

Dig here: Insights from Direct Burial Cable Study and Implications for Electrification

Gomathi Sadhasivan, DNV

Lullit Getachew, DNV

Amber Watkins, DNV

ABSTRACT

Direct Burial Cable (DBC) customers have lower service ampacity, typically 100A, than underground-in-conduit customers, and significantly higher upgrade costs due to trenching to replace wires than overhead delivery customers. They represent a unique challenge to meeting utilities' goals of high penetration of all-electric buildings that also include on-site electric vehicle charging.

While avoiding panel upgrades can save costs, the trenching required to upgrade the wire is a significantly high cost. Upgrading DBC customers' service could cost millions of dollars, with the majority of the upgrade costs absorbed by customers. Utilities will bear costs to upgrade the transmission and distribution system to accommodate new loads.

This paper will present findings from a recent study in California conducted to better understand the DBC customer base and answer the following questions: 1) How can utilities gauge the magnitude of electrical upgrades that will be required to support electrification? 2) What are the "boots on the ground" perspectives that market actors can provide us regarding panel conditions and electrification barriers for DBC customers? 3) What are DBC customer barriers to electrification? 4) What are the low-amp technology options that utilities can test in pilot programs?

This paper brings the focus to a significant blind spot related to electrification and provides insights and recommendations on strategies that providers can adopt to address this customer segment. This presentation will be of interest to key stakeholders working in the EE and electrification space including utilities, program partners, and policymakers.

Introduction

Direct Burial Cable (DBC)¹ customers represent a unique challenge to meeting utilities' goals of high penetration of all-electric buildings with on-site Electric Vehicle Supply Equipment (EVSE) due to the typical relatively low service ampacity of 100A coupled with a high cost of upgrade due to cost of trenching to replace wires.

While 100A panels may suffice for older homes with fewer electrical appliances which use gas heating and gas appliances, they are limiting for many modern homes with a greater

¹ Direct-burial cable is a special type of electrical wiring or cable that is designed to be buried in a trench underground. This type of cable is designed to withstand direct exposure to the soil and moisture and is rated for wet, dry, and damp environments.

number of electrical appliances as 100A panels can fit fewer circuits. Most modern homes use 200A panels that have higher capacity and can fit more circuits.

Below is a schematic of a typical residential DBC customer's electricity service (Figure 1). Wire buried underground is typically capable of 100A service for residences built before 1985 in California. The cost to replace wire ranges from \$4,000 - \$8,000 depending on length of run and whether trenching is under landscaping or hardscaping. The cost of trenching and conduit is typically paid by customer, with cost of wire paid by the utility. Additional costs to the utility may include feeder and transformer upgrades.

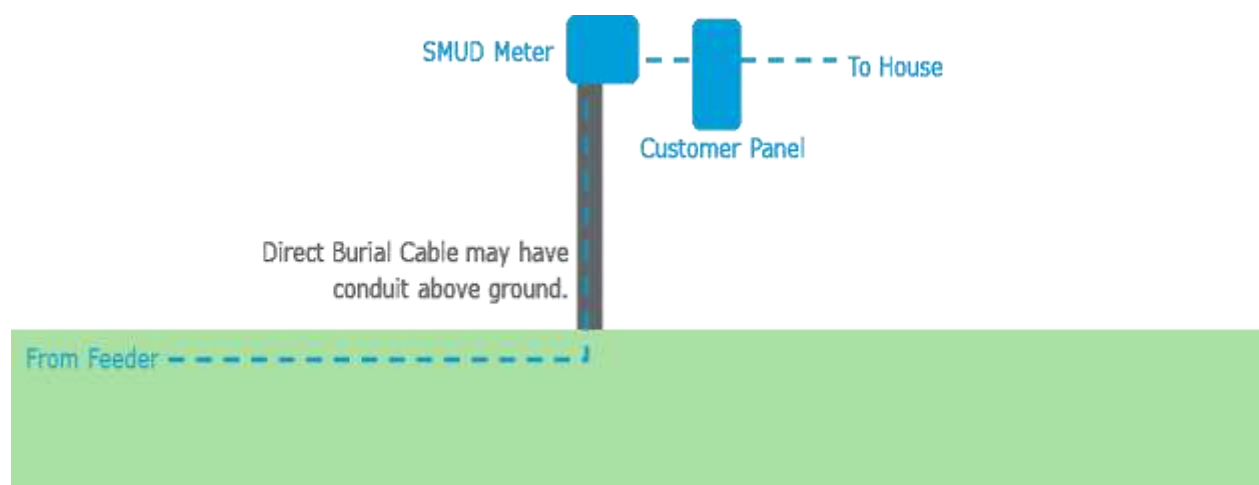


Figure 1. Direct Burial Cable Schematic Diagram

Customer panels may require upgrades for a variety of reasons, including low ampacity, too few breaker spaces, or age and safety of panels. Some panels installed decades prior, such as Zinsco panels, may require replacement due to safety concerns, whether or not an upgrade to 200A is required. Customer panel upgrades can cost anywhere from \$750 to \$2,000 to upgrade to 200A according to HomeAdvisor estimates for the period of study (Q4 2019) in California.

