ENERGY MARKETS & POLICY

BERKELEY LAB

Managing changes in peak demand from building and transportation electrification with energy efficiency

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Executive summary

Motivations

- **Understanding the impact of policy:** Sacramento Municipal Utility District (SMUD) decarbonization goals and state policy will increase the adoption of building electrification technologies and electric vehicles in SMUD's service territory in the coming decades.
- **Managing peak demand**: SMUD's load forecasts currently do not seperate load by electrification technology or by level of building electrification efficiency. This creates uncertainty about how building electrification technologies and electric vehicle charging – independently and in aggregate – will alter SMUD's peak demand timing, magnitude, and duration. Additionally it is unclear if, and to what extent, high-efficiency building electrification can mitigate increases in peak demand due to electrification.
- **Understanding the impact of extreme weather:** SMUD currently plans for extreme *summer* weather (1-in-10 year hot days) but not extreme *winter* weather. However, as heat pumps become a more common source of space heating and cooling, there is a risk that on a very cold day temperature-related reductions in heat pump efficiency could lead to a spike in winter morning demand and create a winter-peaking system.

Executive summary
Research questions

- In collaboration with SMUD, we developed three research questions to guide the project and explore emerging issues of interest to the utility.
  - Does the magnitude and timing of peak demand change under high levels of electrification?
  - How can energy efficiency mitigate the impacts of building and transportation electrification on peak demand?
  - What is the impact of a cold day on winter morning load as the level of heating electrification increase through 2045?

Executive summary

Scenario development and analysis

- In collaboration with SMUD, we developed three scenario-based hourly load forecasts that incorporate the impact of building and transportation electrification on SMUD's system for 2025-2045, which served as the foundation of the analysis.
  - The **baseline** efficiency electrification scenario estimates the peak demand impact of installing currently available, efficient building electrification technologies and light duty electric vehicle (EV) charging.
  - The **high efficiency electrification scenario** estimates the peak demand impact of more efficient building electrification technologies while using the same EV charging assumptions as the baseline scenario.
  - The **cold snap scenario** estimates the peak demand impact of operating space and water heating at minimum efficiency and temperature-sensitive EV charging on winter morning demand from a 1-in-10 year cold day.
- Using the scenarios, we identified:
  - When, why, and how much peak demand changes during the study period.
  - The coincidence of building end uses and vehicle charging approaches with system peak.
  - Impact of high levels of electrification technology adoption and a cold snap on the winter peak.

Results

- Forecasted hourly summer net peak demand in SMUD's system increases significantly through 2045 due to EV charging and new construction in the baseline scenario.
  - Net peak demand will increase 1350 MW (48%) to 4200 MW between 2025 and 2045, largely driven by the coincidence of EV charging with space cooling. SMUD's system remains summer-peaking.
  - Building electrification retrofits cause 5% of the summer net peak increase through 2045.
- Winter net peak demand rises by 1700 MW (110%) between 2025 and 2045 in the baseline scenario due to EV charging and heat pumps, which account for 43% and 42% of the increase respectively.
- High-efficiency building electrification can significantly reduce increases in summer and winter net peak demand from building electrification and new construction.
  - High efficiency heat pumps and building envelope measures reduce 2045 system peak demand by 21% in summer and 22% in winter in our high efficiency electrification scenario.
- Heat pumps for space heating become the largest incremental driver of winter net peak demand in the cold snap scenario. EV charging remains a major load.
  - By 2045, heat pump load increases 85% (725 MW) relative to the baseline efficiency scenario.
- A 1-in-10 year cold snap in which heat pumps operate at minimum efficiency could make SMUD's system winter peaking in 2045.
  - Cold snap winter net peak could reach 4340 MW, slightly above the 4170 MW summer net peak in the baseline efficiency scenario.

Analytical approach

Analytical approach
Scenario-based load forecasting

- The foundation for the analysis is a scenario-based hourly forecast of building and transportation electrification impacts on SMUD’s system for 2025-2045. It serves several purposes:
  - Enabling the identification of when, why, and how much peak demand changes
  - Understanding the coincidence of various building end uses and multiple vehicle charging approaches
  - Determining which modeling parameters peak demand is sensitive to
- Our forecast complements SMUD’s internal forecast by generating separate estimates of the load impacts of:
  - Building electrification technologies (using ResStock and ComStock models)
  - Home, workplace, and public managed EV charging (using EVI-Pro Lite)
  - New construction/retrofit
  - Behind-the-meter solar generation
- There are three forecast load scenarios in the analysis:
  - Baseline efficiency building electrification
  - High efficiency building electrification
  - Cold snap: 1-in-10 year cold day and minimum building efficiency
- Forecast results focus on seasonal peaks, the days that have the highest hourly net demand in summer (June-September) and winter (November-February).

Analytical approach

Technology adoption

- State policy and SMUD's goals inform the electrification technology adoption for all of our scenarios.
- In buildings, we address electrification (e.g. gas furnace to heat pump) but not efficiency improvements to already electrified end uses (e.g. electric resistance to heat pump).
- The analysis focused on residential, commercial and transportation sectors, and considered electrification of six end uses (see table).

Sector	End use	Outcome	Policy driver
Residential	Space conditioning	100% electrification by 2045	[SMUD zero carbon goals]
	Water heating		
	Cooking	78% electrification by 2045	
	Clothes drying		
Commercial	Space conditioning	100% electrification of applicable technologies by 2045	
Transportation	Light-duty transportation	100% EV sales by 2035 (Annual EV counts provided by SMUD)	[California EV-sales mandate]

Building end use load profiles and hourly load forecasts

- We used ResStock and ComStock models to estimate increases in SMUD hourly net demand from residential and commercial building electrification by building electrification technology.
  - ResStock and ComStock leverage the results from 900,000 building energy models.
  - They statistically represent the U.S. residential and commercial building stock as it was in 2018 and as it could be with efficiency and electrification packages implemented.
  - The models capture the diversity of buildings and occupant behavior in SMUD territory.
- Specifically, we used ResStock and ComStock end use load profiles as forecasts of *hourly changes in load* from electrification, not as stand-alone load forecasts.
  - ResStock and ComStock model the SMUD building stock. The end use load profiles do not align perfectly with SMUD system load shape. We calculated changes in load approach because the models:
    - Slightly overestimate the magnitude of summer peak, but align well with peak timing
    - Significantly overestimate magnitude of winter morning load
- We added the electrification load to a base SMUD load shape (2018 load) based on the projected penetration of electrification technologies. We use 2018 SMUD load as the base because ResStock and ComStock represent U.S buildings in 2018.
- Demand flexibility is included in the analysis as managed EV charging (see slide 14), but we do not model the impact of demand response or customer-sited batteries.

Analytical approach

New construction

Residential buildings

- We followed assumptions that SMUD used in its decarbonization planning and applied them in each load forecasting scenario.
  - The annual new construction rate comes from projections of building decarbonization program impacts and is, on average, about 1.1%.
  - We assumed that new construction is 100% all-electric starting in 2030.

Commercial buildings

- We assumed that commercial building stock increases 0.2% per year based on EIA projections of commercial energy usage in the 2020 Commercial Building Energy Consumption Survey.
  - SMUD building decarbonization plan did not include commercial new construction growth rate.
- We used these assumption in each load forecasting scenario.

Analytical approach

Behind-the-meter photovolatic generation

- Residential and commercial photovoltaic (PV) growth assumptions are from the sector-specific self generation projections in SMUD's 2021-2035 Mid-Demand Baseline Forecasts developed for the California Energy Commission's Integrated Energy Policy Report (IEPR).
- We estimated residential and commercial gross electricity usage by class for PV customers by:
  - Scaling down the load shape of non-PV customers based on the ratio of PV to non-PV customer load during the night (12-3am) when there is no PV generation.
    - This approach assumes that PV and non-PV customers use electricity at similar times and levels.
- We calculated the PV generation load shape as the difference between the net and gross load shapes.
- We scaled the PV generation load shape in alignment with the IEPR self-generation growth rates.
- In each year of the analysis, PV generation is subtracted from the gross load forecast to estimate net demand.
- These assumptions are the same for all three scenarios.

Analytical approach

Transportation electrification

- Using EVI-Pro Lite, we generated hourly load shapes for light duty vehicle charging at home, workplace, and public locations and aggregated them at the system level.
- In collaboration with SMUD, we selected EVI-Pro Lite modeling parameters. Detailed assumptions are included in the appendix.
  - EV type (battery-electric versus hybrid)
  - Vehicle type (sedan versus truck)
  - Charging capacity (Level 1 versus level 2)
  - Charging location preference (home versus workplace)
  - Charging strategy (managed versus unmanaged)
  - Miles traveled
  - Temperature
- The managed charging strategy selected with SMUD assumes home charging in the morning and late evening, workplace charging mid-day, and public charging in the early evening. At the system level, charging is relatively level throughout the day.
- SMUD provided a forecast of EV adoption through 2042, which we extended to 2045 by assuming constant annual growth from 2042 through 2045.
- All forecast scenarios use the same transportation electrification assumptions with the exception of temperature. In the cold snap scenario, we use hourly temperature instead of monthly.

Baseline efficiency scenario

Baseline efficiency scenario

Building electrification technologies

- Our baseline efficiency scenario building technologies reflect current market offerings.

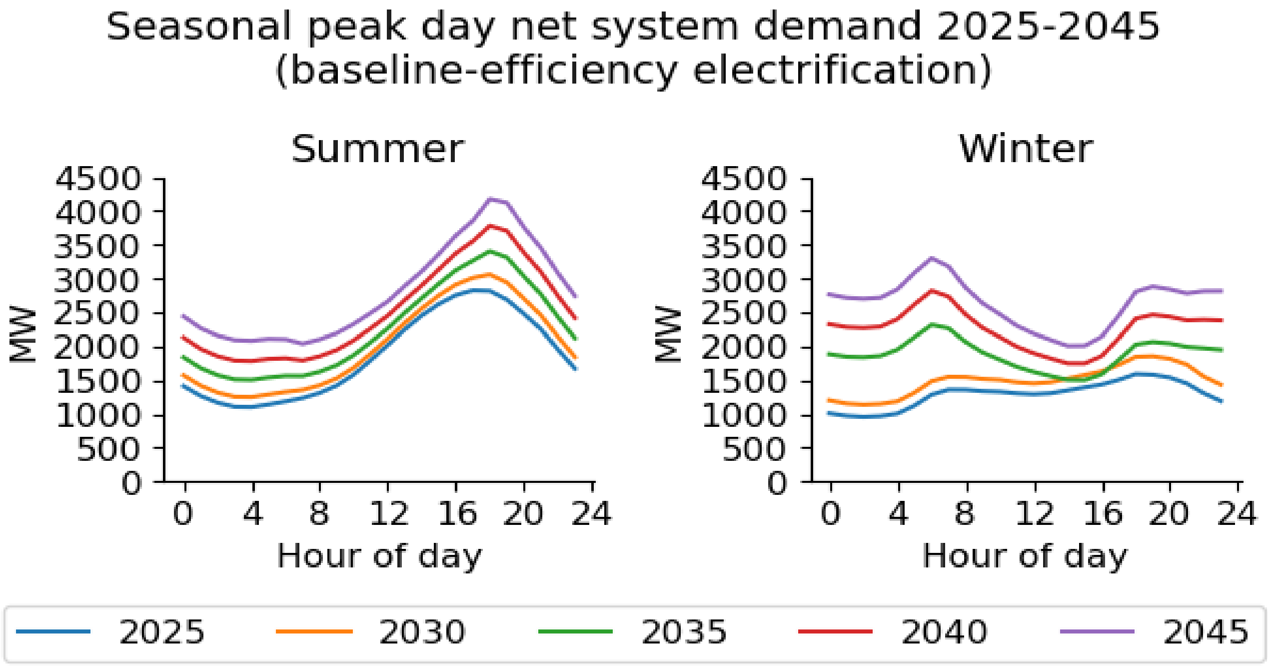
Building type	End use	Baseline efficiency technology
Residential	Space conditioning	Single speed heat pump* (SEER 15, 9 HSPF) with backup electric resistance
	Water heating	Heat pump water heater (3.35-3.45 UEF)
	Cooking	Resistance
	Clothes drying	Resistance
Commercial	Space conditioning - Rooftop packaged unit	Rooftop heat pump with single speed fan and back up electric resistance
	Space conditioning - Fossil boiler	Heat pump boiler with back up electric resistance

SEER – seasonal energy efficiency rating; HSPF – heating seasonal performance factor; UEF – uniform energy factor

*Throughout the report, ‘heat pumps’ refer to heat pumps used for space heating. We refer to ‘heat pump water heaters’ for heat pumps used for water heating.

