Battery Electric versus Fuel Cell Electric Vehicles

Introduction

Battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV) are two available technologies for decarbonizing the heavy-duty trucking sector. Unlike trucks powered by fossil fuels or biofuels (e.g., biodiesel and renewable diesel), BEVs and FCEVs[1] produce no tailpipe emissions, and, when paired with renewable electricity and green hydrogen, can achieve zero operational emissions.

Both technologies use an electric motor as their primary drivetrain, but they differ fundamentally in how they store and generate the electricity that powers the motor. BEVs store energy in an onboard battery pack that is charged from an external power source, while FCEVs generate electricity on demand through a chemical reaction between hydrogen and oxygen. The advantages and limitations of BEVs and FCEVs are explored more below.

Battery Electric Vehicles

Battery electric vehicles replace the internal combustion engine with an electric motor powered by a large, rechargeable onboard battery pack. The battery is charged by plugging into external charging equipment. This lack of an internal combustion engine and exhaust system, and subsequent lack of tailpipe emissions, is why BEVs are classified as zero-emission.

It is important to note that the electricity source does influence a BEV's overall emissions. Where possible, BEVs should draw from renewable electricity, leveraging Power Purchase Agreements (PPAs) and the procurement of renewable energy certificates (RECs).

Benefits of BEVs:

- *Low operating costs:* Although BEVs carry a higher purchase price than comparable diesel trucks, they are typically less expensive to operate than their diesel counterparts, with higher savings in areas with lower electricity costs. Maintenance and repair costs are expected to continue to fall and the cost advantage of BEVs is expected to grow as battery technology matures and charging infrastructure expands.[2]

[1] FCEVs release water vapor (H2O) as exhaust, but no harmful tailpipe emissions or contaminants.
[2] https://energyinnovation.org/wp-content/uploads/Delivering-Affordability-Emerging-Cost-Advantages-of-Battery-Electric-Heavy-Duty-Trucks.pdf

- *Energy efficiency:* BEVs convert approximately 70–90 % of stored electricity into motion[3], far more efficiently than ICE vehicles, which waste the majority of fuel energy as heat. FCEVs, while also electric, face additional energy losses in both the hydrogen production process and the fuel cell conversion process itself, making BEVs the more energy-efficient option.
- *Lower maintenance burden*: Electric drivetrains have significantly fewer moving parts than diesel engines, requiring no oil changes, fewer brake replacements due to regenerative braking, and no exhaust aftertreatment systems.[4] This translates to lower maintenance costs and less downtime over the vehicle's service life.

Challenges of BEVs:

- *Battery material scarcity:* BEV batteries rely on lithium, nickel, and cobalt - materials that are geographically concentrated, subject to supply chain volatility, and associated with environmental and social concerns from their extraction.[5] As BEV adoption scales, the supply of these critical resources may struggle to meet demand.
- *Range limitations:* BEV range is improving, but today's heavy-duty battery electric trucks are best suited for short- to medium-distance applications (e.g., regional distribution, urban delivery, and drayage). Long-haul routes of 500+ miles remain challenging given current battery capacity of most BEVs and available charging infrastructure along freight corridors. Complicating matters is BEV charging speeds. While technology is improving, even the fastest chargers take upwards of 30 minutes.
- *Available infrastructure*: Charging depots remain unevenly distributed, with strong availability in certain metro markets and significant gaps in rural and interstate corridors. The sector also faces a persistent chicken-and-egg dynamic: infrastructure investors are reluctant to build charging hubs without confirmed BEV deployment, while fleet operators are unwilling to commit to electrification without reliable charging access.
- *Interconnection and grid load*: Interconnection involves linking new power generation, like renewables, to the grid and the linking of electrical networks. As infrastructure providers look to build out charging stations, slow and costly interconnection processes can pose a major barrier. Widespread, simultaneous charging of BEVs can overwhelm the grid in some locations leading to increased electricity prices or even power outages.