While avoiding a panel upgrade can save costs, below-grade trenching required to upgrade the wire is a much higher cost. It is estimated that upgrading DBC customers' service could cost hundreds of millions of dollars even for small utilities, with the majority of the costs being absorbed by customers. This estimate does not include the cost associated with upgrading the transmission and distribution system to account for the new loads.

Methodology

This paper presents findings from DNV's Direct Burial Cable study for Sacramento Municipal Utility District (SMUD) with approximately 84,000 residential and 10,000 commercial DBC customers. The utility wished to further its understanding of these customers, their building constraints, and mitigation options in order to begin developing effective decarbonization (through electrification) strategies.

The study involved the following tasks:

- Construct DBC customer profiles based on analysis that combined consumption analysis, utility customer information systems (CIS) data such as rate plan and customer location, American Community Survey (ACS) data such as race and income, and CalEnviroScreen² data that includes information on whether the customer is in a disadvantaged community with respect to environmental risks, exposed to poor air quality, and is economically depressed.
- Determine DBC customer barriers to electrification based on customer surveys and in-depth-interviews (IDIs)
- Estimate maximum draw and available panel capacity for the household using AMI data analysis
- Get a boots on the ground perspective from contractors operating in the area regarding panel capacity in buildings via IDIs
- Conduct a low-amp technology assessment for various end-uses available in the market and summarize feasible alternatives for consideration that have the potential to avoid costly service upgrades for residential DBC customers

Residential DBC customer profile

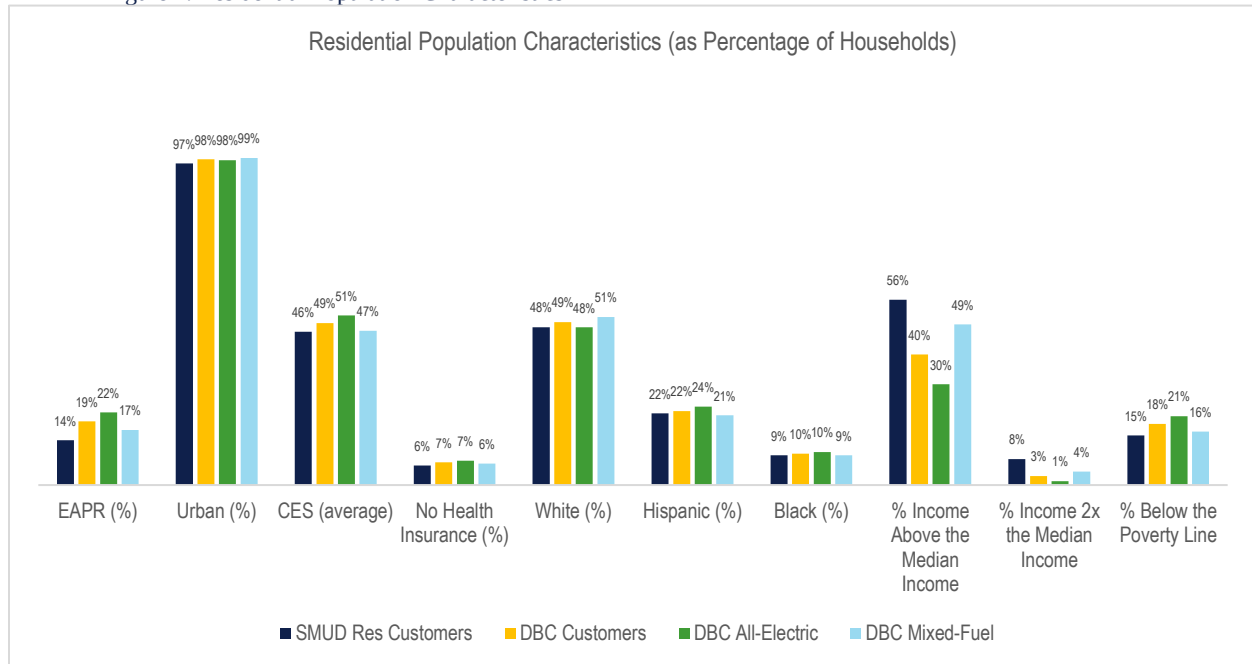
We brought together various data streams including consumption data, Customer Information Systems (CIS) data, American Community Survey (ACS) data, CalEnviroScreen data etc., in order to develop rich customer profiles. The figure below provides a summary profile of residential DBC customers in the utility territory along key dimensions with a breakdown for DBC customers by their fuel type. The figure also contrasts this with the general population of residential customers (Figure 2).