Baseline efficiency scenario

SMUD remains summer-peaking through the analysis period



Scenario results focus on seasonal net peak days, when the highest hourly net demand in summer (June-September) and winter (November-February) occurs. All peaks referenced in report are net of expected PV generation unless they are explicitly identified as gross.

In all scenarios, the summer maximum hourly temperature is 104.0 °F and the winter minimum hourly temperature is 24.8 °F.

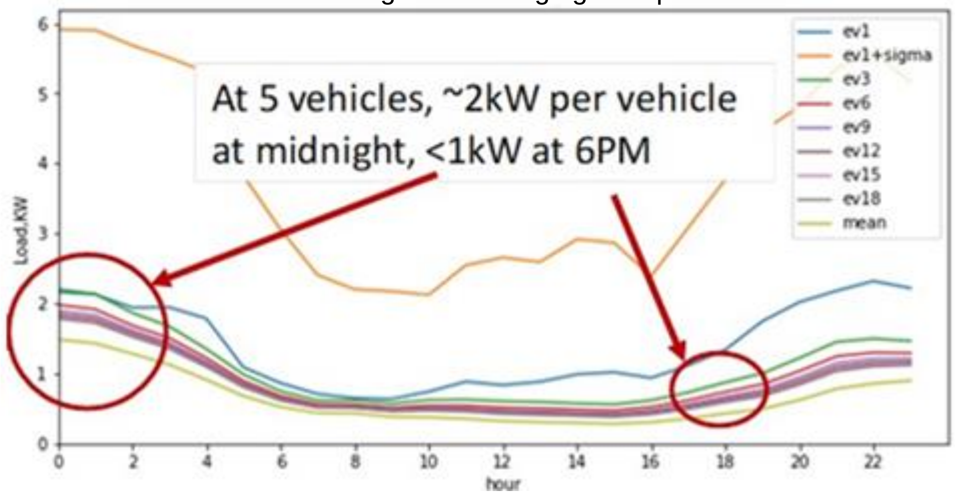
- The figures show net system load for the peak summer and winter days by analysis year (2025-2045). See appendix for load shapes by end use.
- In 2045, SMUD's system remains summer-peaking (the highest hourly net demand occurs in summer) with baseline-efficient electrification.
- *Increases* in winter peak demand (1,700 MW) between 2025 and 2045 exceed *increases* in summer peak demand (1,350 MW).
- Winter peak moves from the evening to the morning starting in 2035.

Baseline efficiency scenario

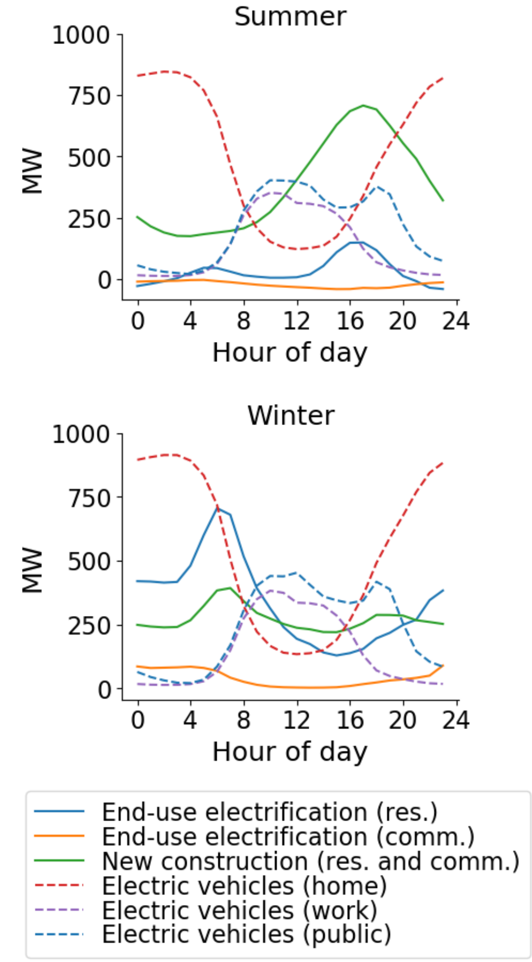
EV charging load shapes vary by location

- EV charging load shapes vary by location:
  - Home charging increases through summer evenings and peaks overnight (2AM).
  - Workplace charging peaks mid-morning (10AM).
  - Public charging peaks mid-morning in summer (10AM) and mid-day in winter (12PM).
- Due to high levels of EV adoption, load forecast results are sensitive to EV charging assumptions.
- EVI-Pro Lite home charging has similar ratio of demand at midnight to 6pm (~1.8) as SMUD's metering data.

SMUD managed EV charging load profile

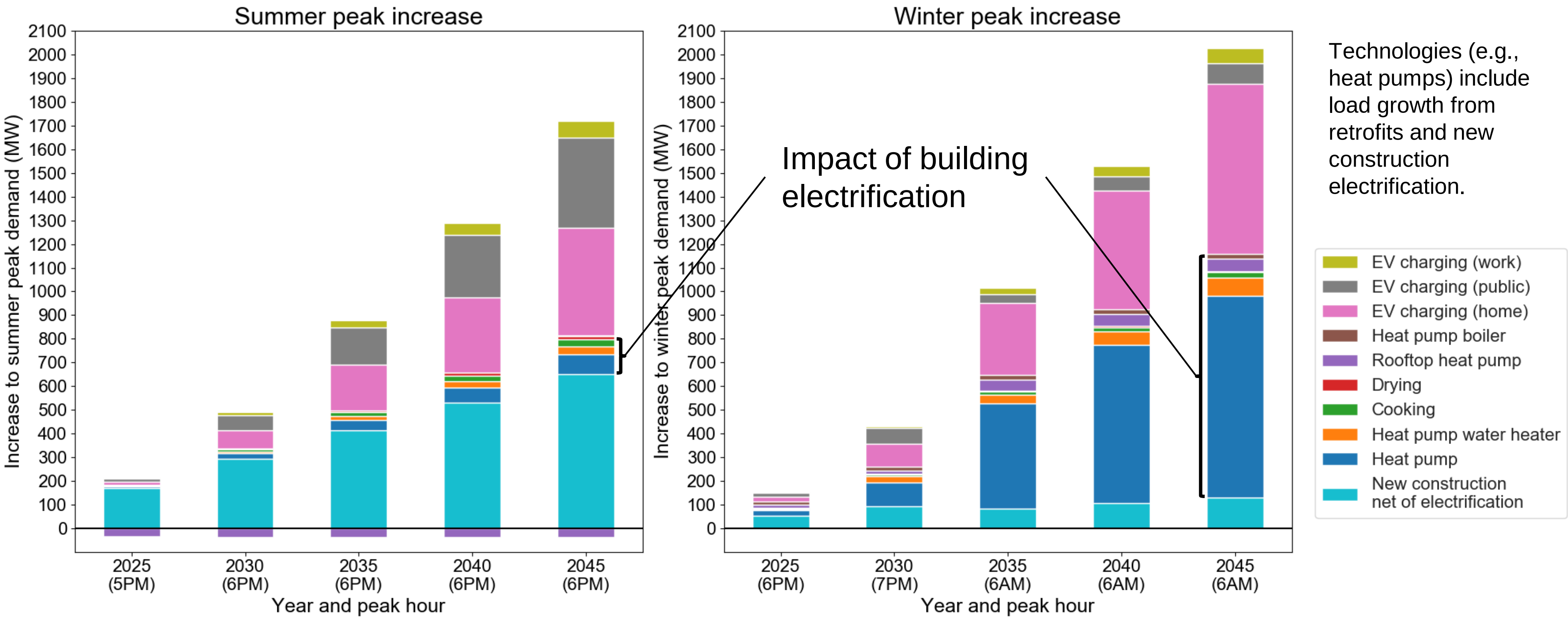


2045 seasonal peak day load shapes (baseline efficiency)



Baseline efficiency scenario

Electric vehicles are the largest driver of gross peak demand increases

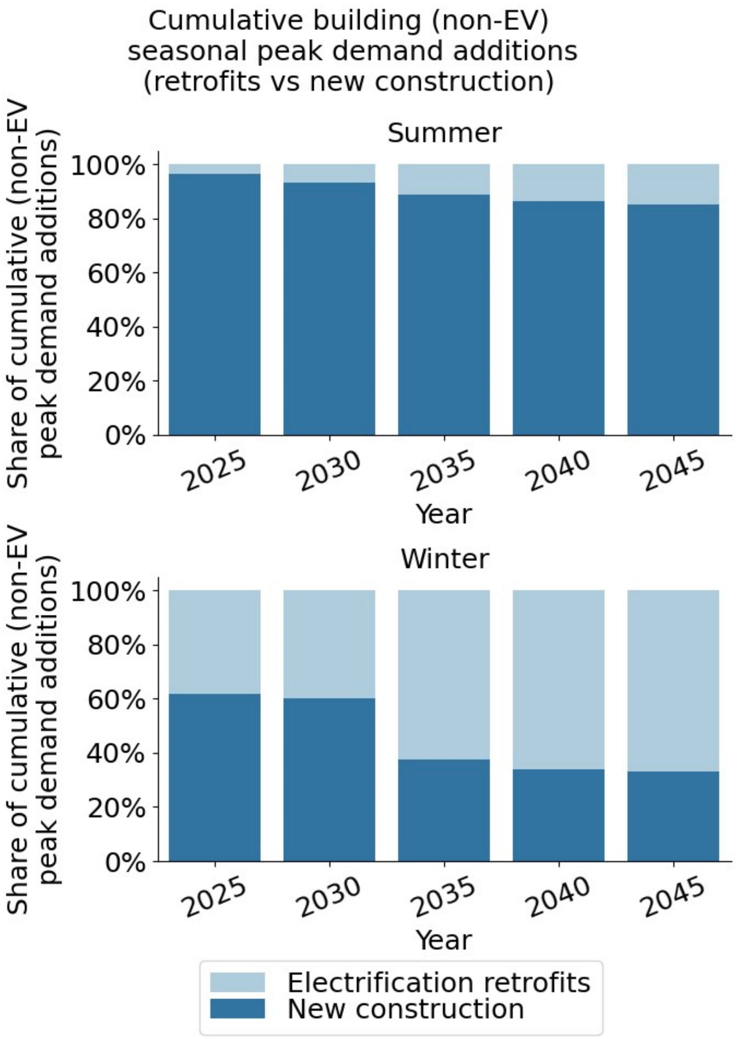


- Home and public EV charging drive 50% of 2025-2045 gross summer peak demand increases.
- EV charging (43% of increase) and heat pumps (42% of increase) drive cumulative winter peak demand increases.
- Building electrification retrofits cause 5% of the summer peak demand increase through 2045.
  - 100% heat pump adoption by 2045 only increases peak demand in houses without pre-existing space cooling (~7% of houses according to the [2019 Residential Appliance Saturation Survey]).
  - Commercial rooftop heat pumps and heat pump boilers reduce summer peak demand.

