Driving the Energy Transition in Airports: Hydrogen-Powered Heavy-Duty Vehicles at Warsaw Airport

Abstract

Introduction

The aviation sector is undergoing a profound transformation in line with global sustainability efforts. Airports, as key elements of the transportation network, are playing a pivotal role in this energy transition by adopting innovative technologies aimed at reducing their environmental impact. Among the most promising advancements, is the adoption of hydrogen-powered heavy-duty vehicles, including ground support equipment (GSE) [1] and airport transport trucks, representing a significant step toward decarbonizing airport operations. These vehicles offer a viable alternative to conventional fossil fuel-powered machinery, addressing the urgent need to reduce greenhouse gas emissions while simultaneously meeting the growing demand for efficient and reliable airport logistics [2]. Hydrogen provides a clean, zero-emission solution with high energy density, making it well-suited for powering essential heavy-duty vehicles in airport operations. As air terminals worldwide seek to meet stringent sustainability targets, hydrogen technology is positioned as a cornerstone in the shift toward more sustainable energy models. This transition is driven not only by regulatory pressures but also by the desire to improve energy efficiency, enhance air quality, and reduce noise pollution.

This paper explores the economic, environmental, and social impacts of future hydrogen-powered vehicles at Warsaw Chopin Airport, Within the framework of the HORIZON-JYI-CLEANH_2 HySPARK project, a pioneering initiative funded by the European Clean Hydrogen Partnership and led by ORLEN Group, in collaboration with 17 international partners. This initiative is a crucial step in decarbonizing airport operations and integrating clean energy technologies into the aviation industry, with the goal of ensuring the economic sustainability of operations, demonstrating that sustainability and economic growth can advance together.

The project, initiated by members of the Mazovian Hydrogen Valley, aims to create a comprehensive hydrogen value chain in central Poland. As part of the HySPARK initiative, hydrogen-powered vehicles, such as ARTHUR BUS buses, Quantron tractors, and ground handling trucks for Chopin Airport by the Italian company ATENA, will be developed and deployed. Additionally, a hydrogen refuelling station, co-financed by CEF AFIF funds, will be established near the airport.

HySPARK is a groundbreaking initiative that brings together the key expertise needed to achieve the objectives of Poland's Hydrogen Strategy. The involvement of the Mazovian Hydrogen Valley consortium is expected to significantly contribute to the decarbonization of transport, with the outcomes of the project serving as a replicable model for other urban regions.

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[1] Blanchard, J. (2020). *Fuel Cell Powered Airport GSE (Ground Support Equipment) Deployment* (No. DOE-Plug Power-0006093). Plug Power, Latham, NY (United States).

[2] www.infrajournal.com/it/w/hydrogen-a-new-challenge-for-greener-airports

The Role of Hydrogen in Airport Operations

Hydrogen, as an alternative fuel, offers distinct advantages over traditional diesel-powered airport vehicles. It provides zero emissions at the point of use, reduces dependency on fossil fuels, and improves air quality around airport facilities. Unlike battery-electric solutions, which often require longer charging times and extensive charging infrastructure, hydrogen fuel cell vehicles (HFCVs) can be refuelled quickly, making them a highly practical option for high-demand airport operations. This capability is especially beneficial for heavy-duty vehicles, such as baggage transporters, aircraft tugs, and cargo loaders, which operate continuously under tight schedules and require constant reliability.

Moreover, hydrogen technology presents airports with an opportunity to future-proof their operations [3], aligning with long-term sustainability goals while meeting the increasing demand for efficient, 24/7 operations. As the global aviation industry continues to prioritize green technologies, these vehicles are expected to play an integral role in reshaping the airport landscape, driving the transition toward more sustainable, reliable, and efficient operations.

Economic Evaluation and Methodology

The integration of HFCVs at airports presents a strategic economic opportunity for the aviation sector, offering both direct and long-term benefits, analysed through *Cost-Benefit Analysis* (CBA) [4] and *Multi-Criteria Decision Analysis* (MCDA)[5]. While the initial capital investment for hydrogen infrastructure, including refuelling stations and hydrogen-powered vehicles, may be higher compared to traditional diesel or battery-electric solutions, the overall lifecycle costs can prove more favourable in the long run. Hydrogen fuel cells offer lower operating costs due to their high energy efficiency, reduced maintenance needs, and longer operational lifespans compared to diesel engines. These factors contribute to a reduction in the total cost of ownership, which can be especially significant for airports relying on continuous, high-utilization heavy-duty vehicles such as baggage transporters, aircraft tugs, and cargo loaders.