The DBC customer segment had a higher proportion of customers on the subsidized energy assistance program rate (EAPR). This may prove to be a barrier to electrification in these homes compared to other utility customer homes overall. However, this may also be an opportunity for equity-focused programs and outreach. DBC customers tend to be lower income than the general residential customer population, with a higher percentage below the poverty line, and lower percentage above the 1x-median and 2x-median utility-service area income brackets. Other socioeconomic indicators, such as CalEnviroScreen (CES), were relatively consistent between utility's general residential and DBC population.

All-electric and mixed-fuel DBC homes are largely similar on the characteristics analyzed. There appeared to be an increased propensity for all-electric homes to be lower income, but that may be due to multi-family units typically only having electric meters dedicated to the unit.

² CalEnviroScreen provides information on several environmental, public health, and socioeconomic conditions and combined indices at a granular geographic level in California. <https://oehha.ca.gov/calenviroscreen>

Figure 2. Residential Population Characteristics



We also examined the age of single family homes served by DBC and found that DBC single-family homes tend to be older on average than the overall residential population for the utility. This is not a surprise given that Direct Burial Cable is no longer installed in homes. The greatest number of DBC homes were built in the 1970s, and many were built before 1940. 59% of DBC customer homes were built before 1980, which may imply that most services are 100A (based on contractor interviews). DBC homes built in the 1970s and 1980s are more likely to be all-electric than mixed-fuel. See Figure 3.

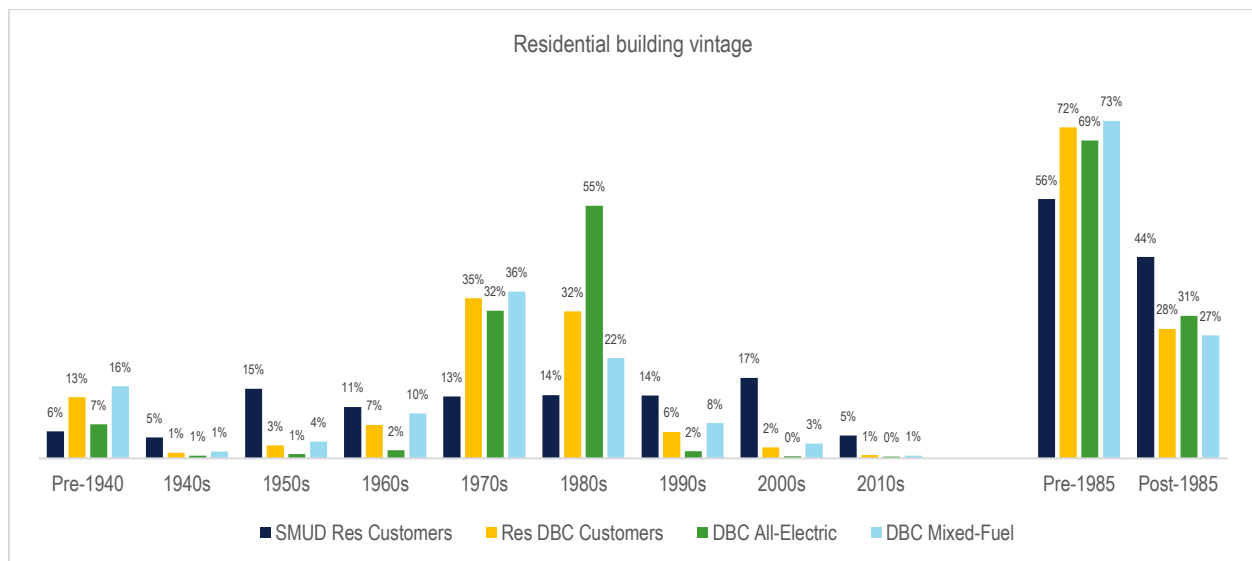


Figure 3. Residential building vintage

Nearly one third of homes in DBC territory are already all-electric, which is a much higher proportion than of all residential utility customers. This is likely due to the trend toward older homes in the DBC population, which may have been built before there were gas pipelines in particular neighborhoods.

The pros of DBC customers already having all-electric homes are that the homes are already electrified, there is energy cost savings potential for resistance to heat pump changeouts, and breaker reuse potential for resistance systems. The cons are that they may lack spare capacity for EVs and other uses and may be adding gas service during renovation work. While all-electric DBC customers have overcome the attitudinal barriers that other customers may have towards electrification, the anticipated growth in transportation electrification may necessitate both panel and service upgrades in the future.

Barriers to Residential Customer Electrification

The findings presented in this section for the DBC study are drawn from multiple primary research efforts undertaken in parallel DNV study efforts for SMUD. The surveys are not specific to DBC customers. These findings from existing research among utility electrification program participants (HPs, HPWHs, EVs) provide directional insight for further in-depth primary research among the utility's DBC residential customers.