Baseline efficiency scenario

Heat pump retrofits are a minor source of summer peak demand increases

- Electrification retrofits and new construction are both significant sources of peak demand but their impacts vary by season.
  - Electrification retrofits drive winter non-EV peak demand increases after 2030.
  - New construction drives summer non-EV peak demand increases in all years.
- Heat pump retrofits account for 8% of the non-EV increases in summer peak demand through 2045.
- See appendix for separate residential and commercial results (slides 44-45).



High efficiency building electrification scenario

High efficiency scenario

Residential building electrification approach

- In our high efficiency electrification scenario, we explore the impact of higher efficiency residential electrification equipment and improved building envelope (see table).
- The high efficiency electrification scenario has the same EV charging and PV generation as the baseline efficiency scenario.
- The efficiency improvements only apply to buildings in which fuel switching occurs, not to buildings where the end use is already electrified.
- The high efficiency scenario does not account for more stringent energy codes.

End use	Baseline electrification	Efficient electrification
Space conditioning	Single speed heat pump (SEER 15, 9 HSPF)* with backup back up electric resistance	Variable speed heat pump (SEER 24, 13 HSPF or SEER 29.5, 14 HSPF based on presence of ducts in the baseline) with backup electric resistance Envelope upgrades: Attic insulation (R-49 if initially <=R-30) Air sealing (30% reduction in ACH50 if initially >=15 ACH50) Duct sealing and insulation (10% leakage, R-8) Wall insulation (R-13 drill and fill)
Water heating	Heat pump (3.35-3.45 UEF)	Heat pump water heater (3.35-3.45 UEF)
Cooking	Resistance	Induction
Clothes drying	Resistance	Heat pump

* The minimum efficiency requirement for split system heat pumps is SEER 15, 8.8 HSPF. Space-constrained products have lower requirements. https://www.energy.gov/sites/prod/files/2016/12/f34/CAC_HP_Direct_Final_Rule.pdf

High efficiency scenario

Commercial building electrification approach

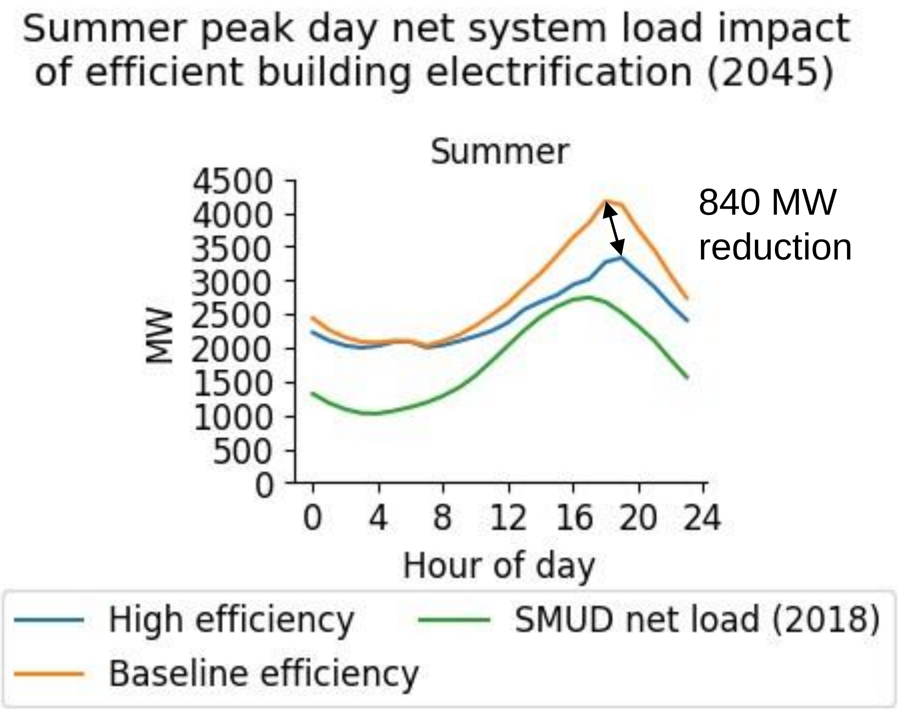
- We developed a load forecast with envelope upgrades occurring alongside commercial building electrification (see table).
- The efficiency improvements apply only to buildings in which fuel switching occurs, not to buildings where the end use is already electrified.
- Because of the range of existing commercial HVAC technologies, the electrification measures do not completely replace all fossil heating; 11% of natural gas consumption for commercial heating remains in the electrification scenarios. For additional details on the commercial electrification methodology, see slide 38.

Existing fossil heating system	Baseline electrification	Efficient electrification	Share of original gas heating consumption
Rooftop packaged unit	Rooftop heat pump with single speed fan and backup electric resistance	Rooftop heat pump with single speed fan, backup electric resistance, and wall insulation (R-16)	64%
Fossil boiler	Heat pump boiler with backup electric resistance	Heat pump boiler with backup electric resistance and wall insulation (R-16)	25%

High efficiency scenario

Increasing the efficiency of building electrification technologies reduces summer peak demand

- The high efficiency building electrification scenario yields significant savings in summer evenings in 2045.
  - Summer peak declines by ~20% (840 MW) and occurs one hour later (7PM).
- The overall change in peak demand between the baseline and high efficiency scenarios is a combination of efficiency upgrades and the timing of loads (peak hour occurs one hour later in the high efficiency case at 7PM).
- In the same hour of the baseline scenario 2045 summer peak (6PM), demand in the high efficiency electrification scenario declines by ~22% (900 MW).

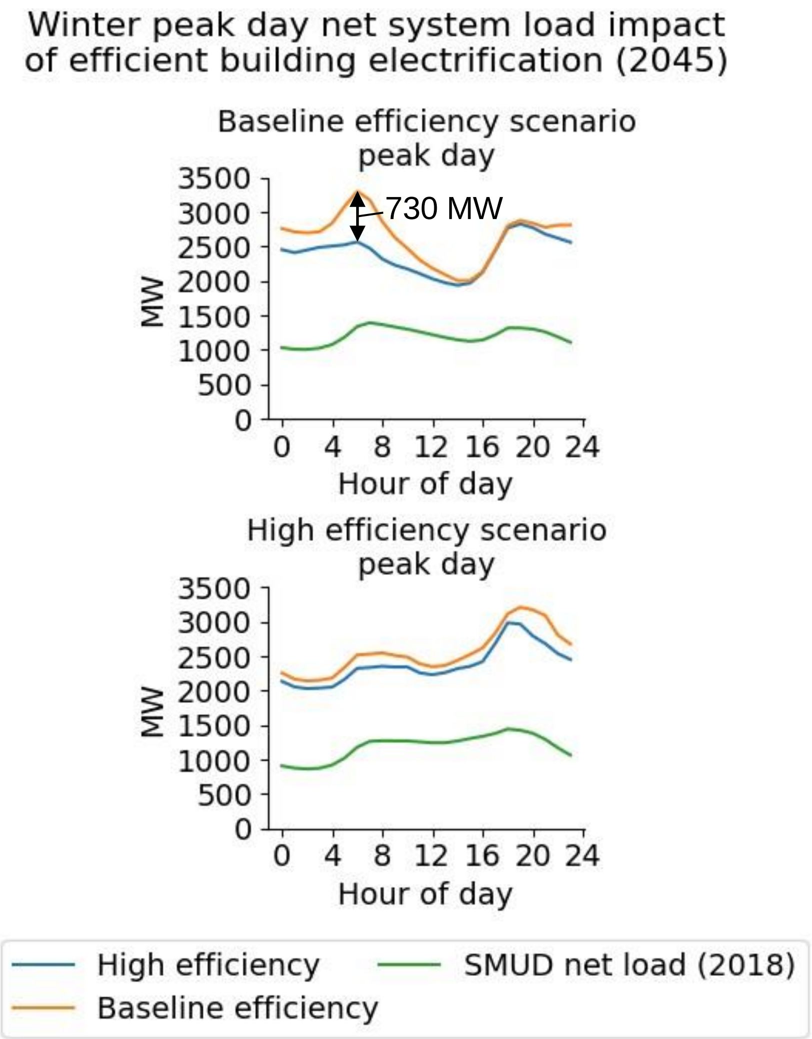


The baseline and high efficiency scenario net load shapes both include expected EV charging load. The 2018 SMUD net load includes actual EV penetration in 2018.

High efficiency scenario

Increasing the efficiency of building electrification technologies reduces winter peak demand

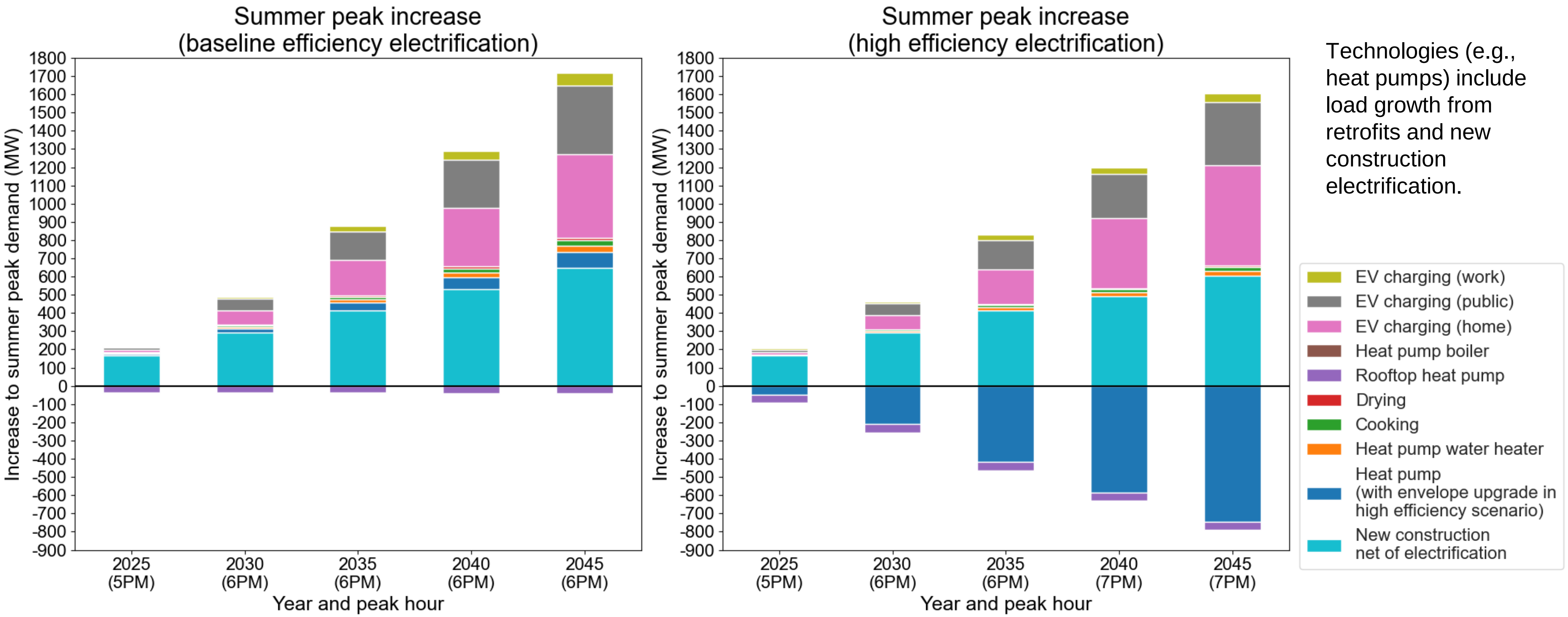
- In the baseline efficiency scenario, winter peak demand occurs on the coldest day of the year, which leads to a large morning peak at 6AM (orange line in top panel of figure).
  - During that peak hour, energy efficiency upgrades reduce demand by 22% (730 MW) in 2045 (blue line in top panel of figure).
- In the high efficiency scenario, winter peak demand occurs in the evening and on a different day due to the large morning demand reductions on the baseline scenario peak (blue line, bottom panel of figure).
- Overall, winter peak demand falls by ~ 10% (320 MW) from the baseline to the high efficiency scenario due to a combination of efficiency upgrades and the change in the timing of peak demand.