Additionally, the operational efficiency of hydrogen fuel cells allows for faster refuelling times, minimizing downtime and maximizing vehicle availability, an important consideration in the high-demand environment of an airport. Unlike battery-electric vehicles, which require long charging periods and extensive infrastructure, they can be refuelled in minutes, ensuring that vehicles are ready to operate promptly without extended interruptions to airport logistics.

Furthermore, adopting hydrogen-powered vehicles positions airports to benefit from various financial incentives and support programs aimed at reducing carbon emissions and promoting clean energy solutions. European funding mechanisms, such as those provided through the Clean Hydrogen Partnership and the Connecting Europe Facility (CEF), offer opportunities for

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[3] Bruce, S., Temminghoff, M., Hayward, J., Palfreyman, D., Munnings, C., Burke, N., & Creasey, S. (2020). Opportunities for hydrogen in aviation. *Csiro*.

[4] Mishan, E. J., & Quah, E. (2020). *Cost-benefit analysis*. Routledge.

[5] Wang, J. J., Jing, Y. Y., Zhang, C. F., & Zhao, J. H. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and sustainable energy reviews*, *13*(9), 2263-2278.

co-financing hydrogen infrastructure projects, significantly reducing the financial burden on terminal operators. These initiatives support the long-term sustainability of airport operations by helping to offset the upfront costs associated with transitioning to hydrogen technology.

In the broader economic context, their widespread adoption has the potential to stimulate local economies by fostering the development of a hydrogen supply chain, including production, distribution, and refuelling infrastructure. This could attract investment in green technologies, contributing to economic growth while supporting the European Union's goals of achieving carbon neutrality by 2050 [6] and reducing greenhouse gas emissions by up to 90% compared to diesel counterparts.

While the transition requires substantial initial investment, the long-term financial and environmental benefits [7] make it a sound economic decision for airports seeking to align with sustainable development goals while ensuring continued efficiency and reliability in operations.

The HySPARK project demonstrates how energy transitions, particularly the shift to hydrogen technology, can address pressing challenges such as climate change, economic uncertainty, and social inequalities. By replacing diesel vehicles with hydrogen-powered alternatives at Warsaw Chopin Airport, it reduces emissions and contributes to environmental sustainability. It also promotes economic resilience by fostering the development of hydrogen infrastructure, creating local jobs, and supporting green innovation.

By focusing on operational efficiency and sustainability, the initiative underscores how energy transitions can help build more equitable economic systems and strengthen social cohesion, providing valuable insights for scaling sustainable energy solutions across other sectors. Ongoing research is essential to demonstrate the viability of this vehicle alternative and expand its use across the aviation sector.

Conclusion

The transition to hydrogen-powered heavy-duty vehicles at airports represents not only a significant environmental advancement but also a strategic economic opportunity for the future [8]. By reducing dependence on fossil fuels, lowering emissions, and improving operational efficiency, hydrogen technology aligns with both environmental sustainability goals and the need for economic resilience. While the initial investment in hydrogen infrastructure may be substantial, the long-term benefits, such as reduced operating costs, quicker refuelling times, and the potential for job creation within the emerging hydrogen supply chain, make it a

[6] Perissi, I., & Jones, A. (2022). Investigating European Union decarbonization strategies: Evaluating the pathway to carbon neutrality by 2050. *Sustainability*, *14*(8), 4728.
[7] Testa, E., Giammusso, C., Bruno, M., & Maggiore, P. (2014). Analysis of environmental benefits resulting from use of hydrogen technology in handling operations at airports. *Clean Technologies and Environmental Policy*, *16*, 875-890.
[8] Yusaf, T., Fernandes, L., Abu Talib, A. R., Altarazi, Y. S., Alrefae, W., Kadirgama, K., ... & Laimon, M. (2022). Sustainable aviation—Hydrogen is the future. *Sustainability*, *14*(1), 548.

financially sound decision for airports. Moreover, financial incentives from European funding mechanisms further enhance the economic viability of these projects.

The HySPARK project at Warsaw Chopin Airport serves as a concrete example of the potential of hydrogen-powered vehicles to transform airport operations, acting as a model for the large-scale adoption of sustainable and economically advantageous solutions in the aviation sector. This project not only demonstrates the feasibility of low-impact technologies but also provides a replicable model that can be extended to other airports, contributing to the achievement of global sustainability goals and economic resilience for the entire sector.