PECAN STREET

Home Load Control: Extending Smaller Electric Panels as Electrification Expands

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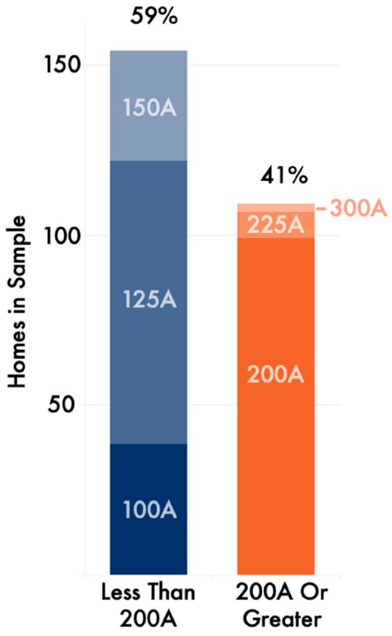
Introduction

Because home electric panel upgrades will be an important element of residential electrification, it is critical to understand how and when they are necessary to prepare homes affordably and reliably while increasing convenience and quality of life.

Most homes built or updated in the last few decades have an electric panel with a capacity of 100 Amps or above. Figure 1 shows the distribution of electric panel sizes from a group of 263 Texas homes in Pecan Street's home energy network. Our previous analysis showed that, in general, homes with 200A panels can almost always fully electrify, while homes with electric panels between 100A - 150A may require panel upgrades, depending on the size of the home and the size and number of "larger" loads like electric vehicle chargers and electric heating.

Figure 1. Sample Homes Above and Below 200 Amp Panel Size



For this report, we explored the impact of increased electrification on homes with smaller panels. We examined second-by-second data from our research network in over 400 homes over the last three years. We scanned more than 12.6 billion data points and analyzed all main breaker loads that exceeded 20kW – a level that would require a 100A main breaker upgrade if the home load is continuous. By studying the home loads and use patterns above this power draw, we can gain insight into the residential load patterns that will drive electric panel replacement over the coming decades.

Quick Takes

- The need for electric panel upgrades will be determined by the largest electric loads in the home. For the foreseeable future, that will be electric vehicle (EV) chargers and heating and air conditioning systems (HVAC).

- In turn, right-sizing EV chargers and HVAC systems will prolong the utility of existing electric panel without requiring a panel upgrade.

- Looking toward a more electrified future, technology that enables home load awareness and flexibility for demand response and virtual power plant (VPP) applications can and should play an increasingly important and capable role in managing demand spikes that would necessitate an electric panel upgrade today.

- The ability to better manage large loads and extend the useful life of existing electric panels will benefit all customers, but especially lower-income families for whom electric panel upgrades would be a disproportionate expense.

Load Spikes at a Glance

Examining home power draws over 20kW offers a glimpse into the future of home electrification because they show home load combinations that can require an electric panel upgrade and can suggest solutions to avoid them. They can serve as a model for how we modify and mass adopt residential electric loads like EVs, heat pumps, water heaters, induction stoves, ovens and dryers, along with all the other existing loads in the home.

