Defining the Electrical Panel Barrier to Residential Electrification

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ABSTRACT

As more homeowners are looking to electrify their homes, reports are arising that the premise electrical panel service capacity can present an unforeseen barrier. Some homes may only have 60 A or 100 A service sizes, and when transitioning to electric appliances and vehicles, a panel upgrade may be triggered by code. But how frequently does this occur, and what are the indicators of a home that needs a panel upgrade to accommodate electrification? Furthermore, how much electrification can a home achieve before having to upgrade its panel? In an extensive two-year research effort, we have gathered what we believe to be the first national dataset on residential electrical panel characteristics. Our analysis has derived estimates for main breaker sizes at the national and census region levels. In addition, we have identified correlations between panel size and specific housing attributes and developed a machine learning algorithm to predict the panel size in the current building stock. In this paper, we present our findings and propose possible solutions to address this potential barrier to electrification.

Introduction

Background

Electrical panels, technically named load centers or panelboards, are used in residential and light commercial buildings to distribute electricity throughout the building. Modern panels contain individual breakers for the various branch circuits of a house that allow for safe shutoff of circuits and electrical fault protection. The breaker sizes are determined based on the loads on the circuit with the breaker often being slightly oversized to accommodate the load without unnecessary tripping.

Homes have a single service size for which the electric equipment is designed. The main breaker on the panel, which feeds the branch circuits, is sized to accommodate the service load. This is determined by the licensed electrician or electrical design firm and must be in accordance with the local electrical code which is typically based on the National Electric Code (NEC). The NEC provides guidance for calculating branch, feeder, and service loads in a house according to various characteristics such as building type, floor area, and what appliances/loads are to be installed. Specifically, Article 220[1] provides guidance for primary (Part III) and optional (Part IV) methods for calculating service loads of homes. Common residential service sizes are 100 A, 150 A, or 200 A, but other sizes are possible. The panelboard, main disconnect, service wires, utility meter, and utility transformer are all appropriately sized to power the home safely and reliably. Sometimes, homes are constructed or retrofitted with oversized electrical infrastructure to accommodate future electric needs.

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[1] It is important to note that Article 220 is inherently a safety code and is often conservative in its sizing guidelines. Article 220.87 describes an alternate means for determining existing load of a building using historical demand data (Earley 2023). Utilization of this article can lead to increased electric load allowances whereas the traditional sizing method may be more exclusionary.

Problem Statement

Driven by the need to decarbonize, some states, governments, businesses, and/or individuals are beginning to transition away from natural gas appliances and gasoline powered vehicles. One of the barriers that has arisen is the issue of available electrical service capacity at a home, as prescribed by the NEC. Many homeowners and electrification implementers have encountered long project delays due to new load calculations requiring an upgraded electrical service. Upgrading an electrical service entails new equipment (panel, meter, breakers, wiring, etc.) with certain costs being borne by the homeowner and other costs being borne by the utility. A report by NV5 and Redwood Energy details the variation in costs for some California utilities and provides examples of costs and project timelines, with costs ranging from $2,000-30,000 and timelines extending up to 6-9 months (Pena et al. 2022).

Because of the potential burdensome costs and project delays, it is imperative that the industry better understands the magnitude of this issue. There have been limited studies published on this topic but there are a few notable ones that formed a foundation for this research. Pecan Street, a non-profit research organization based in Austin, Texas, has been researching residential electrical panel capacity and has published a few whitepapers on the topic. From a 2021 report titled *Addressing an Electrification Roadblock: Residential Electric Panel Capacity*, the team found that 35-45 million U.S. homes can support full electrification today, but many homes will need to upgrade their electric service to accommodate electrification (Pecan Street 2021). This study was based on a small sample size of 263 homes primarily in Texas. In a more recent study entitled *Home Load Control: Extending Smaller Electric Panels as Electrification Expands*, Pecan Street shared findings on a U.S. national residential load monitoring study that included 407 homes over three years. The results found that, for the homes monitored, only 0.001% of the second-level data ever resulted in a home's load surpassing 20 kW (~83 Amps) (Pecan Street 2023). The times where 20 kW was surpassed were generally due to electric resistance heat, EV charging, and a combination of other appliances all being on at the same time.

While these are good initial studies, there is a significant gap in data on home electrical panel information and there has not been statistically significant research to support the need for funding to address this barrier.

Paper Overview

To further understand this electrification barrier, EPRI has performed research to illuminate the magnitude of the issue and to identify which regions and building types are most likely to be impacted. The following sections will present EPRI's work on the first national survey of residential electric panels in the U.S. as well as modeling results from the gathered data. The modeling evaluates the impact of various electrification scenarios on home service capacity. Furthermore, machine learning algorithms were applied to predict panel size based on home characteristics such as house size, house age, and heating fuel type.

Materials and Methods

EPRI Panel Survey

In the fall of 2022, EPRI conducted an online survey across the United States to gather information on residential electrical panels. The survey was conducted through a third-party provider. Each respondent was asked 15 questions about their household characteristics such as breaker information, home size, and appliance ownership. Additionally, the survey collected demographic information and asked respondents to include a photo of their electrical panel. The photos were used to validate the responses about breaker size and open breaker slots. The final survey data included 2,949 responses, 1,857 of which were from respondents living in single-family detached homes. Based on the demographics of the participants, the third-party survey host listed the national margin of error at 2% and the census region margin of error at 3-5%.

