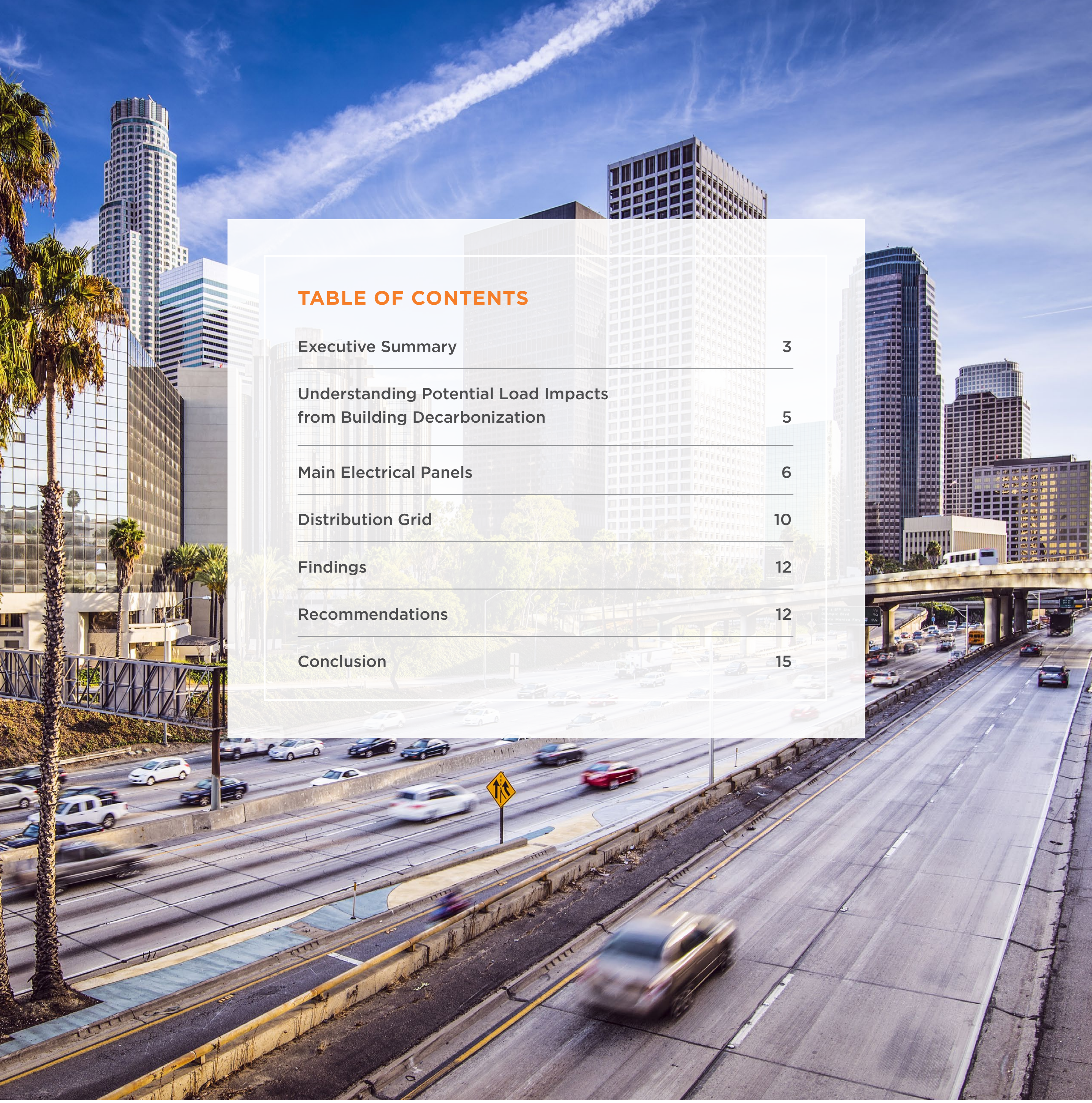
DECODING GRID INTEGRATED BUILDINGS REPORT

JANUARY 2020

BUILDING DECARBONIZATION COALITION



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ACKNOWLEDGEMENTS

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Ms. Alyona Ivanova and Dr. David Chassin of the SLAC National Accelerator Laboratory made critical contributions through financial support from the California Energy Commission.

EXECUTIVE SUMMARY

California has ambitious and aggressive goals for decarbonizing its building sector (Figure ES-1).[1] Turning over fossil gas-combusting space and water heating equipment, clothes dryers, and cooktops to equipment using renewable electricity requires the availability of adequate capacity on main electrical panels, increased capacity and improved communications within the distribution grid system, and market mechanisms to recognize and reward grid and climate benefits of electrification and load shifting. However, there has been uncertainty about the readiness of building electrical panels and distribution infrastructure to serve and optimize significant new electric load related to building electrification. The uncertainty around infrastructure-readiness is furthered by the possibility that panel and grid impacts may be affected by simultaneous deployment of default residential time-of-use rates, vehicle electrification, and adoption of distributed generation, each of which can change customer behavior and timing of peak electricity demand.

DECARBONIZATION OF THE BUILDING SECTOR

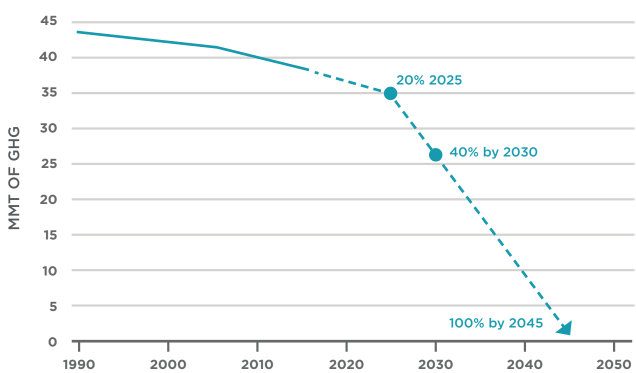

FIGURE ES-1. *Building Sector Decarbonization Milestones*

To ensure that building-level infrastructure and the secondary distribution grid system are ready to support building decarbonization and electrification, California needs four interrelated solutions: (1) pilots and incentives; (2) implementation of load management technologies and strategies; (3) coordination and collaboration on load calculation approaches and how they are used in distribution system planning; and (4) ongoing customer support. More specifically, from stakeholder input gathered at the *Decoding Grid Integrated Buildings Summit*, the Building Decarbonization Coalition and Gridworks note that addressing uncertainty related to electrical panel readiness will require: (1) re-evaluating panel sizing protocols with consideration for energy efficiency improvements and load management tools; (2) co-offering end use electrification with demand-side load management programs; (3) a better understanding of potential equity issues, including who pays and who benefits from end use electrification; and (4) clarity on the economics of various approaches to managing the electrical panel when installing distributed energy resources. Further, in order to address distribution grid planning and investments to increase clean electric loads, California needs: (1) better modeling tools and data analytics for multiple new future loads; (2) clear principles and goals to guide new grid investments; (3) user-friendly guidance to customers on utility versus customer costs and information about the most economic pathways to decarbonize; and (4) inclusion of clear definitions and valuation of grid services from load flexibility in integrated resource and procurement plans.

