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Assessing the peak demand implications of air-source heat pumps in Canada and identifying potential mitigation strategies

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Abstract

Heat pumps are a critical element of a decarbonized built environment, but their widespread adoption can increase house level electrical demand. This paper uses a simulation-based approach to examine the peak demand implications of replacing natural gas furnaces with air-source heat pumps in four Canadian cities. Results show that the peak demand impacts of heat pumps are closely tied to climate. In colder regions (Ottawa, Winnipeg), peaks occur when outdoor temperatures are lowest and auxiliary heating is needed to supplement or replace heat pump operations. Peak demand increases vs. gas heating may approach up to 8 kW in Ottawa and 9 kW in Winnipeg. In milder regions (Halifax, Vancouver), peak events are linked to heat pump use coincident with higher non-HVAC electrical loads. Peak demand increases may reach up to 3 kW in Halifax and Vancouver. Simulations show these increases may be mitigated by using energy stored in the building thermal mass to reduce heat pump operation during peak hours. Results can be used to understand the implications of greater heat pump adoption in Canada and identify approaches to address potential challenges.

Keywords: air-source heat pumps; heat pump peak electrical demand; cold climate heat pumps; peak electrical demand mitigation

1. Introduction

The *Canadian Net Zero Accountability Act* outlines Canada’s commitment to achieving carbon neutrality by 2050 [1]. Heat pumps have strong potential to drive the decarbonization of Canadian buildings via their ability to efficiently electrify space heating and cooling. However, transitioning from fossil fuel to heat pump systems can increase demand on electrical grids, affecting their ability to provide reliable decarbonized energy. Demand increases can be particularly significant for air-source heat pumps (the most common form of heat pump integration in Canada [2]), which often require supplemental electrical heating to maintain space temperatures during colder winter days typical in Canada. Understanding the peak demand implications of heat pumps, and any potential mitigation strategies, is essential in supporting an increased adoption of these systems in Canada.

Quantifying the peak demand of heat pumps via building simulation can be a challenge. Peak demand analysis requires the use of smaller time steps, where the impact of controls, heat pump transients (e.g., defrost and start-up), and the interaction with any auxiliary systems can be represented. Yet, many typical building simulation programs average performance across an hourly time step and are unable to adequately capture shorter term heat pump transients. Several simulation-based studies have examined the peak demand impacts of heat pump adoption in Europe [3,4], and two locations in Canada [5]. However, further work is needed to better understand how the peak electrical demand implications of heat pumps vary across additional Canadian regions, and what measures can be taken to mitigate added demand.

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This paper uses a simulation-based approach to (I) examine the electrical demand implications of transitioning from natural gas furnaces to air-source heat pumps, and (II) explore how increased demand may be mitigated during peak periods via improved controls. First, detailed models of new construction housing are developed in four Canadian cities (Halifax, Ottawa, Winnipeg, Vancouver), and combined with a series of non-HVAC load profiles to quantify baseline thermal and electrical performance. An enhanced data-driven heat pump model is then used to examine the peak demand implications of air-source heat pump integration, and how this added electrical demand may be minimized via the application of a preheat/setback strategy. Results provide an overview of the potential challenges faced in the widespread deployment of air-source heat pumps, and how they may be addressed using improved controls and other approaches.

2. Base Case Housing Models

Climate and the type of heating system being replaced have an important impact on the magnitude of peak electrical demand increase associated with heat pump systems. This study examines four Canadian regions, each representing a unique set of boundary conditions. Key parameters are summarized in Table 1 [6,7]. The percentage of homes currently heated using fossil fuels is derived from available data at the provincial level [7], in the absence of reliable information for each specific city examined. While this percentage varies greatly between areas, these systems represent at least 50% of single detached homes in all selected regions.

Table 1. Summary of climate characteristics by region [6,7]

Characteristic	Halifax NS	Ottawa ON	Winnipeg MB	Vancouver BC
Climate Type	Cold-Humid	Cold-Humid	Very Cold	Marine
Heating Degree Days (18°C)	4000	4440	5670	2825
Heating Design Temperature (°C)	-16	-25	-33	-7
% Homes Heated Using Fossil Fuels*	63%	75%	53%	59%

*By respective province

All analysis is performed for a typical Canadian single family detached home. Housing geometry is based on the Canadian Centre for Housing Technology (CCHT) test homes located in Ottawa, Canada [8], and consists of two above ground floors and a finished basement with a total heated floor area of 284 m^2. The building envelope is modified to represent new construction in each selected region, based on the requirements specified in the National Building Code of Canada [6]. All base cases use natural gas furnaces for space heating, to examine the impact of transitioning from gas to heat pump systems. Key housing characteristics are summarized in Table 2.

Table 2. Summary of housing characteristics

Characteristic	Description/Value (All Cities)
Central Air Distribution	Yes
Primary Heat Fuel & System	Natural Gas Forced Air Furnace
Heating Efficiency	92%
Space Cooling System	Central AC COP = 3.5*
DHW Fuel	Natural Gas
Heat Recovery Ventilator (HRV)	Yes

* At AHRI Rating Conditions (95°F Outdoor Dry Bulb Temperature, 80°F Indoor Dry Bulb/67°F Wet Bulb)

Non-HVAC Load Profiles: Non-HVAC (i.e., lighting, appliances and plug loads) electrical load profiles have an important impact on house-level electrical demand. Analyzing the peak demand of heat pumps in homes with different electrical load profiles can provide an idea of how the added electrical demand associated with heat pumps may vary under different internal gains and space use types. This work uses a detailed load profile generator model (LPGM) developed using the bottom-up stochastic approach outlined by Wills [9], with additional refinements to better represent the homes and cases used in this study. Further details can be found in Mollier *et al.* [5].

