Docket No. A.21-12-009

Exhibit No.: Ex. CLE-03

Date served: October 12, 2022

Exhibit Sponsor: CLECA

CLECA Response to SCE Data Request, Set 1, with attachments

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL® Company

Proceeding Number:	A.21-12-009
Proceeding Name:	Application of Southern California Edison Company for Approval for its Building Electrification Programs
Date:	September 29, 2022
Responses Due:	October 7, 2022
Originated by:	Ka-Wing Maggie Poon Regulatory Case Manager Southern California Edison Company 8631 Rush Street Rosemead, CA 91770 (626-302-1194) Ka-Wing.Poon@sce.com
Cc:	Olivia.Samad@sce.com Case.Admin@sce.com
Data Request No:	Response to SCE-CLECA-001

Questions:

The following questions refer to CLECA's rebuttal testimony attachments C, D, and E, submitted on September 19, 2022.

1. Were CLECA representatives authors of any of the presentations attached?

Response: No.

2. Was the presentation given under oath?

Response: Not to our knowledge.

3. Was the presentation given on the record of a proceeding and subject to cross examination?

Response: Not to our knowledge.

4. Is CLECA planning to make the authors of the presentations available for cross-examination? If so, which ones?

Response: No.

5. (Page C-9) Would the proposed circuit controls in the presentation be able to accommodate whole home electrification, including solar panels, battery charging, electric vehicle charging, induction cooking, electric dryers, heat pump pool water heaters, etc.?

Response: The slide states that the circuit pauser pauses the circuit when the load on the panel exceeds 80% of capacity. The load on the individual circuits could be created by electric vehicle charging, induction cooking, electric dryers, heat pump pool water heaters, etc., or some subset of those items. The usage placed on panel and the circuits would be determined by application of NEC 220.83(B) and NEC 220.87.

6. (Page C-13) How many homes within SCE's service area would be able to fully electrify their homes with 100-amp electric panels?

Response: As stated in CLECA's rebuttal testimony, the great majority of homes with 100-amp electric panels in SCE's service area could be fully electrified using power efficient equipment and circuit controls. CLECA does not have exact figures.

7. (Page C-13) In reference to NEC 220.87 electric load panel calculation methodology, being that this approach is specific to retrofits and utilizes historical peak power use data to calculate load; what considerations are provided for changes in behavior or energy consumption if a home is sold, or in the case of rental units whenever a new tenant moves in (e.g., more occupants, increased hot water usage, etc.)? What time interval is allowed by NEC 220.87 and permitting authorities to determine the historical peak power?

Response: Slide C-13 refers to NEC 220.83(B) which uses nameplate ratings for the appliances instead to make sure that loads are within the capacity of each circuit. Furthermore, once the loads are examined per NEC 220.83(B), they can be evaluated with NEC 220.87 to demonstrate that adequate capacity exists given current usage patterns and determine how much unused capacity would be expected to exist given the current household. (See D-12). Finally, the circuit controller described on slide C-9 that temporarily interrupts a larger load, such as an EV charging, if the overall load on the system exceeds 80 percent of the 100A panel capacity could be relied upon to prevent the panel from being overloaded even after a household has changed, introducing new usage patterns.

The following questions refer to CLECA's rebuttal testimony submitted on September 19, 2022.

8. (CLECA Rebuttal Testimony, Page 4) What is the status of the Building Decarbonization and Electric Vehicle Charging Equipment Web Guide (California Energy Commission Docket 22-DECARB-02) project referenced on page 4 of CLECA's Rebuttal Testimony?
   a. Is that web guide project complete? If not, when is it anticipated to be completed?

   Response: No, it is not complete. CLECA does not know when the CEC will complete its project.

   b. As a result of this web guide project, what best practices have been identified and published to help building owners, the construction industry, and local governments overcome barriers to electrification of buildings and the installation of electrical vehicle charging equipment?

