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Citation:

Knittel, T.; Lowry, C.; wild, P.; Rowe, A. (2024) Electrification of medium- and heavy-duty road transportation increases grid flexibility requirements. *IESVic Energy Brief*.

Published: October 2, 2024

ISSN 2818-159X (Print)
ISSN 2818-1603 (Online)

Electrification of medium- and heavy-duty road transportation increases grid flexibility requirements

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Key messages

- Electrification of end-uses changes the shape of electricity demand.
- Shape of electricity demand drives electric grid infrastructure needs.
- Future ramping rates are driven by electrification of medium- and heavy-duty commercial vehicles.
- Electric vehicle charging control can limit capacity and flexibility requirements of the grid.

Importance: Electrification of medium- and heavy-duty transportation makes up 80% of future ramping rates

Electrification of end-use demands is among the most effective demand-side strategies to reduce greenhouse gas emissions (Davis et al., 2018; Williams et al., 2012). However, electrification of end-use demands may, itself, change the magnitude and shape (i.e. spatial and temporal profile) of electricity demand in ways that will stress current infrastructure. Examining the spatiotemporal profile of electricity demand after end-use electrification is therefore necessary to support electric utilities in planning for sufficient electrical capacity and system flexibility.

Historically, system planners have focused on peak capacity analyses and resource adequacy. However, the intermittency of variable renewable energy resources in combination with increased variability of electricity demand causes *grid flexibility* requirements to be a concern for system planners (Koltsaklis et al., 2017). Grid flexibility is the ability of the electricity system to balance supply and demand at short timescales (Lund et al., 2015). Having sufficient grid flexibility is key to the resilience and reliability of future electricity systems (Fridgen et al., 2020; Heffron et al., 2020).

To better understand the capacity and dynamic response requirements of future electricity grid operations, demand models with high spatial and temporal resolution are needed that capture individual end-use demands (Powell et al., 2022; Staffell et al., 2023). In this study, the Road Transportation Energy Simulator is used to generate electricity demand profiles for individual vehicle weight classes (Lowry, 2023). Two transportation scenarios are simulated for the province of British Columbia (BC) in 2050 utilizing an immediate high power and an off-peak load leveling charging strategy[1], respectively.

Large-scale electrification of road transportation in BC will significantly increase grid flexibility requirements. For an immediate charging strategy, the model predicts positive and negative ramping rates in 2050 that are 1200% and 830%, respectively, higher than those in 2020 (Figure 1). The largest drivers of these higher ramping rates are electrified medium-duty (MD) and heavy-duty (HD) commercial vehicles which are responsible for 75% of these future ramping rates. Off-peak electric vehicle (EV) charging can mitigate increased ramping rates to some extent; however, positive ramping rates are still projected to increase fivefold, compared to historical ramping rates.

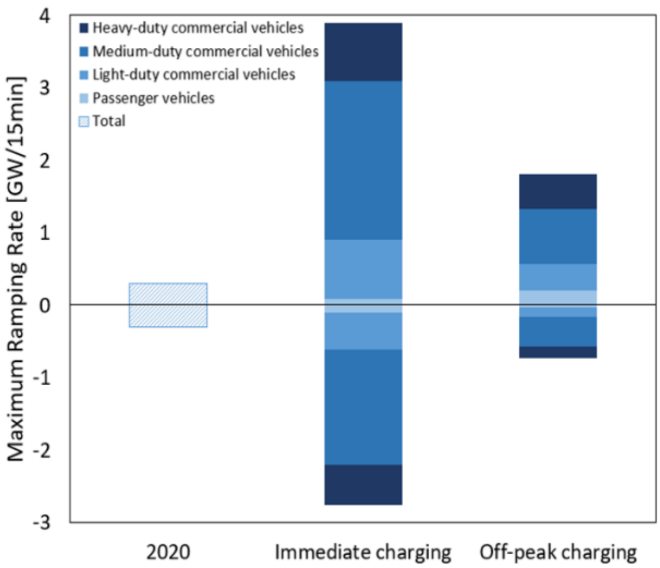

Figure 1: Maximum positive and negative system ramping rates by vehicle weight class in 2050 as compared to historical 2020 ramping rates.

[1] This work assumes that the number of vehicles will grow at the same rate that is projected for the population of BC, i.e., at a rate of 1.1% per year (Province of British Columbia, 2019). It is further assumed that 60% of medium- and heavy-duty commercial vehicles and all passenger vehicles and light-duty commercial vehicles will be electrified by 2050.

Opportunities and barriers: Other low carbon fuel technologies such as hydrogen for medium- and heavy-duty transportation may reduce grid flexibility requirements

Low carbon fuels may achieve emission reductions comparable to end-use electrification while significantly limiting the associated increase in ramping rates (Lowry, 2023; Palmer-Wilson et al., 2022). When using low carbon fuels for MD and HD road transportation, the increase in positive ramping rates would be limited to 87% in the case of off-peak EV charging (compared to an increase in positive ramping rates of 500% including MD and HD electrification). This significant reduction in positive ramping rates offers benefits to electricity systems such as decreased transmission and distribution requirements, better utilization of capacity, and increased reliability.

Next steps: Are there additional strategies to reduce grid flexibility requirements?

In the absence of low carbon fuels for commercial road transportation, increased end-use electrification will require expanding dispatchable generation capacity and transmission and distribution infrastructure. While energy storage can reduce imbalances in supply and demand, targeted strategies to reduce future grid capacity and flexibility requirements can be deployed in different end-use sectors. Among those are demand-side management strategies, such as EV charging and space heating control, which are, individually, projected to decrease both, capacity and flexibility requirements of the electricity grid (Knittel et al., 2023; Lowry, 2023). However, the feasibility and realizable benefit of combined utility-controlled EV charging and space heating control in cold climate regions such as BC are uncertain. Thus, accommodating decarbonization of road transportation end-use energy demands may require a synergy of strategies to limit the expansion of electricity grid infrastructure while simultaneously increasing the resilience of the electrical grid.

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