The baseline and high efficiency scenario net load shapes both include expected EV charging load. The 2018 SMUD net load includes actual EV penetration in 2018.

High efficiency scenario

High efficiency residential heat pumps and envelope upgrades reduce summer peak demand by 21%



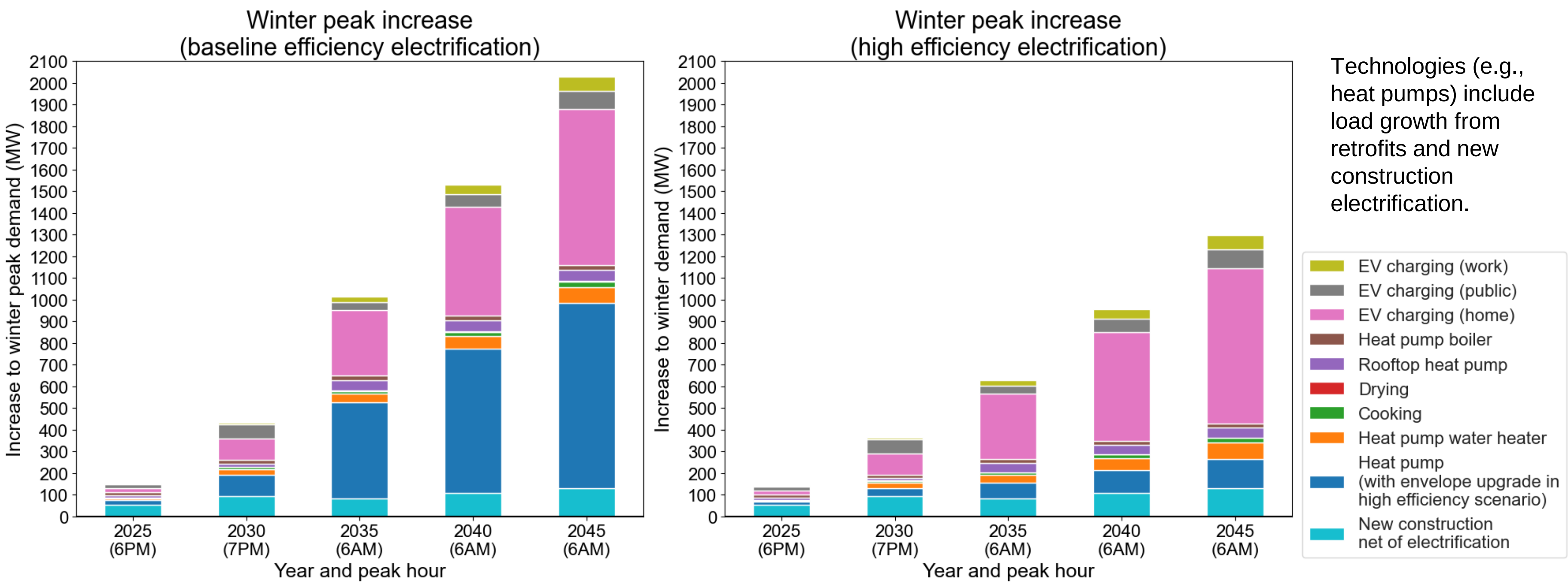
Technologies (e.g., heat pumps) include load growth from retrofits and new construction electrification.

- High efficiency residential heat pumps and envelope upgrades produce net peak demand savings in each year of the study period. During the hours of the 2045 baseline scenario peaks, they reduce:
  - Summer peak demand by ~ 9% and 12 % (~21% in total).
- Efficiency upgrades in cooking and drying account for the remaining ~1% reduction in demand during the hour of the 2045 baseline peak.

High efficiency scenario

Heat pump and envelope upgrades reduce winter peak demand in the baseline scenario by 22%

Baseline efficiency scenario winter peak day

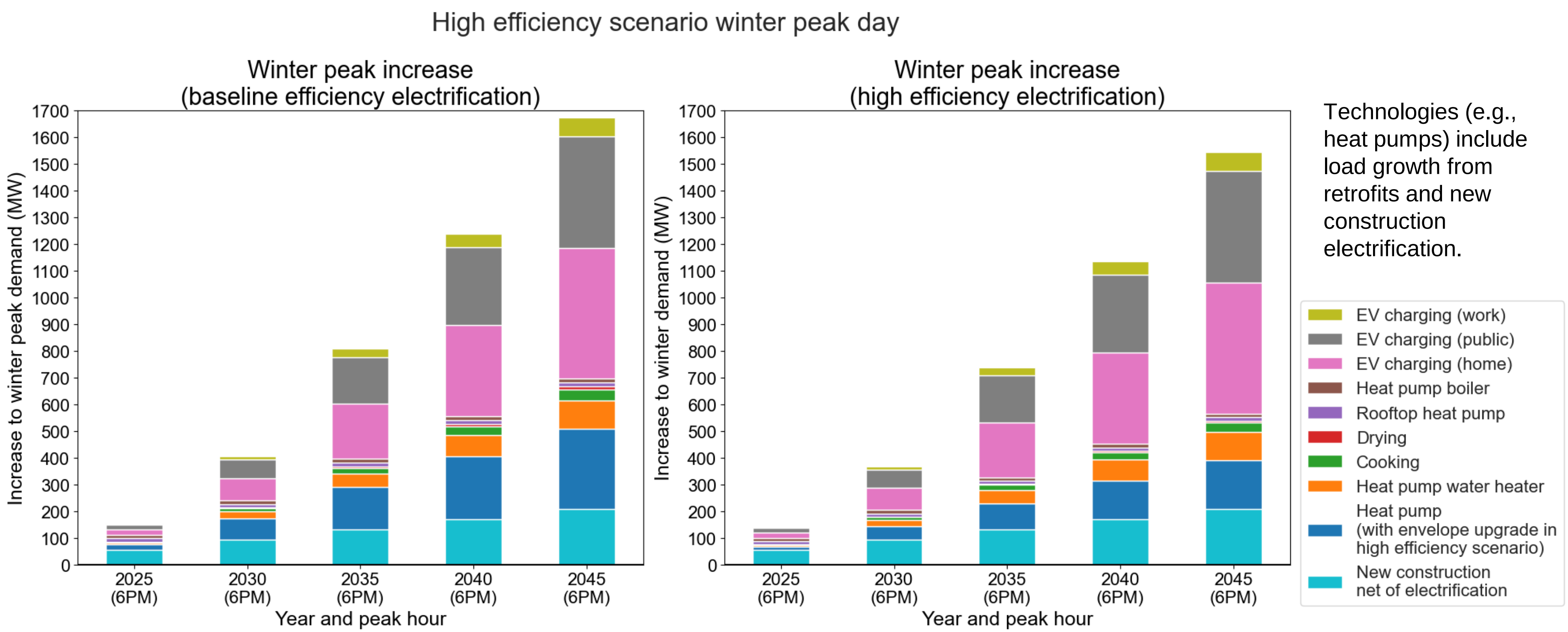


Technologies (e.g., heat pumps) include load growth from retrofits and new construction electrification.

- In the hour of the 2045 baseline scenario winter peak, heat pumps and envelope upgrades reduce peak demand by ~11% (370 MW) and 10% (350 MW), or ~22% (730 MW) combined.
- In the same hour, heat pumps and EVs account for:
  - 42% and 43% of peak demand increases in the baseline efficiency scenario.
  - 10% and 67% of peak demand increases in the high efficiency scenario.

High efficiency scenario

Impact of heat pump and envelope upgrades is smaller during the high efficiency scenario winter peak



- The high efficiency winter peak occurs in evening and has significantly less space heating than the morning baseline efficiency winter peak.
- During the hour of the 2045, high efficiency winter peak, heat pumps and envelope reduce demand by 3.8% combined.

Cold snap scenario

Cold snap scenario

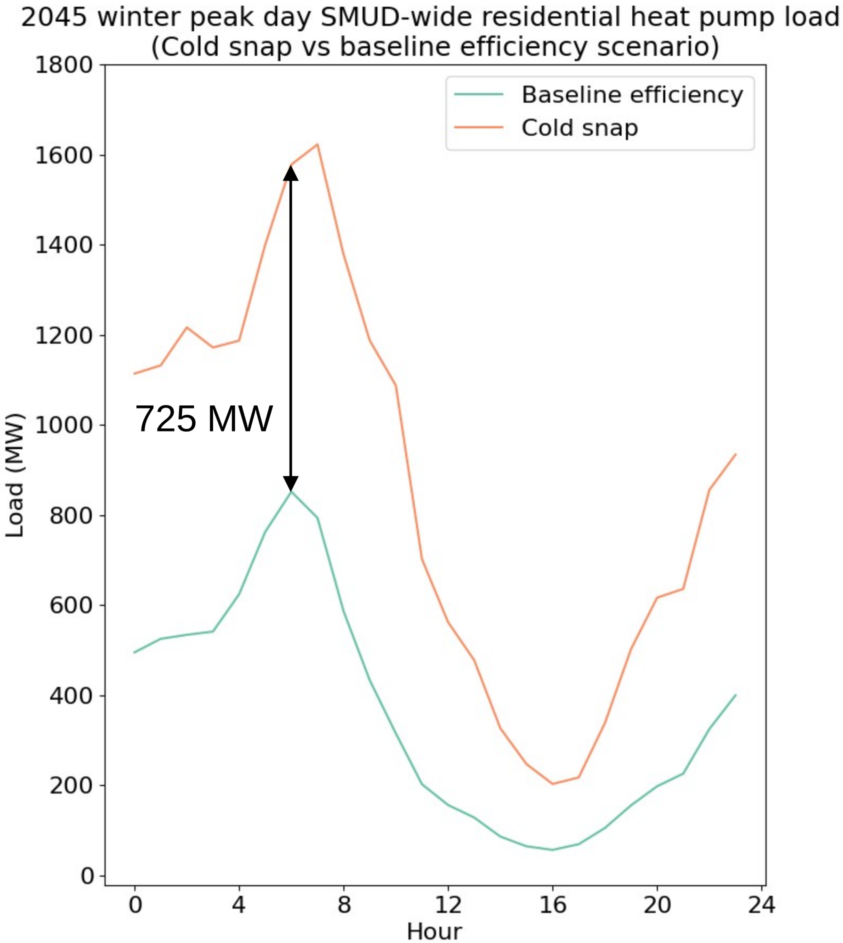
Approach

- We explored the impact of a cold snap on SMUD net system demand in each year of our analysis to address SMUD's uncertainty of the impact of high levels of electric heating on winter morning load.
  - We only consider a single day cold-snap, not a multi-day event.
- We identified a 1-in-10 year cold snap planning temperature (24.8 °F), which occurred on February 23, 2018.
  - The cold snap minimum nighttime temperature is about 15 degrees lower than that of a average winter day in 2018.
  - Since ResStock and ComStock are based on 2018 weather, our forecasts already included the cold-snap day.
- To simulate a worst-case scenario, we assume space and water heating operate at minimum efficiency during the cold snap.
- We then compare load during the cold snap to load on the same day in the baseline scenario.