Action is needed from local and state leaders to connect the pathways and streamline access and understanding among stakeholders. Table 1 identifies the near-term actions that state leaders should take to decode grid integrated buildings. While the scale of transitioning the building sector to a decarbonized future is significant, there is ample opportunity to leverage existing programmatic and market options to offer approaches that meet a broad set of customer needs. The building's main electrical panel, though often overlooked, can serve as a critical key to unlocking California's decarbonized future.

1 Assembly Bill 3232 (Friedman, 2018) requires the California Energy Commission by January 1, 2021, to assess the potential for the state to reduce the emissions of greenhouse gases from the state's residential and commercial building stock by at least 40% below 1990 levels by January 1, 2030.

TABLE 1. *Recommendations to Decode Grid Integrated Buildings*

PILOTS AND INCENTIVES	LOAD MANAGEMENT STRATEGIES	LOAD CALCULATION APPROACHES	ONGOING CUSTOMER SUPPORT
1. The CPUC should direct the administrators of the Energy Savings Assistance Program to upgrade electrical panels for all qualified customers to meet industry standard in new construction (e.g., 125 Amp panel service for each unit in a multifamily building). Additionally, the CPUC should direct the investor-owned utilities to offer incentives for low amperage equipment in their energy efficiency portfolios. Further, the CPUC, in its Building Decarbonization Rulemaking 19-01-011, should offer panel upgrades to facilitate building decarbonization in all customer segments.	1. The CEC should include in the next Integrated Energy Policy Report an assessment of the potential load increase from building electrification and of the potential for load management tools and equipment to shift load and defer infrastructure upgrades.	1. The CEC should work with the California Building Standards Commission and local governments including permitting offices and building inspectors on the interpretation of the National Electrical Code and its application in the California Electrical Code. This coordination effort should include a review of options for load calculation approaches that meet safety standards while minimizing the need for construction of new infrastructure.	1. The CPUC should support a statewide consumer education campaign to promote the benefits of building decarbonization.
2. The CEC, CPUC, and utilities should meet and coordinate with stakeholders to identify opportunities and best practices to co-offer electrical panel upgrades when rooftop solar PV and/or electric vehicle charging infrastructure are installed.	2. The CPUC should direct the investor-owned utilities, through the Rule 21 Working Group process, to conduct an assessment of the potential for load management tools and equipment to defer distribution grid upgrades. This assessment should include an estimate of deferred infrastructure costs to help monetize and value the grid services offered in load management.	2. The CPUC should direct the investor-owned utilities to clarify and update base load assumptions through their Distribution Resources Plans to ensure that efficiency standards are accurately considered.	2. The CEC should support a customer-facing project guidance platform into its AB3232 implementation efforts. This should include coordination and consultation with contractors and labor representatives to ensure accurate representation of feasible project options, costs, and timelines.
3. Local governments should coordinate on options and best practices for offering incentives for panel upgrades and/or requiring panel upgrades when a property is sold.	3. The CEC, CPUC, and distribution system operators should coordinate on the potential for and reliability of virtual power plants to reduce anticipated load increases from building electrification. Outputs from this coordination effort should include quantification of the value that virtual power plants provide in smoothing demand ramp, avoiding carbon-intensive energy generation, and reducing construction of increased distribution grid capacity.	3. The CEC and CPUC should consult with the Governor's Office of Business and Economic Development on the potential to develop a Building Electrification Permitting Guidebook to clarify acceptable load calculation approaches and inform stakeholders about the process to retrofit to an all-electric building.	3. The CPUC and CEC should consult with housing organizations to identify tenants' needs and property owners' capacity to install building decarbonization end uses, and identify opportunities to streamline program administration and stack incentives in underserved customer segments.

GATHERING PERSPECTIVE ON THE ISSUES

On November 12 and 13, 2019, the Building Decarbonization Coalition and Gridworks hosted the *Decoding Grid Integrated Buildings Summit* to better understand the challenges and opportunities facing electrical panels and local distribution grid infrastructure from building decarbonization. More than 65 participants across 47 organizations attended the summit with representation from local governments, utilities, community choice aggregators, housing advocates, environmental advocates, program and project implementers, and manufacturers. Industry experts shared their perspectives and experiences on the topics and break out sessions defined opportunity statements to address challenges. The discussions and opportunity statements shared during the Summit provided invaluable insight for this report.

UNDERSTANDING POTENTIAL LOAD IMPACTS FROM BUILDING DECARBONIZATION

According to Synapse's *Decarbonization of Heating Energy Use in California Buildings*, if all space and water heating converted from natural gas to electricity, without complementary efficiency measures, California's electricity use would increase by approximately 19%.[2] Given that California has a summer peaking electricity system, the increase in electricity demand from space heating could actually improve, rather than degrade, the year-round utilization of bulk grid infrastructure (i.e., high voltage transmission lines).[3] Impacts to electrical panels and the distribution grid, however, could reflect a different story.

All-electric homes could have a peak demand as high as 10-15 kW, whereas a mixed fuel home generally peaks around 6 kW.[4] Potential load impacts from building decarbonization will vary depending on the occupancy, climate zone (i.e., heating/cooling demand), building size and efficiency (e.g., thermal integrity), and equipment efficiency. In building retrofits, it's possible that load changes from electrifying end uses would be offset by increasing efficiency of the building envelope, lights, and appliances.[5] Understanding the demand factor[6] and load diversity on a feeder is critical to estimating potential load impacts from building decarbonization.