Figure 1(a) shows that across all survey respondents about 21% had main breakers of 100 A or less (dark blue). In the Midwest and Northeast 33% and 27% respectively had main breakers of 100 A or less. As expected, in the highly electrified South only 12% of respondents had main breakers of 100 A or less. Additionally, in each region about 10% of respondents had main breakers of 101-150 A (orange). Despite the large concentration of respondents with small or medium sized breakers, about 36% of respondents across the US were unable to find their main breaker size (light blue and green).

When looking only at single-family homes, as shown in Figure 1(b), the percentage of respondents unable to identify their main breaker shrinks to about 23% nationally. In single-family home respondents the percentage of those with small or medium breakers stays similar and the percentage of respondents with 150-200 A breakers grows as compared to all respondents. Because many multi-family residences do not have in-unit main breakers and landlords or property managers are likely to be responsible for service upgrades rather than tenants, the team opted to focus on single family homes for the remainder of the project. The rest of this paper will follow suit.

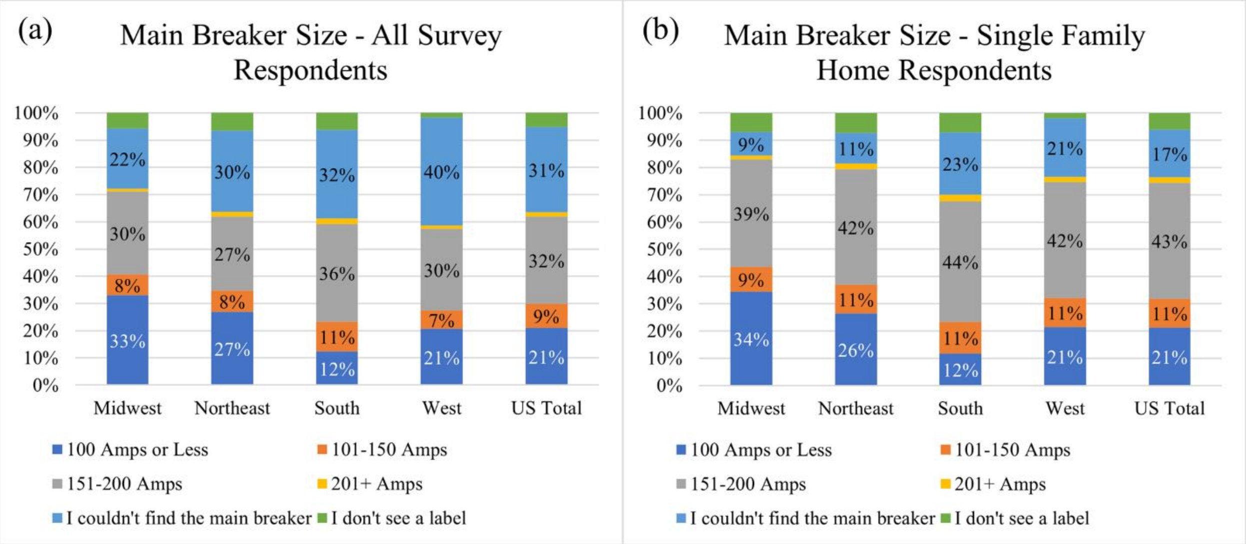

Figure 1: (a)- main breaker size for all survey respondents (n=2,949) and (b) for single family home respondents (n=1,857).

Figure 2(a) shows that respondents living in smaller homes are more likely to have 100 A or less main breakers. As shown, 37% of respondents living in single family homes smaller than 1,000 sq ft have 100 A or less main breakers, while only 7% of those living in homes larger than 2,500 sq ft have small breakers. Similarly, Figure 2(b) shows the breakdown of main breaker size by home vintage for respondents residing in single-family homes. As shown, the percentage of respondents with main breakers of 100 A or less decreases in newer homes. Specifically, over 39% of respondents living in homes built before 1960 have main breakers of 100 A or less. In homes built after 2000 this number is less than 5%. This is significant as older homes are more likely to have structural problems or not be up to code, which could increase the cost and complexity of a service upgrade.

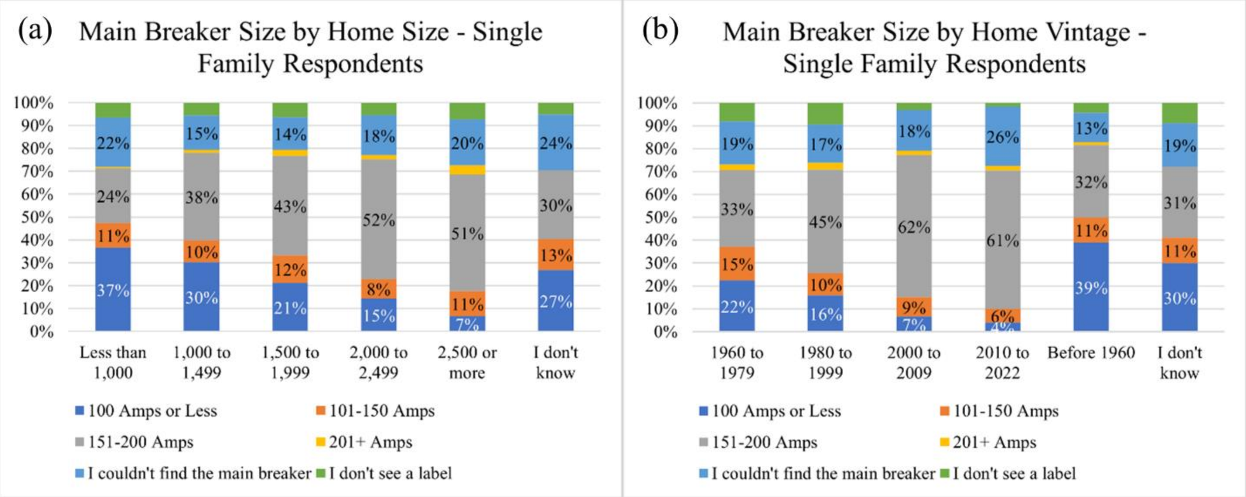

Figure 2: (a) Home size vs main breaker size for respondents living in single-family homes (n=1,857). (b) Home vintage vs main breaker size for respondents living in single-family homes (n=1,857).