Cold snap scenario

Heat pump load increases by 85% during cold snap in 2045

- Coefficient of performance (COP) is the standard measurement of heat pump efficiency.
  - It is the ratio of *heating delivered* by a heat pump to *energy used* by a heat pump.
  - Minimum efficiency corresponds to a coefficient of performance (COP) of 1 (the efficiency of electric resistance heat).
- We derived COPs for heat pumps and heat pump water heaters based on hourly electricity usage and delivered heat.
- We then estimated hourly electricity load with a COP of 1 by multiplying the reported hourly electricity load by the derived COP.
  - This approach simulates electric resistance heat meeting every building's heating demand.
- Under these assumptions, 2045 SMUD residential heat pump load could increase 85% (725 MW) during the 6AM winter peak relative to the baseline efficiency scenario.

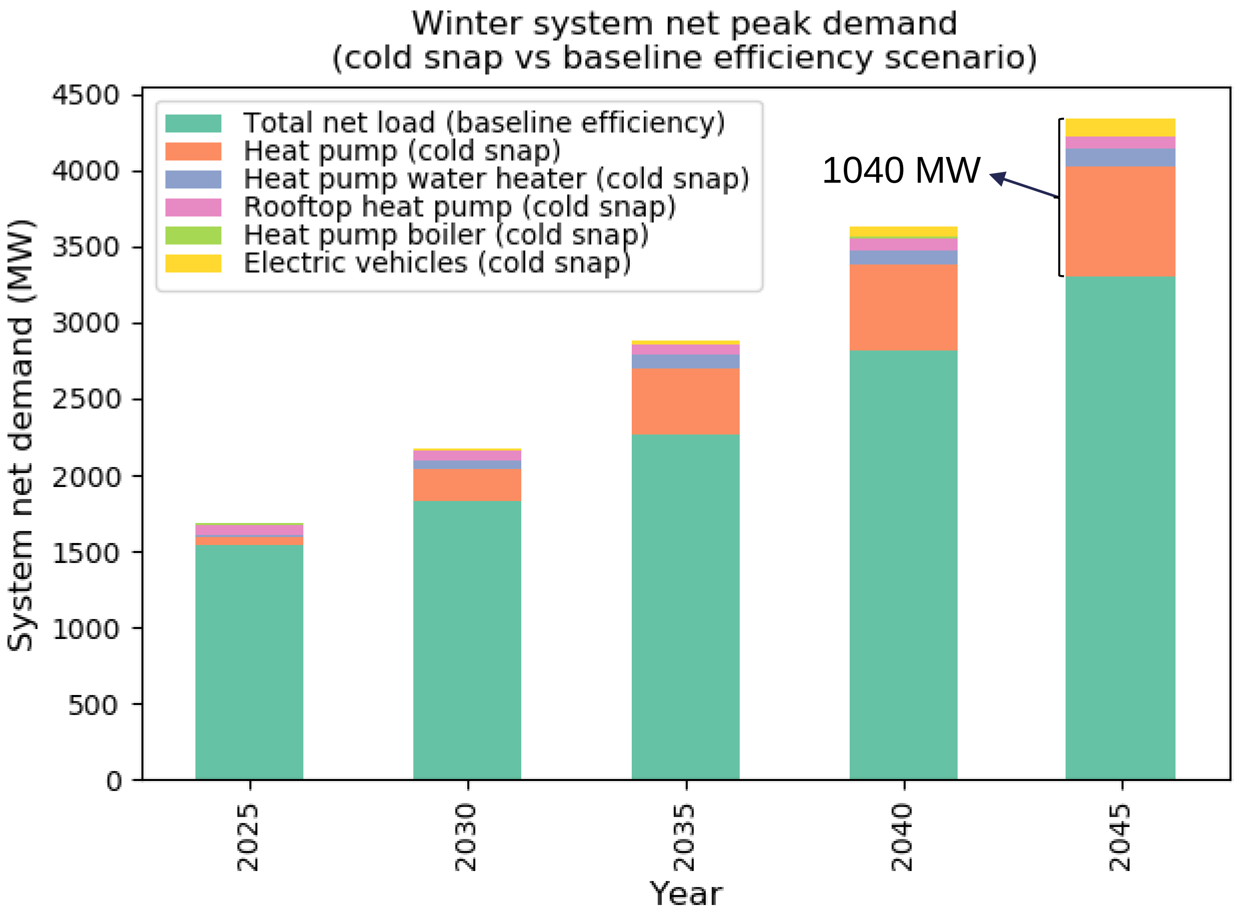


2045 winter peak occurs at 6AM in baseline and cold snap scenarios, but heat pump demand peaks at 7am in cold snap scenario.

Cold snap scenario

Winter morning peak load increases by ~30% (1040 MW) relative to the baseline scenario in 2045

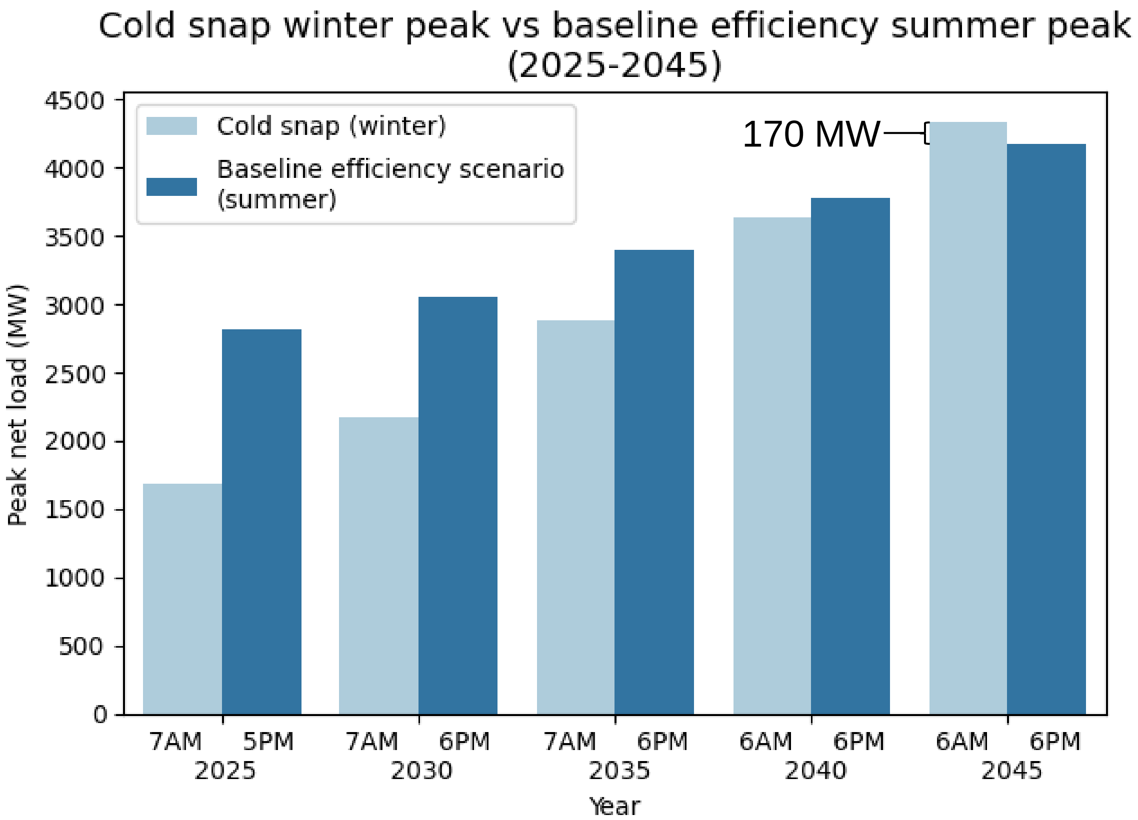
- *Total winter morning peak* demand in 2045 increases ~ 30% (1040 MW) relative to baseline efficiency scenario.
- Heat pumps account for ~70% of the increase in peak demand (725 MW).
- Heat pump water heaters and electric vehicle charging each account for ~11% of the increase (~100 MW).



Cold snap scenario

Using conservative cold snap scenario assumptions, SMUD's system could peak in winter in 2045

- In the cold snap, hourly winter peak demand (4340 MW) exceeds the baseline efficiency scenario hourly summer peak (4170 MW) in 2045 by 4% (170 MW).
- The cold snap scenario is quite conservative.
  - The derived ResStock heat pump COPs were ~2 in the hours around the 1-in-10 year cold temperature (24.8 °F)



Observations

Observations

SMUD system results

- Policy-driven adoption of building and transportation electrification will significantly increase peak demand through 2045.
  - EV charging is be the largest driver of summer and winter peak demand increases in the baseline efficiency scenario.
  - Heat pumps become the largest incremental driver of winter peak demand in the cold snap scenario. EV charging remains a major load but does not significantly increase in the cold snap scenario.
- High-efficiency building electrification can significantly reduce increases in peak demand from building and transportation electrification.
  - High-efficiency heat pumps can reduce peak demand by displacing less efficient air conditioners in both new construction and existing buildings.
- New construction will be a major source of new summer peak demand, regardless of electrification.
- SMUD's system could become winter peaking in 2045 during a 1-in-10 year cold snap during in which heat pump space and water heating systems operate at minimum efficiency.
  - SMUD may want to consider the combination of extreme cold weather and high levels of space and water heating electrification in its planning processes.

Observations

Load forecast methods

- Building energy model-based forecast
  - Technology-level forecasting allows analysts to identify which technologies drive increases in peak demand and where there are opportunities for efficiency and demand flexibility to manage peak demand.
  - Accounting for the range of buildings and usage patterns in a forecast is important for capturing the diversity and coincidence of loads.
  - When using building modeling tools, it is important to compare predicted load shapes to actual load shapes to identify potential model bias in the magnitude and timing of peak demand and the overall load shape.

- Electric vehicle modeling
  - Assumptions on EV charging strategies have a significant impact on the load forecast.
  - Future analysis could explore varying levels of dependence on home, workplace, and public charging as well as the timing of home charging.
  - Future analysis could also explore the sensitivity of EV charging load to temperature as EV penetration increases.