The National Electrical Code sets the foundation for electrical safety standards in buildings. The National Fire Protection Association, a non-profit trade association established in 1896, publishes the National Electrical Code, but the code is not adopted as federal law. The California Electrical Code, which is adopted as Part 3 of Title 24 in the California Code of Regulations, is based on the National Electric Code with amendments specific to California.[7] The interpretation of the National Electrical Code and requirements of the California Electrical Code determine panel sizing practices in the Golden State.

The two most common methods to calculate building electricity demand, and therefore necessary panel capacity, are (1) summation of the total electrical demand when all electrical end uses are running, with consideration of demand factors by end use; and (2) 30-day load monitoring and study.[8] Leveraging these two methods, we can start to consider the trade-offs in approaches and anticipate impacts related to end use electrification. Under the total summation approach, if energy intensive end uses like space and water heating are electrified at the same time without complementary efficiency

2 Synapse, October 2018, *Decarbonization of Heating Energy Use in California*, page 44, https://www.synapse-energy.com/sites/default/files/Decarbonization-Heating-CA-Buildings-17-092-1.pdf.

3 E3, April 2019, *Residential Building Electrification in California*, page 82.

4 Electric Power Research Institute (EPRI), November 2015, Grid Integration of Zero Net Energy Communities, page v.

5 EPRI, November 2016, *Grid Integration of Zero Net Energy Communities*, page 2-12.

6 Demand factor is the ratio of the maximum coincident demand of a system, or part of a system, to the total connected load on the system. The demand factor is always less than one.

7 2019 California Electrical Code, https://www.nfpa.org/codes-and-standards/all-codes-and-standards/codes-and-standards/free-access?mode=view

8 Note that this is a simplified description for the purposes of this paper; a licensed electrician should be consulted to determine proper load calculation methods.

measures, we can expect that a panel upgrade to at least 200-Amp service would be recommended. The load study approach could provide a more precise understanding of coincident loads; however, this would require time and expenses for the utility to conduct the study, and may not actually avoid the panel upgrade.

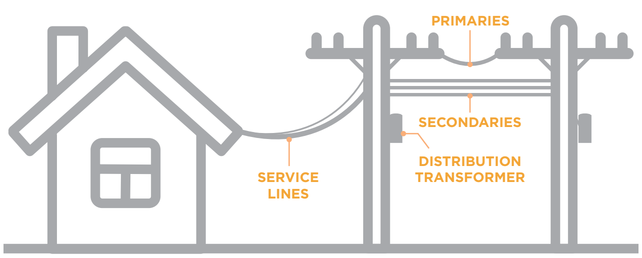

FIGURE 1. *Example of Residential Distribution Grid Service Line*

On the distribution grid, building electrification has the potential to trigger upgrades to service lines, transformers, and low voltage feeder lines, as well as upstream infrastructure. For the purposes of this paper, we focus on the secondary distribution system, which connects the service transformer to the building meter (Figure 1). Feeder and circuit sizing must consider peak demand, voltage regulation, thermal overloading, and reliability, among other factors. Load diversity is also important for local load management as there are many resources competing for existing distribution grid capacity including distributed generation, electric vehicle charging, and new connections from population growth, urban expansion, and increasing density and zoning changes within existing urban areas. Given the simultaneous competition for remaining capacity, customers electrifying or adopting DERs later in time may be more likely to be thought to "trigger" a distribution upgrade and could be exposed to greater costs.

Each utility has its own distribution planning practices and design standards to ensure quality of service. Because of the different practices of each utility, understanding and anticipating the possible impacts from building electrification is challenging for non-utility stakeholders. The need for more transparent and collaborative distribution planning practices is an ongoing policy priority in California and is one of the principles of the California Public Utilities Commission's Distribution Resources Planning proceeding.[9] This report reaffirms the need for transparent distribution planning processes but does not repeat the myriad reasons on why transparency and collaboration are important.

9 See the CPUC's Distribution Resources Plan proceeding website for more information: https://www.cpuc.ca.gov/General.aspx?id=5071.

MAIN ELECTRICAL PANELS

The electrical gateway into a building is through the main electrical panel. A building's electrical panel connects the structure to the electrical grid and distributes electricity to outlets, light fixtures, and appliances through circuits. In the home, some circuits may be dedicated to high demand end uses such as the water heater or electric dryer, or circuits may be dedicated to areas of the home such as bathrooms and kitchens and shared with end uses (Figure 2). If a circuit doesn't have enough capacity to transfer the necessary current, the circuit breaker will trip to prevent the wiring from overheating and creating a safety hazard.

The panel capacity is determined by amperage (Amp), which is the current available to serve the building. In combination with the voltage, this determines the power capacity (watts) available to deliver to end uses. In residential new construction today, 200 Amp panels are industry standard for single-family homes and 125 Amp panels are standard for multi-family.[10] In existing residential buildings, the panel size depends on the year the structure was built and whether the owners have upgraded the panel for safety, property resale value, construction of an additional room, or installation of rooftop solar or an electrical vehicle charger.

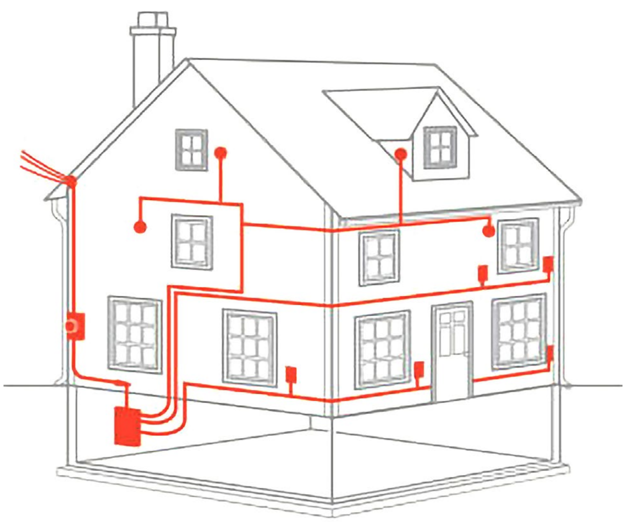

FIGURE 2. *Electrical Circuitry Within a Home*

Source: Complete Electrical Solutions, https://complete-electrical.biz/how-does-home-electricity-work-understanding-your-home-electrical-system/

