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Literature Review

Green Technology in Unmanned Aerial Vehicle (UAV) Electric Propulsion System: A Review

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Abstract
The use of fossil energy and coal has a significant impact on global warming through increased greenhouse gas emissions, particularly carbon dioxide (CO2). To address this issue, green technologies offer sustainable solutions, including the development of electric propulsion systems on unmanned aircraft (UAVs). Electric propulsion uses clean energy sources such as batteries and hydrogen fuel cells, significantly reducing emissions and air pollution. This research explores the importance of applying green technologies in the optimization of electric propulsion on UAVs, and the resulting environmental and economic benefits. Electric propulsion technology not only reduces carbon footprint and air pollution, but also improves energy efficiency and extends the operational life of UAVs. In addition, it allows UAVs to operate more quietly, reduces noise pollution, and can be used in various sensitive environments. The implementation of green technologies in UAV electric propulsion systems faces challenges such as limited battery capacity and recharging infrastructure. However, with collaboration between industry, government and research institutions, as well as regulatory support and incentives, the development of these technologies can be accelerated to achieve more environmentally friendly and sustainable UAV operations. Through the application of electric propulsion technology, UAVs are expected to provide innovative and sustainable solutions in areas such as aerial surveying, security surveillance, and freight forwarding, while making a positive impact on the environment and sustainability of the global ecosystem.
Keywords: Green Technology, Electric Propulsion, UAV, Energy Efficiency, Emission Reduction

Introduction
The use of energy from fossils and coal has an impact on global warming. Global warming is caused by an increase in greenhouse gas emissions, especially CO2 from the burning of fossil fuels. The combustion of fossil energy, especially coal, is a major contributor to carbon dioxide emissions, and the use of propulsion technology on unmanned aircraft is still dominated by fossil fuel engines (Figure 1). This has an impact on global warming and climate change, making it a major issue (Gruber et al., 2023). Around 67% of Indonesia's electrical energy supply comes from coal (Akbar Bagaskara & Raden Raditya Yudha Wiranegara, 2023). This dependence is an obstacle to achieving carbon emission reduction targets and energy sustainability. The result is climate change, rising sea levels, extreme weather, and threats to biodiversity. Green technology offers sustainable solutions through the development of environmentally friendly technologies, one of which is through unmanned aircraft (UAV) technology that uses electric propulsion systems.

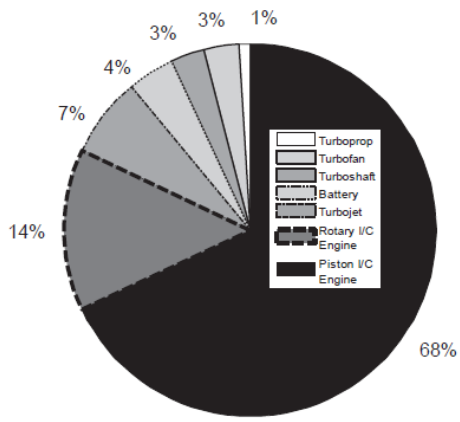

Figure 1. Application of Propulsion Technology to Unmanned Aerial Vehicle (UAV) (Babayomi & Makarfi, 2019)

Green technology is technology designed to preserve and protect the environment, and minimize negative impacts on the earth (Wu & Strezov, 2023). It encompasses innovations in various fields, including renewable energy, energy efficiency, waste management, and sustainable transportation (Behera et al., 2024). The ultimate goal is to reduce the carbon footprint and other negative environmental impacts of human activities in order to preserve nature and the environment.

The development of green technology has become a major focus in this modern era, as global awareness of climate change and environmental degradation increases. The implementation of green technology not only has the potential to improve environmental quality, but also offers economic benefits through reduced energy costs and increased operational efficiency. In addition, these technologies also encourage innovation and create new job opportunities in sustainable sectors (R. Wang et al., 2025).