The figure below summarizes barriers to electrification based on a residential customer survey conducted amongst 173 utility customers in Q3 2020. Upfront installation costs, permitting or compliance processes, and panel upgrade requirements are among the top barriers for electrification cited by residential customers. These barriers were cited by customers who had already embarked on some electrification in their home (survey conducted among program participants who availed of SMUD's residential electrification program incentives for HPs and HPWHs).

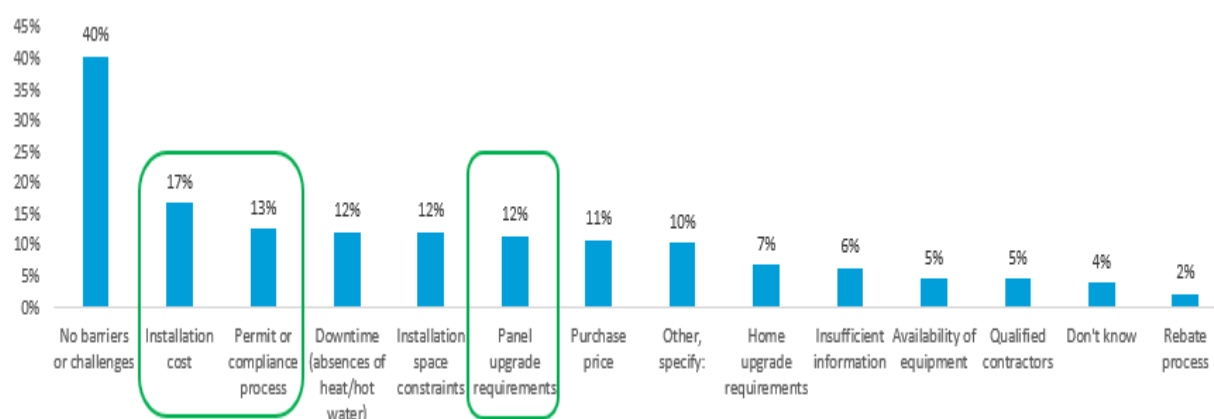


Figure 4. Barriers to residential electrification

While this survey did not focus specifically on DBC customers, barriers are likely to be as high or greater among the general population and the subsegment of DBC customers among

them who are yet to undertake any electrification upgrades. Programs that seek to encourage customers to electrify will need to continue to offer incentives to surmount upfront cost barriers, streamline the permit or compliance process to reduce customers' transaction burden with the electrification upgrade, and finally continue to help customers defray ancillary costs due to any required panel upgrades.

Barriers to Commercial DBC customer electrification

We also conducted interviews with 11 commercial DBC customers across a range of different NAICS codes chosen for their large water heating need/use and their potential need to support EVSE charging. The table below summarizes why certain NAICS codes were prioritized for the study due to a potential load increase issue associated with electrification.

NAICS3	Reason for Prioritization
Food Services and Drinking Places	Commercial kitchen equipment and the high domestic hot water requirements for food preparation
Food and Beverage Stores	Commercial kitchen equipment and the high domestic hot water requirements for food preparation
Justice, Public Order, and Safety Activities	High potential domestic hot water demand if these buildings include detention facilities
Ambulatory Health Care Services	High domestic hot water demand
Nursing and Residential Care Facilities	High domestic hot water demand
Religious, Grantmaking, Civic, Professional, and Similar Organizations	Potential high domestic hot water demand
Amusement, Gambling, and Recreation Industries	Potential high domestic hot water demand
Personal and Laundry Services	High domestic hot water demand
Professional, Scientific, and Technical Services	High domestic hot water demand and process loads for sterilization
Museums, Historical Sites, and Similar Institutions	Potential high domestic hot water demand
Motor Vehicle and Parts Dealers	High electric loads to heat unconditioned working bays typically heated by heat-vent units
Accommodation	High domestic hot water demand

Performing Arts, Spectator Sports, and Related Industries	High domestic hot water demand and potential cooking loads
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Interviews with commercial DBC customers indicate that about half of the commercial DBC customers expressed concerns that going all-electric would not meet their needs (Figure 5). Installation and maintenance costs and upgrades are among the top concerns or challenges they anticipate when considering replacing their gas equipment with all-electric equipment, echoing findings from the residential customers.