Service Upgrade Model

The survey of residential electrical panels revealed that over 20% of respondents residing in single-family homes have main breakers of 100 A or less. An additional 11% of respondents have breakers of 101 A -150 A. Many of these homes rely on fossil fuels for large appliances and vehicles. This means that the addition of large loads such as electric vehicle charging equipment or heat pumps could trigger a service upgrade.

To get a better understanding of which homes may need service upgrades to accommodate electrification, the EPRI team built a computational model to calculate needed service sizes under different electrification scenarios. The model takes a bottom-up approach by using each individual survey response to perform the calculations. The backbone of the calculations is Part IV of Article 220 in Chapter 2 of the 2023 NEC. This section of the electrical code details the optional method for performing feeder and service load calculations. The optional method is only applicable to dwelling units with loads served by a single 120/240V or 120/208V supply. The team opted for employing the optional method in their calculations as less site-specific knowledge is needed as compared to the general method.

To assess the impact of varying degrees of electrification, multiple equipment adoption scenarios were selected by the project team. The scenarios modeled were by no means all encompassing. Rather they intended to capture nationally average technology adoption possibilities, describe the current system state, and isolate the effects of specific electrification efforts. More granular studies could better address the impacts of location specific technologies such as cold climate heat pumps or multiple EV chargers. This paper will report upon the following 4 scenarios:

- **Electric Vehicle Adoption:** In this scenario each respondent who currently does not have an EV adopts one and installs one 32A charger (40A double pole breaker). No other changes from the baseline survey responses are made. This scenario analyzes the effects of installing electric vehicle service equipment (EVSE) in single-family residences.
- **Heat Pump Adoption with Backup Strip Heating:** In this scenario each survey respondent with non-electric heating equipment installs a single-speed heat pump with backup strip heating. Heat pumps are assumed to have heating COP=3 and cooling COP=3.5. Backup heating is assumed to have COP=1. The heat pump is sized to accommodate the larger of the heating and cooling load. The backup heating is sized to accommodate the entire heating thermal load. This scenario aims to analyze the effects of installing heat pumps in single-family residences.
- **Full Electrification without Backup Strip Heating:** In this scenario each household is assumed to have adopted a 32A EV charger and all electric appliances. If the respondents have fossil fuel-based heating, they are assumed to adopt heat pumps as described in the previous scenario, but without backup strip heating (like with multi-split heat pumps). This scenario aims to assess the impacts of whole home electrification without backup strip heating. Strip heat has a large impact on service sizing so the elimination of it can help prevent the need for a service upgrade.
- **Full Electrification with Backup Strip Heating:** This scenario is the same as the previous but assumes backup heating is installed with all heat pumps. This scenario aims to assess the effects of electrifying entire households, adding a 32A EV charger, and installing heat pumps with backup heating as sized in the heat pump adoption scenario.

Although the NEC provides some general numbers to use for calculating service size, the nameplate rating of large appliances is needed to accurately complete the calculations. The EPRI survey asked respondents which appliances they owned and, where applicable, what fuel type the appliances use, but it did not collect any information on the technical specifications of the equipment. Because of this, many assumptions regarding appliance size were needed to complete the service sizing calculations. For most large appliances – clothes dryers, ranges or cooking equipment, water heaters, EV charging, hot tubs, and pool pumps – a single nameplate value was applied to each respondent. These values were determined through market surveys of common products and in-house subject matter expertise. For HVAC equipment, an EPRI developed residential HVAC sizing tool was used to determine nameplate power of heating and cooling equipment. The tool takes climate zone, home size, and equipment COP as inputs. For other electrical loads such as lighting and small appliances the NEC provided values were utilized.

Figure 3 shows the percentage of respondents to the EPRI Panel Survey who would trigger a service upgrade by scenario according to the NEC method applied in the service upgrade model. Figure 3(a) shows all respondents, and Figure 3(b) shows only respondents with 100 A or smaller main breakers. As shown, in the Full Electrification with Backup Strip Heating scenario, 24% of all respondents and 83% of respondents with small breakers would trigger a service upgrade according to the methodology used. When looking at the Full Electrification

Scenario without Backup Strip Heating, the percentage of respondents who would trigger service upgrades shrinks to 15.5% for all homes and 56.9% for homes with small breakers. This is a significant decrease in the number of respondents triggering upgrades that indicates installing heat pumps without backup heating may mitigate the need for a service upgrade in many instances. When looking at the EV and Heat Pump Adoption Scenarios, around 4% of all survey respondents and 15% of respondents with small breakers would trigger a service upgrade.