Before 1950, single-family homes typically had 30 Amp fuse panels that allowed only 120 volt circuits. Between 1950 and the mid-1960s, 240 volt service became available through 60 Amp fuse panels which soon grew in popularity. By the late 1960s, 100 Amp circuit breaker panels were the norm to provide 120 volt and 240 volt circuits. Since the 1990s, 200 Amp panels have been the industry standard size for single-family homes, though 100 Amp panels remain the minimum.[11]

The potential for building decarbonization to trigger the need for a panel upgrade depends on the building age, building size, climate zone, and demand of installed technology (Figure 3). We expect four main scenarios for panel upgrades in existing single-family buildings:

1. Pre-1978 buildings where a panel upgrade has not historically occurred;
2. Pre-1978 buildings where a panel upgrade occurred, but adequate capacity[12] is not available for end use electrification;
3. Post-1978 buildings where adequate panel capacity is available but circuitry and wiring is outdated or worn and in need of upgrade; and
4. Post-1978 buildings where there is not adequate capacity on the panel for end use electrification.

Multi-family residential and commercial buildings likely have different upgrade scenarios, but we would expect that the need for upgrades correlates with building age (i.e., older buildings have higher likelihood to require panel upgrades). Multi-family residential and commercial buildings are a high priority for future research about electrification-readiness.

Total costs to upgrade a panel commonly range from $2,500 to more than $4,000. Costs vary due to equipment cost, installation cost (e.g., circuit upgrades within the building), permitting, and labor. For instance, in the Palo Alto area, the cost to upgrade from 60 Amp to 200 Amp service can range from $2,500 to $5,000, depending on the

10 TRC, September 2018, *Palo Alto Reach Code Cost-effectiveness Draft*, prepared for the City of Palo Alto, page 9-10, https://cityofpaloalto.org/civicax/filebank/documents/66742.

11 Thiele, Timothy, How Electric Service Panels Have Evolved, Updated May 29, 2019, Accessed July 26, 2019, https://www.thespruce.com/service-panels-changed-in-the-1900s-1152732

12 For the purposes of this paper, we define "adequate capacity" on a panel to mean that coincident load does not exceed the panel's nameplate capacity and the panel has adequate space in its breakers for all end uses (e.g, rooftop solar PV, electric vehicle charging, appliances).

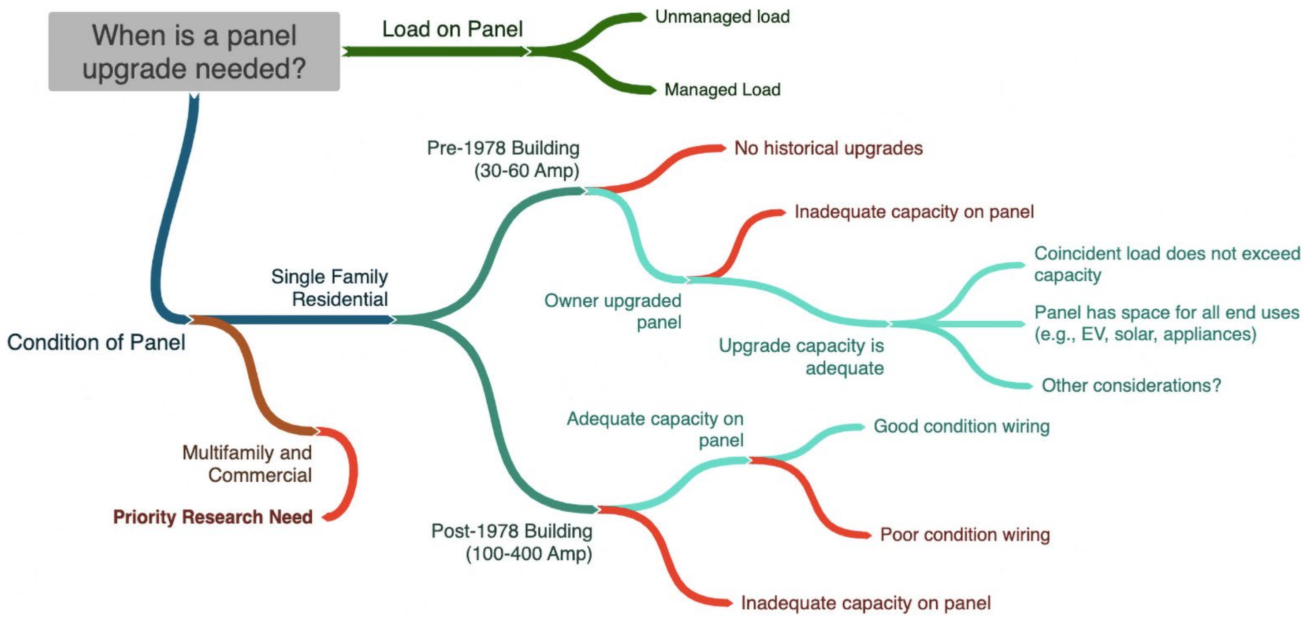

FIGURE 3. *Electrical Panel Upgrade*

configuration of the household and permitting fees, among other factors.[13] For customers of the Sacramento Municipal Utility District (SMUD), the cost of the panel seems to be less of a concern than the cost of a direct buried cable,[14] which could require significant costs to trench, upgrade in size, bury new conduit, and run new cable, in addition to incremental costs to repair the trenched areas.[15] Further, depending on the age of the home and electrical code at the time of construction, there may be other types of variable costs including upgrades to the wires in the panel, the need for clearance around the panel, grounding, or relocation (in case the panel is located in a closet for example).

