

Editorial

Fueling the Future: The Case for Heavy-Duty Fuel Cell Electric Vehicles in Sustainable Transportation

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 <https://doi.org/10.31603/ae.11285>

Published by Automotive Laboratory of Universitas Muhammadiyah Magelang

Article Info

Online first:
27/04/2024

Abstract

In the global pursuit of transportation decarbonization, this article asserts that heavy-duty fuel cell electric vehicle (FCEV) technology represents a more compelling path forward than light-duty FCEVs. The inherent advantages of fuel cells, such as extended range, rapid refueling, and sustained performance, make them well-suited for demanding applications like trucking and public transit. Heavy-duty FCEVs offer significant potential for emissions reduction, integration with existing infrastructure, and economies of scale through commercial fleet adoption. While the upfront investment is substantial, this article examines how operational benefits can gradually offset costs, emphasizing the importance of heavy-duty FCEVs in sustainable transportation solutions.

Keywords: FCEV, Decarbonization, Heavy Duty Vehicles, Infrastructure, Emission Reduction

1. Introduction

The urgent need to reduce transportation emissions and combat climate change has brought fuel cell electric vehicles (FCEVs) into focus as promising solutions [1]. While both light-duty and heavy-duty FCEVs have advantages, heavy-duty FCEV technology emerges as a more compelling choice due to its effectiveness in demanding applications, environmental benefits, operational efficiency, compatibility with current infrastructure, and economic feasibility [2]–[4]. However, addressing challenges like hydrogen production, infrastructure development, and vehicle costs is crucial to fully realizing the benefits of heavy-duty FCEVs and transitioning to a greener transportation future [5].

2. Definition

Light-duty FCEVs are fuel cell-powered vehicles designed primarily for personal or

commercial transportation. This category typically includes:

- Passenger Cars and Crossovers,
- Small/Medium Vans, and
- Light Trucks (Gross Vehicle Weight Rating under 8,500 lbs or 3,856 kg).

These vehicles are intended for shorter-range travel and lower payload/towing capacities than their heavy-duty counterparts. The hydrogen storage tanks, and fuel cell systems are designed with more modest capacities to meet the requirements of personal or light commercial applications.

On the other hand, heavy-duty FCEVs are fuel cell-powered vehicles designed for more demanding commercial and industrial applications involving heavier payloads and longer-range travel. This category includes:

- Semi-Trucks and Tractor-Trailers,
- Transit Buses and Coaches,



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- Delivery Vans and Trucks (Gross Vehicle Weight Rating over 8,500 lbs or 3,856 kg), and
- Other Heavy-Duty Specialty Vehicles (e.g., refuse trucks, construction vehicles).

These vehicles require larger hydrogen storage capacities and more robust fuel cell systems to provide the necessary range, performance, and durability under heavy loads and continuous operation. Rapid refueling, extended range, and sustained power output are critical for heavy-duty FCEV applications [6].

The critical distinction between light-duty and heavy-duty FCEVs lies in their intended applications, payload capacities, and operational requirements. Light-duty FCEVs prioritize factors like passenger comfort and moderate performance. At the same time, heavy-duty FCEVs are engineered to meet the rigorous demands of commercial and industrial operations involving significant cargo or passenger loads over extended distances.

3. The Inherent Advantages of Fuel Cells for Heavy-Duty Applications

At the core of the argument for heavy-duty FCEVs lies their suitability for long-haul trucking, public transportation, and other demanding applications requiring extended range, rapid refueling, and sustained underload performance. Fuel cells, which generate electricity through an electrochemical reaction between hydrogen and oxygen, offer several advantages over battery-electric powertrains in these heavy-duty use cases [2].

Energy Density and Range - Hydrogen fuel cells provide a higher energy density than current battery technologies, enabling more excellent range and reduced downtime for refueling. This characteristic is crucial for heavy-duty vehicles engaged in long-haul operations or continuous service, where maximizing uptime and minimizing refueling stops are paramount [7].