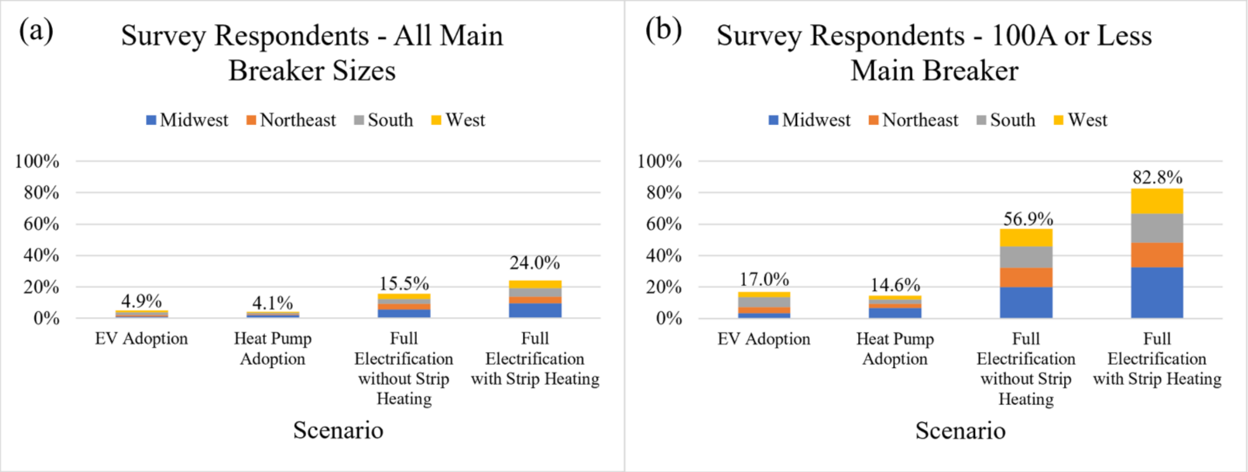

Figure 3: (a) Percentage of EPRI Panel Survey respondents triggering a service upgrade under various electrification scenarios (n=1,419). (b) Percentage of EPRI Panel Survey respondents with main breakers 100 A or smaller triggering a service upgrade under various electrification scenarios (n=395).

Random Forest Classification Model

Because such a large portion of the panel survey respondents were calculated to trigger service upgrades under full electrification scenarios, the EPRI team sought to extrapolate their results to larger housing datasets. The team did this through a machine learning random forest classification model. Machine learning facilitates the exploration of intricate patterns and interdependencies among variables present in the panel survey data, enabling predictions about electric panel size for buildings not directly surveyed. In this work, a supervised learning approach was used in which a random forest classifier was trained with the panel survey data collected. The machine learning model was then used to predict the main breaker size of all single-family homes in the U.S.

Random forests serve as powerful and accurate predictors for both classification and regression problems. Their training process involves randomly selecting and subsampling data for different decision trees, alongside a random selection of input features. This methodology ensures robustness against overfitting (Breiman, 2001). Additionally, the independence of each individual decision tree and the randomness in forming subsets of input data make random forests insensitive to outliers and noise (Chan and Paelinckx, 2008). Furthermore, they can handle heterogeneous data from various sources, units, and scales, as they do not require a normal distribution of input data.

Decision trees are the fundamental building block of a random forest classifier. They are constructed by iteratively splitting the feature space until the resulting training samples in the branches exhibit low predictive error. This iterative process continues until a predefined maximum tree depth is reached. To predict the response variable of a test sample, the input features are fed into all trees and individual tree predictions are averaged. This approach improves the performance compared to individual predictors (Izenman 2008).

A total of seven housing characteristics, namely building vintage, building size, presence of central air conditioner, space heating fuel, water heating fuel, clothes dryer fuel, and cooking fuel, are utilized as features for predicting the size of the main electric breaker. Features and labels are extracted directly from EPRI's panel survey as categorical variables with the values listed in Table 1. The learning dataset is divided into a training and a test set with an 80:20 split. The number of trees in the forest and the maximum depth of a tree, i.e., the main parameters of a random forest classifier, are determined through a sensitivity analysis, wherein both parameters are varied, and the model's accuracy is calculated. Given the training dataset, the classifier with the highest accuracy in this work results from 361 independent trees with a maximum depth of seven. The overall model accuracy achieved was 70%.

Table 1: Label and features from panel survey used for training supervised machine learning model.

Description		Abbr.	Values
Label	Electric panel size	amp	<=100 A, 101-150 A, 151-200 A, >201 A
Feature	Building vintage	bv	< 1960, 1960-1980, 1980-2000, 2000-2020, >2022
Feature	Building size	bs	small, large
Feature	Presence of air conditioner	air	yes, no
Feature	Space heating fuel	sph	electric, gas, other
Feature	Water heating fuel	wth	electric, gas, other
Feature	Clothes dryer fuel	dry	electric, gas, other
Feature	Cooking fuel	ckg	electric, gas, other

The performance of the trained random forest classifier is summarized in the confusion matrix in Figure 4(a) where the expected values are compared against the predicted panel size category in the test set (20% of the data). In the confusion matrix, the number in each cell denotes the number of samples and the background color indicates the density estimation of the prediction. Higher numbers and darker background colors signify more accurate predictions. Notably, the machine learning model adeptly characterizes the panel size category of 151-200 A, with a significant proportion of test samples correctly predicted within this range. Additionally, samples featuring small electric panels (<=100 A) are also effectively characterized by the model. The most influential housing characteristics for predicting panel size include building vintage, water heating fuel, and building size, as illustrated in Figure 4(b).