   Response: The CEC has yet to issue any report based on the workshop, but there are clear inferences to be drawn. Best practices maximize the cost efficiency of conversions between natural gas appliances and electrical appliances consistent with safe practices. As presented in the slides that were attached to CLECA's testimony, best practices involve converting gas appliance to highly efficient electric appliances that minimize required amperage. This approach maximizes the use of existing housing infrastructure and minimizes the cost associated with the conversion from gas appliances to electric appliances. Best practices also involve the use of electrical controls to protect and manage the electrical system such that a larger load such as an electric vehicle charger can be temporarily suspended while other demands on the capacity of the circuits are met.

   Furthermore, a study commissioned by PG&E, Service Upgrades for Electrification Retrofits Study Final Report, May 27, 2022, which was cited to on slide D-4, shows at page 6 that panel upgrades can on average range in cost between $2,000-$4,500 but notes that a panel upgrade can lead to an upgrade in the customer's utility service line, which can cost the customer between $2,850-$30,000, depending on the number of customers attached to the transformer and other factors. Taking into account the utility allowances creates a cost range for all components between $2,000-$30,000.

Slide D-4 presents a narrower range $3,000-$25,000 which is closer to the average cost. The study is attached: Service-Upgrades-f or-Electrification-Re

c. What is market availability of electrical equipment that can minimize service capacity requirements? Please provide a list and product specifications.

Response: Please see, for example, the attached document (pp. 41-87) that presents currently available equipment. This document was cited in slide D-18.

Pocket-Guide-to-All -Electric-Retrofits-of

d. How does low-amperage 120V equipment compare to equipment with higher amperage in terms of energy efficiency and energy bills? Are customers who adopt low-amperage 120v equipment expected to have lower, equal, or higher energy bills?

Response: First, a 100A panel is not necessarily entirely installed with 120A circuits. Panels may have one or more circuits at 240A. (See for example slide D-7.) Second, an installation at 240V would have lower losses than an installation at 120 V for the same load. However, highly efficient appliances that minimize current so as to fit within the homeowner's 100A budget would also serve to minimize the electricity bill. The energy savings is something that a homeowner would be in a position to factor in when considering whether and/or how to upgrade the panel or individual circuits while electrifying.

e. Are all equipment ETL or UL Listed to confirm that the product is safe for use?

Response: CLECA does not have that information but as the document provided in response to Q.8.c was prepared by an electrical contractor on behalf of several entities, there is no reason to assume that unsafe appliances are being listed.

9. (CLECA Rebuttal Testimony, Page 4) CLECA states that "a great majority of homes with 100A or greater electrical panels can be fully electrified without a panel or service line increase. This can be accomplished by optimization of the use of the existing panel's capacity through adding efficient electrical devices with low rated amps and the use of circuit sharing devices…"

a. What is the percentage of homes that can be fully electrified without a panel upgrade?

Response: CLECA has only estimates available from information provided in the CEC workshop however several citations provided by the workshop materials are of use. For example, housing surveys are performed regularly for the Housing and Urban Development (HUD) by the U.S. Census Bureau, see website https://www.huduser.gov/portal/datasets/ahs.html. There is a link provided to the American Housing Survey website which can provide information about the age of housing nationally as well as in California and several urban areas relevant to SCE, namely, Los Angeles/Long Beach/Glendale and Anaheim/Santa Ana. These surveys provide information regarding the age distribution of the housing which then can be applied to the prevailing building standards applicable in various time periods to determine the likelihood of the presence of 100A panels in homes if they have not already been upgraded due to a homeowner pursuing a remodeling project. The houses that are most likely to have 100A panels are those homes built between the mid-1960s and the early 1980s because this was the period during which the 100A panel was required in new houses. Older houses that were remodeled during this timeframe are also likely to have 100A panels. For example, the 2019 statewide housing survey shows the following breakdown in terms of age for housing:

prior to 1960	29%
1960-1969	14%
1970-1980	17%
post 1980	41%

From the survey it is apparent that about 41% of the housing units are post 1980 so the panel size should not be an issue because by the 1980s a 200A panel was required in new housing. Houses older than about 1965 (36%) would require a panel upgrade unless they have been remodeled because the older houses have less than 100A and typically have fuse style panels. (CLECA does not know the percentage of older homes that have been remodeled although CLECA suspects that the percentage is substantial.) The remaining 24% would fall into the category where they were built with 100A panels that could support electrification provided they were electrified using highly efficient appliances and circuit control to prevent overloads.