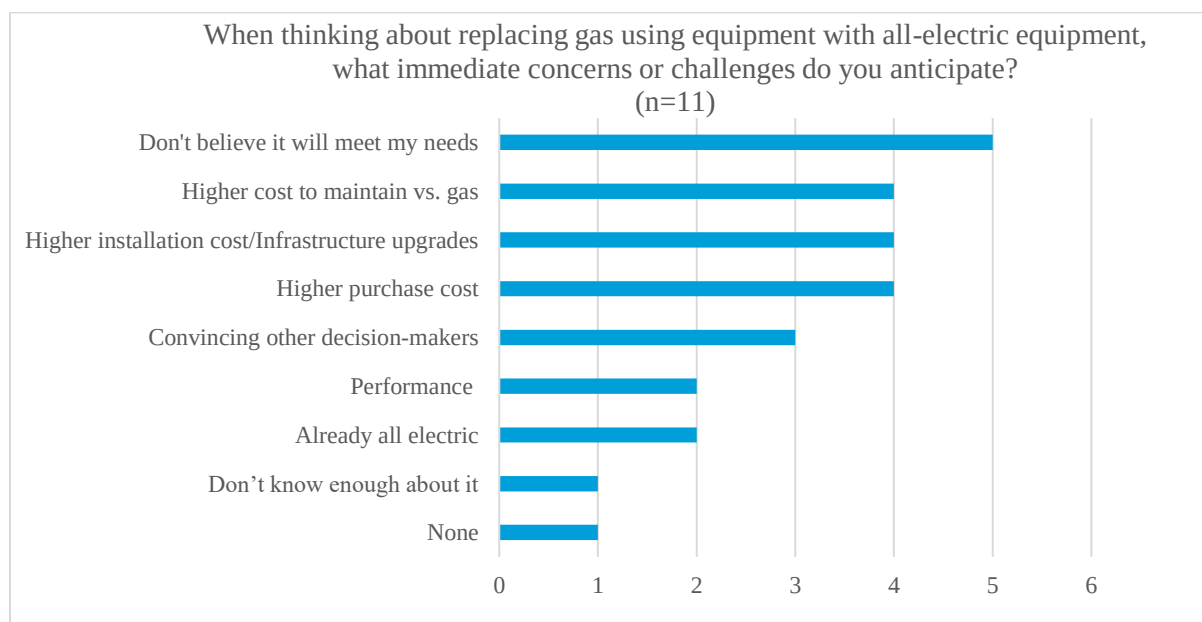


Figure 5. Barriers to electrification among commercial DBC customers

Panel size, capacity, and projected upgrades

The survey also asked customers about their current panel size and the majority of customers were unaware. See Figure 6. Of those who were aware of panel size, 95% are at 100 amps or higher and 80% are at 200 amps or higher. Those who upgraded their panel, did so to support installation of a heat pump water heater, home remodel, solar, heat pump space heater, and use of EVs. Other motivators for panel upgrades include: Safety/Fire risk, outdated Zinsco panel technology, panel age, replace knob and tube wiring, support addition of pool, support other devices etc.

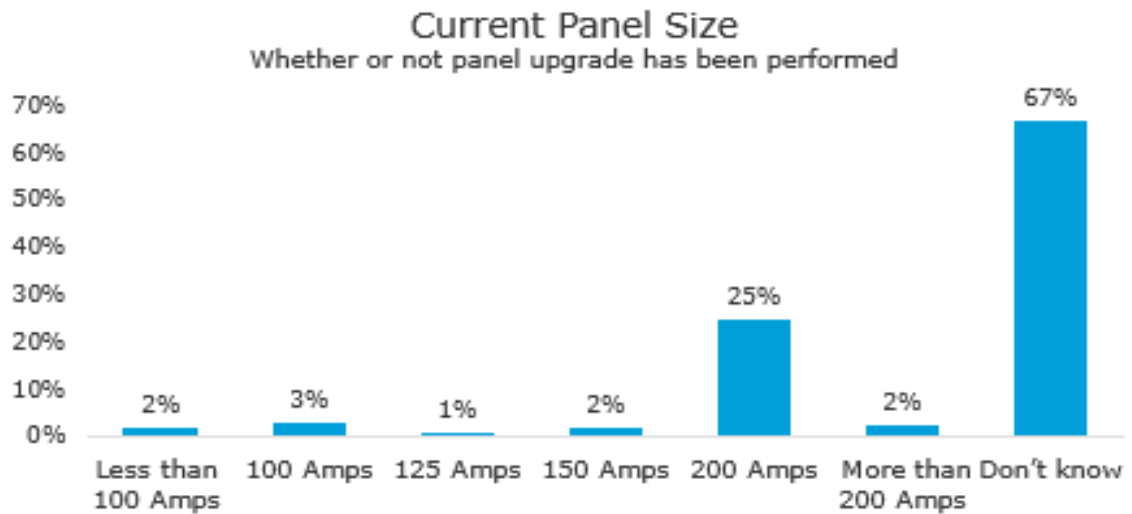


Figure 6. Current household electric panel size

While detailed site level information on panel size is not available for all customers, the study included five contractor in-depth-interviews to gain a “boots on the ground” perspective of panel size and conditions observed. Contractors noted that for residential customers in dwellings built prior to 1980, panel size was typically 100 amps and that 200 amps was the standard panel size for dwellings built 1980 onwards. Given the pattern of development, neighborhoods closer to the center and within a certain radius from the greater downtown Sacramento area, also referred to as old or mid-town Sacramento, have the highest concentration of older homes with panels of lower capacity.