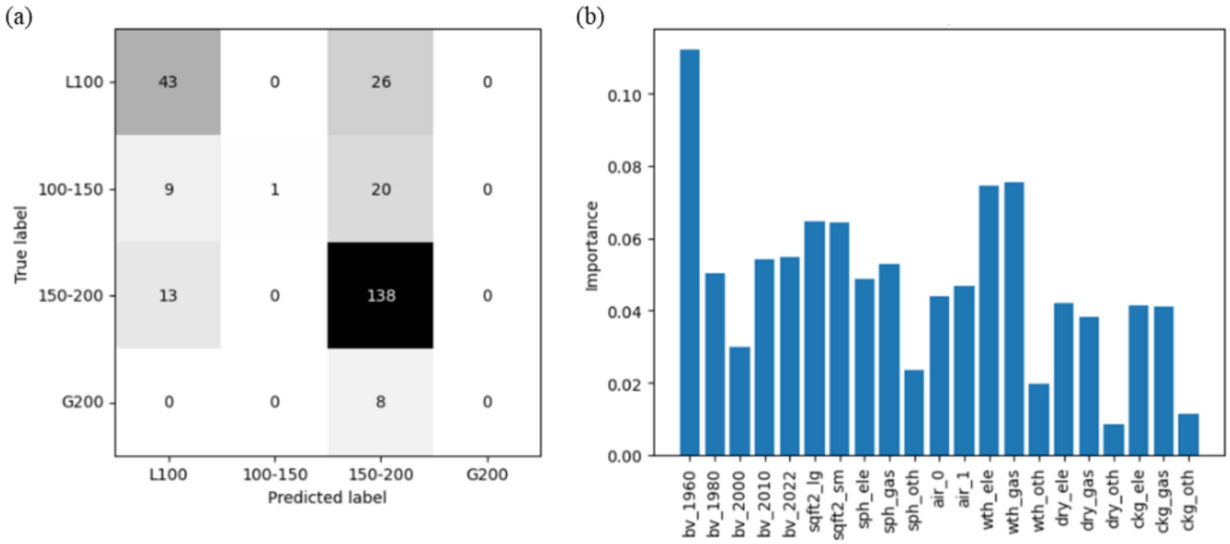

Figure 4: (a) Confusion matrix and (b) feature importance of random forest classifier with 361 independent estimators, a maximum tree depth of seven and an overall accuracy of 70%.

Predicting Electric Service Sizes Among Single-Family Homes in the U.S.

The random forest classifier trained with EPRI's panel survey data as described in the previous section, was used to predict the panel size category of all detached single-family homes in the U.S. The housing characteristics, required as input features for the model, were extracted from the 2020 Residential Energy Consumption Survey (RECS). Figure 5 shows the estimated number and share of detached single-family homes by panel size category. Among the 76,633,279 detached single-family homes reported in the 2020 RECS, our model estimates that 75% have a panel size within the range of 151-200 A, while 23% have a panel size 100 A or below. The distribution predicted with the random forest classifier for the four census regions is shown in Figure 6.

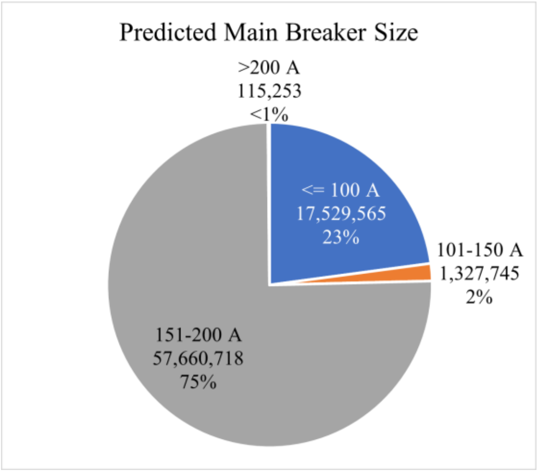

Figure 5: Distribution of electric panel sizes among detached single-family homes in the U.S., predicted using a random forest classifier trained on EPRI's panel survey data and applied to the 2020 RECS dataset.

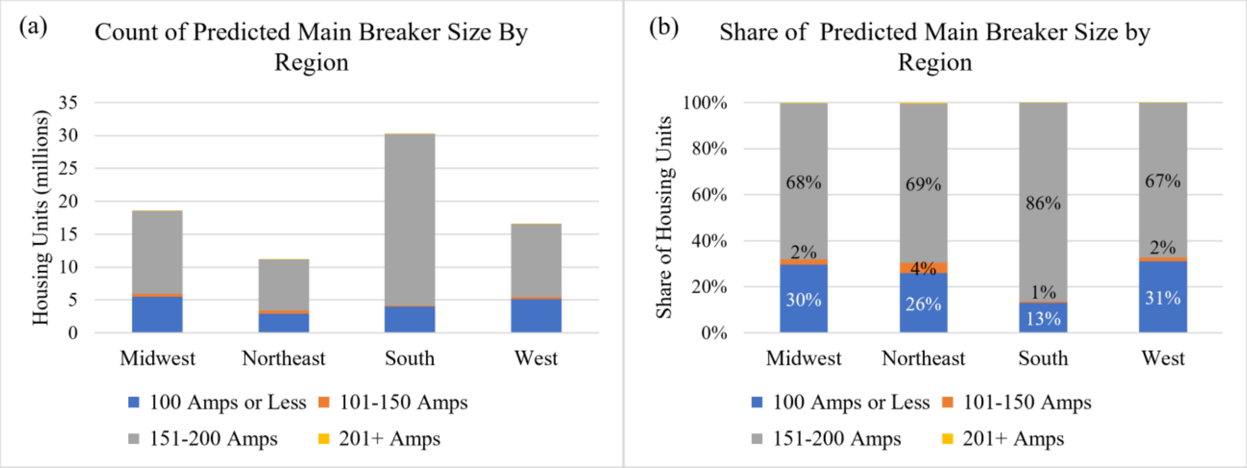

Figure 6: (a) Predicted count and (b) share of detached single-family homes by panel size category for census regions using random forest classifier.