Countries and international organizations have adopted policies and initiatives to support the development and implementation of green technologies (Intergovernmental Panel on Climate Change (IPCC), 2023). For example, the widespread use of renewable energy such as solar and wind power, and the development of electric vehicle technology aim to reduce greenhouse gas emissions from the transportation sector. In the area of waste management, environmentally friendly recycling and waste treatment technologies are being developed to reduce the volume of waste going to landfills.

Green technology in Indonesia has great potential to be applied due to its abundant natural resources and environmental challenges. The development of renewable energy such as geothermal and hydropower, as well as improving energy efficiency in the industrial and household sectors, are important steps to achieve sustainable development (Idroes et al., 2024). Thus, green technology is not only a technical solution to environmental problems, but also part of a global strategy to achieve long-term sustainability and prosperity. Therefore, research and innovation in this field must continue to be developed and supported by various parties, including the government, industry, and the wider community.

The application of green technology in electric propulsion optimization in UAVs is very important to improve energy efficiency and reduce carbon emissions (Zhao et al., 2021). Electric propulsion systems use cleaner energy sources, such as batteries or hydrogen fuel cells, which significantly reduce air pollution and negative impacts on climate. In addition, these technologies are designed to maximize performance with minimal energy consumption, yet enable longer flights and greater range without the need for frequent recharging (Babayomi & Makarfi, 2019; BBVL et al., 2023; H. Li & Liu, 2023). Noise pollution reduction is also an important added benefit for operations in sensitive areas such as urban areas and in wildlife protection zone areas.

In addition to environmental benefits, attention to green technology in electric propulsion optimization in UAVs is driving innovation and compliance with increasingly stringent environmental regulations. These technologies help UAVs meet environmental standards, opening up wider commercial application opportunities. Despite the high initial investment, long-term benefits such as energy savings, reduced operational costs, and increased UAV lifespan offer significant economic returns. Thus, the application of these green technologies is an important step towards achieving more environmentally friendly, efficient and sustainable UAV operations (Y. Li et al., 2021).

The purpose of this article is to explore the importance of applying green technology in electric propulsion optimization in UAVs (Unmanned Aerial Vehicles) and identify the resulting environmental and economic benefits. This article also aims to discuss recent innovations in environmentally friendly electric propulsion technologies and how these technologies can meet increasingly stringent environmental regulatory standards. As such, this article is expected to provide a comprehensive understanding of the role of green technologies in improving the performance and sustainability of UAVs, and encourage more research and development in this area.

The Role of UAVs in Addressing Environmental Issues

It is important to consider the environmental impact when using UAVs, because while this technology can provide great benefits, its use can also cause environmental problems if not managed properly. Air pollution due to exhaust emissions from UAV engines using fossil fuels is one of the negative environmental impacts that needs attention. UAV engines that use fossil fuels can cause an increase in greenhouse gas emissions and air pollution that adversely affect human health and the surrounding environment (Bahari et al., 2022). Therefore, the development of environmentally friendly electric propulsion technology can be an effective solution to reduce the negative impact of UAVs on the environment. Electric propulsion technology can help reduce harmful exhaust emissions, making UAVs more environmentally friendly. In addition, the use of fossil fuels can also be minimized with the adoption of electric propulsion technology. Thus, UAVs can still provide great benefits without harming the surrounding environment.

With the growing electric propulsion technology, UAVs can become more efficient and sustainable in operation. The use of electrical energy as a power source can also reduce operational costs by efficiently managing the use of electrical energy, both in amount and time (Y. Li et al., 2016). This can benefit power companies in reducing fuel costs, operating costs, and maintenance costs. This will help improve the efficiency and sustainability of UAV use in areas such as aerial surveying, security surveillance, and freight forwarding. In addition, electric propulsion technology can also extend the service life of UAVs and reduce the risk of fires caused by traditional fuels. Thus, the use of UAVs can be a more environmentally friendly and safe option in the long run. In addition, electric propulsion technology also allows UAVs to be quieter and produce less noise pollution, allowing them to be used more flexibly in various environments and operational conditions (Zong et al., 2021). As this technology develops, it is expected that the use of UAVs will expand and provide greater benefits for activities that require unmanned aerial access.

