OPORTUNITIES AND CHALLENGES OF HYDROGEN AND FUEL CELL APPLICATIONS IN ROAD TRANSPORTATION

Amela Ajanovic, Vienna University of Technology - TU WIEN, Energy Economics Group, ajanovic@eeg.tuwien.ac.at

Overview

Over the past few decades, alongside electrification, hydrogen has emerged as a means of decarbonizing the transport sector. Hydrogen offers solutions to pressing challenges, such as reducing greenhouse gas emissions and decreasing dependency on fossil fuel imports. When combined with fuel cell vehicles (FCVs), hydrogen provides a clean and efficient alternative to conventional internal combustion engine vehicles. Like battery electric vehicles (BEVs), hydrogen FCVs produce zero emissions at the point of use, emitting only water vapor as a byproduct.

Compared to BEVs, FCVs offer advantages in terms of faster refueling times and extended driving ranges. These features make hydrogen particularly suitable for heavy-duty and long-haul road transport, where BEVs often face limitations due to battery size and weight. Furthermore, the growing adoption of renewable energy creates opportunities for hydrogen to serve as a storage medium for surplus electricity and to enable sector coupling, integrating energy systems across transport, industry, and power generation. Hydrogen thus represents a critical component in building a sustainable and resilient transportation ecosystem.

Methods

The primary goal of this paper is to analyze the development and adoption of FCVs in the EU. The focus is on the economic and environmental assessment of hydrogen and FCVs in comparison to BEVs and conventional internal combustion engine vehicles. Total costs of ownership are calculated for various types of road FCVs, including passenger cars, trucks, and buses.

A key aspect of the analysis is identifying the major factors influencing total mobility costs, such as vehicle investment costs and energy expenses. In this context, hydrogen production costs are examined, along with their emissions. Comparative analyses are conducted using conventional fossil-fuel-powered vehicles and BEVs as benchmarks.

Additionally, this paper documents and evaluates policy measures supporting the adoption of zero-emission vehicles, with a particular focus on strategies to accelerate the transition toward sustainable transport solutions.

Results

The results demonstrate that FCVs could serve as an attractive alternative, particularly for conventional trucks and buses, especially when combined with increased green hydrogen production and cost reductions in fuel cell technologies driven by technological learning. However, high capital costs and substantial infrastructure requirements across the entire supply chain—from hydrogen production to refueling stations—remain critical barriers to widespread adoption. The analysis underscores the importance of sector coupling and prioritizing hydrogen use in key areas, alongside implementing targeted policy interventions to address major challenges. These measures are essential for achieving global decarbonization targets and fostering a sustainable future for mobility. It is important to note that for larger vehicles, such as trucks, which require longer driving ranges, FCVs are more competitive with BEVs compared to passenger cars.

Conclusions

The future of hydrogen in the road transport sector is promising, with potential to contribute to the decarbonization of various transportation modes, particularly in areas where electrification faces challenges, such as heavy-duty and long-haul applications. As hydrogen production technologies advance, as well as fuel cells as conversion technologies, and green hydrogen becomes more affordable and widely available, the total costs of ownership of FCVs are expected to decrease, making them more economically competitive with conventional vehicles.

Furthermore, the integration of hydrogen into broader energy systems, including renewable energy storage and sector coupling, will enhance its role in supporting sustainable mobility. However, challenges such as infrastructure development and the high capital costs of fuel cell vehicles remain critical barriers to widespread adoption. In addition, future improvements should be made with respect to the efficiency of FCVs. With a clear long-term vision and targeted policy support, hydrogen has the potential to become a key enabler of clean, efficient, and resilient road transport systems in the future.