Seven distinct active occupancy profiles are examined to better represent the range of peak demand increases possible when replacing a natural gas furnace with an electrically driven heat pump. For each occupancy profile type, occupancy levels between 2 and 5 people are considered, generating a total of 28 non-HVAC load profiles for each city. Table 3 summarizes the different occupancy profiles examined.

Table 3. Summary of occupancy profiles used in analysis

No.	Type	Description
1	Teleworking	Occupants are home most of the day, except during lunchtime.
2	Normal	67% of occupants are away during the day [10]
3	Pyramidal	Active occupancy slowly increases in the morning and decreases in the evening.
4	Morning and evening	100% of occupants are away during the day.
5	All day	Occupants are home all day.
6	Armstrong	Active occupancy profile such that resulting load profiles match Armstrong *et al.* [11]
7	Armstrong inverse	Morning and evening peaks from Armstrong *et al.* [11] are swapped.

A daily average of each selected load profile is provided in Fig. 1 for a three-person household in Vancouver. While each daily profile is unique, they tend towards the averages shown below.

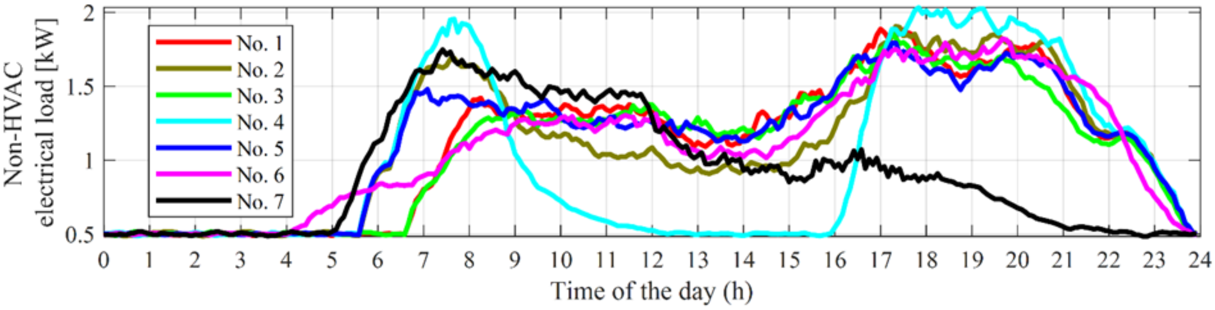

Fig. 1. Average daily occupancy profiles for a three-person household in Vancouver.

3. Heat Pump System Integrations

The added electrical demand associated with heat pump systems in Canada is closely linked to the operating range and cold climate performance of the selected system. Two heat pump performance curves are examined in this paper to better understand the influence of these characteristics.

Variable Capacity Heat Pump (VCHP): This unit is a typical market-available variable capacity heat pump. These systems have achieved a growing market share in Canada, driven by their ability to better modulate to space heating or cooling loads vs. more traditional single or two-stage units. However, these systems are not necessarily well adapted to cold climates, and may experience significant capacity degradations at the colder outdoor temperatures common in Canadian winters.

Cold Climate Variable Capacity Heat Pump (CCHP): As an alternative to the *VCHP*, a second heat pump system is modelled. This heat pump has an extended operating range, and is able to maintain a more substantial portion of its heating capacity at the colder outdoor temperatures common in Canada. As an illustration, the performance of the *VCHP* and *CCHP* are summarized below in Fig. 2.

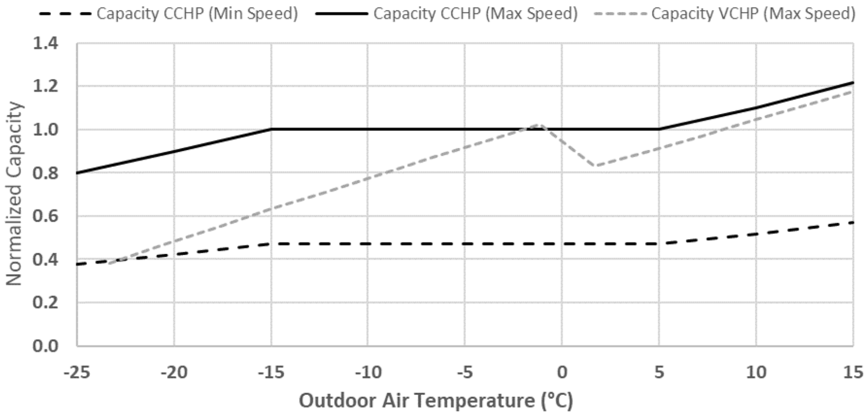

Fig. 2. Comparison of VCHP system performance [12,13].

Table 4 summarizes additional heat pump characteristics for both systems examined.

