harvesting system for Parafoil-Payload Aircraft. *Journal of Aircraft*, *55*(5), 2127–2136. https://doi.org/10.2514/1.c034832

Hepperle, M. (2012). Electric Flight - Potential and Limitations. *UNCLASSIFIED*. https://elib.dlr.de/78726/1/MP-AVT-209-09.pdf

Kaminsky, C., Filush, A., Kasprzak, P., & Mokhtar, W. (2012). A CFD study of wind turbine aerodynamics. In American Society for Engineering Education & Grand Valley State University, *Proceedings of the 2012 ASEE North Central Section Conference*. https://asee-ncs.org/proceedings/2012/Full%20Papers/Kaminsky.pdf

Riley, K., Cook, R., Carr, E., & Manning, B. (2021). A systematic review of the impact of commercial aircraft activity on air quality near airports. *City and Environment Interactions*, *11*, 100066. https://doi.org/10.1016/j.cacint.2021.100066

Rosato, A., Perrotta, A., & Maffei, L. (2024). Commercial Small-Scale Horizontal and Vertical Wind Turbines: A Comprehensive Review of geometry, materials, costs and performance. Energies, 17(13), 3125. https://doi.org/10.3390/en17133125

Saad, M., Mohd, S. B., & Zulkafli, M. F. (2017). A survey on the use of ram air turbine in aircraft. AIP Conference Proceedings. https://doi.org/10.1063/1.4981189

Saad, M. M. M., Mohd, S., Zulkafli, M. F., Samiran, N. A., & Didane, D. H. (2021). CFD simulation study on the performance of a modified RAM air turbine (RAT) for power generation in aircrafts. Fluids, 6(11), 391. https://doi.org/10.3390/fluids6110391

Trevisi, F., Cassoni, G., Gaunaa, M., & Fagiano, L. M. (2025). Concurrent aerodynamic design of the wing and the turbines of airborne wind energy systems. *European Academy of Wind Energy*. https://doi.org/10.5194/wes-2025-134

Walter-Robinson, D. M., & Llc, E. (2014, June 20). WO2015195856A1 - Energy cell regenerative system for electrically powered aircraft - Google Patents. https://patents.google.com/patent/WO2015195856A1/en