UAVs with electric propulsion technology can be an environmentally friendly and safe solution in the long run. In addition, this technology also makes UAVs quieter and does not produce annoying noise pollution, so it can be used more flexibly in various environments and operational conditions (Koenhardono et al., 2017). As this technology develops, it is expected that the use of UAVs will become more widespread and provide greater benefits for activities that require unmanned aerial access. In addition, UAVs can also help reduce environmental impacts by reducing CO2 emissions and saving fuel (Benmoussa & Gamboa, 2023). With the widespread use of UAVs, it is expected that this technology can continue to grow and provide better solutions in various fields, such as surveillance, mapping, agriculture, and so on. The ability of UAVs to reduce emissions and noise pollution can be a more environmentally friendly alternative to manned aircraft (Cardone et al., 2021). The utilization of UAVs in the future is expected to provide great benefits to various sectors and society as a whole. For example, the use of UAVs in environmental surveys can help identify air pollution hotspots without having to send manned aircraft, thereby reducing the resulting CO2 emissions (Dantsker et al., 2020). In addition, UAVs can also be used to efficiently and accurately monitor plantations, which can help farmers increase their yields without having to use a lot of resources. With evolving technology, UAVs can also be used to deliver medicines and medical supplies to remote areas more quickly and efficiently than ground transportation. This would be especially beneficial in emergency situations or natural disasters where access to isolated areas is difficult. With this great potential, the utilization of UAVs in various fields is expected to provide innovative and sustainable solutions for the future.

UAV Challenges in Energy Efficiency

Technological developments and research in this area are expected to produce more environmentally friendly and sustainable solutions. One way to address this challenge is by developing more efficient and environmentally friendly fuels (De Sousa & Moita, 2018). In addition, design optimization and the use of more advanced sensors can also help improve energy efficiency and reduce the environmental impact of UAV use. With continued efforts, it is expected that UAVs can become a better and more sustainable solution for various transportation and delivery needs in the future. A relevant example is the development of a UAV aeronautical hybrid propulsion system, which can reduce carbon emissions and reduce environmental impact. In addition, the use of advanced sensors on UAVs can assist in environmental monitoring and more efficient waste management, thus strengthening the contribution of UAVs as an environmentally friendly transportation solution. The development of more efficient battery technologies can also help reduce the environmental impact of UAV use, by reducing dependence on fossil fuels. UAVs are expected to become an integral part of a sustainable transportation system in the future, keeping the environment healthy and sustainable.

In addition, collaboration between government, industry and research institutions can also accelerate innovation in the development of environmentally friendly UAVs. With supportive regulations and incentives for green technology developers, more solutions can be found to reduce the carbon footprint of UAVs. In addition, public education and awareness also play an important role in supporting the sustainable use of this technology. Cooperation and shared commitment can create a cleaner and more sustainable future through the use of environmentally friendly UAVs. However, there are still obstacles in implementing regulations that support green technology and incentives for developers, and further efforts are needed to ensure compliance and effectiveness in reducing the carbon footprint of UAVs.

Green Technology in UAV Electric Propulsion System

Electric propulsion systems use electric motors and batteries as power sources, in contrast to conventional propulsion systems that rely on fossil fuels. Some of the main components in this system are:

- Electric motors in UAVs provide higher energy efficiency than internal combustion engines (A. Mohammed et al., 2022). In addition, electric motors are lighter and require less maintenance. This makes UAVs using electric propulsion more environmentally friendly as they do not produce greenhouse gas emissions and air pollution like UAVs with internal combustion engines. The cost of using and maintaining an electric propulsion system is still a challenge, given the high price of batteries. Therefore, to realize the widespread use of environmentally friendly UAVs, economic and political factors that support the development of green technologies need to be considered.