Table 4. Summary of heat pump performance characteristics [12,13]

	HP Type	
	VCHP	CCHP
Heating COP*	3.7 (2 ton) 4.1 (3 ton)	3.8 (All)
Cooling COP*	3.8 (2 ton) 4.1 (3 ton)	3.3 (All)
Min. Outdoor Operating Temperature, Heating Mode (°C)	-23	-25
% Capacity at Cut-Off Temperature (Max Speed)	38%	80%
Average Min: Max Capacity Ratio	0.3	0.3

*At AHRI Rating Conditions (47°F Outdoor Dry Bulb/43°F Wet bulb, 70°F Indoor Temperature)

Heat pump integration and sizing approaches can also have an important influence on performance. All heat pump systems are examined in a centrally ducted configuration, supplying space heating and cooling to all three levels of the home. Each heat pump integration is sized to cover a majority of the space heating load in each region, as per Option C of NRCan’s *Air-Source Heat Pump Sizing and Selection Guide* [14]. CCHP sizing in Vancouver is limited by the lack of available units under 2 tons for the model line used in the analysis [13].

Electric resistance elements in the ductwork are used to supplement heat pump operations as needed to maintain comfort. Details on heat pump and auxiliary sizing are provided in Table 5. All auxiliaries are sized to either meet the difference between heat pump capacity and building load at design conditions (in regions where the design temperature is above the heat pump minimum operating temperature), or the full design load (in regions where the design temperature is below the heat pump minimum operating temperature). Auxiliaries activate in 2.5 kW stages to provide a more realistic representation of their impact on electrical demand.

Table 5. Summary of heat pump and auxiliary sizing

	Heat Pump Size (ton)		Aux. Size (kW)
City	VCHP	CCHP	All
Halifax	3	2	5
Ottawa	3	2	10
Winnipeg	3	2	12.5
Vancouver	2	2	2.5

4. Heat Pump Modelling

Accurately representing the performance characteristics of each heat pump system is critical to properly estimate peak electrical demand. All system models are developed in TRNSYS v. 18 [15] using the appropriate Canadian Weather for Energy Calculation (CWEC) weather file. TRNSYS offers a vast library of components for modelling of space conditioning systems, as well as the ability to easily add custom component models (as was done in this paper with the heat pump component described below). Unlike many building simulation programs which typically use an hourly time step, TRNSYS also allows the user to select a fixed time step for simulation. In this study, all simulations use a 2.5-minute timestep to better represent the control logic of the heat pump and auxiliary heating systems.

Heat Pump Performance Modelling

A custom component is used in TRNSYS to model each heat pump system. This enhanced model (TRNSYS Type 3255) is developed based on extensive test experience at the CanmetENERGY in Varennes facility and integrates a series of new capabilities including performance variations with compressor speed, and short-term transients including start-up, defrost, and cycling. Further details are provided in Breton *et al.* [16].

Type 3255 follows a data-driven approach to heat pump performance, using a performance map to represent variations in heat pump capacity and power with outdoor temperature and compressor speed. Performance data in this study has been derived via available manufacturer literature. Data sources are summarized in Table 6.

Table 6. Summary of data sources for heat pump modelling

Heat Pump System	Rated Performance	Part Load Performance
VCHP	Manufacturer [12]	Manufacturer [12]
CCHP	Manufacturer [13]	Manufacturer [13]

Heat Pump Control

A PID controller is used to vary the speed of the compressor to maintain the first floor of the home at 21°C in heating and 23°C in cooling. The controller also contains a minimum operating frequency, below which the heat pump remains off. This feature enables the model to capture on/off cycling at warmer conditions when building loads fall below the minimum capacity of the heat pump. Additional controls prevent the heat pump from operating beyond its manufacturer specific range of outdoor temperatures.

Capturing the interaction of the heat pump with any electric auxiliary heating is critical to accurately estimate electrical demand. Auxiliary systems have three modes, depending on heat pump operations:

I. Heat pump is defrosting: The auxiliary duct heater turns on at a constant, fixed, limited capacity to minimize occupant discomfort during defrost. This capacity is calculated based on the estimated indoor cooling effect in defrost, to ensure a minimum supply air temperature of 12°C to the home, as per building code minimum requirements [6]. Defrost length is fixed at 5 minutes (future work will add varying defrost lengths). As will be discussed later, the sizing of the auxiliary system for defrost has important electrical demand implications. Future work will examine the use of different sizing methods (e.g., different minimum temperatures) to more fully quantify and illustrate these impacts.

II. Heat pump is operating: The first stage of auxiliary heating operates with a lower setpoint (20°C vs. 21°C for the heat pump) to ensure space temperatures are maintained within an acceptable range while prioritizing heat pump operations. Subsequent auxiliary stages follow a setpoint 0.5°C below the previous stage (e.g., second auxiliary stage activates at 19.5°C). The heat pump and auxiliaries may operate in parallel.

III. Heat pump is unable to operate: When ambient temperatures are too cold for the heat pump to operate, the first auxiliary stage activates when space temperatures fall below the desired setpoint of 21°C. Subsequent auxiliary stages follow a setpoint 0.5°C below the previous stage.

5. Results

This section compares the peak demand implications of the *Base Case*, *VCHP*, and *CCHP* for each city, under each of the 28 load profiles outlined in Section 2. Focus is placed on heating mode, given the importance that space heating electrification has for Canadian electricity grids, with the analysis period defined as Oct. 1st to May 1st.