Rapid Refueling - Unlike battery recharging, which can take hours, especially for the large battery packs required in heavy-duty electric vehicles, hydrogen refueling is a relatively rapid process comparable to conventional gasoline or diesel refueling. This aligns well with the operational requirements of heavy-

duty vehicles, where minimizing downtime is essential for productivity and profitability [8].

Sustained Performance - Fuel cell systems can maintain consistent power output over extended periods, making them well-suited for heavy-duty applications that involve hauling heavy loads or operating under continuous stress. Conversely, battery performance can degrade significantly under such demanding conditions, impacting vehicle range and efficiency [3].

Load Capacity - Compact hydrogen storage systems' weight and space advantages over heavy battery packs increase fuel cell heavy-duty trucks' potential payload and cargo capacity. This higher utilization of available cargo space can yield significant economic benefits for commercial freight operations [9].

By capitalizing on these inherent strengths of fuel cell technology tailored for heavy-duty demands, operators can achieve substantial operating cost reductions, productivity gains, and improvements in freight efficiency. These operational advantages can offset the higher upfront capital outlay over time and potentially provide a competitive edge in the marketplace. Moreover, as production volumes ramp up and technology matures further, economies of scale are expected to drive down costs for heavy-duty fuel cell systems and hydrogen infrastructure investments. Initiatives focused on high-impact, heavy-duty applications can accelerate this virtuous cycle, benefiting wider adoption across vehicle classes in the future.

4. Environmental Impact and Decarbonization Potential

One compelling reason to prioritize heavy-duty FCEVs is their significant potential to reduce greenhouse gas emissions in the transportation sector. Studies indicate that medium- and heavy-duty trucks contribute disproportionately to transportation-related emissions despite comprising a relatively small portion of the overall vehicle population [10], [11]. This disproportional impact highlights the need to focus on these sectors for emissions reduction efforts.

The environmental benefits could surpass those achieved with light-duty passenger vehicles by concentrating on deploying fuel cell technology in heavy-duty sectors. Heavy-duty

trucks often travel long distances and carry heavy loads, leading to substantial fuel consumption and emissions. Shifting these vehicles to hydrogen-powered FCEVs could significantly decrease their carbon footprint. For example, a single heavy-duty truck running on hydrogen could offset the emissions of several light-duty vehicles, providing a more efficient and impactful method of reducing overall transportation-related emissions.

Furthermore, directing FCEV deployment towards commercial and industrial fleets could result in economies of scale. With the increased deployment of heavy-duty FCEVs, these vehicles' manufacturing and maintenance costs are expected to decrease. This cost reduction could make FCEVs more affordable and appealing for other applications, including light-duty vehicles. Moreover, the expanded deployment of FCEVs in heavy-duty fleets could drive further technological advancements and infrastructure development, benefiting the entire FCEV ecosystem and expediting the transition to a more sustainable transportation future.

In summary, prioritizing heavy-duty FCEVs offers a strategic and impactful approach to reducing greenhouse gas emissions in the transportation sector. By targeting sectors with the most significant emissions potential and leveraging economies of scale, the environmental benefits of FCEVs can be maximized, leading to a more sustainable and efficient transportation system.

5. Infrastructure Alignment and Operational Advantages

The alignment of heavy-duty fuel cell electric vehicles (FCEVs) with existing refueling and distribution infrastructure represents a significant advantage over battery-electric alternatives, particularly in long-haul operations. Hydrogen refueling stations can be strategically designed to mirror the familiarity and convenience of current diesel or gasoline stations, thereby minimizing disruptions to established logistics and operational practices [12]. This inherent infrastructure compatibility highlights the practicality of heavy-duty FCEVs and underscores their logistical integration and operational efficiency superiority. In contrast, recharging the substantial battery packs of heavy electric trucks

presents a formidable challenge, characterized by its time-consuming nature and logistical complexity [13]. This process often necessitates establishing dedicated charging depots or extensive infrastructure modifications along transportation routes, adding complexity and cost to the operational model.