AMI data analysis helped fill in the blanks on panel capacity for DBC customers as well. See Figure 7. A 100-amp panel at 240V can deliver 24kW – a substantial amount of power. According to our analysis of SMUD’s DBC customers’ AMI data, DBC customers are only using a fraction of this capacity. The chart below shows the max hourly kWh for SMUD residential customers. The space the right of the histogram represents unused capacity that can be leveraged for electrification, if SMUD and its customers can work together, thinking in the long-term, and using a whole-building approach.

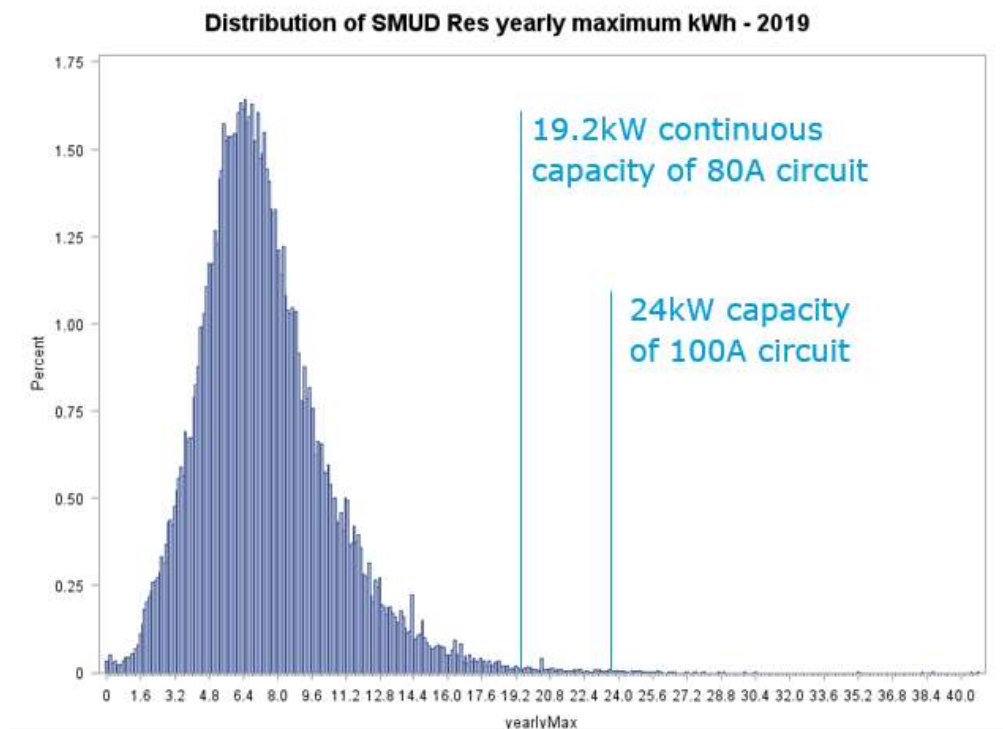


Figure 7. Unused panel capacity of DBC customers

Many utility customers will increase their panel and service sizes over the upcoming years due to projects such as: renovations, additions, pools, solar PV installation, EVSE installation, and other high-demand needs. It is predicted based on our analysis under certain assumptions (such as 50% of EV drivers use Level 2 chargers), that 15% of DBC customers will have voluntarily upgraded their panels by 2030 without intervention (Figure 8).