Transitioning from Natural Gas to Air-Source Heat Pumps in Colder Climates ($T_{Design}<T_{HP,min}$)

This section examines results for two cities (Ottawa, Winnipeg) where outdoor temperatures fall below the minimum operating temperature for the selected heat pump systems. Fig. 3 shows the occurrence of peak electrical demand for each non-HVAC profile over the heating season in Ottawa. Each bar represents the number of simulation runs that experience their maximum house-level electrical demand during the defined time period (i.e., the number of simulation runs where a peak occurs during the time period, out of the 28 times each system is simulated using a different electrical load profile). *Base Case* peaks are far more dispersed vs. the two heat pump systems, as peak demand in these cases is driven by occupant behavior. Conversely, peaks for the *VCHP* and *CCHP* occur when outdoor temperatures fall below the minimum operating temperature of the heat pump and auxiliary heating must be used to maintain space temperatures.

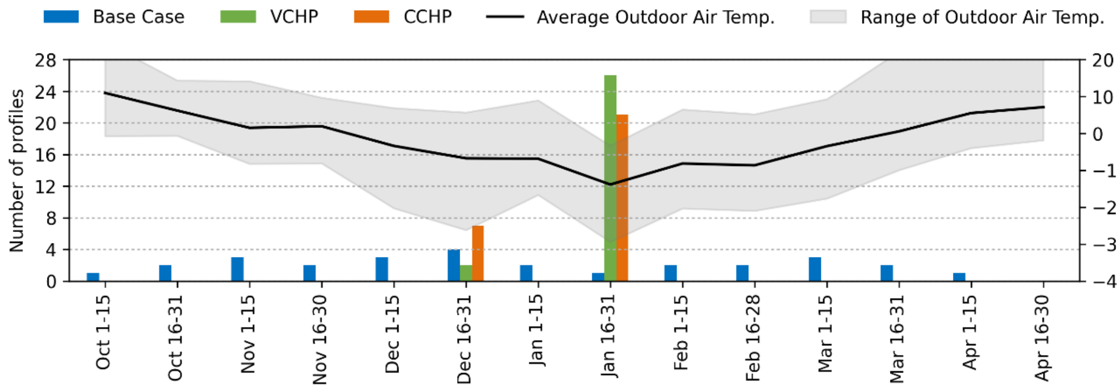

Fig. 3. Occurrence of peak demand by system type over the heating season in Ottawa

Fig. 4 shows the occurrence of peak demand by system in Winnipeg. Results follow a similar trend to Ottawa: *Base Case* peaks are dispersed due to their occupancy driven nature, while heat pump peaks occur during periods when ambient temperatures fall below the operating range of the heat pump. The distribution of peaks is identical for both the *VCHP* and *CCHP* units, as both systems experience an extended period when the heat pump is not able to operate and heating must be met using electric auxiliary elements. In both cities, it is important to note that peaks may occur with a high degree of coincidence across multiple homes, given that all heat pumps in a region will experience similar outdoor temperatures.

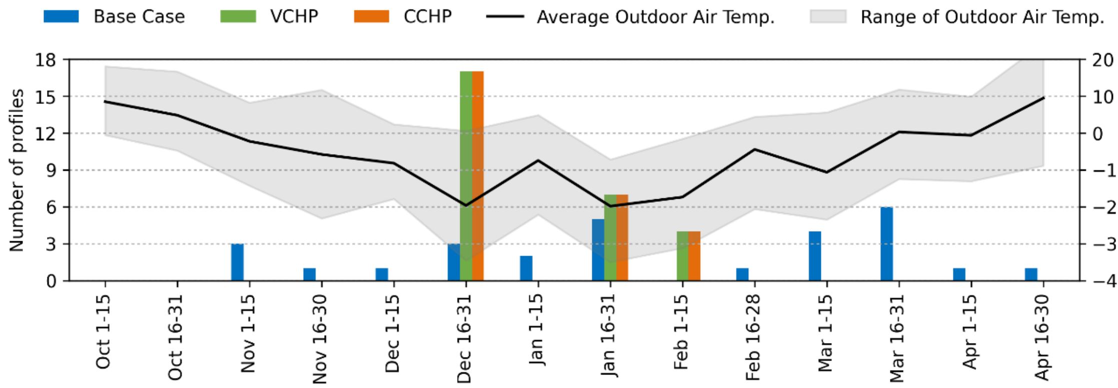

Fig. 4. Occurrence of peak demand by system type in Winnipeg.

Fig. 5 compares the magnitude of peak electrical demand increase associated with each heat pump vs. the *Base Case* in Ottawa and Winnipeg. Given that both the *VCHP* and *CCHP* must rely fully on auxiliary heating during the coldest winter days, both systems demonstrate similar peak demand increases. In Ottawa, peak electrical demand may increase between 2.9 kW and 7.7 kW with the *VCHP*, and between 2.5 kW and 7.6 kW with the *CCHP*. In Winnipeg, *VCHP*s may increase electrical demand between 5 kW to 8.8 kW, while *CCHP* systems may increase electrical demand from 3 kW to 9 kW. It should be noted that the lower minimum increase (3 kW) associated with the *CCHP* system in Winnipeg primarily results from the random nature of the load profiles, rather than a difference between *VCHP* and *CCHP* systems. In all cases (both Ottawa and Winnipeg), peak load increases are driven by a combination of auxiliary electric heating plus some degree of non-HVAC electrical loads. In the Winnipeg *CCHP* case, during one simulation run the non-HVAC loads that coincided with maximum auxiliary energy demand were lower, leading to this smaller minimum increase.