Appendix

Methodological details and additional results

Appendix

Commercial building electrification details

- ComStock represents the energy consumption of 64% of commercial floor area (ComStock documentation). We assume that the remaining 34% of commercial floor area has the same percent change in electricity consumption when the upgrades are installed. Because we apply percent multipliers to SMUD's measured load, we calculate changes in load cover all commercial floor area.
- As of August 2023, the results from upgraded buildings do not include packages of measures, so there are no model results with rooftop heat pumps or heat pump boilers with wall insulation. To estimate the effect of wall insulation on buildings with electrified space heating, we apply the percent change in space conditioning load from the wall insulation measure to the changes in load we calculate for the electrification measures.
- These assumptions apply to all three scenarios.

Appendix

Electric vehicle charging assumptions (1)

Parameter	Input options	Assumption	Rationale
EV technology type	• Partial Hybrid EV (PHEV) dominant - 75% PHEV, 10% 100-mile Battery EV (BEV), 15% 250-mile BEV • BEV dominant - 25% PHEV, 25% 100-mile BEV, 50% 250-mile BEV • BEV/PHEV equal - 50% PHEV, 15% 100-mile BEV, 35% 250-mile BEV	BEV dominant 25% PHEV 25% 100-mile BEV 50% 250-mile BEV	Aligns with current trends in vehicle mixes
Vehicle type	• Sedan dominant - 80% sedan, 20% SUV • SUV dominant- 80% SUV, 20% sedan • Sedan/SUV equal- 50% SUV. 50% sedan	Sedan/SUV equal	Recent LBNL analysis found that changes to the vehicle mix did not affect energy usage and peak demand
Charging location	• Share of drivers that prefer home charging - 60%, 80%, or 100% • Share of drivers that have charging access at home - 50%, 75%, 100%	Medium preference (80%) and access (75%). This blend results in 60% of residential customers home charging.	Combined medium preference and access to reduce dimensions.

Appendix

Electric vehicle charging assumptions (2)

Parameter	Input options	Assumption	Rationale
Charging capacity	• L1 (1.4kW) dominant (80% LI, 20% (L2)) • L2 (6.8 kW) dominant (20%L1, 80% L2) • L1/L2 equal (50%Li, 50%L2)	Residential: L2 Dominant Workplace: L1/L22 equal	Recommendation from EVI-Pro Lite team to other Berkeley Lab researchers
Charging strategy	• Residential/workplace - Max intensity, charge immediately (residential evening peak; workplace morning peak) • Max intensity, delayed charge (residential morning peak; workplace late afternoon/evening peak) • Low intensity, charge immediately (levels charging out over time • Residential only • Overnight	Levelized charging: low intensity, charge immediately. Residential charging takes place from late evening to early morning. Workplace charging peaks midday. Public charging in midday and early evening	SMUD aims for a flat system level EV charging load shape.

L1 = Level 1 charging; L2 = Level 2 charging

Appendix

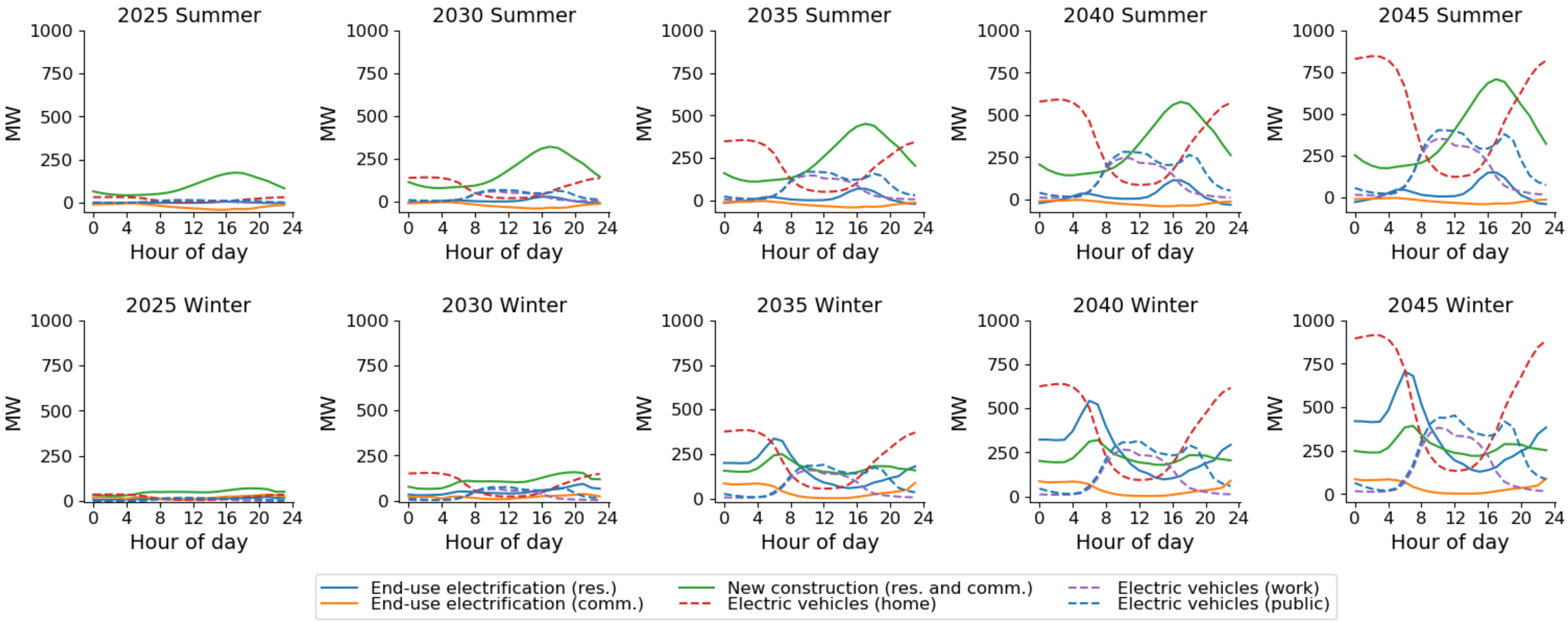
Electric vehicle charging assumptions (3)

Parameter	Input options	Assumption	Rationale
Miles traveled	• 25 miles/week day (low) • 35 miles/week day (medium) • 45 miles/week day (high)	35 miles per week day	Estimated average daily miles driven with FHWA data from 2019 (Sacramento: 32.4) Weekday driving is likely higher but. 45 miles/day would be conservative
Temperature	-20, -10, 0, 10, 20, 30, 40 Celsius	For each month, select temperature that is closest to monthly average temp For cold snap analysis, select temp that aligns with cold snap temperatures	Monthly temperature as default and hourly temperatures during cold snap balances model complexity and research priorities

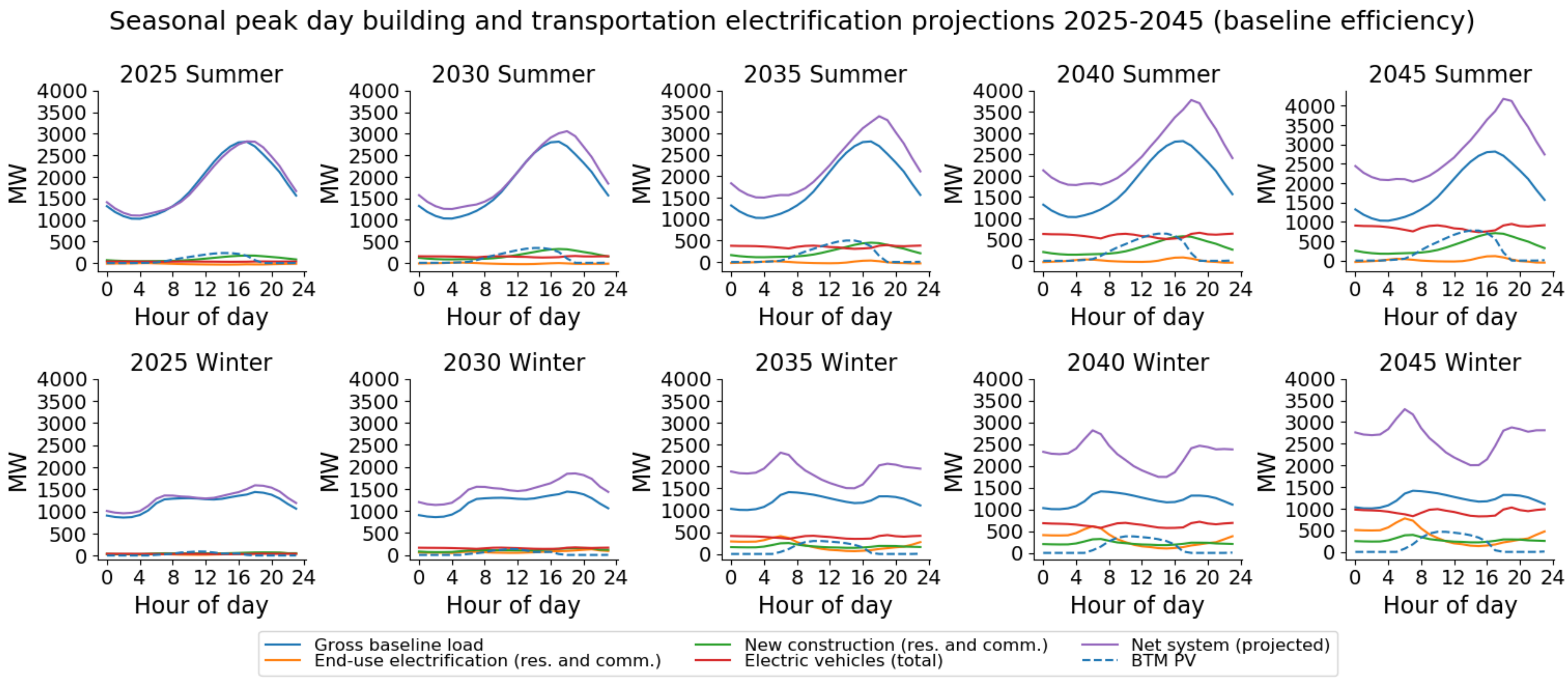
Appendix

Baseline efficiency scenario peak day building and transportation load shapes (2025-2045)