Service Upgrade Prediction

To assess the number of homes across the United States that may need service upgrades, the EPRI team input the 2020 RECS data with predicted electric breaker sizes to the service upgrade computational model. As discussed in the previous sections, the random forest classifier predicted ranges of service sizes for each home rather than a single value. Because of this, the team had to make an assumption about the value within the range to allow for comparison with calculated values. A single value was assumed for each range as there are some panel sizes that are most common and assuming a single value simplifies the modeling approach. Table 2 shows the mapping of range to single value. Using these assignments, if a respondent was calculated to need a service size greater than the single applied value it was assumed a service upgrade would be needed.

Table 2: Range to value mapping for predicted amperages.

Amperage Range	Value Used for Calculations
<= 100 A	100 A
101-150 A	150 A
151-200 A	200 A
>201 A	225 A

Figure 7(a) shows the breakdown for all 76.6 million US single-family homes represented by the RECS. Under the assumptions employed by the service upgrade model and the predictions made via random forest classification, 21.1% of all homes would trigger service upgrades with full electrification. This corresponds to 16.2 million single-family homes across the United States that may need service upgrades to accommodate electrification. The plot also shows that 11.3% of homes would trigger an upgrade in the scenario where homes fully electrify but do not install backup strip heating with heat pumps. Though this is still a substantial number of homes (8.7 million), it highlights the importance of assessing different technologies to mitigate service upgrades.

As shown in Figure 7, in both homes with small breakers and all US homes, the percentage breakdowns of the RECS homes are similar to the breakdowns of the panel survey respondents' homes. The most significant discrepancies lie in the EV adoption scenario, where a significantly smaller percentage of all US homes are calculated to trigger service upgrades as compared to the EPRI panel survey respondents. The reason for this discrepancy could be legitimate, due to the much larger housing stock represented in the RECS. Or it could have to do with modeling limitations, such as small datasets and lack of numerical data. Nevertheless, the results shown in Figure 7 seem to further indicate that many homes will likely trigger service upgrades with electrification.

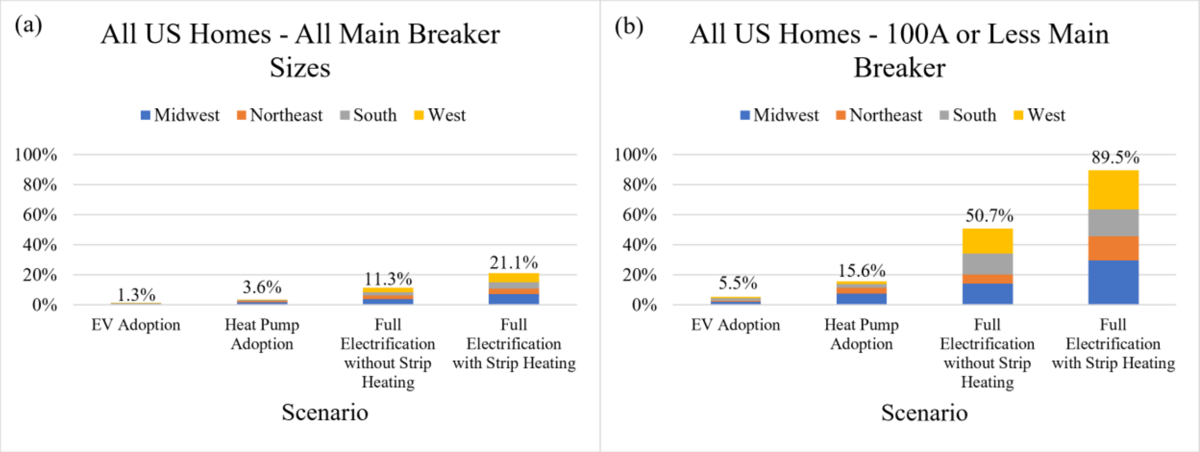

Figure 7: (a) Percentage of RECS represented single-family homes triggering a service upgrade under various electrification scenarios (n=76.63 million). (b) Percentage of RECS represented single-family homes predicted to have main breakers of 100 A or less triggering a service upgrade under various electrification scenarios (n=17.52 million).

Figures 8 and 9 show the results of calculating needed service size of all RECS represented homes for the four electrification scenarios. The X-axis of the plots is the predicted panel size, and the Y-axis is the calculated size needed under the scenario specified. Randomly distributed noise was added to the X-axis for visualization purposes. Each dot on the plots represents one of the 11,950 single-family home respondents to the RECS. The size of the dot represents the weight of the point according to the RECS dataset. As shown, no homes predicted to have service sizes over 200A would need service upgrades in any of the four electrification scenarios selected. Despite this, in each of the four scenarios, some respondents with service sizes predicted to be 151-200A (200A assumed for calculations) may need service upgrades. Additionally, some of the homes in the 151-200A category were predicted to need service sizes up to nearly 250A, indicating that 200A may not always be sufficient.