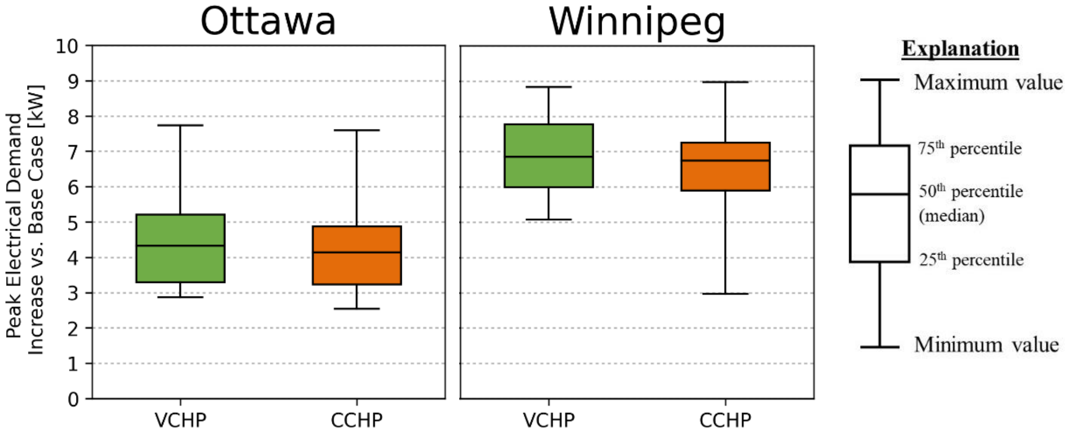

Fig. 5. Peak electrical demand increase for each heat pump system in Ottawa and Winnipeg.

The duration of any peak event can also be of value to electrical utilities. Fig. 6 compares the load duration curves (all load profiles) for both the *VCHP* and *CCHP* units in Winnipeg. Unlike the previous graphs, a comparison of the two insets shows a clear difference between the *VCHP* and *CCHP* systems. The *VCHP* system experiences a plateau at higher load for approximately 180h over the year, primarily associated with an extended duration of auxiliary heating. *CCHP* units reduce the duration of this plateau by over 30 hours, minimizing the added load placed on the grid by the heat pump system. Similar results are seen in Ottawa, although the magnitude of the reduction (8 h *CCHP* vs. 18h *VCHP*) is smaller due to the milder climate.

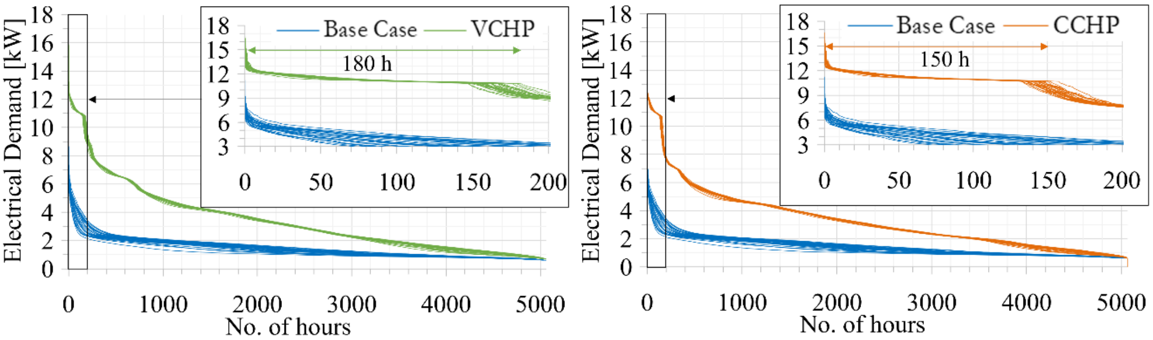

Fig. 6. Load duration curves for VCHP and CCHP systems in Winnipeg over heating season.

Transitioning from Natural Gas to Heat Pumps in Milder Canadian Climates (T_{Design}>$T_{HP,min}$)

The drivers of peak demand differ significantly in climates where the outdoor temperature always remains within the operating range of the heat pumps selected. Fig. 7 shows the distribution of peak electrical demand for all three systems in Halifax. Heat pump peaks are more dispersed, as peak demand is now driven by a combination of heat pump operations and occupancy-based non-HVAC electricity use (rather than aux. heating). Some correlation to colder temperature remains, as the heat pump must operate at higher compressor speeds (and power) to meet building loads during these periods, while defrosting is also needed. Results can have important implications for utilities, as it suggests that peak demand associated with heat pumps in milder climates may occur with a lower degree of coincidence, mitigating grid level peak demand increases.

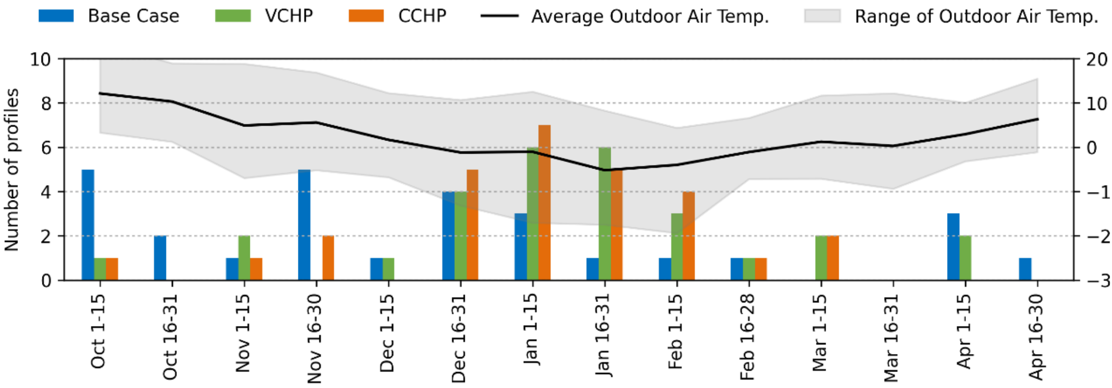

Fig. 7. Occurrence of peak demand for all three systems in Halifax during heating season.