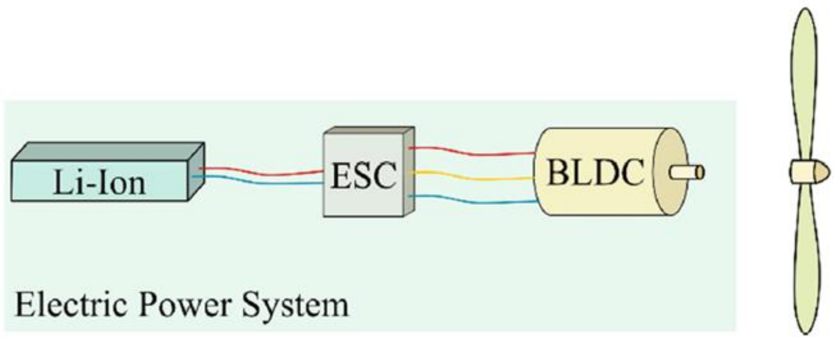

Figure 2. Electric Propulsion System

- Battery technology, such as Lithium-ion and Lithium-polymer, has progressed rapidly. These batteries are capable of storing high-density energy and providing sufficient power for longer flights. A comparison of the performance of various types of energy storage is presented in Figure 3. As battery technology continues to advance, it is expected that the cost of using and maintaining electric propulsion systems in UAVs will become more affordable. Thus, the use of eco-friendly UAVs may become a more economically attractive option. In addition, support from government and industry in the development of green technologies will also accelerate the adoption of electric-based UAVs in various sectors.

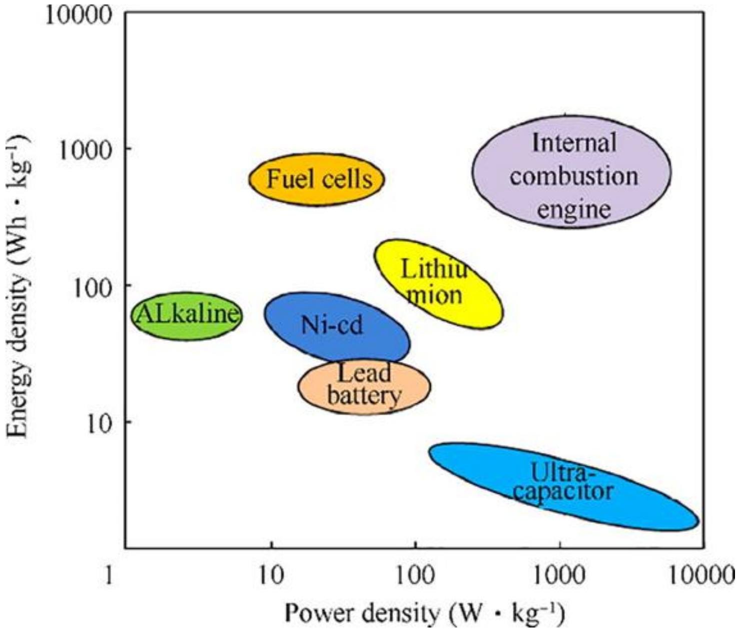

Figure 3. Performance Comparison of Different Types of Energy Storage Based on Energy Density and Power Density (LEI et al., 2019)

- Energy management systems are useful for optimizing the use of energy from batteries, ensuring maximum efficiency and reducing energy waste (Duy & Kim, 2020). The development of an effective energy management system will be key in ensuring optimal performance of the electric UAV. Figure 4 shows the architecture and power paths of the distributed propulsion system. With this system in place, the use of energy from the battery can be optimized so that maximum efficiency can be achieved. This will not only reduce energy waste, but will also help reduce the maintenance and usage costs of electric propulsion systems on UAVs. Thus, the use of eco-friendly UAVs will become more desirable and an economically beneficial solution.