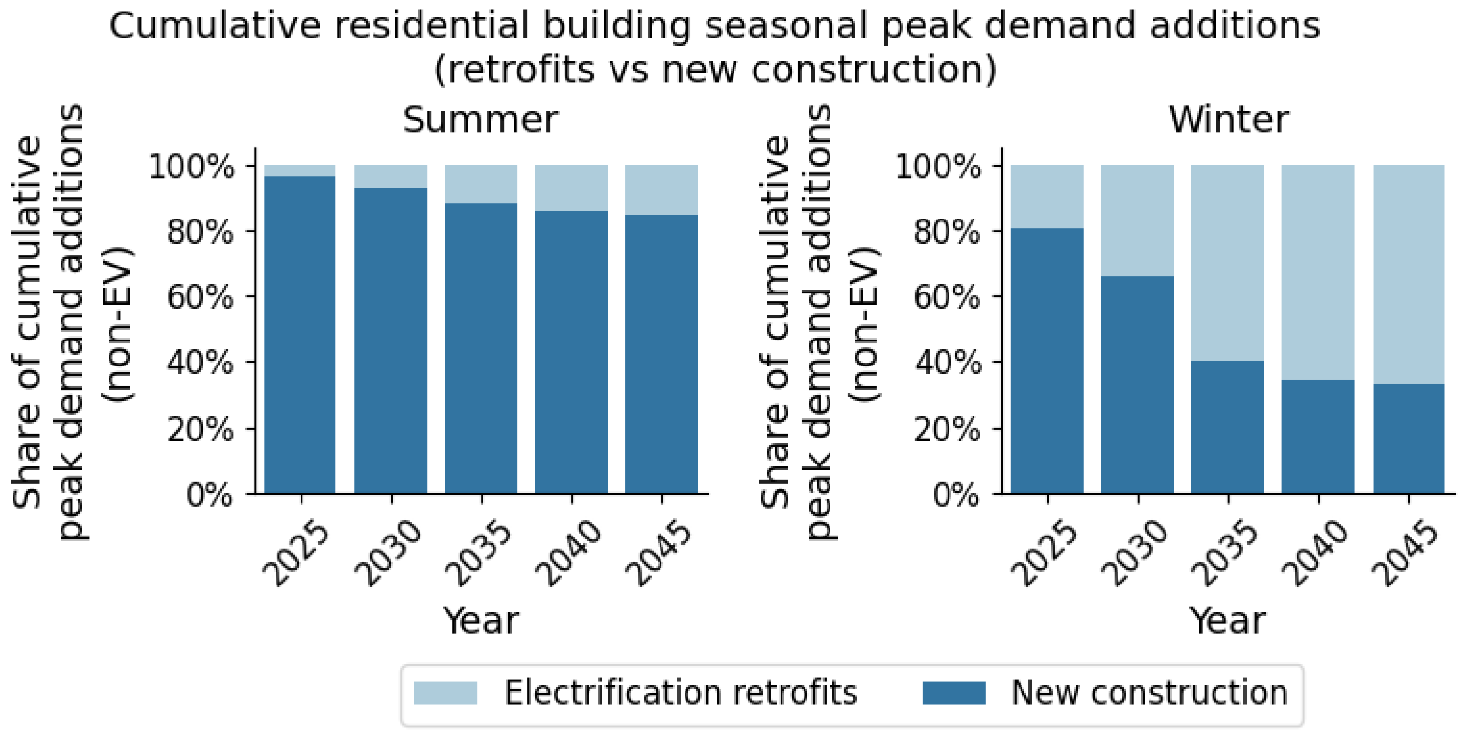
Seasonal peak day building and transportation electrification projections 2025-2045 (baseline efficiency scenario)



Baseline efficiency scenario seasonal net system peak day load shapes (2025-2045)



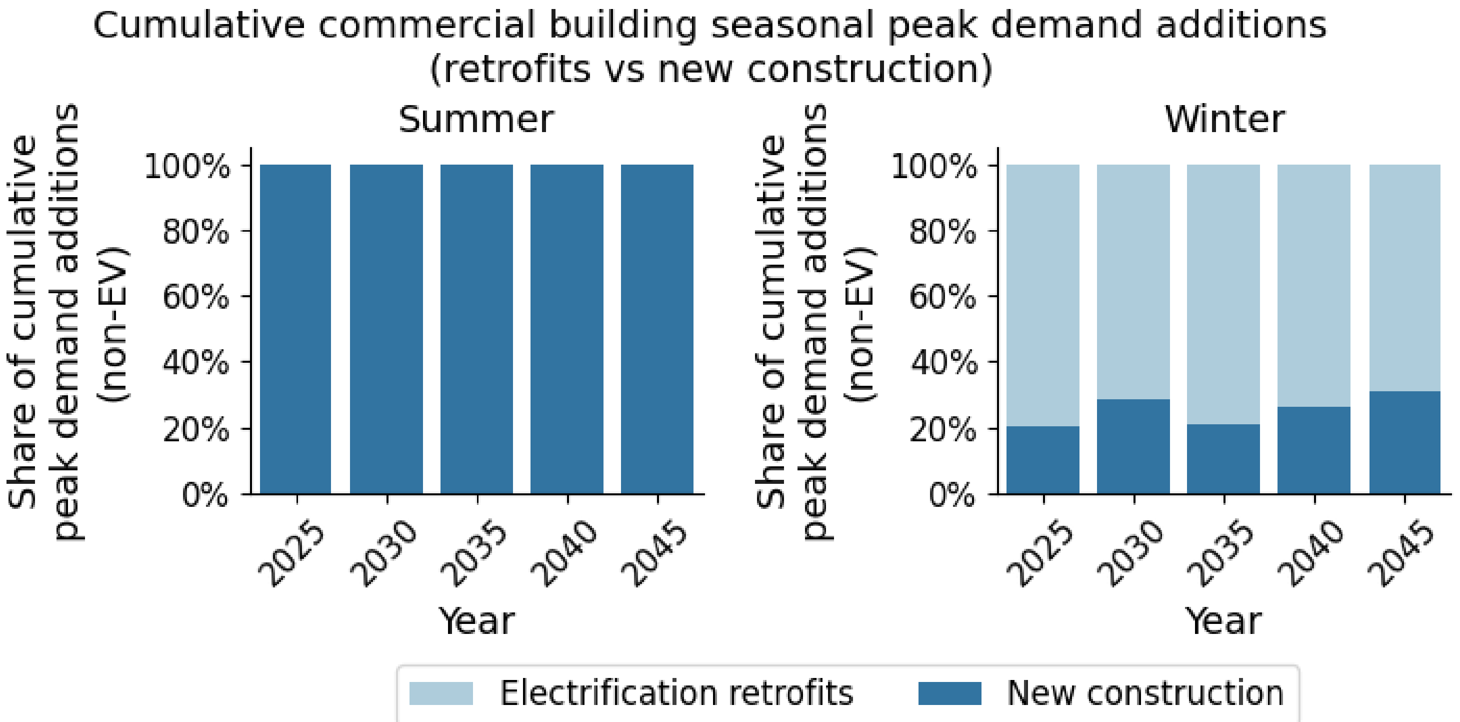
Residential new construction and electrification retrofit impacts in the baseline scenario



- Electrification retrofits increase peak demand in winter more than they do in the summer.
- New construction load increases summer residential peak demand significantly more than electrification in residential buildings.

Appendix

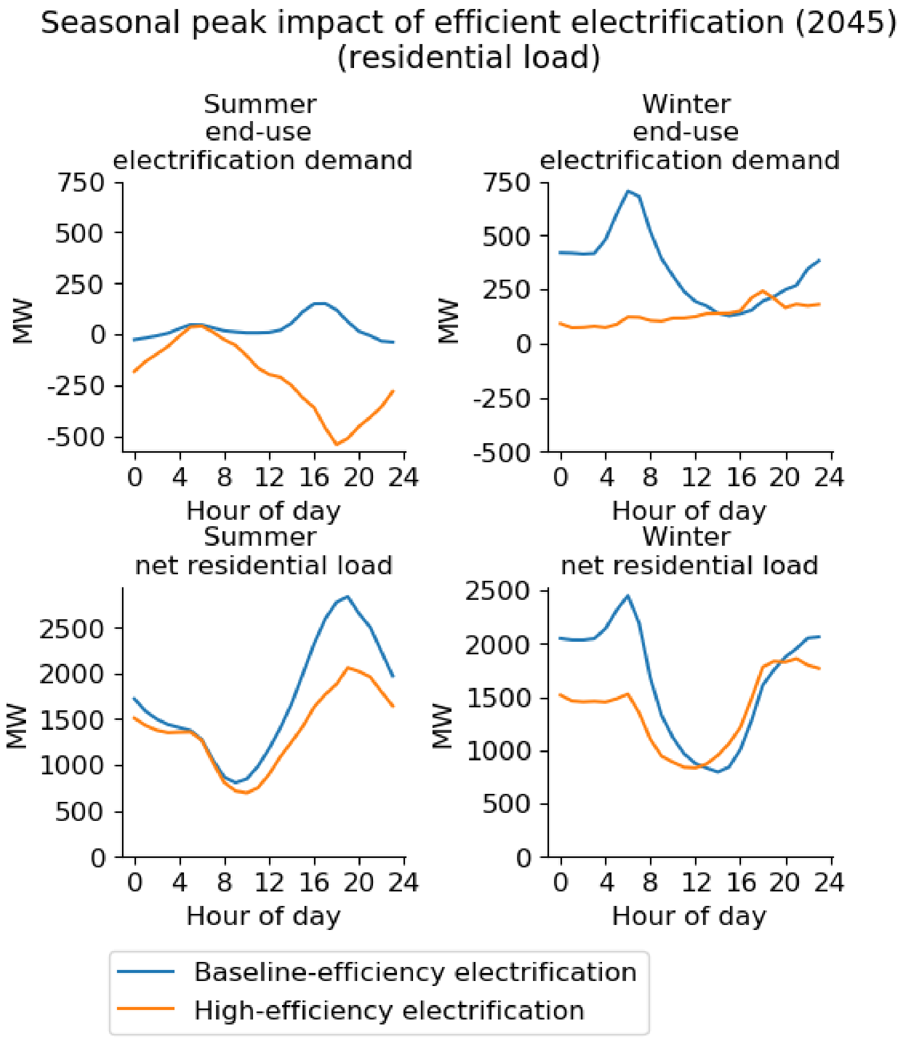
Commercial new construction and electrification retrofit impacts in the baseline scenario



- In the summer, heat pumps lead to net demand reductions by displacing less-efficient air conditioning. As a result, only new construction load increases commercial summer peak demand.
- Electrification retrofits increase winter peak demand.

Residential load impact of high-efficiency electrification

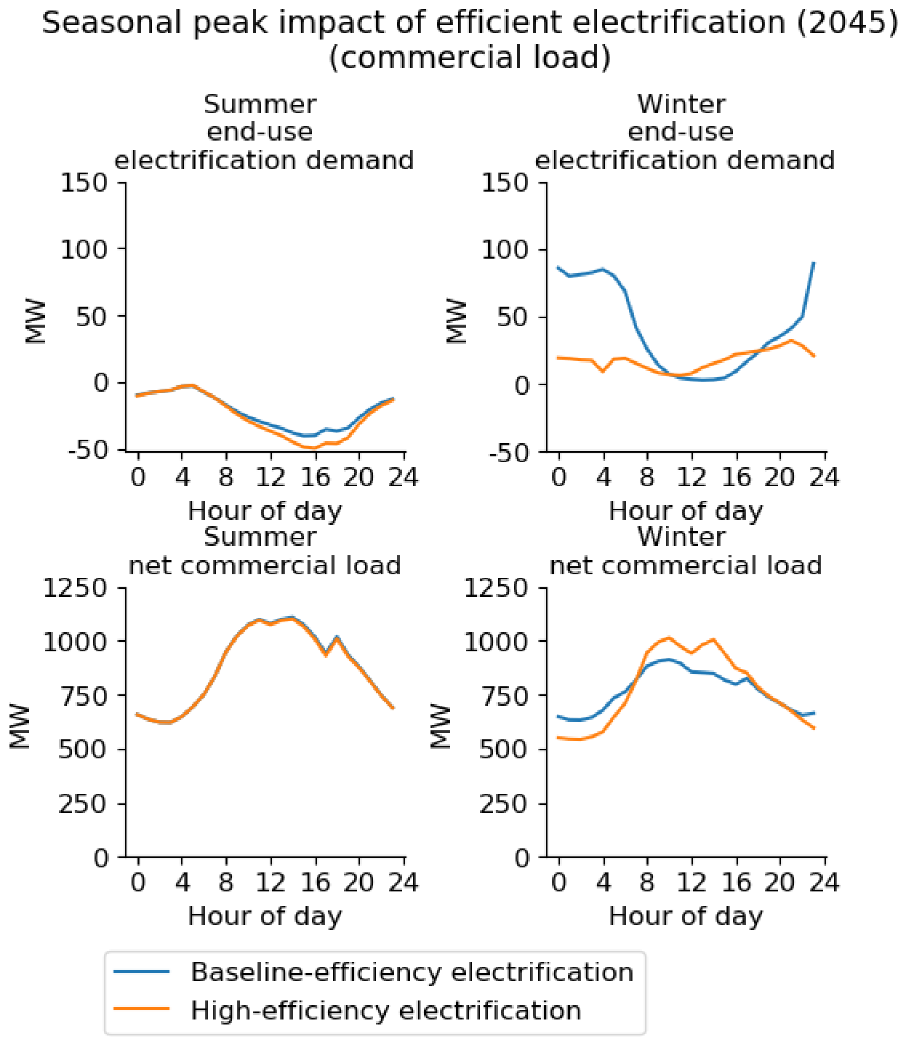
- High efficiency residential electrification yields significant savings in winter mornings.
- The displacement of less efficient air conditioning by heat pumps results.
- There is a net summer peak demand reduction with high efficiency electrification.