Fig. 8 compares the occurrence of peak demand across all three systems in Vancouver. Results follow a similar trend to Halifax, with a dispersion of peak demand across the heating season. The milder climate in Vancouver allows both heat pump systems to operate consistently without the need for any auxiliary heating (except when the heat pump defrosts), with peak demand events instead driven mainly by heat pump use coincident with non-HVAC end uses.

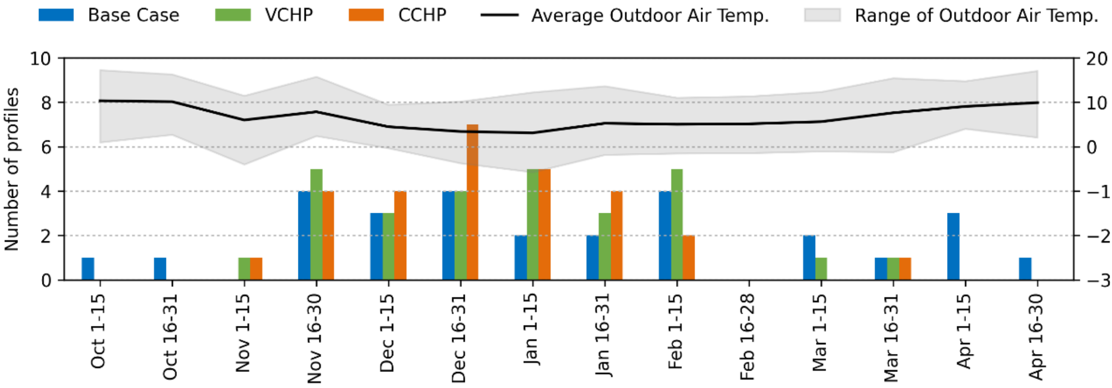

Fig. 8. Occurrence of peak demand for all three systems in Vancouver during heating season.

Fig. 9 compares the range of peak demand increase vs. the *Base Case* for each heat pump system in Halifax and Vancouver. Peak demand increases are smaller vs. the previous cities examined, as the heat pump operates consistently throughout the year. In both cities the *VCHP* and *CCHP* systems exhibit a similar range of peak demand increase, primarily because (i) they are sized according to the same objectives, and (ii) the outdoor temperature is not cold enough to reach the minimum operating temperature of either unit. In Halifax, peak demand increases range from 0.1 kW to 3 kW with the *VCHP*, and between 0.1 kW to 2.9 kW with the *CCHP*. Larger peak demand increases are associated with heat pump defrost (which activates a portion of aux. heating, as noted in Section 4) coinciding with higher non-HVAC electrical demand. Smaller peak demand increases are associated with the heat pump operating at lower speeds in combination with higher occupant driven loads. Peak demand increases are similar in Vancouver, ranging from 0 kW to 1.7 kW with the *VCHP*, and 0 kW to 3.1 kW with the *CCHP* case. Cases with peak demand increases near 0 kW relate to peak events driven solely by non-HVAC electrical loads, with the heat pump remaining in standby mode.

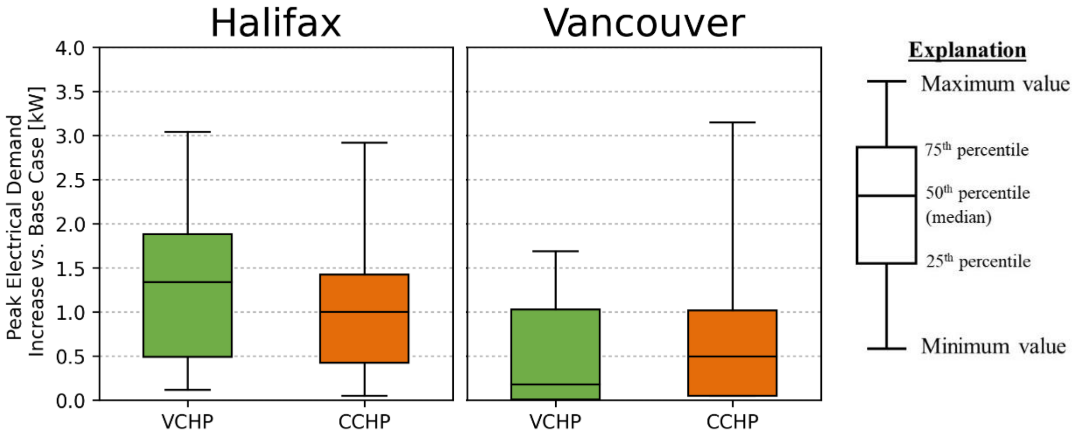

Fig. 9. Range of peak demand increase with each heat pump system in Halifax and Vancouver over the heating season.