INSIGHTS FROM THE FIELD (SUMMIT OUTPUTS)

From the Grid Integrated Buildings Summit, we understand that electrical panel upgrades currently occur in approximately 20-30% of rooftop solar PV projects. This is likely due to the "120% rule" prescribed in the National Electrical Code to prevent current flowing through the main electrical panel from the grid and the rooftop solar PV system from overloading the circuits.[16] Usually, this requires at least a 200 Amp panel.[17] Alternatively, a panel upgrade may be necessary because of a lack of space in the panel itself (i.e., all breakers are occupied). A rough estimate of statewide costs to upgrade all residential panels to 200 Amp could be on the order of $15 billion.[18] For SMUD alone, upgrading all customers from 100 Amp to 200 Amp service could cost more than $1 billion.[19]

There are limited existing programmatic options to offset the cost of building electrification, though offerings seem to be increasing. For low-income multifamily buildings, the statewide Low Income Weatherization Program (LIWP) provides heat pump space and water heating equipment and panel upgrades.[20] At a local level, some Community Choice Aggregators are piloting incentives for heat

13 City of Palo Alto Utilities, May 2015, *A Cost-Effectiveness Study of Building Appliances and Passenger Vehicles*, page 31, https://www.cityofpaloalto.org/civicax/filebank/documents/47998.

14 A direct bury cable is a type of cable used for underground connection between the utility service transformer and an individual building or home.

15 Conversation with SMUD representatives, October 15, 2019.

16 See https://www.purepower.com/blog/120-rule-explained-nec-705-12d2

17 California Energy Commission (CEC), 2001, A Guide to Photovoltaic System Design and Installation, page 17, https://ww2.energy.ca.gov/reports/2001-09-04_500-01-020.PDF

18 Comments from East Bay Community Energy at the Decoding Grid Integrated Buildings Summit, November 12, 2019.

19 Comments from SMUD at the Grid Integrated Buildings Summit, November 12, 2019.

20 California Housing Partnership and Association for Energy Affordability, March 2019, California's Cap-and-Trade-Funded Low-Income Weatherization Program Multifamily: Impact Report, https://chpc.net/new-low-income-weatherization-program-liwp-multifamily-report-assesses-cap-and-trade-program-benefits/.

pump water heaters and related panel upgrades. For instance, Silicon Valley Clean Energy's FutureFit Heat Pump Water Heater pilot is offering incentives for the replacement of 100 natural gas water heaters for electric heat pump water heaters in its service territory. Customers can receive $2,000 for a heat pump water heater, $300 for a related data monitor, and $2,500 to upgrade the electrical panel to 200 Amp service; low-income customers may be eligible to receive an additional $1,500.[21] In SMUD's Home Performance Program, customers can receive up to $8,000 to electrify their end uses, including up to $2,500 for circuit and panel upgrades.[22] To date, SMUD has not had significant uptake of panel upgrade incentives. Less than 50 customers have received incentives for the panel upgrade, compared to about 800 heat pump water heaters and 400 heat pump HVAC systems.[23] It's possible that customers are only electrifying one end use and, therefore, avoiding a panel upgrade.

Stakeholders raised concerns with the National Electric Code several times throughout the summit. Most stakeholders were familiar with the summation of total demand as the most conservative approach to calculating load and there was little collective knowledge regarding when or how alternative calculations may be accepted. There was a noted lack of clarity on the correct "order of operations" to calculate estimated loads to ensure that energy efficiency and actual equipment amperage ratings on circuits are accurately considered, as well as lack of clarity about how automated demand response and other load management strategies might be considered in load calculations. Given that cities and counties may adopt more strict interpretations of the National Electric Code and/or the California Electrical Code, city and county building inspectors and leaders should be engaged to better understand the acceptable alternative options for load calculation methods. Actual meter data should be used to better understand the difference in peak between all-electric and mixed-fuel homes.

End use electrification is not the only trigger for requiring a panel upgrade. In pre-1978 buildings, a panel upgrade could be required before any change in electrical load for safety purposes or to improve the quality of electric service in the building. In buildings where rooftop solar PV and/or electrical vehicle charging are installed, a panel upgrade may be needed to serve those distributed energy resources with capacity and/or breaker space within the panel. The impacts of coincident versus non-coincident demand between electric vehicle charging and building electrification could have a significant influence on the likelihood to trigger upgrades to the electrical panel and distribution infrastructure. Similarly, battery storage could also have a significant influence on the ability to manage coincident loads. Additional research is needed to better understand the potential impacts and opportunities from installation of multiple DERs along with building electrification end uses. For instance, installation of rooftop solar PV could serve to reduce the grid impact of end use electrification by encouraging greater use of electricity generated on-site. While this may not avoid a panel upgrade, it could limit upstream impacts to distribution grid infrastructure.

From discussions throughout the summit, it was apparent that stakeholders are still working to understand the potential for panel upgrades. There was interest to clarify when a panel upgrade could be avoided, such as through circuit reconfiguration and optimization, load management devices, and/or site-specific load summation methods, but it was not clear whether behind-the-meter load management would be able to meet safety standards established through the National Electrical Code and California Electrical Code.

To address the uncertainty related to the scope of panel upgrades in California necessary to accommodate end use electrification, stakeholders identified that California needs: (1) to re-evaluate panel sizing protocols with consideration for energy efficiency improvements and load management tools; (2) to co-offer end use electrification with demand-side programs (e.g., energy efficiency and demand response); (3) a better understanding of potential equity issues, including who pays and who benefits from end use electrification; and (4) clarity on the economics of various approaches to managing the electrical panel when installing distributed energy resources.

21 Silicon Valley Clean Energy Heat Pump Water Heater Program website, Accessed December 8, 2019, https://www.svcleanenergy.org/water-heating/.

22 SMUD, Home Performance Program Go-Electric Bonus Package Website, Accessed July 25, 2019, https://www.smud.org/en/Rebates-and-Savings-Tips/Improve-Home-Efficiency/Go-Electric-Bonus-Package.

23 Conversation with SMUD, October 15, 2019.

> **PANEL UPGRADE APPRENTICESHIP**
>
> To prepare the market for increased demand for electrical panel upgrades, East Bay Community Energy is considering the potential to collaborate with labor organizations on an apprenticeship program to advance a skilled electrical workforce.
>
> The program would support the education and training of novice electricians through a four to five year apprenticeship focused on upgrading electrical panels and the related wiring and circuitry to support a decarbonized future.
>
> The program would include classroom education with hands-on job experience, a living wage, and a pathway to a high quality career as an electric journeyperson. Without this type of opportunity and benefits for the apprentice, California will be hard-pressed to find a workforce prepared to install a decarbonized future.