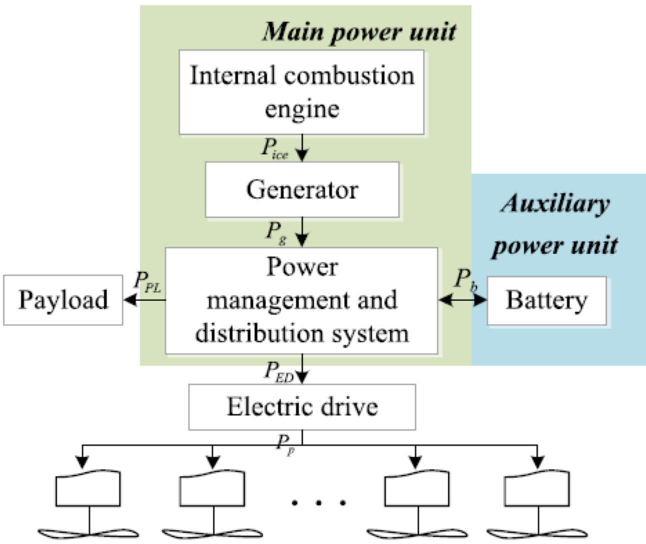

Figure 4. Architecture and Power Paths of a Distributed Propulsion System (He et al., 2020)

Environmental Benefits of Electric Propulsion

- Reduction of Carbon Emissions

  UAVs with electric propulsion do not produce greenhouse gas emissions during operation, unlike fossil-fueled UAVs that release CO2 and other pollutants. The use of electrically propelled UAVs can help reduce carbon emissions and air pollution that harm the environment (Alnumay et al., 2022). In addition, more efficient use of energy will also help extend battery life and minimize the impact of e-waste. As awareness of the importance of environmental protection continues to increase, the use of eco-friendly UAVs will become an increasingly desirable option in the future due to their environmental friendliness.

- Energy Efficiency
  Electric motors are more efficient in converting electrical energy into propulsion, resulting in optimized energy usage. This will help in reducing operational costs and also reduce the carbon footprint produced by the UAV. As the technology continues to develop, it is expected that the use of UAVs with electric propulsion will be increasingly used in various industries, not only for commercial purposes but also for research and environmental monitoring purposes. Thus, it can achieve the goal of protecting the environment and reducing the negative impact on the global ecosystem.

Environmental Challenges and the Future

UAVs Despite the many benefits offered, the implementation of electric propulsion systems on UAVs still faces several challenges, including:

- Battery Life
  Limited battery capacity is still a major obstacle in long-term flight. In addition, the problem of recharging batteries efficiently and quickly is also a major focus in the development of electric propulsion technology in UAVs (M. Wang et al., 2020). The development of more advanced and efficient battery technology is expected to be a solution to this challenge. In addition, strict regulations and safety standards also need to be implemented to ensure safety and security in the use of UAVs with electric propulsion in various sectors. With collaborative efforts between industry, government and other stakeholders, it is expected that the implementation of electric propulsion in UAVs can continue to grow and have a positive impact on the environment and the sustainability of the global ecosystem.
- Charging Infrastructure
  Infrastructure availability for UAV battery recharging still needs to be improved to support wider operations (He et al., 2020). Investment is needed in the development of UAV battery recharging infrastructure in strategic locations, so that users of electrically propelled UAVs can easily access these facilities. In addition, safety and quality standards should also be applied to the battery recharging infrastructure to prevent the risk of fire or damage to the UAV. With adequate charging infrastructure, it is expected that the use of electrically propelled UAVs will increase and provide greater benefits to various sectors.

Conclusions

Green technology is an innovative approach designed to preserve and protect the environment by minimizing its negative impacts. It covers areas such as renewable energy, energy efficiency, waste management, and sustainable transportation. The development of green technology is becoming increasingly important as global awareness about climate change and environmental degradation increases. In addition to environmental benefits, green technologies also offer economic advantages through reduced energy costs and improved operational efficiency, as well as creating new employment opportunities.

Indonesia, with its wealth of natural resources, has great potential to implement green technologies. The development of renewable energy such as geothermal and hydropower and the improvement of energy efficiency in the industrial and household sectors are important steps towards sustainable development. The application of green technology in electric propulsion optimization on UAVs (Unmanned Aerial Vehicles) is also very important. Electric propulsion systems use clean energy sources such as batteries or hydrogen fuel cells, which reduce air pollution and carbon emissions. In addition, this technology improves energy efficiency and enables longer flights with minimal energy consumption.

