Analysis of Global Exploration and Application of Hydrogen-powered Buses in China

Leying Yu, Chao Tang, Hui Tan, Anqi Peng

Guangzhou City University of Technology, Guangzhou City, Guangdong Province, 510800.

Abstract: This research comprehensively analyzes the development status and technical progress of hydrogen energy buses around the world. Firstly, the development history of hydrogen buses around the world is reviewed, and its technical maturity assessment is discussed. Secondly, the technical maturity of hydrogen buses in China was assessed. Finally, strategic suggestions are put forward for the future development prospects of hydrogen energy buses. The purpose of this research is to provide reference for the development of hydrogen energy buses, and to contribute to the promotion of sustainable transportation development and environmental protection.

Keywords: Hydrogen-Powered Buses; Fuel Cell; Hydrogen Storage; Powertrain Integration; Carbon Reduction

1. Introduction

The global focus on sustainable development has positioned hydrogen as a key clean and renewable energy source. Buses, vital to urban transport, significantly impact the environment and air quality due to their energy consumption and emissions. Transitioning buses to hydrogen energy is thus crucial.

Hydrogen is a secondary energy source with numerous benefits, including being lightweight, widely available, and pollution-free upon combustion. At standard conditions, hydrogen's density is as low as 0.08g/L, and it primarily exists in water, making it abundant. Its combustion only produces water, offering a pollution-free alternative and making it a viable solution for global climate crises. Hydrogen can replace oil and gas, reducing dependency on imports and ensuring energy security. Hydrogen-powered buses are zero-emission and environmentally friendly, generating electricity on-site through a chemical reaction during refueling.

This research assesses the global status and application of hydrogen-powered buses, focusing on China. We will evaluate their technological maturity, economic feasibility, and environmental benefits, and identify challenges and opportunities for China's adoption of hydrogen-powered buses. This paper aims to provide insights for global exploration and application in China, promoting sustainable transportation and environmental protection.[1]

2. Development Journey of Hydrogen-Powered Buses Worldwide

2.1 Early Pilot Projects

Early hydrogen-powered bus development saw pilot projects in countries like Canada, the US, and Japan in the 1990s. Japan, considering hydrogen as “future energy”, led the way with fuel cell vehicle demonstrations in 2002 and the JFHC project from 2002 to 2013, enhancing energy utilization and fuel economy of fuel cell electric vehicles.

2.2 Commercialization Phase

Technological progress and cost reductions have led hydrogen-powered buses into commercialization. European nations like Germany, the UK, and the Netherlands spearheaded their promotion. The CUTE project from 2001 to 2009, involving

47 vehicles across Europe, Australia, and China, aimed to develop hydrogen infrastructure and assess fuel cell safety and environmental impact.[2]

2.3 Global Development Trends and Case Analysis

The adoption of hydrogen-powered buses is growing globally, with countries like China, South Korea, Denmark, and Australia joining in. Shanghai Re-Fire Technology Co., Ltd., Toyota, and Suzhou Golden Dragon Bus Co., Ltd. launched Suzhou Golden Dragon Haige hydrogen fuel cell buses, marking the first use of Toyota's hydrogen fuel cell technology in China.

Alexander Dennis Limited (ADL), part of NFI Group, leads in double-decker bus design and manufacturing. ADL's vehicles, known for their low emissions and reliability, are used worldwide. The company's commitment to low-emission and zero-emission buses contributes to sustainable, fair, and accessible development in transportation.[3]

3. Assessment of Technological Maturity of Hydrogen-powered Buses in China

3.1 Fuel Cell Technology

Fuel cells are essential for hydrogen-powered buses, with recent improvements in their stability, efficiency, and lifespan. These advancements have led to fuel cells meeting commercial application standards, and they are now implemented in buses in various cities.