DISTRIBUTION GRID

The distribution grid serves as the connection and manager for delivering electricity from high voltage transmission lines and electricity substations into a building. Historically, power flowed only in one direction from the generation source, through transmission and distribution networks, and finally to the end use customer. In California, however, the power distribution landscape is changing as more distributed generation like rooftop PV solar and behind-the-meter battery storage is adopted. As a result of the diversification of generation sources, demands on the distribution grid are evolving. Rather than only providing one-way flows of relatively predictable energy demand, the distribution grid must accommodate a variety of variable generation sources and greater fluctuation in demand.

For the purposes of this paper, we focus primarily on the secondary distribution grid system that connects low voltage (less than 500V) electricity from the service transformer to the building (Figure 4). Typically, a service transformer serves 5-7 homes or small buildings in a neighborhood, but this varies by utility based upon their design standards and load characteristics. Medium-sized buildings may have a dedicated service transformer, and large buildings could have multiple dedicated service transformers. Secondary distribution grid system infrastructure that may need to be upgraded to serve increased load can include the service transformer and the service line connecting the transformer to the building meter.

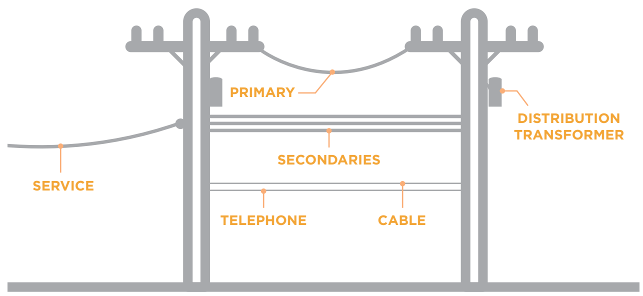

FIGURE 4. *Example of Distribution Grid Service Lines and Transformer*

Factors determining how end use electrification impacts the distribution grid include the coincidence of the various loads, clustering of all-electric buildings on a service transformer or upstream feeder, and prevalence of other distributed energy resources that impact the distribution grid, such as distributed generation, battery storage, and electric vehicle charging. Because each utility has its own design standards based upon climate zone, customer demographics, geography, building types, safety standards, and other factors, developing potential scenarios for likely upgrades (as done for electrical panels above) is not straightforward or applicable across service territories. Therefore, we draw upon existing literature and experience with transportation electrification to better understand the potential impacts from building end use electrification.

Much of the literature addressing distribution grid impacts from increasing electricity load relates to transportation electrification. Transportation electrification results in substantial (e.g., 3.7 kW), sustained electricity demand for electric vehicle charging, as opposed to the potentially “peakier” and relatively lower demand resulting from building end use electrification. Additionally, it is generally more simple to shift demand from electric vehicle charging than from building end uses such as space heating and cooking. If, however, end use electrification results in electricity demand exceeding secondary distribution grid system capacity, upgrades to distribution grid infrastructure to serve the building end uses would be similar to upgrades to serve electric vehicle charging load (e.g., increasing capacity on service lines) so we apply study results from transportation electrification to building electrification.

From the literature we find that, at SMUD, a service transformer is considered overloaded and in need of replacement if it experiences sustained loads over 115% of the device's nameplate rating. The cost of replacing a transformer varies between $4,800 and $6,700 based on the type (pole-mount vs. pad-mount), capacity, and installation labor. If the service line connecting the transformer to the building electric meter also needs to be upgraded, this cost can be, approximately, an additional $8,000 per building.[24] Typically, the utility and customer split the cost of distribution grid upgrades, with the utility (or rather, utility ratepayers) paying up to a certain allowance,[25] as determined by the CPUC's Rule 2, Rule 15, and Rule 16 for investor-owned utilities. After the allowance is exceeded, the customer typically is responsible for additional infrastructure costs.[26]

Between July 2011 and December 2018, transportation electrification resulted in just over 600 service line and/or distribution system upgrades in PG&E, SCE, and SDG&E territories across more than 415,000 plug-in electric vehicle owners. The range of costs varied widely - from $1 up to more than $338,000. The highest costs have been in PG&E territory, where the average cost of distribution system upgrades was more than $19,000; average distribution upgrade costs for SCE and SDG&E were approximately $4,500 and $4,000, respectively.[27] Further, local jurisdictions may have local restrictions placing service transformers in public rights of way, necessitating alternative siting to be paid by the property or building owner.[28] As transportation electrification and adoption of other DERs increases, the likelihood of necessary distribution system upgrades is expected to increase as well.

INSIGHTS FROM THE FIELD (SUMMIT OUTPUTS)

To enable a high DER future and a decarbonized economy, updates to distribution grid system planning and infrastructure improvements are necessary. California needs a two-way power flow system with advanced communication and control technologies to support DER adoption and integration, flexibility, and resiliency. Building end use decarbonization and electrification are part of the group of factors to consider and plan for, however, the incremental impacts to distribution infrastructure are expected to have relatively less impact than those resulting from widespread rooftop solar and electric vehicle adoption. That said, to support the distribution grid in relation to building decarbonization, stakeholders at the summit discussed the need for improved grid data transparency and access; coordination among city planners, grid planners, developers, and DER manufacturers; increased availability of load management technologies and strategies; and promotion of end use efficiency and on-site consumption of rooftop solar energy.

Stakeholders discussed the need to share and update load assumptions used in distribution grid planning. For instance, assumptions about the efficiency of household appliances (e.g., refrigerators) could be outdated and reflect greater demand than existing industry standard. Additionally, street light efficiency assumptions may be outdated now that street lights are converting to LEDs and additional capacity may be available, but stakeholders lack insight into the extent of this potential. Overall, stakeholders identified that in order to address distribution grid planning and investments to increase clean electric loads, California needs: (1) better modeling tools and data analytics for multiple new future loads; (2) clear principles and goals to guide new grid investments; and (3) user-friendly guidance to customers on utility vs. customer costs and information about the most economic pathways to decarbonize.

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24 Berkheimer, J., Jeff Tang, Bill Boyce, and Deepak Ashwani, May 2014, *Electric Grid Integration Costs for Plug-In Electric Vehicles, SAE International Journal of Alternative Power, Volume 3*, Issue 2, page 3.

25 The current residential allowance for PG&E customers is $2,341, $3,084 for SCE customers, and $3,241 for SDG&E customers, as determined by Electric Rule 15, Section C.3.