Although the upfront cost investment is high, long-term benefits such as energy savings, reduced operational costs, and increased UAV lifespan offer significant economic benefits. Green technologies in electric propulsion on UAVs also help meet increasingly stringent environmental regulatory standards, opening up wider commercial and civilian application opportunities. Challenges include battery life and availability of recharging infrastructure. The development of more efficient battery technologies and investment in recharging infrastructure are critical to support widespread UAV operations.

With collaboration between industry, research institutions and government, as well as regulatory support and incentives for green technology development, it is expected that more solutions will be found to reduce the carbon footprint of UAVs. Public education and awareness are also important in supporting the sustainable use of green technology. The implementation of electric propulsion technology on UAVs is an important step towards more environmentally friendly, efficient and sustainable operations, and has a positive impact on the environment and the sustainability of the global ecosystem.

Acknowledgments

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References

A. Mohammed, A., Shinkafi, A. A., Isah, A., Ajayi, J. A., Pedro, P. T., Asooto, B. C., Ejakita, J. O., & Johnson-Anamemena, N. (2022). Prospects and Challenges of Propulsion Technologies of Unmanned Aerial Vehicles: A Review. Nigerian Journal of Technology, 40(6). https://doi.org/10.4314/njt.v40i6.8

Akbar Bagaskara, & Raden Raditya Yudha Wiranegara. (2023, August 11). Akhiri batu bara: ini daftar PLTU baru yang cocok diubah jadi pembangkit biomassa. The Conversation.

Alnumay, Y., Jifri, H., Albrahim, A., Felemban, A., & Abdellatif, F. (2022, October 31). Carbon Footprint Reduction Through the Use of Drones for Inspection Activities. Day 2 Tue, November 01, 2022. https://doi.org/10.2118/210836-MS

Babayomi, O. O., & Makarfi, A. U. (2019). Energy Efficiency in Unmanned Aircraft Systems: A Review. 2019 IEEE PES/IAS PowerAfrica, 569–574. https://doi.org/10.1109/PowerAfrica.2019.8928766

Bahari, M., Rostami, M., Entezari, A., Ghahremani, S., & Etminan, M. (2022). Performance evaluation and multi-objective optimization of a novel UAV propulsion system based on PEM fuel cell. Fuel, 311. https://doi.org/10.1016/j.fuel.2021.122554

BBVL, D., Pal Singh, D., Kumar Kuppa, S., & Jayanthi Rao, M. (2023). Design optimization of drone BLDC motor for delivery service applications. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2023.07.370

Behera, P., Behera, B., & Sethi, N. (2024). Assessing the impact of fiscal decentralization, green finance and green technology innovation on renewable energy use in European Union countries: What is the moderating role of political risk? Renewable Energy, 229. https://doi.org/10.1016/j.renene.2024.120715

Benmoussa, A., & Gamboa, P. V. (2023). Effect of Control Parameters on Hybrid Electric Propulsion UAV Performance for Various Flight Conditions: Parametric Study. Applied Mechanics, 4(2), 493–513. https://doi.org/10.3390/applmech4020028

Cardone, M., Gargiulo, B., & Fornaro, E. (2021). Modelling and experimental validation of a hybrid electric propulsion system for light aircraft and unmanned aerial vehicles. Energies, 14(13). https://doi.org/10.3390/en14133969

Dantsker, O. D., Caccamo, M., & Imtiaz, S. (2020). Propulsion system design, optimization, simulation, and testing for a long-endurance solar-powered unmanned aircraft. AIAA Propulsion and Energy 2020 Forum, 1–18. https://doi.org/10.2514/6.2020-3966

De Sousa, N., & Moita, M. (2018). Optimization of the Propeller-Driven Propulsion System for a Small UAV.