While heat pump peaks are more dispersed in Halifax and Vancouver, it is interesting to note when these peaks may occur during the day. Fig. 10 compares the occurrence of peaks over a 24h period for the *Base Case*, *VCHP* and *CCHP* systems in Halifax. Typical peak periods for the grid in the morning (7 AM to 9 AM) and evening (5 PM to 7 PM) are also shown [17]. Given the closer link to occupancy driven loads, it is not surprising to see that peaks are more likely to occur during the core periods of the day when occupants are active. This information is important to grid operators and planners, as it suggests that heat pump peaks may occur during periods of the day when demand is already higher, necessitating some form of demand reduction strategy to ensure grid capacity and stability.

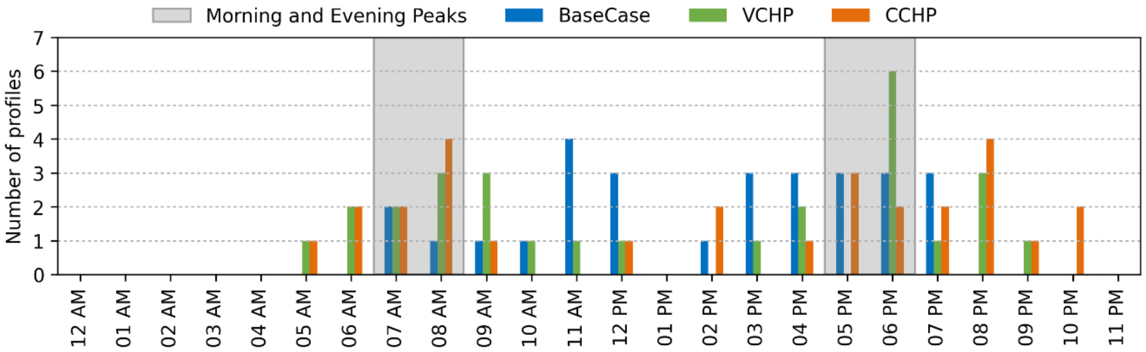

Fig. 10. Occurrence of peak event over day in Halifax during heating season.

Mitigating Peak Demand Associated with Heat Pump Systems

Peak demand increases associated with heat pump systems can also be mitigated in a number of ways, including improved controls or the integration of energy storage. As a simple example, a preheat and setback strategy is examined to reduce heat pump peak demand during defined morning (7 AM – 9 AM) and evening (5 PM – 7 PM) periods. Heat pump indoor temperature setpoints used in the analysis are presented in Fig. 11, and aim to heat up the interior space prior to peak periods, and then utilize the thermal capacitance available in the building mass to coast until the end of the two-hour peak. During all preheat periods, auxiliary setpoints lag behind the heat pump setpoint to prioritize heat pump operations. The setpoint strategy is presented as an initial analysis and will be further examined and optimized in future work.

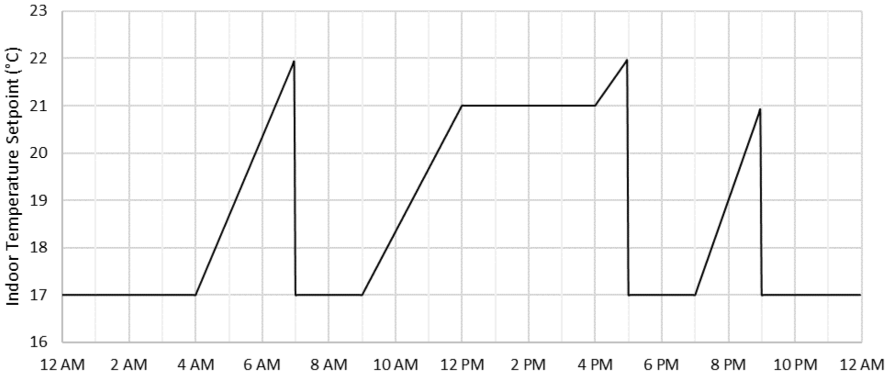

Fig. 11. Setpoint strategy used in initial peak demand mitigation strategy for Halifax.

Fig. 12 compares the peak demand increase <u>during the defined peak periods only</u> (7AM-9AM, 5 PM-7PM) in Halifax with and without the mitigation strategy. It is immediately clear that the applied strategy greatly reduces the electrical demand of the building during peak hours by avoiding the use of the heat pump and any auxiliary systems. However, it is important to note that this demand reduction occurs <u>only during the peak periods</u>: Higher system electrical demand occurs just before and after these periods to preheat and recover space temperatures. In fact, *overall* peak electrical demand increases vs. the base case are actually higher when the mitigation strategy is applied, reaching up to 6 kW (vs. only 3 kW when no preheating/setback strategy is used). Applied on a larger scale, the associated electrical demand before and after the two-hour peak window could pose a significant challenge for utilities. As such, some form of dispersed strategy, where not all systems follow the preheat and setback schedule, may be required to achieve sufficient results at the grid level.

