Hydrogen Fuel Cell Application for Port Drayage Truck: Integrated Transportation and Energy Modeling

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Introduction

Port drayage operations (trucking operations that move goods a short distance to and from ports) are a critical yet emissions-intensive component of freight logistics. In California alone, tens of thousands of heavy-duty diesel trucks move goods short distances between seaports and distribution centers daily, contributing significantly to greenhouse gas emissions and local air pollution. Decarbonizing this sector is essential to meeting state and national climate goals.

Hydrogen FCEVs offer a compelling zero-emission alternative to traditional fossil fuels for medium- and heavy-duty trucks. They provide fast-refueling, long range, and operational characteristics well-suited to drayage applications. This study evaluates the technical feasibility and economic viability of deploying hydrogen FCEVs in port drayage fleets. Using second-by-second operational data from active diesel trucks, the research develops a microscopic energy consumption model and assesses the LCOH under various deployment and infrastructure scenarios. The results offer practical insights for transportation planners, policymakers, and private sector stakeholders seeking to scale zero emission solutions at California's ports and beyond.

Study Methods

The study integrates detailed transportation modeling with comprehensive cost analysis to assess hydrogen FCEVs in port drayage. Data were collected from 38 Class 8 diesel trucks operating in Southern California. Each vehicle was equipped with GPS and engine control unit loggers to record second-by-second data on speed, location, and engine parameters. This resulted in over 130,000 miles and 15,000 hours of operational data, capturing realistic driving behavior across urban and port environments.

A microscopic energy model was constructed by converting diesel truck activity into equivalent FCEV performance. Key variables—vehicle mass, drivetrain efficiency, aerodynamic drag, and rolling resistance—were adjusted to reflect fuel cell technology. The model calculated hydrogen consumption rates for 749 distinct trips.

To assess cost viability, two economic analyses were conducted. The first—a parametric study—evaluated five fleet adoption scenarios (5% to 25%) with hydrogen station capacities ranging from 4,000 to 10,000 kg/day. Both blue hydrogen (produced via steam methane reforming with carbon capture) and green hydrogen (from electrolysis) were considered.

The second analysis used established models from the U.S. Department of Energy: H2A Lite (for production costs) and HDSAM-4.5 (for delivery and dispensing). These tools enabled the detailed evaluation of grey, blue, and green hydrogen pathways under both gaseous and liquid delivery systems. (These colors indicate differences in how the hydrogen is produced.) Cost estimates accounted for station size, utilization rates, and technology-specific capital and operational inputs. Together, these methods offer a robust framework for evaluating hydrogen viability in heavy-duty fleet applications.

Findings

The energy consumption model estimated that hydrogen FCEVs used an average of 0.15 kg of hydrogen per mile during port drayage operations. Fuel economy was highest at moderate speeds (approximately 50 mph), which aligns well with typical drayage activity characterized by moderate-speed travel and frequent stops. Economic analysis revealed that hydrogen fuel costs are highly sensitive to station utilization and fleet adoption rates. In low-demand scenarios (5% of a 1,000-truck fleet), the LCOH for green hydrogen reached \$17.40/kg due to underutilized infrastructure. In contrast, under a 25%

fleet conversion scenario, LCOH dropped to as low as $1.80/kg for green hydrogen and $1.40/kg for blue hydrogen—indicating strong economies of scale.

Production-level cost estimates from H2A-Lite found that grey hydrogen remained the lowest cost option at $1.30/kg. Blue hydrogen cost approximately $2.73/kg, while green hydrogen ranged from $3.94 to $6.65/kg depending on the energy source and plant utilization rate. Hybrid renewable energy systems (solar and wind) emerged as the most competitive green hydrogen option. Delivery and dispensing cost modeling (HDSAM) showed that liquid hydrogen delivery systems perform better under low-utilization conditions, with smaller marginal cost increases compared to gaseous systems. As demand increases, gaseous hydrogen becomes more cost-effective.

Increasing fleet conversion from 5% to 25% reduces hydrogen fuel cost from $17.40/kg to $1.80/kg—demonstrating the importance of high infrastructure utilization.

Overall, the study underscores the importance of aligning infrastructure scale with projected demand. High station utilization is critical to reducing hydrogen costs. The findings confirm that hydrogen is a technically feasible and economically promising option for decarbonizing port drayage—provided deployment is strategically planned and demand is sufficiently aggregated.

Policy Recommendations

To enable cost-effective deployment of hydrogen FCEVs in port drayage, several policy and planning strategies are recommended:

1. **Align station capacity with fleet adoption targets.** Underutilized stations significantly increase LCOH (costs); strategic sizing and phased deployment can mitigate this risk.
2. **Support early-stage infrastructure through public investment.** Liquid hydrogen delivery is more cost-resilient at low utilization and may serve as a bridge to larger-scale pipeline systems as demand grows.
3. **Prioritize hybrid renewable energy systems for green hydrogen production**. These offer the best balance of cost and sustainability when scaled appropriately.
4. **Integrate station placement with drayage patterns.** Clustering station deployment near major ports and freight hubs will ensure high usage and operational efficiency.
5. **Foster collaboration across public agencies and private operators**. Streamlined permitting, infrastructure funding, and technical training are essential to scaling up hydrogen adoption and decarbonizing freight.

These measures will help create a robust, cost-effective foundation for zero-emission freight transport, advancing environmental goals while supporting economic activity at major ports.

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To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2437

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