Appendix

Commercial load impact of high-efficiency electrification

- Additional wall insulation reduces winter morning heating load in commercial buildings.
- In both the baseline and high efficiency scenarios, rooftop heat pumps and heat pump boilers result in net demand reductions due to displacement of less efficient air conditioning.



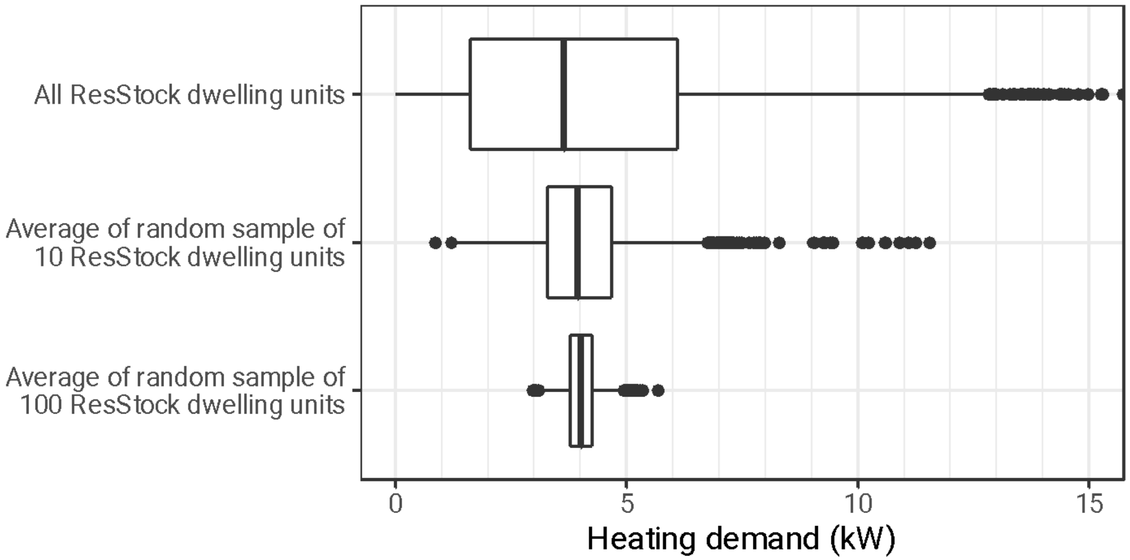
Appendix

Cold snap validation

- With space and water heating operating at a COP of 1, we found that the average SMUD residential building had a demand of 3.4 kW during the cold snap peak.
  - 3.4 kW was lower than SMUD's expectation, given that field data indicate that electric resistance strip heating back up in heat pump systems is typically 5kW.
- We validated this result by analyzing the distribution of peak demand in residential dwelling units (including single and multifamily) in ResStock.
- Importantly, the peak demand values from ResStock that we show in the following slides are not appropriate comparisons to the 3.4kW average estimate. As discussed earlier, when we compared ResStock and SMUD system load shapes for 2018, we found that ResStock overestimated morning heating.
  - However, the distribution of peak demand in ResStock tells us whether our analysis is accounting for variability in the magnitude and timing of dwelling unit peak demand.
- SMUD also performed an analysis that validated our estimate of 3.4kW average residential demand during the cold snap.
  - Using historical metering data, they found an average demand of 3.2 kW for single family customers without EVs on electric-heating rates during the hour of the February 23, 2018 cold snap (see slide 51).
  - SMUD also found that some buildings had demand much higher than the average demand during peak, consistent with the variation we show in slides 49-50.

The magnitude of residential building-level demand varies significantly during cold snap peak demand

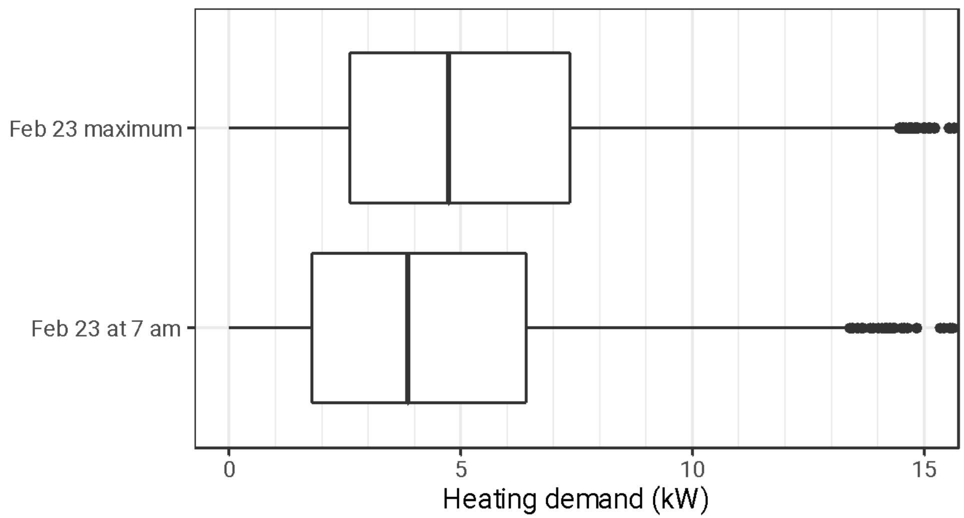
- We found that there is significant variability in peak demand between dwelling units in ResStock during a winter morning cold snap.
  - If we look at random groups of homes in ResStock and average their demand, there is significantly less variability in demand. There still are building that have very high demand, but when we considered many buildings together, such as in a neighborhood or a feeder area, they don't have and outsized effect.
- This variation in ResStock dwelling unit demand during peaks shows that our *average* estimate of 3.4kW per household during the cold snap peak allows for buildings with much higher peak demand.



Appendix

Building peaks do not all coincide with cold snap peak

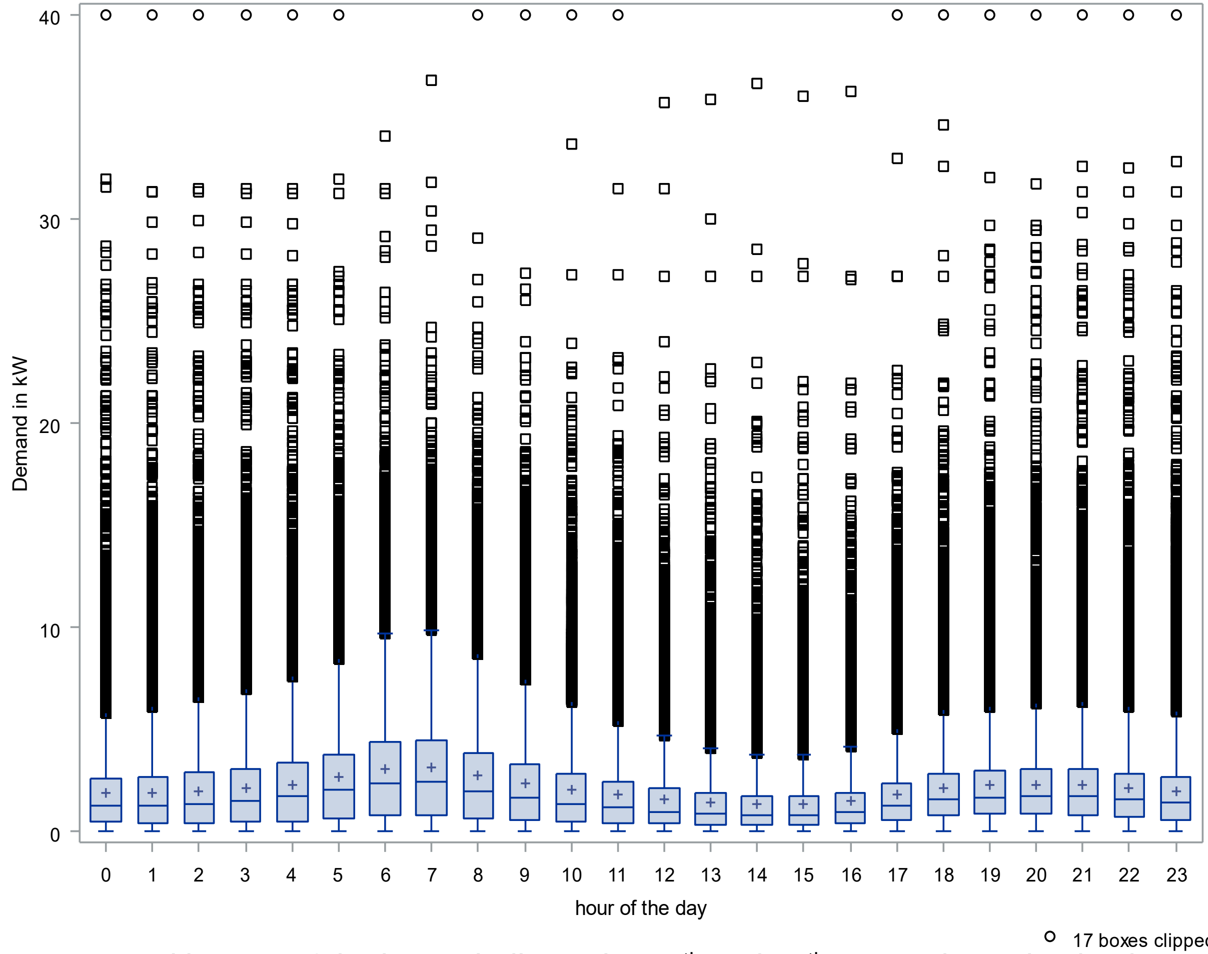
- We also found that on the day of the cold snap, most buildings did not peak during the system peak.
  - The 25th, 50th, and 75th percentile for ResStock dwelling unit peak demand exceed the demand of ResStock dwelling units during the cold snap peak.
- The variation in the magnitude and timing of residential peak demand during the cold snap suggests that planning for winter morning peaks should consider both a diversity of buildings and the coincidence/non-coincidence of their load.



Appendix

SMUD metering data analysis supports cold snap results

- The figure shows average hourly demand during (2/23/18) for all SMUD residential single-family customers without EVs on an electric heating rate (n=29,877).
- During the peak hour (7-8AM), average demand was 3.2 kW, in line with our estimate of 3.4 kW.



Top and bottom of the boxes indicate the 25th and 75th percentiles. The line in the middle of the box indicates the median and the + indicates the average.

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