26 Energy Solutions, November 2019, *Electric Vehicle Infrastructure Cost Analysis Report for Peninsula Clean Energy and Silicon Valley Clean Energy*, page 17.

27 PG&E, SCE, and SDG&E, April 2019, Table IOU-2 in *Joint IOU Electric Vehicle Load Research Report, 7th Report*, page 8, filed on April 2, 2019 in Rulemaking R.09-08-009/R.13-11-007.

28 Energy Solutions, November 2019, *Electric Vehicle Infrastructure Cost Analysis Report for Peninsula Clean Energy and Silicon Valley Clean Energy*, page 19.

FINDINGS

Upgrades to main electrical panels and local distribution infrastructure are needed to facilitate the adoption of DERs, reduce emissions from the building sector, and achieve California's greenhouse gas reduction goals. Even before any end use electrification, some buildings will require upgrades to electrical panels to modernize for the 21st century and improve the quality of electrical service within the building. Similarly, the distribution grid system requires updates and upgrades to accommodate bi-directional power flow from distributed generation, interconnect DERs such as electric vehicles and battery storage, and facilitate automated demand response and load management.

Relative to demand from electric vehicle charging, building electrification is expected to have less absolute impact to total demand, but could exacerbate challenges with managing peak demand and evening ramp. That said, demand increases could be mitigated with load management devices and strategies and may not necessarily require capacity increases in all cases. The extent to which load management can mitigate and avoid capacity increases and infrastructure costs depends upon many factors, but importantly the interpretation and enforcement of the National Electrical Code and California Electrical Code, and the way that distribution planners, stakeholders, and distribution system operators consider and act upon the resulting load calculations.

Where electrical panel upgrades and secondary distribution grid system infrastructure upgrades are necessary, costs can range significantly. For panel upgrades, costs for individual customers can range between $2,500 to more than $5,000 depending on equipment, installation, and labor costs. For distribution system upgrades, costs are split between individual customers and utilities (or rather, utility ratepayers) and can vary significantly into the tens of thousands of dollars or more, depending on the condition of the existing infrastructure. Options for programmatic incentives are currently limited and would only partially cover the customer costs for panel upgrades. As adoption of DERs increases, the likelihood to trigger distribution grid upgrades increases as well.

To address the uncertainty related to the scope of panel upgrades in California necessary to accommodate end use electrification, California needs: (1) to re-evaluate panel sizing protocols with consideration for energy efficiency improvements and load management tools; (2) to co-offer end use electrification with demand-side programs (e.g., energy efficiency and demand response); (3) a better understanding of potential equity issues, including who pays and who benefits from end use electrification; and (4) clarity on the economics of various approaches to managing the electrical panel when installing distributed energy resources. In order to address distribution grid planning and investments to increase clean electric loads, California needs: (1) better modeling tools and data analytics for multiple new future loads; (2) clear principles and goals to guide new grid investments; (3) user-friendly guidance to customers on utility vs. customer costs and information about the most economic pathways to decarbonize; and (4) inclusion of clear definitions and valuation of grid services from load flexibility in integrated resource and procurement plans.

RECOMMENDATIONS

To ensure that building-level infrastructure and the secondary distribution grid system are ready to support building decarbonization and electrification, California needs four interrelated solutions: (1) pilots and incentives; (2) implementation of load management technologies and strategies; (3) coordination and collaboration on load calculation approaches and how they are used in distribution system planning; and (4) ongoing customer support.

PILOTS AND INCENTIVES FOR PANEL UPGRADES AND LOW AMPERAGE TECHNOLOGIES

All customer segments should be offered incentives for panel upgrades in addition to incentives available for decarbonization equipment. Particular focus should be applied to low income and disadvantaged communities where existing infrastructure could be older and customers less likely to be aware of and able to afford upgrades. Given that older buildings are more likely to require panel upgrades, investor-owned utilities could leverage the more than $580 million dollars of unspent and authorized Energy Savings Assistance Program funds[29] to support panel upgrades and improve comfort and safety in low-income homes.

29 Natural Resources Defense Council, May 2019, Utility Low-Income Efficiency Programs in Need of Upgrade, https://www.nrdc.org/experts/miles-muller/utility-low-income-efficiency-programs-need-upgrade.

There is also an opportunity to target communities that have historically been left out of energy policy decision-making and are already underserved by existing infrastructure to encourage "all-electric ready retrofits," akin to "make ready" incentives for electric vehicle charging infrastructure.

Incentives should also be available for existing low amperage equipment or support technologies (e.g., smart plugs and smart panels) that can avoid or defer the need for a panel upgrade and reduce competition for remaining distribution grid capacity. The utilities' Integration Capacity Analysis maps developed via the Distribution Resources Planning proceeding could provide actionable data to identify areas of the distribution grid to target low amperage solutions.

Incentives should be funded by a variety of resources, rather than only relying on utility ratepayers. Local governments can implement creative financial solutions to provide incentives for electrification technologies. For instance, a portion of the City of Berkeley's property transfer tax is currently eligible to incentivize a seismic retrofit. A portion of the transfer tax could instead be reallocated to incent clean energy retrofits at the time of sale.[30] Local governments should collaborate on best practices to ensure inclusive financing solutions are available.

To operationalize pilots and incentives for panel upgrades and low amperage technologies:

1. The CPUC should direct the administrators of the Energy Savings Assistance Program to upgrade electrical panels for all qualified customers to meet industry standard in new construction (e.g., 125 Amp panel service for each unit in a multifamily building).
2. The CPUC, in its Building Decarbonization Rulemaking 19-01-011, should offer panel upgrades to facilitate building decarbonization in all customer segments.
3. The CPUC should direct the investor-owned utilities to offer incentives for low amperage equipment in their energy efficiency portfolios.
4. The CEC, CPUC, and utilities should meet and coordinate with stakeholders to identify opportunities and best practices to co-offer electrical panel upgrades when rooftop solar PV and/or electric vehicle charging infrastructure are installed.
5. Local governments should coordinate on options and best practices for offering incentives for panel upgrades and/or requiring panel upgrades when a property is sold.