Figure 8(a) shows the results for the EV adoption scenario and Figure 8(b) shows the results for the heat pump adoption scenario. The spread of calculated service sizes is much larger with heat pump adoption as compared to EV adoption. This is expected as thermal equipment varies in amperage with home size and climate zones while EV charging does not. Figure 9 compares full home electrification without 9(a) and with 9(b) backup strip heating. This plot clearly shows how much larger service panels would need to be with backup heating.

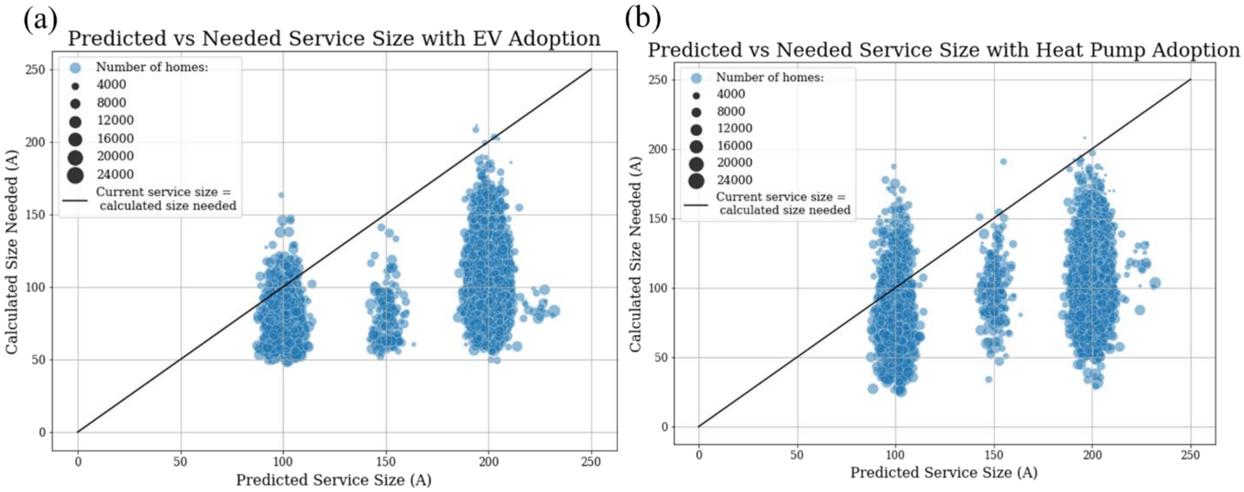

Figure 8: (a) Predicted service size vs calculated needed service size for Electric Vehicle adoption scenario and (b) Heat Pump adoption scenario (right) (n=11,950).

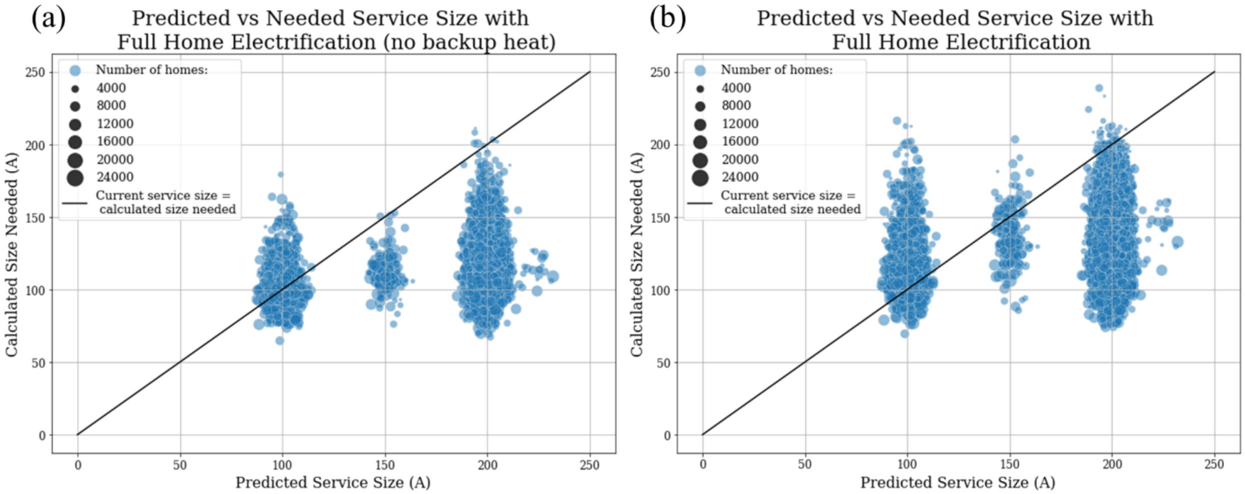

Figure 9: (a) Predicted service size vs calculated needed service size for full home electrification without backup heat scenario and (b) full home electrification with backup heat scenario (n=11,950).

Discussion

Limitations of Models

Four main limitations were identified in this work: survey design, number of respondents, building type, and model accuracy. The lack of numerical data and appliance specifications collected in the panel survey impacted the results of the service size modeling. By only asking respondents about appliance ownership and fuel type, the team was able to simplify the survey, but in-turn had to make general assumptions about appliance sizing. In future studies, asking respondents to include appliance model numbers or photos may greatly improve confidence in service size calculations.