b. Please provide studies or analysis used to derive this percentage.

Response: Several surveys have been attached to this response. Note that the only Anaheim/Santa Ana survey available was performed in 2011.

2011 Anaheim-Santa Ana | 2019 California Housing Survey.xlsx | 2019 LA-LB-Glendale Hou

c. How large is the population (number of homes) or data set that was used to make this determination?

Response: Please see the response to Q.9.b.

d. How many of the homes evaluated are in the SCE service area?

Response: Please see the response to Q.9.b.

e. Are permitting authorities sufficiently trained about circuit control technologies and NEC load calculation methods?

Response: CLECA has not conducted a survey of local permitting authorities to determine their extent of training.

f. Are there sufficient numbers of trades employees and electrification experts trained to support the full electrification of homes without panel upgrades?

Response: CLECA has not conducted a survey of available trades employees and electrification experts.

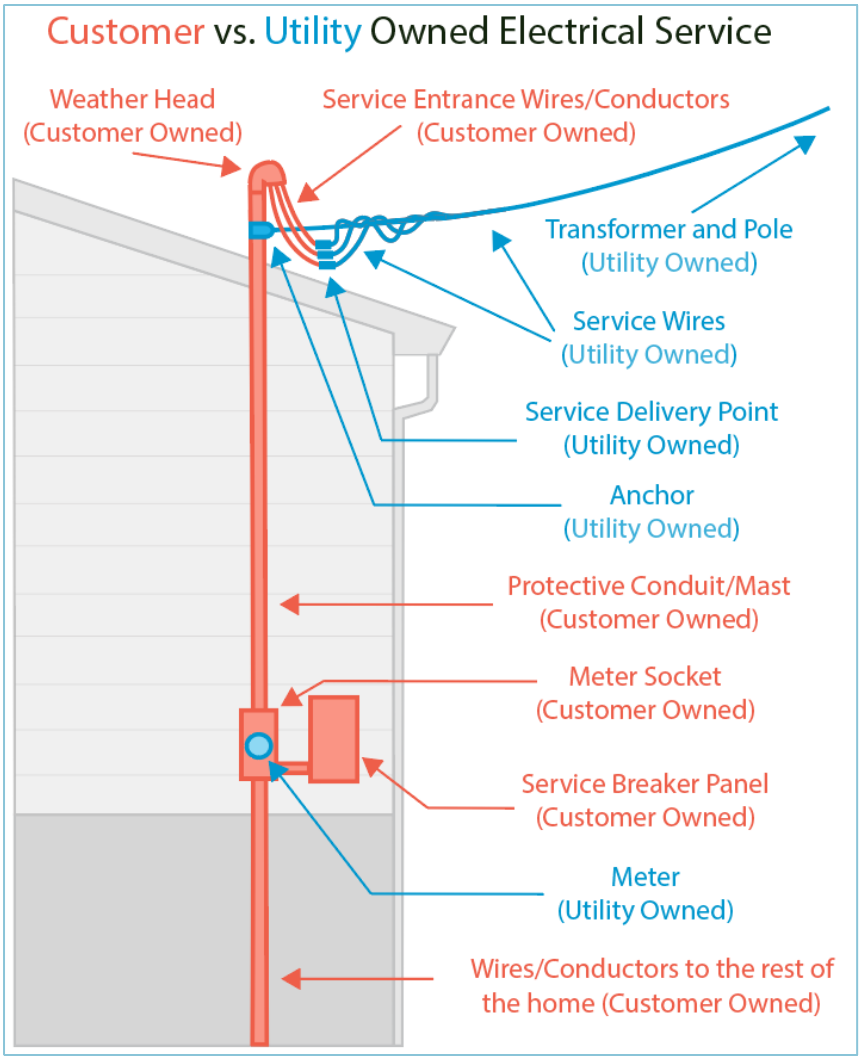
g. Please provide studies on the expected useful life of the circuit sharing devices and evaluations of the device performance and reliability.