LOAD MANAGEMENT TOOLS AND STRATEGIES TO REDUCE OR AVOID IMPACTS

There are many existing technologies and strategies to manage load and reduce peak demand. For example, utilities and community choice aggregators are deploying default time-of-use rates, which disincentivize peak electricity use by charging higher rates during the evening peak period and encouraging load shift. Additionally, automated demand response programs are growing in popularity and impact, with the ability to function as a 50 MW virtual power plant from residential peak demand reductions.[31] Devices such as a smart plug splitter can also help to manage load and mitigate peak demand by splitting a plug between an electrical dryer and an electric vehicle charger or a heat pump water heater. This can avoid the need for panel or wiring upgrades and offers an option to increase access to electrification technologies for renters.[32] Further, a smart panel could enable load management and control within the entire building from one device, and offer detailed tracking and feedback on building energy use.

To operationalize load management tools and strategies to mitigate demand impacts:

1. The CEC should include in the next Integrated Energy Policy Report an assessment of the potential load increase from building electrification and of the potential for load management tools and equipment to shift load and defer infrastructure upgrades.
2. The CPUC should direct the investor-owned utilities, through the Rule 21 Working Group process, to conduct an assessment of the potential for load management tools and equipment to defer distribution grid upgrades. This assessment should include an estimate of deferred infrastructure costs to help monetize and value the grid services offered in load management.

30 City of Berkeley, November 2019, Fossil Fuel Free Buildings in California Presentation, delivered November 13, 2019, https://gridworks.org/wp-content/uploads/2019/11/Day-2-Grid-Integrated-Buildings-Summit-Slides.pdf.

31 OhmConnect, November 2019, OhmConnect Presentation, delivered November 13, 2019, https://gridworks.org/wp-content/uploads/2019/11/Day-2-Grid-Integrated-Buildings-Summit-Slides.pdf.

32 NeoCharge website, https://www.getneocharge.com/products.

3. The CEC, CPUC, and distribution system operators should coordinate on the potential for and reliability of virtual power plants[33] to reduce anticipated load increases from building electrification. Outputs from this coordination effort should include quantification of the value that virtual power plants provide in smoothing demand ramp, avoiding carbon-intensive energy generation, and reducing construction of increased distribution grid capacity.

COORDINATION AND COLLABORATION ON LOAD CALCULATION APPROACHES AND HOW THEY ARE USED IN DISTRIBUTION SYSTEM PLANNING

Stakeholders, including local permitting departments, building inspectors, and contractors, need guidance, coordination, and collaboration on load calculation approaches to help avoid unnecessary panel upgrades. In turn, stakeholders, including distribution planners and distribution system operators, need to collaborate on how those load calculation approaches feed into distribution system planning assumptions and infrastructure decisions. Meter-based data should be leveraged to analyze the demand factor, validate load calculation models, and better understand load profiles and peak of all-electric homes, with and without electric vehicle charging.

Local governments would be a critical partner to identify load calculation approaches that can simultaneously meet safety standards and avoid excessive or redundant infrastructure costs. City, county, and state leaders may also consider developing a guidebook that can help stakeholders navigate the building electrification process, including guidance on panel cost responsibilities. The Governor's Office of Business and Economic Development developed an Electric Vehicle Charging Station Permitting Guidebook, which can serve as a useful template for building electrification.[34]

To update load calculation approaches and their application in distribution planning:

1. The CEC should work with the California Building Standards Commission and local governments including permitting offices and building inspectors on the interpretation of the National Electrical Code and its application in the California Electrical Code. This coordination effort should include a review of options for load calculation approaches that meet safety standards while minimizing the need for construction of new infrastructure.
2. The CPUC should direct the investor-owned utilities to clarify and update base load assumptions through their Distribution Resources Plans to ensure that efficiency standards are accurately considered.
3. The CEC and CPUC should consult with the Governor's Office of Business and Economic Development on the potential to develop a Building Electrification Permitting Guidebook to clarify acceptable load calculation approaches and inform stakeholders about the process to retrofit to an all-electric building.

A CUSTOMER-CENTRIC OUTREACH PLATFORM TO PROVIDE TECHNICAL SUPPORT, EDUCATE ON THE ECONOMICS OF VARIOUS DECARBONIZATION PROJECT OPTIONS, AND PROMOTE CHOICE

Throughout the building decarbonization transition, customers and the customer experience should stay at the forefront of policy and programmatic options. Customers should be able to understand their options for decarbonizing their homes, offices, and buildings and have access to information platforms that can help clarify the time, costs, contractors, and permits involved. Program administrators should consult with contractors and project implementers to develop project guidance tools so that customers can better understand when optimizing circuits within an existing panel is preferable to increasing panel capacity. Customers should also have education opportunities to understand the long-term retrofit options to decarbonize over time and access to incentives for technologies that can help manage load and avoid upgrades. Ongoing support is also necessary so that customers know how to manage their electrical load after fuel switching (e.g. rate options, automatic demand response programs).

To create a customer-centric platform to support building decarbonization:

1. The CPUC should support a statewide consumer education campaign to promote the benefits of building decarbonization.
2. The CEC should support a customer-facing project guidance platform into its AB3232 implementation

33 See *Silicon Valley Clean Energy Virtual Power Plan Options Analysis* (https://gridworks.org/wp-content/uploads/2019/08/GW_Silicon-Valley-Clean-Energy-report.pdf)

34 California Governor's Office of Business and Economic Development, July 2019, Electric Vehicle Charging Station Permitting Guidebook, http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf.

efforts. This should include coordination and consultation with contractors and labor representatives to ensure accurate representation of feasible project options, costs, and timelines.

3. The CPUC and CEC should consult with housing organizations to identify tenants' needs and property owners' capacity to install building decarbonization end uses, and identify opportunities to streamline program administration and stack incentives in underserved customer segments.

CONCLUSION

There is significant opportunity to leverage existing customer marketing and education efforts to incorporate building decarbonization and electrification needs. Indeed, it would be best to streamline existing programmatic efforts to avoid redundancies or the possibility to create customer confusion. Given that deep decarbonization requires co-offering solutions with energy efficiency, distributed generation, battery storage, and electric rate design efforts, stakeholders should mobilize today to continue to build the foundations for a low carbon future. While the electrical panel is the gateway to electrical service within a building, it need not become the gatekeeper to a decarbonized future.


BUILDING
DECARBONIZATION
COALITION


23°/74°