Hydrogen is produced commercially from natural gas, petroleum, coal, and electrolysis, with methods evolving to include innovative techniques like nano-electroplated aluminum alloy powder. The development of hydrogen production technology is rapid, offering a bright future for this energy source.[4]

3.2 Hydrogen Storage Technology

Hydrogen storage is crucial for the range and safety of hydrogen buses but faces challenges in safety, density, and cost. Efforts are underway to develop new materials and technologies to enhance storage performance. With the hydrogen energy industry's growth, the storage cylinder market is expanding. High-pressure gaseous storage is the most common due to its efficiency and simplicity, with steel cylinders being the most mature and cost-effective. The use of carbon fiber-wrapped cylinders is increasing, especially with the potential growth in demand for Type IV cylinder technology.

3.3 Optimization and Innovation in Powertrain Integration

The powertrain integration of hydrogen fuel cell buses involves the coordination of components such as fuel cells, electric motors, and batteries. With technological advancements, the integration efficiency and reliability of powertrain systems have improved. New powertrain system designs and control strategies have been applied to hydrogen fuel cell buses, enhancing energy utilization efficiency and vehicle performance.

Breakthroughs in key technologies and materials for fuel cell systems, as well as scale production, are two major driving factors for the reduction in fuel cell system prices. The cost is closely related to factors such as quantified scale, localization rate of key components, and so on. As fuel cell technology performance improves, durability and lifespan increase, and the overall lifecycle cost of downstream fuel cell applications will be greatly improved. The localization of catalysts, proton exchange membranes, carbon papers, the improvement of stack power density, and the localization of compressors and hydrogen circulation pumps are the main iterative factors for cost reduction.

3.4 Analysis of Case Studies on Technological Maturity

China is pushing for greener, low-carbon transportation, with hydrogen buses playing a key role due to their efficient energy conversion and emission-free operation. Cities like Guangzhou and Dalian have adopted these buses, benefiting from their short refueling times and long ranges. Hydrogen buses are quieter and more convenient than traditional fuel buses, offering a compelling alternative for urban transportation.[5][6]

Compared to traditional fuel buses, hydrogen fuel cell buses emit water instead of carbon dioxide, thus avoiding air pollution. Traditional fuel buses continuously generate noise from the engine and exhaust system after starting, while

hydrogen fuel cell buses produce only minimal electromagnetic noise during operation, resulting in low noise levels. Hydrogen fuel cell buses only require braking and acceleration, without the need for gear shifting, making them more convenient to operate compared to traditional fuel buses. Compared to current pure electric buses on the market, hydrogen fuel cell buses have faster refueling and longer driving range. Fully charging a pure electric bus generally takes 1-2 hours, while refueling a hydrogen fuel cell bus only takes about ten minutes. In terms of driving range, a fully charged pure electric bus can travel between 70-300 kilometers depending on the model, while a hydrogen fuel cell bus can achieve a range of 300-500 kilometers. Hydrogen fuel can also be stored at -40℃ and started at -30℃, meeting various operating conditions for urban public transportation.

4. Future Development Prospects and Strategic Recommendations

4.1 Development Trend of Hydrogen-powered Buses

Advancements in fuel cell and hydrogen storage technologies are set to enhance the performance and reduce the costs of hydrogen-powered buses. With new materials and processes, fuel cell efficiency and lifespan will improve, and hydrogen storage will become denser and safer. Governments are expected to increase policy support and incentives, encouraging the adoption and market growth of hydrogen buses. International cooperation will play a crucial role in sharing technology and experiences, addressing climate change and energy transition challenges.

The market for hydrogen buses is anticipated to grow as technology matures and demand rises, leading to more cities adopting these buses and the development of innovative commercial models. Integration with renewable energy systems and smart transportation infrastructure will further optimize energy management and contribute to sustainable urban transportation[7].

