From Diesel to Electric: Overcoming Grid Integration Challenges in the Medium- and Heavy-Duty Vehicle Sector

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1. Motivation

Medium- and heavy-duty vehicles (MHDVs) contribute an outsized share of local air pollution and greenhouse gas emissions within the transportation sector. Decarbonizing these vehicles is crucial for achieving the clean energy transition and for improving the health and wellbeing of communities most affected by transportation pollution. Electric trucks and buses are a promising solution but electrifying these vehicles will not be easy. One of the greatest challenges is the massive amount of electric grid investments required to support MHDV electrification and integrate these new vehicles onto the grid.

2. Approach and Findings

This paper details the grid investments required to support MHDV electrification and the technological solutions, existing policies, and new policies that can help reduce costs and accelerate grid integration. The paper concludes with a discussion of open research questions that can enable a more equitable, efficient, and cost-effective transition to medium- and heavy-duty electric vehicles (MHD EVs).

Grid investments required to support vehicle electrification

*Generation capacity and renewables integration***:** MHDV electrification may require significant generation investments to meet increased electricity demands, depending on charging patterns. Integrating greater generation into the grid will also require more transmission lines, which are costly and require community support and siting approval subject to numerous regulations at all levels of government.

*Distribution grid***:** MHD EVs have massive batteries; a single fleet's depot is likely to exceed the locally available capacity. Meeting electricity demand will require investments in the distribution grid, including upgrades to the local system and potential substation expansions and replacements. Electric utilities face significant challenges in making these investments due to high costs and uncertainty about where these new electric fleets will emerge. These uncertainties can lead to regulatory hurdles, increasing the total long-run investment cost and delaying fleets from electrifying.

*Charging station investments***:** Required charging station infrastructure includes significant and costly investments into the charger on a fleet's lot and the "make-ready" infrastructure. Public MHD EV charging stations can help reduce fleets' investment burdens, but the availability of such stations is minimal.

Technological solutions

Technological solutions exist to reduce and overcome some of the barriers described above; including managed charging, vehicle-to-grid (V2G) technology, co-located storage and solar, and battery swapping. Managed charging software can optimize charging patterns to reduce grid costs. V2G technology can allow a vehicle owner to return excess energy stored in their battery to the grid when the vehicle is not in use or charging and provide ancillary services such as voltage regulation. However, payments for V2G services are uncertain, and frequent charging and discharging may degrade the battery.

Investing in rooftop solar and storage at the charging station site can reduce fleets' total net loads, reducing generation and transmission investments and mitigating peaks during congested hours. However, the benefits of these investments are limited by space constraints and potentially high investment costs.

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Battery swapping technology can also improve charging patterns and lower the upfront payment for the vehicle. However, it doesn't work well for larger vehicles, investment and maintenance of battery swapping stations can be high, and it requires battery compatibility across different vehicle types and use cases.

Current Policies and Incentives

Governments at all levels have engaged in and implemented policies to help integrate MHD EVs onto the grid. At the federal level, the Inflation Reduction Act incentivizes new renewable energy investments by expanding and extending existing production and investment tax credits for clean energy projects.

The Infrastructure Investment and Jobs Act created the National Electric Vehicle Infrastructure Formula Program and the Charging and Fueling Infrastructure Discretionary Grant Program to fund public charging station investments. It also broadened the definition of a National Interest Electric Transmission Corridor, which can help accelerate transmission siting.

At the state level, policymakers have implemented programs to meet their renewable energy goals such as renewable energy standards. Twelve eastern states have joined the Regional Greenhouse Gas Initiative – a regional cap-and-trade program that covers carbon dioxide emissions from the power sector. California has its own cap-and-trade program, AB32, which sets a declining cap on power sector emissions.

At the local level, utilities can implement programs that help fund make-ready infrastructure for charging stations.

3. Policy Implications of the Work

Future policy pathways

Though policymakers at all levels of government have taken steps to integrate MHD EVs onto the grid at the least cost, there are still substantial opportunities for complementary policies. Two such policies include providing government funding to help cover electric utility distribution costs, which can help mitigate increases in electricity prices; and electric tariff reform, which can help shift demand toward cleaner and cheaper times of day.

How research can improve outcomes

Future research can help enable a cost-effective and environmentally friendly integration of MHD EVs onto the electric grid. The paper discusses several areas which require further investigation to improve policymaking. For example, as adoption begins to increase, conducting ex-post analyses of the new federal incentives can help identify the effectiveness of these policies in accelerating adoption; these learnings can shape future decisionmaking and potential extensions to subsidies.

Given the bottlenecks in integrating renewables and local stakeholder challenges for investment siting, research can also help by identifying challenges, providing policy solutions to overcoming challenges, and engaging with local community groups to ensure increased support.

In the realm of charging station investments, more research is needed to understand the impact of these investments on fleet electrification decisions, logistics, total cost of ownership, range anxiety, and adoption incentives. Understanding private investment incentives and the role of government is also vital for facilitating greater public charging station investment and more affordable charging prices.

Finally, future research can quantify the benefits of technology such as V2G and regulatory frameworks to ensure that tariffs accurately compensate fleet owners for the environmental and economic benefits that the technology provides.