Assessing the impact of hybrid heating systems in combination with off-peak EV charging on grid capacity requirements

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Citation:

Knittel, T.; Lowry, C.; Wild, P.; Rowe, A. (2025) Assessing the impact of hybrid heating systems in combination with off-peak EV charging on grid capacity requirements. *IESVic Energy Brief*.

Published: January 29, 2025

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

Key messages

- Future capacity requirements are driven by electrification of heating and road transportation.
- Hybrid heating systems switching from electric to gas heating operations during cold weather events reduce electricity demand for residential space heating.
- Electric vehicle charging control can significantly limit capacity requirements of the electricity grid.

Importance: Electrification of end-use demands causes electricity load dynamics to change

In cold climate regions, electrification of building heat may have profound impacts on electricity system capacity due to a significant rise in heating demand served by electric heating technologies (Eggimann et al., 2019). If combined with electrification of road transportation, where cold temperature events affect electric vehicle (EV) charging performance (Zhao et al., 2021), there are concerns that current system capacities are insufficient to accommodate large-scale electrification of these end-uses (Chaudry et al., 2023). The temporal characteristic of demand for electrical power after electrification of building heat and road transportation makes electricity grid planning challenging. To better support the planning and management of future electricity grids, demand models with high temporal resolution are required to identify the technical requirements of adequate balancing, transmission and distribution capacity (Powell et al., 2022; Staffell et al., 2023).

In this study, we use the Road Transportation Energy Simulator by Lowry (2023) to generate electricity demand profiles for individual vehicle weight classes using two different charging strategies. The building energy demand model by Knittel et al. (2023) is used to generate electricity demand profiles for residential and commercial space and water heat with varying heating technology mixes. The projected electricity demand time series are aggregated to represent two potential futures for the province of British Columbia (BC) in 2050.

Annual population growth of 1.1% per year is assumed and the number of EVs and residential floor space are scaled accordingly. Thus, the number of EVs and residential floor space in 2050 stays constant for both scenarios. The heating technologies included in this work are baseboard heaters, high-efficiency air source heat pumps (ASHP), and hybrid heating systems. Hybrid heating systems switch from high-efficiency ASHP to gas furnace operations at a temperature switch-over point of -4°C. EVs are assumed to charge using an immediate or an off-peak charging strategy. For the immediate charging strategy, it is assumed that EVs charge once they are off-shift while EVs using the off-peak charging strategy charge over the entire off-shift period at the minimum power required to fully charge before the next vehicle shift.

Two scenarios are modeled. In the *Electric Heat* Scenario, it is assumed that 60% of medium- and heavy-duty commercial vehicles, all passenger vehicles and all light-duty commercial vehicles will be electrified by 2050 using an immediate charging strategy. 76% of residential space heat demand is assumed to be served by high-efficiency ASHPs while the remaining share is served by baseboard heaters (24%). In the *Hybrid Heat* scenario, 80% of EVs use an off-peak charging strategy while the remaining 20% use an immediate charging strategy. In this scenario, 60% of residential space heat demand is served by hybrid heating systems. The share of residential heat demand served by baseboard heaters stays constant at 24%, resulting in 17% of residential space heat demand that is served by high-efficiency ASHPs.

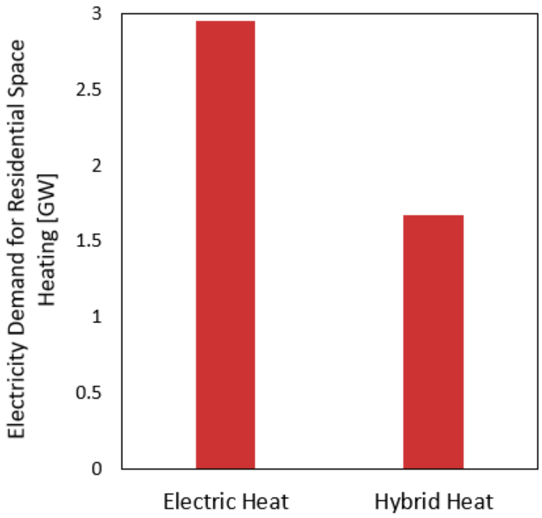

Figure 1: Electricity demand for residential space heating for two scenarios in British Columbia by 2050.