Duy, V. N., & Kim, H. M. (2020). Review on the hybrid-electric propulsion system and renewables and energy storage for unmanned aerial vehicles. In International Journal of Electrochemical Science (Vol. 15, pp. 5296–5319). Electrochemical Science Group. https://doi.org/10.20964/2020.06.13

Gruber, N., Bakker, D. C. E., DeVries, T., Gregor, L., Hauck, J., Landschützer, P., McKinley, G. A., & Müller, J. D. (2023). Trends and variability in the ocean carbon sink. Nature Reviews Earth & Environment, 4(2), 119–134. https://doi.org/10.1038/s43017-022-00381-x

He, C., Jia, Y., & Ma, D. (2020). Optimization and Analysis of Hybrid Electric System for Distributed Propulsion Tilt-Wing UAV. IEEE Access, 8, 224654–224667. https://doi.org/10.1109/ACCESS.2020.3044449

Idroes, G. M., Hardi, I., Rahman, M. H., Afjal, M., Noviandy, T. R., & Idroes, R. (2024). The dynamic impact of non-renewable and renewable energy on carbon dioxide emissions and ecological footprint in Indonesia. Carbon Research, 3(1). https://doi.org/10.1007/s44246-024-00117-0

Intergovernmental Panel on Climate Change (IPCC). (2023). Overarching Frequently Asked Questions and Answers. https://www.ipcc.ch/report/ar6/wg2/downloads/faqs/IPCC_AR6_WGII_Overaching_OutreachFAQ2.pdf

Koenhardono, E. S., Prananda, J., & Danian, E. (2017). Analysis of Engine Propeller Matching of DC Motor as a Main Propulsion. In International Journal of Marine Engineering Innovation and Research (Vol. 2, Issue 1).

LEI, T., YANG, Z., LIN, Z., & ZHANG, X. (2019). State of art on energy management strategy for hybrid-powered unmanned aerial vehicle. In Chinese Journal of Aeronautics (Vol. 32, Issue 6, pp. 1488–1503). Chinese Journal of Aeronautics. https://doi.org/10.1016/j.cja.2019.03.013

Li, H., & Liu, K. (2023). Aerodynamic Design Optimization and Analysis of Ducted Fan Blades in DEP UAVs. Aerospace, 10(2). https://doi.org/10.3390/aerospace10020153

Li, Y., Li, D., Hu, W., & Tang, X. (2021). Throughput Maximization for the System of UAV as Mobile Relay Between Moving Vehicles. In M. Guan & Z. Na (Eds.), Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST (Vol. 342, pp. 492–504). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-030-66785-6_53

Li, Y., Xiang, S., Wang, S., Huang, J., Zhao, Y., & guo, J. (2016). Research on Optimization Design of UAV Main Propulsion Motor Based on Particle Swarm Optimization Algorithm. International Conference on Mechatronics and Automation, 2472–2476.

Wang, M., ZHANG, S., DIEPOLDER, J., & HOLZAPFEL, F. (2020). Battery package design optimization for small electric aircraft. Chinese Journal of Aeronautics, 33(11), 2864–2876. https://doi.org/10.1016/j.cja.2020.04.021

Wang, R., Wang, X., & Zhu, T. (2025). Research progress and application of carbon sequestration in industrial flue gas by microalgae: A review. Journal of Environmental Sciences (China), 152, 14–28. https://doi.org/10.1016/j.jes.2024.04.018

Wu, J., & Strezov, V. (2023). Green technologies and sustainability. Green Technologies and Sustainability, 1, 1–2.

Zhao, S., Wang, X., Liu, S., & Hao, Y. (2021). Analysis and Optimization of Asynchronous Induction Electromagnetic Propulsion System. In X. Ning & Y. Feng (Eds.), ICMLCA 2021 - 2nd International Conference on Machine Learning and Computer Application (pp. 759–764). VDE VERLAG GMBH. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85137042857&partnerID=40&md5=950577dec7b78c0eb5b8bd52ec92911f

Zong, J., Zhu, B., Hou, Z., Yang, X., & Zhai, J. (2021). Evaluation and comparison of hybrid wing vtol uav with four different electric propulsion systems. Aerospace, 8(9). https://doi.org/10.3390/aerospace8090256.