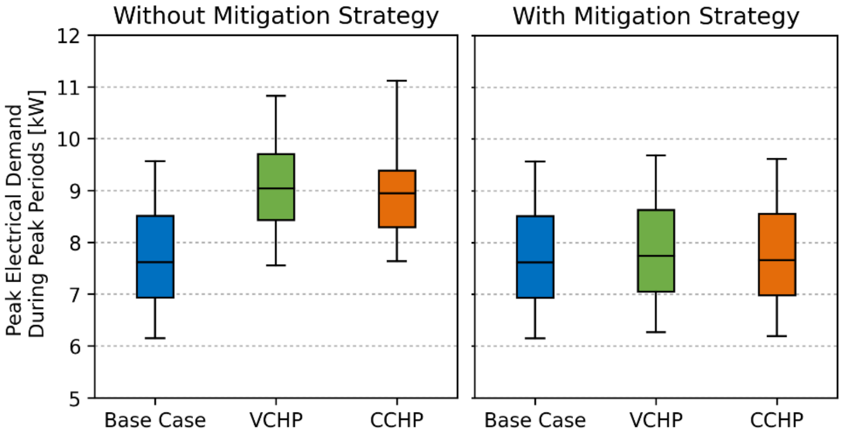

Fig. 12. Comparison of peak demand distribution <u>during peak hours</u> in Halifax with and without mitigation strategy.

Application of this strategy relies on the willingness of the homeowner to accept lower space temperatures over a short duration, and the ability of the building mass to maintain space temperatures within the desired range over the two-hour period. The current analysis shows that this strategy is viable for newer construction buildings but may be more challenging in older housing vintages with poorer envelope construction and higher rates of infiltration. Alternative strategies, including integrating thermal or electrical storage with the heat pump system (e.g., in a Climate & Comfort Box configuration [18]), holds strong promise to extend the peak management and energy flexibility potential of heat pump systems.

Discussion

Results highlight that the peak demand implications of heat pump systems are highly dependent on local climate. In areas where outdoor air temperatures fall below the minimum operating temperature of the heat pump, the occurrence of peak events is tied closely to colder periods when the heat pump requires partial or full auxiliary heating to maintain space temperatures. Given the link to outdoor temperatures, it is also possible that these peaks may occur with a greater degree of coincidence in the same region, imposing a larger aggregated load on the electrical grid. In regions where outdoor temperatures remain within the operating range of the heat pump, peak demand events tend to be more dispersed and may occur with a lower degree of coincidence. However, given that peak demand behavior in these cases is linked to heat pump operations coinciding with non-HVAC electrical use, peaks are likely to occur during periods of higher grid demand.

A brief analysis of the results would appear to show little difference between the *VCHP* and *CCHP* technologies in terms of peak demand. However, *CCHP* systems hold strong promise in reducing auxiliary heating, which has been shown in this study to be a leading driver of peak electrical demand in colder regions. The extended operating range of these systems also minimizes the period of time the home must be heated solely via the auxiliary system, reducing the probability that auxiliary heating will coincide with a larger non-HVAC electrical draw. As climate change brings more extremes in outdoor temperature, *CCHP* systems may also provide a degree of added resilience for both homeowners and grids, particularly in regions like Halifax where the need for heating down to -25°C is not currently required.

Heat pump sizing can also have an important impact on peak demand. In this study, all systems were sized with a focus on heating, as per Option C of NRCan's *Air-Source Heat Pump Sizing and Selection Guide* [14]. Heat pumps sized to meet a smaller portion of the heating load will likely require further supplemental electric heating, increasing the duration and magnitude of peak demand vs. the results presented in this paper. The application of similar sizing objectives for the *VCHP* and *CCHP* cases also explains why peak demand increases are similar for both systems. Should both cases use the same size of heat pump (e.g., both 2 ton) instead of targeting the same percentage of annual heating load, results would likely reflect a strong preference for the *CCHP* system due to a reduced reliance on auxiliary heating.

6. Conclusion

This study has examined the peak demand implications of transitioning from natural gas furnaces to air-source heat pumps in four Canadian regions. Results show a strong link between climate and heat pump peak demand. In colder climates (i.e., Ottawa and Winnipeg, where ambient temperatures fall below the minimum operating temperature of the heat pump), peak demand is closely associated with periods of low outdoor temperatures when the heat pump must be supplemented partially or fully via electric auxiliary heating. Peak demand increases may reach up to 7.7 kW in Ottawa, and 9 kW in Winnipeg vs. a natural gas heated home. Given the link to outdoor temperature, peaks may also occur with a higher degree of coincidence, creating a larger aggregated load on the grid. In milder regions (i.e., Halifax and Vancouver, where outdoor temperatures remain within the operating range of the heat pump) peak demand is more closely linked to heat pump operations coincident with higher non-HVAC electrical loads. These peaks were more dispersed throughout the heating season but often occurred during peak hours when occupant activity was higher. Peak demand increases may reach up to 3.1 kW in both Halifax and Vancouver. An initial analysis of demand mitigation via preheating and temperature setback showed a strong ability to reduce electrical demand in Halifax during two-hour peak events in the morning and evening. However, this strategy also increased electrical demand before and after defined peak periods vs. the non-mitigation case, and as such requires careful application. Further work is needed to examine the viability of this strategy in other regions, and in older vintages of construction where the thermal capacitance of the building is reduced.

Future work will examine the peak demand implications of heat pumps in additional regions, and in a greater variety of residential building archetypes. Planned analysis also includes an in-depth examination of heat pump plus storage systems (e.g., Climate & Comfort Box solutions) to better mitigate peak demand without affecting thermal comfort in the building. Larger scale assessments of mitigation strategies at the grid level should also be performed to ensure that these strategies appropriately address the needs of utilities and avoid any unintended consequences (e.g., large peaks directly after a demand reduction period has ended).

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