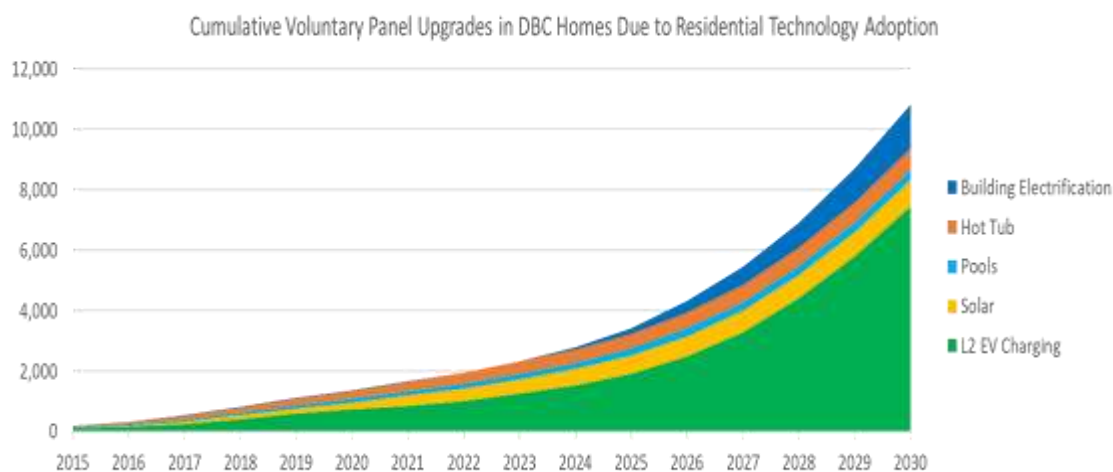


Figure 8. Forecast for residential panel/service upgrades based on projected EV adoption rates

Low amp technology summary

Low amp technologies provide an opportunity to enable total electrification for DBC customers, while maintaining existing panel and service size. DNV research indicated that many residential DBC customers may be able to electrify their homes and add EVSE within a 100A service. Staying under 100A (80A continuous) will require careful, whole building electrical design considerations. Figure 9 outlines an example path to Low Amp Total Home Electrification³.

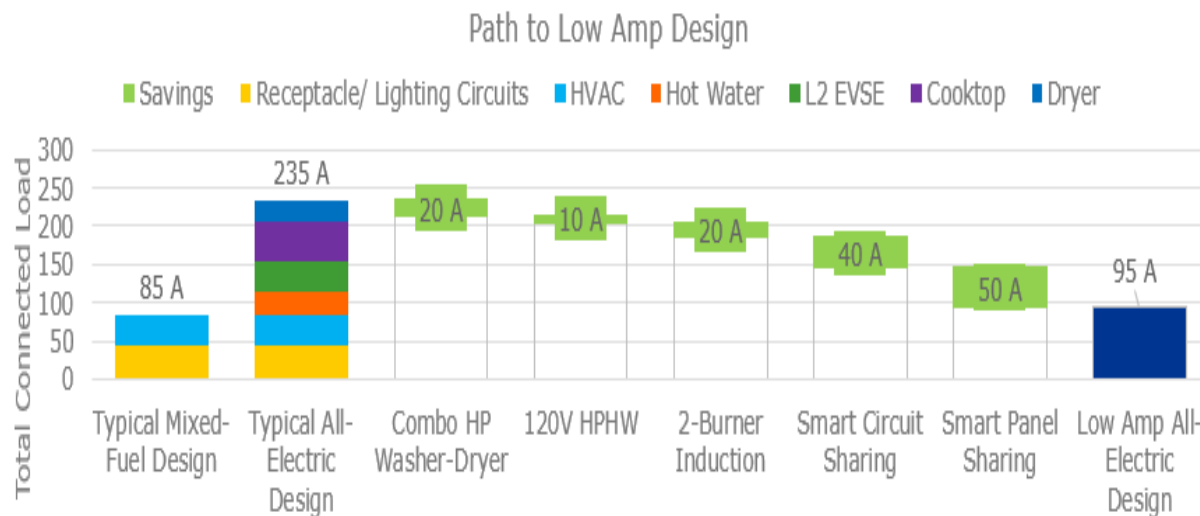


Figure 9. Path to Low Amp Design

The table below (Table 1) outlines the low amp technologies currently available that utilities should consider implementing in residential DBC electrification programs and planning. The low amp technology assessment conducted also included an estimate of amp savings potential at the panel, equipment cost, breaker space savings, and the pros and cons of the technology options.

Table 1. Low Amp Technology Summary

Low Amp Technology	Description
Re-use Radiant Electric Circuits	Customers with other means of space heating may consider retiring their radiant heaters. This a straightforward way to free up panel capacity and a breaker space
Circuit Sharing	These devices allow a customer to share a 30A, 40A, or 50A circuit between a two (2) 240V loads.
Level 1 EV Charging	Level 1 chargers have a slower charge rate than level 2 chargers, but do not necessitate a dedicated circuit
Low Power Level 2 EV Charging	Selecting Level 2 charging with lower capacity (15A, 20A, 30A) allows for reasonably quick charging without the amperage penalty

³ It is possible to connect more than 100A on a 100A panel safely due to diversity of loads. The National Electric Code (NEC) has two load calculation methods that can be used to determine dwelling load.