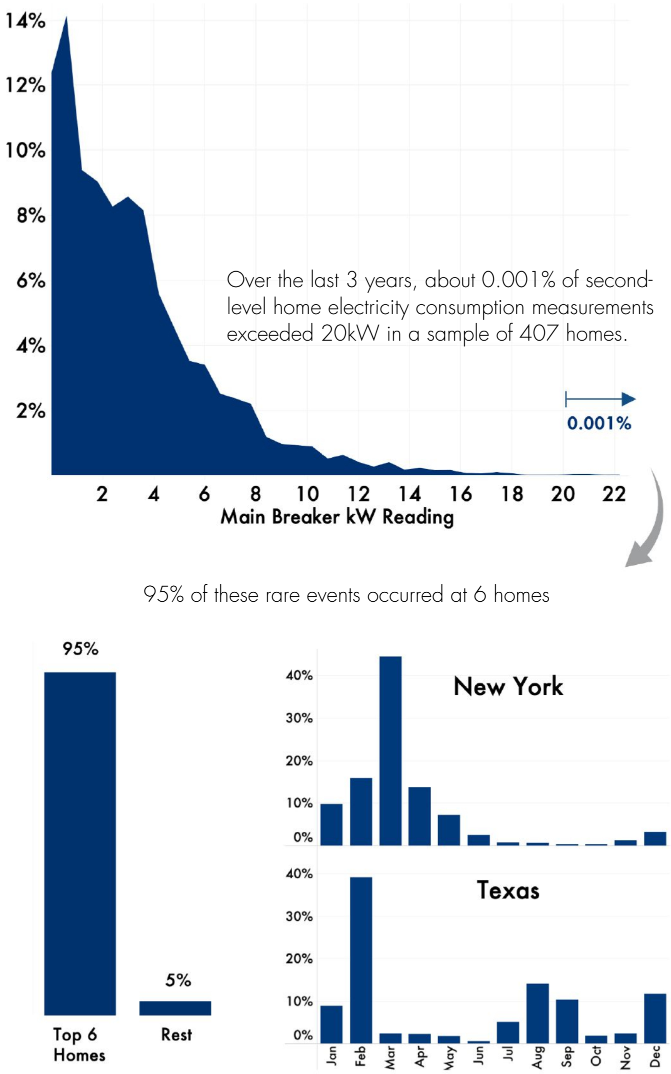
To be clear, the incidence of peak loads above 20kW today is rare; six homes (1.5%) in our 407 home sample accounted for more than 95% of data points above 20kW. These homes have many large electric loads and large electric panels and show the loads and use patterns of homes that are mostly or fully electric. The other 98.5% of homes that account for 5% of the data points above 20kW are more likely to have gas furnaces and less likely to have electric vehicles or large-load electric appliances. However, they still provide valuable insights about the future; more homes will be fully electric and more will have larger loads.

The main loads driving power draws over 20kW were electric resistance heat (i.e., not electric heat pumps), EV charging and combinations of several small to moderate appliance loads.

As homes electrify, they will have more electric loads, and the times those loads coincide will be important for utilities and grid managers. In our New York and Texas homes, we found the most common load driving power draws above 20kW is resistance heating during cold weather. This highlights an important part of the residential electrification transition.

Two-way heat pumps are the most energy-efficient alternative to fossil fuel heat. In most climates, heat pump systems have electric resistance backup heat to assist the heat pump when outside temperatures are very low. But backup resistance heat is far less efficient than heat pumps. Therefore, it's important to right-size the heat pump and backup resistance heat systems to ensure each is most efficiently used. Too small a heat pump system will trigger high electricity use from the resistance heater.

Figure 2. Rarity of 20+kW Loads



Over the last 3 years, about 0.001% of second-level home electricity consumption measurements exceeded 20kW in a sample of 407 homes.

95% of these rare events occurred at 6 homes

New York homes exceeded 20kW almost exclusively in winter.
Texas homes exceeded 20kW in both winter and summer.

EV charging events were the second most common load that pushed home power draws over 20kW. Most home EV chargers draw 7kW or less. However, some can charge at higher rates of 10-19kW, and the number of these moderate- to high-power Level 2 home EV chargers in our network is growing. Higher power achieves a faster EV charge rate but requires a larger share of the home's total amperage and puts more strain on the grid.

The last commonality we saw in homes was many smaller and varied home loads that coincide for a short-lived high power draw. This usually involved thermal cycling appliances like water heaters and refrigerators and event-based loads like cooking and laundry appliances. If these groups of loads are used at similar times, they can align and cause a high load in the home.

A Deeper Dive

Backup Electric Resistance Heat

Residential heat pump installations are poised to rapidly accelerate over the next decade as part of the effort to electrify homes and reduce greenhouse gas emissions. Two-way heat pumps are the most efficient way to heat and cool most homes, but proper installation with consideration for regional climate, home condition and potential auxiliary heating sources play a crucial role in their performance and whether an electric panel upgrade is required.