Response: CLECA does not have this information.

Attachment to Question 8b: Service Upgrades for Electrification Retrofits Study

Service Upgrades for Electrification Retrofits Study Final Report

May 27, 2022



Courtesy of Emily Higbee, Redwood Energy Research Director

The above image displays ownership of basic electrical service equipment that will be assessed by an electrification retrofit contractor to complete an overhead Service Upgrade. All the components depicted in the diagram are within the scope of an electrical Service Upgrade discussed in the report except for new wires to the rest of the home.

CALMAC STUDY ID: **PG&E0467.01**

CONTRIBUTORS

NV5 INC.
Shoshana Pena, Director of Program Services
Collin Smith, Program Manager
Greg Butsko, Vice President of Distribution Services
Rick Gardner, Director of Distribution Services

REDWOOD ENERGY
Sean Armstrong, Principal
Emily Higbee, Research Director
Dylan Anderson, Senior Staff Researcher
Rebecca Hueckel, Senior Staff Researcher

PROJECT SPONSORS
Pacific Gas and Electric Company: Robert Kasman, Victoria Culter, and Kati Pech
San Diego Gas and Electric Company: Kelvin Valenzuela and Dan Hudgins

TABLE OF CONTENTS

Executive Summary ... 4
Key Findings ... 5
Key Recommendations ... 7

1.0 Introduction ... 9
1.1 Objectives ... 9
1.2 Methodology ... 11
1.3 Background ... 14

2.0 Study Findings ... 17
2.1 Map out existing process ... 17
2.2 Understand costs incurred by all parties ... 31

3.0 Conclusions and Recommendations ... 35
3.1 Conclusions ... 35
3.2 Recommendations ... 39

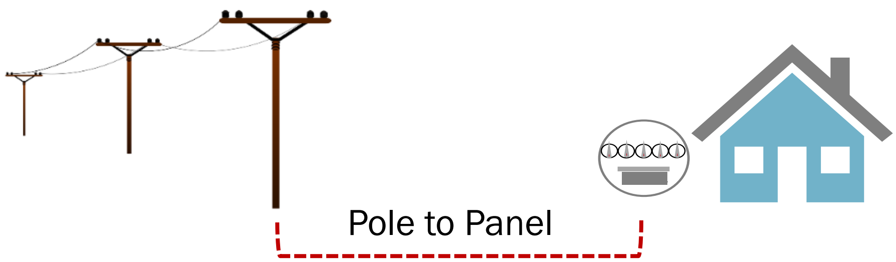
4.0 Appendix A ... 45
4.1 Customer Online Surveys ... 45
4.2 Contractor Interviews ... 47
4.3 Literature Review ... 50
4.4 Research plan and Interview Study Guides ... 58

5.0 Appendix B ... 59
6.0 Appendix C – Standardized Catalog of Recommendations ... 60

EXECUTIVE SUMMARY

The Service Upgrades for Electrification Retrofits Study (Study) conducted on behalf of Pacific Gas and Electric Company ("PG&E" or "Utility") and San Diego Gas and Electric ("SDG&E" or "Utility") began in June 2021 with the goals to examine both the processes and costs required to upgrade electrical service capacity when completing residential electrification retrofits, and make recommendations to PG&E and SDG&E (collectively "Utilities") and future program implementers on process improvements for integrating service upgrades into electrification projects. Electrical service upgrades (Service Upgrades) are typically defined as an upgrade in amperage capacity from the pole to the residential meter. For the purposes of this Study, Service Upgrades may include work from the pole to the panel but excludes anything on the home side of the panel such as new wiring (Figure 1).