The second limitation was the small number of survey responses. The final survey consisted of 1,857 single-family home responses and of that only 1,419 were able to identify their main breaker. Because of the limited sample size, statistical significance and scalability were not properly assessed in the service sizing model. Additionally, because the survey was administered online and offered a small compensation to those who responded, there may be a response bias. Both the relatively small number of responses and survey bias limit the accuracy of the prediction of electrical service sizes.

A third limitation stems from the lack of sufficient survey responses from other residential building types. Although the survey design aimed to gather comprehensive data on the whole residential building landscape, the responses from multi-family buildings with identified breaker size were limited, thus rendering them unsuitable for inclusion in our analysis.

Lastly, the fourth limitation concerns the accuracy of the random forest classifier utilized for generalizing the insights from EPRI's panel survey to the broader single-family home population in the U.S. While the overall machine learning model accuracy stands at 70%, this accuracy is not consistent across panel size categories. Medium-sized (101-150 A) and large services (>200 A) are less accurately characterized. Despite most electric service upgrades being triggered in the smaller panel size category (<=100 A), there is some potential for underestimation of the number of housing units triggering a service upgrade, given the machine learning model tendency to misclassify the category 101-150 A as 151-200 A.

Pathways to Address the Service Capacity Barrier

While the modeling work provided a greater understanding of the size of the problem, there are several pathways available to address the issue of limited electrical service capacity under full electrification scenarios. These solutions range in cost and complexity but are worthy of consideration in all applications.

- **Watt-diet/Amp-diet** – One way to electrify is to reduce the electric consumption of a home by using highly-efficient devices and 120V versions of products where possible. For example, there are now 120V versions of water heaters, heat pumps, heat pump dryers, cooktops, and more. Single phase devices can allow for more breaker space in the panel and will likely result in a lower load calculation for the building. Redwood Energy has produced a Watt-Diet Calculator tool (https://www.redwoodenergy.net/watt-diet-calculator) that helps a user perform a load calculation and provides recommendations for conserving space in an electrical panel. The cost of this option depends on how many new appliances would be needed.
- **Energy management systems and devices** – There are a variety of energy management systems that can help to expand the capacity of the electrical service size by managing load and/or supply. The following devices are examples of commercially available products that may prevent service upgrades in various electrification situations.
    - **Smart circuit splitters** – Circuit splitters or circuit switches are relatively low-cost products that allow for an individual circuit (often a 240V circuit) to alternate power between two loads instead of just one. These are typically installed at the plug of one of the end-use devices, although installation at the electrical panel is sometimes an option. The splitter then prioritizes powering one load over the other depending on user configuration. Example manufacturers of these devices include NeoCharge, SimpleSwitch and BSA Electronics. An example use case is for an electric dryer and EV charger to share a circuit. An EV can take a long time to charge but can often be charged overnight. In this example, the dryer can take priority first, and when its

    cycle is finished, the splitter automatically would begin charging the EV. Large 240V circuits that can be easily alternated are the primary targeted applications. One downside to most of these devices is the two loads often must be in close proximity to each other.
    - **Smart panels** – A smart panel is an intelligent load management system for electric circuits. Common features of smart panels include advanced metering, internet connectivity, automated load control, data monitoring, and microgrid integration. Smart panels can either be full panel replacements or panel additions to supplement an existing load center. Example manufacturers include SPAN, Lumin, and Koben. Smart panels are still an emerging technology that may or may not be more expensive than service upgrades, with the service upgrade cost largely depending on if the home is fed from overhead or underground service wires. However, there are additional features being released that can provide additional value to the homeowner and the utility, such as demand response and TOU load management. EPRI has recently conducted a laboratory experiment on the SPAN smart panel, including evaluating the performance of its new PowerUp feature. The PowerUp feature automatically pauses user-prioritized circuits when the amperage on a single phase reaches 80-100% of the main breaker rating. With this feature, the smart panel can safely expand the capacity of the panel beyond the existing service size (EPRI 2023).
    - **Meter collars** – Another emerging technology to prevent some service upgrades is the meter collar. ConnectDER is an example of a meter collar manufacturer that makes a product that installs between the home’s meter and the meter socket to create a parallel circuit separate from the main service panel. The primary use-case for the company thus far has been to accelerate solar installations, but they are working towards future product iterations to accommodate new end-use loads such as electric vehicle chargers.
- **Service upgrade** – In some cases, it may make the most sense to the homeowner to pursue a service upgrade. In situations where the homeowner can plan out their home electrification project (no emergency replacements, flexible timeline), this option may still be the most convenient in the long run. Some homeowners may desire high-powered electric devices that provide non-energy benefits like increased comfort or have improved/faster performance, and in these situations a service upgrade may still be the preferred option by the homeowner. If the service wires feeding the building are currently underground, it is likely that this option is not the most cost-effective due to trenching costs that are often passed on to the homeowner. Overhead service wires typically indicate a lower upgrade cost, but every case is unique and may run in to other costs such as a service transformer upgrade.

Conclusion

This paper provided discussion on several research activities pertaining to the electrification barrier of electric panel/service capacity constraints. A presentation of EPRI’s national survey of electric panels project revealed that many homes in the U.S. have 100 A or smaller electrical service sizes. The electrification scenario modeling of the survey results showed that most 100 A or smaller homes will trigger an upgrade when fully decarbonizing. The machine learning model that EPRI has developed helped to predict which homes are more likely to have 100 A or less service sizes. Several alternatives to panel/service upgrades were presented. As this issue continues to hinder electrification, there will likely be more technological advancements and policy changes to accelerate decarbonization. EPRI intends to continue researching this important topic in order to provide scientific data and insights.

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