Low Amp Technology	Description
120V Heat Pump Water Heater	Being piloted in 2022 to determine performance, 120V heat pump hot water heaters can offer tremendous amperage savings at the panel but may result in lower efficiencies and will result in fewer showers per hour available.
Combo Condensing Washer/Dryer	Installing these units is a simple way to reduce amperage and save breaker poles at the panel. It is recommended to use the larger capacity 4.5 cu. ft. unit.
40A Slide-in Induction Range	Modern induction ranges with power management functionality have lower breaker requirements than traditional models. Manufacturers include: Samsung, GE, LG, and Frigidaire.
Countertop Microwave	Microwaves on dedicated circuits can be replaced with countertop models with the same functionality, resulting in a free 20A circuit
Electric Kettle	Substituting instant hot water devices with electric kettles is a straightforward way to reduce the amount of panel space dedicated to kitchen equipment.
240V Low Amp Heat Pump Water Heater	New to the market in 2020, low amp heat pump hot water heaters provide similar efficiency and form factor to 30A units, while avoiding costly electric upgrades.
High-SEER Heat Pump Condensing Unit	Customers may be able to downsize the breaker for their condensing unit by upgrading to a high-SEER heat pump model.
Energy Recovery Ventilation	Especially in homes that have undertaken envelope upgrades, ERV systems can allow for downsizing of HP capacity. This does not appear to have potential for breaker savings.
Combo Air-to-Water Heat Pump	Air-to-water heat pumps offer a highly efficient turnkey solution for space conditioning and hot water needs in residential buildings. A single outdoor unit provides HVAC and hot water.
Battery Storage	Battery storage can allow customers to minimize their power draw from the grid during times of heavy usage
Smart Panels	Loads can be prioritized to ensure that panel capacity is not exceeded. These products also present a slew of co-benefits

The table below outlines some example preliminary low-amp package options that will maintain a 100A service for typical DBC homes in SMUD territory. These packages may result in panel upgrades due to safety requirements or an increase in number of breakers required, but the packages avoid a costly service upgrade. There are many potential combinations of low amp packages.				
	Package 1	Package 2	Package 3	Package 4
Package Name	Low Amp HPHW	Low Amp Dryer	Multiple Shared Circuits	High AC Load
HVAC	4-ton Heat Pump	4-ton Heat Pump	4-ton Heat Pump	5-ton Heat Pump

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	Package 1	Package 2	Package 3	Package 4
Package Name	Low Amp HPHW	Low Amp Dryer	Multiple Shared Circuits	High AC Load
Water Heating	15A HPHW (Low Amp)	30A HPHW	30A HPHW	30A HPHW

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	Package 1	Package 2	Package 3	Package 4
Package Name	Low Amp HPHW	Low Amp Dryer	Multiple Shared Circuits	High AC Load
Cooking	40A Induction Slide-in	40A Induction Slide-in	40A Induction Slide-in	40A Induction Slide-in

Dryer Type	Traditional Electric	120V Combo Washer/Dryer (Low Amp)	Traditional Electric	120V Combo Washer/Dryer (Low Amp)
Disposal	Yes	Yes	Yes	No
Hard-wired Microwave	Yes	Yes	Yes	No
EVSE	Level 2, 15A Breaker, No circuit share	Level 2, 40A Breaker, with circuit share	Level 2, 40A Breaker, with circuit share	Level 2, 40A Breaker, with circuit share (for e.g., 40A induction cooktop and EVSE)
Circuit Share	One shared - Range + Dryer	One Shared - Range + EVSE	Two shared - Range + EVSE & Dryer + Water Heater	One shared - Range + EVSE
Service Size	98.7	96.4	96.4	98.8

Table 2. Low Amp package options

Conclusions and Recommendations

This study relied on hourly AMI data which was insufficient to conduct a virtual panel sizing analysis. Given the lack of panel and service size information at the site level, recommendations from this study included a field study with site visits or additional AMI data analysis to explore load disaggregation with shorter AMI intervals.

As SMUD customers engage in energy efficiency, electrification, and EVSE programs there is an opportunity to integrate low amp technologies into SMUD's programs. Electrification and EVSE programs have long been a concern with regards to demand and infrastructure growth. This is even more challenging with DBC customers given the expensive cost the customer will be expected to bear if they need to upgrade their service.

Low amp technologies could be a big opportunity to accommodate full electrification on a 100A panel in single-family homes. Getting technology packages right is critical to low amp electrification. While low amp design strategies have been a focus in certain regions of coastal California over the 12 months preceding this study, we are not aware of any projects that have occurred within a climate zone with such high cooling loads as in the Sacramento area. Solving the problem quickly is also critical because as customers electrify without considering low amp measures, they may be painting themselves into a corner with regards to service upgrades. Recommendations provided to SMUD included performing a specific desktop study as soon as possible to determine a longer list of low amp package options and performing a minimum of three low-amp, single-family, DBC electrification pilot projects.

By offering higher incentives on a sliding scale for lower amp options for various end-uses such as EVs, HPWHs, induction cooktops etc., both customers and SMUD would benefit by avoiding costly upgrades. By incentivizing the right equipment, SMUD can offer building and vehicle electrification programs that not only reduce carbon emissions, but also help to prevent future service upgrade requirements.

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