In our analysis, HVAC electric resistance heat was the most common driver of power draws above 20kW. Auxiliary or backup resistance heat is used to assist and defrost heat pumps in extreme cold weather, and, naturally, the amount of backup resistance heat installed determines the power draw. Ideally, HVAC installers will size the backup resistance heat by considering several key factors to determine how many BTUs and kilowatts (kW) of resistance heating capacity are required to meet the heating demand of the home during extremely cold weather conditions when the heat pump's efficiency decreases. Thus, the local climate is a critical factor. Areas with colder winters and more extended periods of freezing temperatures will require a larger backup heating capacity. Larger homes or those with poor insulation may lose more heat and require a larger backup heating system. Installers will often perform heat loss calculations to determine the insulation's effectiveness and the home's overall heating needs. The capacity and efficiency of the heat pump itself are crucial. More efficient heat pumps can provide more heat and reduce the reliance on backup resistance heating.

In practice, the power sizing for backup resistance heating systems for heat pumps can have a wide range. Backup resistance heaters are inexpensive, so HVAC contractors have a natural incentive to oversize them. But this can place unnecessary stress on the grid and create unnecessarily high power draws on the main breaker.

Another key factor for heat pump installation is proper control configuration. Backup heat is usually activated when there is a certain temperature difference between the thermostat setpoint and the indoor or outdoor temperature. Setting these configurations carefully can maintain comfort without unnecessarily activating the backup heating. Also, it's best to configure the heat pump condenser to turn off while the auxiliary heat is activated to reduce the overall power draw.

Figure 3. Texas Home with Two Heat Pumps in Winter

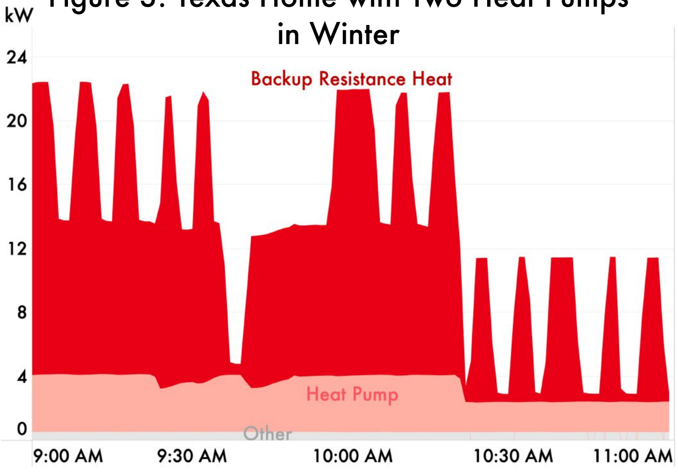


Figure 3 shows a home with oversized backup heat being activated while the heat pump condenser remains in service; the system is pulling 22kW of load. This is not only inefficient, but it can stress the grid in times of peak demand, particularly on cold winter mornings when everyone is trying to warm up their homes. A more ideal configuration for this home could likely size down the backup heating and turn off the heat pump when auxiliary heat is activated. Together, these measures could reduce the power draw 20% to 50%. These considerations will help limit the need for panel upgrades, reduce overall demand on the grid, and save homeowners money.

Electric Vehicle Charging

Level 2 EV chargers provide a balance between charging speed and convenience. Level 2 chargers require a dedicated 240V circuit, and the amperage of the EV charger will determine the size of the circuit required to serve it. On the low end, a 16A charger can draw 3.3 kW. On the high end, an 80A charger can draw up to 19.2kW. If other major uses in the house are electrified, it's easy to see how a high-powered Level 2 charger can bump the total load above 20 kW.

Figure 4 illustrates how, within our network, EV drivers are moving away from very low powered Level 2 chargers (under 5kW) toward 5-9kW chargers. We expect this trend to continue as more people purchase EVs with larger batteries.

When choosing a Level 2 charger, it's important to consider the kilowatt (kW) rating of the charger and the driver's preferences.

Daily Driving Habits - Shorter daily drivers who have the flexibility to charge overnight may be fully satisfied with a 3.3 kW to 7.2 kW charger. Heavy drivers who need larger charges will likely need chargers that can deliver more power to charge faster.