From an economic standpoint, the higher initial costs associated with fuel cell technology may be more justifiable for heavy-duty applications, given the potential for increased range, efficiency, and long-term productivity gains compared to light-duty vehicles [14]. The cost-benefit analysis for FCEVs becomes more nuanced when considering light-duty personal use cases with relatively low annual mileage. In these scenarios, the lower utilization of the vehicle and the higher upfront costs associated with fuel cell technology presents unique challenges that must be carefully weighed and evaluated [15]. Furthermore, government policies and incentives are crucial in supporting the adoption and deployment of heavy-duty FCEVs. Policies such as tax incentives, grants, and subsidies can help offset the higher upfront costs of FCEVs and hydrogen infrastructure, making them more attractive to fleet operators and businesses. Additionally, regulations mandating the reduction of emissions from heavy-duty vehicles can drive demand for zero-emission technologies like FCEVs, creating a more favorable market environment for their adoption [16]. Overall, the strategic alignment of heavy-duty FCEVs with existing infrastructure, coupled with their potential for long-term economic and operational benefits, positions them as a compelling choice for the future of sustainable transportation.

6. Addressing Counterarguments and Challenges

While the case for heavy-duty FCEVs is compelling, addressing some of the counterarguments and challenges associated with this technology is essential. One of the primary concerns revolves around hydrogen production and distribution challenges. Critics argue that a significant portion of hydrogen is currently derived from fossil fuels, negating some environmental benefits. However, this criticism applies equally to light-duty FCEVs. It highlights the need for a concerted effort to transition

towards renewable or low-carbon hydrogen production methods, such as electrolysis powered by renewable energy sources. Furthermore, by focusing on the FCEV rollout on high-impact, heavy-duty applications first, investments in hydrogen infrastructure could be leveraged more effectively and establish a foundation to enable broader adoption across various vehicle classes over time.

Another challenge is the perceived lack of a well-established hydrogen refueling infrastructure. While this is a valid concern, it is essential to recognize that infrastructure development often follows demand. By prioritizing heavy-duty FCEVs with a clear operational and economic rationale, the necessary infrastructure investments may become more attractive and viable for both the public and private sectors. Additionally, the potential for heavy-duty FCEVs to leverage existing refueling and distribution networks, albeit with modifications, could accelerate infrastructure development compared to the more disruptive requirements of widespread battery-electric vehicle charging.

7. Synergies with Other Decarbonization Strategies

It is important to note that heavy-duty FCEVs should not be viewed as a silver bullet solution but rather as a critical component of a broader decarbonization strategy for the transportation sector. They can complement and synergize with other initiatives, such as improvements in public transportation, sustainable urban planning, and the deployment of battery-electric vehicles for shorter-range or urban applications. By focusing efforts on heavy-duty FCEVs, where their advantages are most pronounced, the transportation sector can make significant strides toward decarbonization while allowing for the continued development and adoption of other zero-emission technologies in their respective niches.

8. Conclusion

In the race to decarbonize the transportation sector and combat climate change, prioritizing heavy-duty fuel-cell electric vehicle technology presents a compelling and appropriate path forward. Their inherent advantages in range,

refueling speed, and sustained performance make them well-suited for demanding long-haul and commercial applications. Moreover, the potential for heavy-duty FCEVs to make a substantial impact on reducing greenhouse gas emissions, their alignment with existing infrastructure, and their operational advantages create a strong case for accelerating their development and deployment. While challenges and counterarguments exist, many of these hurdles apply across various zero-emission technologies and should not deter progress. Focusing on high-impact, heavy-duty applications first, investments in hydrogen infrastructure and production can establish a foundation for broader adoption, enabling a diverse portfolio of sustainable transportation solutions. Ultimately, the path to decarbonizing the mobility sector requires a multifaceted approach, and heavy-duty fuel cell electric vehicles represent a crucial piece of the puzzle – one that holds the promise of driving meaningful change and paving the way toward a more sustainable transportation future.

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