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A Systems Approach Can Lower Costs and Protect the Grid as Freight Electrifies

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POLICY BRIEF

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A Systems Approach Can Lower Costs and Protect the Grid as Freight Electrifies

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Issue

California is transitioning heavy-duty freight trucks from diesel to battery-electric vehicles to help meet its climate and air quality goals. Unlike passenger vehicles, electric trucks require much larger batteries and high-powered chargers, creating concentrated demands on the electric grid. At the same time, freight carriers operate under strict schedules that leave little flexibility in when and how long trucks can charge. As freight electrification expands, coordinating truck operations, charging infrastructure, and grid planning will become increasingly important.

Without that coordination, simultaneous truck charging, particularly during periods of high electricity demand, can increase electricity costs, strain local grid infrastructure, and create congestion at charging stations. These challenges are compounded by state and regional incentives that may unintentionally encourage trucks with the largest batteries and fastest chargers rather than the most efficient charging strategies. The result is a more expensive freight electrification system for fleets, utilities, infrastructure providers, and ultimately taxpayers.

To identify strategies that support both efficient freight operations and a reliable electric grid, we developed a grid-aware optimization model using 3.9 million real-world California truck loads. We evaluated how battery size, charger speed, charging schedules, and charger locations affect both fleet operating costs and grid performance.

Key Research Findings

Medium-sized truck batteries provide the best balance between cost and operational performance. Our analysis found that a medium-sized battery, approximately 600 kilowatt-hours (kWh), minimizes the total cost of truck ownership (i.e., vehicle purchase price, maintenance, fueling) to an optimal $5.56 per mile while maintaining efficient freight operations. Smaller battery options (e.g., 400 kWh) require more frequent charging, reducing vehicle productivity. Larger batteries (e.g., 1,000 kWh) nearly eliminate charging stops but substantially increase vehicle purchase costs with little additional operational benefit. Consequently, public policies or grant programs could support the transition to a system that balances public and private costs considering near-term technical feasibilities without the need to wait for when longer range vehicles are technically or economically feasible.

Charging speeds of approximately 350 kW balance operational efficiency while avoiding unnecessary grid impacts. We evaluated fleet performance across three distinct charging power levels: standard fast charging (150 kW), high-power charging (350 kW), and megawatt-scale ultra-fast charging (1,000 kW). Increasing charging power from 150 kW to 350 kW cut charging-related downtime by more than half while achieving the lowest operating cost (Figure 1a). Increasing charging power further to 1,000 kW produced only minimal additional cost savings (Figure 1b) but increased peak demand at busy charging stations to 8.0 megawatts (MW), nearly four times higher than the 2.MW observed under the 350 kW scenario (Figure 1c). Our findings suggest that widespread deployment of megawatt-scale charging could require substantial grid upgrades with little additional benefit to fleet operations.

Smart charging policies can lower fleet operating costs while improving grid reliability. Commercial fleets typically charge whenever operational schedules allow, often concentrating charging during periods of high electricity demand. Our model found that shifting charging to lower-demand periods reduced fleet operating costs by 11.4% while maintaining delivery schedules and fleet performance. Time-of-use electricity rates, real-time pricing, and freight-specific utility tariffs are promising strategies for encouraging more efficient charging behavior.

Charging infrastructure should prioritize major freight corridors and logistics hubs. Simulations based on nearly 4 million real-world California truck loads showed that charging demand naturally concentrates along major freight corridors, including Interstate 5, State Route 99, and State Route 58, and around logistics centers. Prioritizing investments in these high-demand locations can improve charger utilization and reduce the risk of underused infrastructure and stranded public investments. These investments can increase the potential for electrified miles throughout the state. Alternatively, fostering infrastructure around logistics hubs could help maximize the benefits where density of feasible movements (based on current technological constraints) is the highest.

Policy Implications

Our findings suggest that California's freight electrification policies should prioritize system efficiency rather than maximum equipment specifications. State agencies should review incentive and grant programs that encourage the largest battery capacities or megawatt-scale ultra-fast charging to ensure these investments produce meaningful operational benefits relative to their cost and grid impacts. The state may also benefit from pursuing policies that encourage smart charging, such as time-of-use electricity rates, freight-specific utility tariffs, and other incentives that shift charging away from periods of peak electricity demand.

Finally, successful freight electrification will require closer coordination among utilities, transportation agencies, regional planners, and infrastructure providers. Aligning charging infrastructure deployment with grid planning, permitting, interconnection timelines, and make-ready investments can help reduce unnecessary costs, accelerate deployment, and ensure charging infrastructure is built where it will provide the greatest benefit.

More Information

This policy brief summarizes findings from the report: "Grid-Aware Electric Truck Routing: Development and Evaluation of the ALNS-GS-EVRP Framework," authored by Miguel Jaller and Runhua (Ivan) Xiao with the University of California, Davis. The full report provides detailed methodology, scenario analysis, and results. It can be found at: www.ucits.org/research-project/2025-09/. For more information, contact Miguel Jaller at mjaller@ucdavis.edu.

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