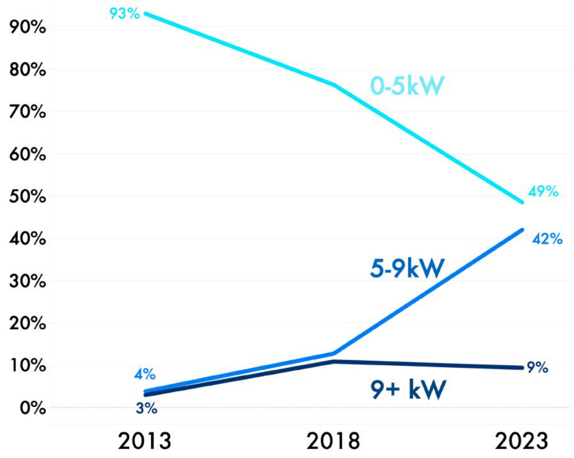
Charging Time - Higher power Level 2 chargers can significantly reduce the time required to fully charge an EV.

EV Battery Capacity - Larger batteries (more range) require more energy per full charge. For instance, an EV with a 100 kWh battery would require 10 hours of a 10kW charge, the same amount of time a 60kW battery would require with a 6kW charge.

Currently, there are several devices, like meter collars and smart splitters, that can help avoid an electric panel upgrade when adding a larger Level 2 EV charger to a home. These solutions automatically switch off the EV charger to avoid tripping a home's main circuit breaker. EV chargers are an obvious first application for this technique because they are extremely flexible and draw a significant amount of power. However, this concept can also be expanded and enhanced to manage other loads in the home while avoiding an electric panel upgrade in a similar manner.

Figure 4. Home EV Charge Cycle Mode (kW)

% of >300K EV Charge Cycles by Binned Mode



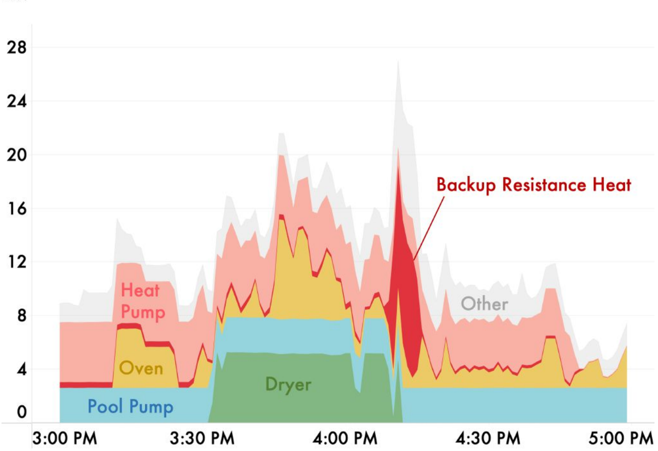
Load Communication and Flexibility

There's a significant opportunity to improve the "manageability" of large loads. Imagine a system or product that could monitor home electricity use and adjust flexible demands, like EV chargers and electric dryers. If an EV is plugged in and set to charge, it could check whether loads like HVAC systems or water heaters are running and adjust the charge time and power level accordingly. Since many loads in the home cycle on and off predictably, the EV charger could charge only when they are cycled off to limit the total power draw of the home and calculate how long it will take to complete charging.

Hardware and software that enable communication between home loads have been introduced piecemeal in a variety of applications over decades. The reason this capability is not widely realized in residential settings is the lack of interoperability between devices (different companies use different protocols and don't share their data) and the dearth of policies and programs from utilities and PUCs that would properly incentivize these functions.

We know EVs can flex their charging to opportune times. But EV charging is not the only opportunity. Figure 5 illustrates other potentially flexible loads in the home.

Figure 5. Texas Home - Winter Day
Electric Backup Resistance Heat + Other Home Loads



Simply making the dryer load mutually exclusive of the HVAC backup resistance heat could avoid a costly electric panel upgrade. If this home had an EV, it could also flex charging around the backup resistance heating. There is further potential to make less common flexible loads like pool pumps mutually exclusive to resistance heating. Since backup electric resistance heat is rarely activated in Texas, developing home solutions to flex certain loads can potentially avoid an electrical panel upgrade with extremely minimal functional consequences.

Beyond extending the life of existing panels, this type of communication and control could be a huge benefit to the grid. Once these devices have remote control capability, they can be aggregated in demand response programs that help the distribution grid in times of need and compensate the homeowner for providing these benefits. Increased home load communication via shared protocols and program development could allow smaller electric panels to serve more loads and allow homes to be more reactive to grid conditions. Both of these outcomes would make residential electrification more popular and more affordable.