Results of this work show that electricity demand for residential space heat is significantly reduced in the *Hybrid Heat* scenario (Figure 1). A 60% penetration of hybrid heating systems with a temperature switch-over point of -4°C reduces peak hourly electricity demand for residential space heat by 43%, relative to fully electrified residential space heating. To serve hybrid heating systems in gas mode, 6.8 PJ of renewable gas would be needed across the province of BC, assuming a 95% efficiency for gas furnaces. However, the reduction in electricity demand and the resulting renewable gas demand for residential space heat are dependent on the temperature switch-over point and penetration of hybrid heating systems across the province.

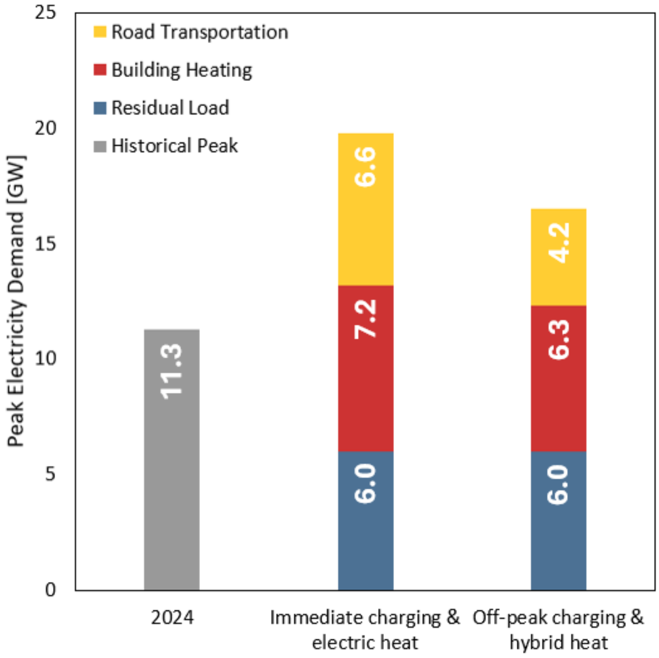

Figure 2: 2050 peak electricity demand by sector for two scenarios, relative to historical peak demand in British Columbia (BC Hydro, 2024).

For large-scale electrification of building heat and road transportation, total system peak electricity demand increases by 75%, relative to the historical peak demand in 2024 (Figure 2)[1]. However, combining the use of hybrid heating systems with an off-peak charging strategy for most EVs limits the increase in peak electricity demand to approximately 46% compared to 2024.

Opportunities and barriers: Combined utility-controlled EV charging and space heating control will achieve the largest reduction in grid capacity requirements

Insufficient grid capacity poses a challenge for system operators during a few critical hours of the year. Utility-controlled EV charging or space heating control can be utilized to reduce demand during these hours (Salpakari et al., 2017). Previous work identified the potential benefit of utility-controlled EV charging in BC, showing that total system capacity can be reduced by approximately 7% (Keller et al., 2019). The opportunities of hybrid heating systems to shift peak heating loads during cold weather events away from the electrical and towards the gas grid have been previously studied; however, a ban on installation of fossil-fuel heating technologies is already in place in Vancouver, BC (Suarez & Brockman, 2024). This will prevent utilities and system operators from harnessing the grid capacity benefits of hybrid heating systems (Smillie et al., 2024). Our results show the combined benefit of EV charging and space heating control in lowering grid capacity requirements by avoiding peak electric loads; however, the feasibility and realizable benefit of combined utility-controlled EV charging and space heating in cold climate regions such as BC are yet to be determined.

Next steps: Assessing the impact of end-use electrification across all economic sectors under future climate scenarios

The move towards electrification of building heat and road transportation in BC seems likely and additional electrification of end-use demands in the industrial sector may further increase provincial capacity requirements (Province of British Columbia, 2021). Additional analyses are needed to examine the impact of end-use electrification across all economic sectors on provincial grid capacity requirements. In addition, consideration of the impact of climate change on future ambient temperatures may exacerbate the effects of end-use electrification on future capacity requirements while simultaneously changing energy supply potential from variable renewable sources such as wind and hydroelectricity. This work uses historical temperature data to project heating and road transportation demands but it will be important to examine the impact of end-use electrification on electric grid infrastructure requirements under a range of future climate scenarios.

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[1] The residual load shown in Figure 2 captures as a 5-year average of historical electricity demands in the industrial and agricultural sectors and any non-heating and non-cooling related electricity demands in the building sector.

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