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[3] Togun, H., Basem, A., Abdulrazzaq, T., Biswas, N., Abed, A. M., Dhabab, J. M., Chattopadhyay, A., Slimi, K., Paul, D., Barmavatu, P., & Chrouda, A. (2025). Development and comparative analysis between battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV). Applied Energy, 388, 125726. https://doi.org/10.1016/j.apenergy.2025.125726
[4] https://afdc.energy.gov/vehicles/electric-maintenance
[5] https://rmi.org/the-ev-battery-supply-chain-explained/

Fuel Cell Electric Vehicles

Fuel cell electric vehicles have an electric motor powered by electricity generated onboard through a hydrogen fuel cell. In the fuel cell, hydrogen gas reacts with oxygen to produce electricity, with water vapor as the only byproduct. Unlike batteries, which store a fixed quantity of energy, fuel cells generate electricity continuously as long as hydrogen fuel is supplied.

Although FCEVs are classified as zero-emission vehicles as they produce no tailpipe emissions, the overall environmental benefit depends on how the hydrogen is produced. Hydrogen can be produced a number of ways[6], but three production methods are most broadly recognized: 1) grey hydrogen, produced from natural gas, which can result in higher GHG emissions than diesel[7], 2) blue hydrogen, produced from natural gas but paired with carbon capture and storage (CCS) to reduce emissions, and 3) green hydrogen, produced via electrolysis powered by renewable electricity. Of the three, only green hydrogen is considered truly clean, producing no direct emissions.[8]

Benefits of FCEVs:

- *Long driving range:* FCEVs are well-suited for long-haul applications, with ranges of 500 miles or more.[9] This makes them a potential complement for BEVs while battery storage capacity continues to be built out.
- *Rapid refueling:* Hydrogen refueling takes approximately 3-5 minutes[10], on par with the diesel incumbent, making FCEVs highly attractive for high-utilization fleets where vehicle downtime for charging is operationally costly.
- *Climate resilient:* FCEVs maintain consistent performance across a wide range of conditions — including environments as cold as -40 degrees F.[11] This makes them particularly suitable for freight operations in northern climates and temperature-variable corridors.

[6] https://spectra.mhi.com/energy-transition/the-colors-of-hydrogen-expanding-ways-of-decarbonization
[7] Churchman, P., Dekker, T., Pangbourne, K., & Rodrigues, V. S. (2025). Hydrogen for long-haul road freight: A realist retroductive assessment. *Renewable and Sustainable Energy Reviews*, *221*, 115898. https://doi.org/10.1016/j.rser.2025.115898
[8] https://climate.mit.edu/ask-mit/how-clean-green hydrogen
[9] https://ww2.arb.ca.gov/our-work/programs/truckstop-resources/zev-truckstop/zev-101/hydrogen-fuel-cell-electric-vehicle-101
[10] https://afdc.energy.gov/fuels/hydrogen-basics#fueling-times
[11] https://ww2.arb.ca.gov/our-work/programs/truckstop-resources/zev-truckstop/zev-101/hydrogen-fuel-cell-electric-vehicle-101

Challenges of FCEVs:

- *Infrastructure scarcity:* Hydrogen refueling infrastructure remains very limited outside of California, which hosts the most developed network in the United States.[12] Carriers seeking to operate FCEV fleets on routes outside major metro areas face significant refueling gaps, limiting practical deployment to specific corridors and regions.

- *Clean hydrogen availability:* As of 2023, low-emission hydrogen represented less than 1% of total global hydrogen production.[13] Heavy-duty trucking is also competing with the maritime, aviation, and industrial sectors for access to limited clean hydrogen supply, creating further constraints on availability and pricing.

- *High operating costs:* FCEVs are more expensive to operate than BEVs, primarily due to the cost of hydrogen fuel. Green hydrogen, desired for being zero-emission, has the highest price premium given its limited production scale.[14,15]

- *Policy uncertainty:* Federal support for clean hydrogen infrastructure has faced recent setbacks. Notably, the eligibility window for the 45V hydrogen production tax credit, a key incentive for green hydrogen projects, has been narrowed, potentially slowing investment in clean hydrogen production capacity in the U.S. and undermining the longer-term cost trajectory for FCEV fuel supply.

[12] https://afdc.energy.gov/fuels/hydrogen-basics#fueling-times
[13] https://www.iea.org/reports/global-hydrogen-review-2024/hydrogen-production#abstract
[14] https://energy.sustainability-directory.com/question/why-is-green-hydrogen-production-more-expensive/
[15] https://www.iea.org/energy-system/low-emission-fuels/hydrogen