4.2 Recommendations for China

China should provide clear policy support, including subsidies and incentives, to lower the costs of hydrogen buses. Establishing a robust hydrogen supply chain and investing in research and innovation are essential. Selecting cities for demonstration projects and encouraging public transportation operators to adopt hydrogen buses will help commercialize the technology. International collaboration will be vital to learn from global experiences and hasten the progress of hydrogen bus technology. These strategic measures aim to promote the widespread use of hydrogen buses in China, supporting the nation's green travel and sustainable transportation goals.[8][9]

5. Conclusion

Hydrogen-powered buses have been widely explored and applied globally as an environmentally friendly and sustainable transportation solution. Technological advancements in fuel cell and hydrogen storage technologies have improved their performance, while scaling up production has enhanced their economic feasibility. These buses significantly reduce emissions, improving urban air quality and benefiting the environment.

In China, although the government has prioritized the development of hydrogen-powered buses and implemented supportive policies, their adoption is still in the early stages. Challenges include technological maturity, cost-effectiveness, hydrogen supply chain, and infrastructure development, while opportunities lie in government support, market demand, and industrial chain development.

In conclusion, hydrogen-powered buses have global potential, but their application in China requires collaborative efforts from the government, enterprises, and society. Recommendations have been provided to promote their widespread adoption, contributing to sustainable transportation and environmental protection.

References

[1] Ling Wen, Li Quansheng, Zhang Kai. Research on the development strategy of hydrogen energy industry in China. China Engineering Science 24 (3), 80-88,2022.

[2] Hydrogen Fuel Cell Vehicles; Current Status and Future Prospect by Yogesh Manoharan, Seyed Ehsan Hosseini*, Brayden Butler, Hisham Alzhahrani, Bhi Thi Fou Senior, Turaj AshuriORCID and John Krohn Appl. Sci. 2019, 9(11), 2296.

[3] Xiangyu Meng, Alun Gu, Xinguo Wu, Lingling Zhou, Jian Zhou, Bin Liu, Zongqiang Mao, Status quo of China hydrogen strategy in the field of transportation and international comparisons, International Journal of Hydrogen Energy, Volume 46, Issue 57, 2021, Pages 28887-28899.

[4] Hydrogen energy as future of sustainable mobility Suprava Chakraborty, Santanu Kumar Dash, Rajvikram Madurai Elavarasan, Arshdeep Kaur, Devaraj Elangovan, Sheikh Tanzim Meraj, Padmanathan Kasinathan, Zafar Said Frontiers in Energy Research 10, 893475, 2022.

[5] Review of Energy Challenges and Horizons of Hydrogen City Buses by Valery Vodovozov 1,*ORCID, Zoja Raud 1ORCID and Eduard Petlenkov 2ORCID Energies 2022, 15(19), 6945.

[6] Pederzoli, D.W., Carnevali, C., Genova, R. et al. Life cycle assessment of hydrogen-powered city buses in the High V.LO-City project: integrating vehicle operation and refuelling infrastructure. SN Appl. Sci. 4, 57 (2022).

[7] Adoption of Hydrogen Fuel Cell Vehicles and its Prospects for the Future MD SHEHAN HAbIb, Paroma Arefin, Rudy Situmeang Oriental Journal of Chemistry 38 (3), 621, 2022.

[8] Guoqiang Zhang, Juan Zhang, Tian Xie, A solution to renewable hydrogen economy for fuel cell buses – A case study for Zhangjiakou in North China, International Journal of Hydrogen Energy,Volume 45, Issue 29, 2020, Pages 14603-14613.

[9] Li S, Long J, Sui P C, et al. Addition of hydrogen refueling for fuel cell bus fleet to existing natural gas stations: A case study in Wuhan, China[J]. International Journal of Energy Research, 2019, 43(13): 7557-7572.

Funding Project: Guangdong Provincial Special Funds for Science and Technology Innovation Strategy Project “Research on Carbon Emission Reduction Benefits of Hydrogen-powered Buses Based on the Green Supply Chain Perspective under the Dual Carbon Goals”. (pdjh2022b0762)