Figure 1 - Service Upgrades



As the California residential building market is rapidly shifting towards electrification and reductions in natural gas construction and appliances, the Utilities created this Study to explore potential support opportunities for customers who may be impacted by Service Upgrades due to electrification retrofits.

This Study contains findings and recommendations to address challenges for integrating Service Upgrades into electrification projects. These recommendations include ways that Utilities can improve the Service Upgrade process, recommendations for potential program implementers on incorporating Service Upgrades into electrification programs, and identifies future research needs for the Utilities and program implementers.

The Study participants were homeowners and contractors in the PG&E and SDG&E service territories that completed a Service Upgrade in 2020 and Q1 2021. They were interviewed and completed online surveys from August 2021 through December 2021. Subject matter experts (SMEs) from PG&E and SDG&E, local jurisdictions, and California Public Utility Commission (CPUC) were interviewed.

- A total of 34 homeowners from PG&E and SDG&E service territories responded to the survey out of the 136 homeowners contacted. Of the 136 total homeowners contacted, 58 homeowner contacts were provided in the PG&E data request response and 78 were provided in the SDG&E data request response,
- 23 contractors completed interviews out of the 141 residential electrical contractor companies contacted.
- A total of 12 Utility, CPUC, and building department staff were surveyed or interviewed out of the 29 contacted. A breakdown of the 12 completed interviews is:

- Three Building Department staff (two from PG&E service territory and one from SDG&E service territory)
- Three CPUC staff members
- Six Utility SMEs (three from PG&E and three from SDG&E)

KEY FINDINGS

The key findings from the Study are summarized below:

Service Upgrade Triggers

1. When a Service Upgrade is required, it is most often a direct result of an electrical panel upgrade triggered by insufficient service capacity required to meet a customer's increasing electrical load. Most customers and contractors are unaware of available options to mitigate the need for a panel upgrade that would trigger a Service Upgrade.

Service Upgrade Process

1. Some customers reported that the overall Service Upgrade process is confusing, and it took longer than expected, often exceeding six to nine months. Some customers stated there was a lengthy waiting period between the initial application and initial project estimate from the Utility.
2. Some Utility staff Subject Matter Experts (SMEs) reported a perception that a lot of time is spent communicating with customers as opposed to reviewing and processing Service Upgrade applications. This may be due to a variety of issues including time spent addressing customer response accuracy, a lack of automated updates to customers through the Utilities' customer information system, time needed to fully address customer questions and concerns, and time spent educating customers on the process.
3. Applications with missing or erroneous information may be voided by one Utility after 30 days of no applicant update, requiring a full application restart despite any work previously reviewed.
4. Some Utility staff and contractors reported they would benefit from customers and contractors having access to increased educational information on the process, requirements, and costs associated with Service Upgrades. There are manuals and guidance docs available such as Utility's Electric and Gas Service Requirements,[1] but contractors were unaware of them.
5. SDG&E SMEs reported that it is common for solar photovoltaic sales teams to submit Service Upgrade applications for a batch of customers in a neighborhood that they canvass prior to signing an agreement. This results in Utility staff working on applications that typically never become projects. PG&E did not report this issue which may be due to the requirement to submit load calculations and onsite photos as part of the application.

Service Upgrade Costs

1. **Customers are typically unaware of the full cost of a Service Upgrade.** The contractor's bids are typically an all-inclusive cost that includes all equipment, material, labor, and panel upgrade costs

1 Green Book Manual. Accessed February 2022. PG&E Website. https://www.pge.com/en_US/large-business/services/building-and-renovation/greenbook-manual-online/greenbook-manual-online.page

with minimal to no cost breakdown. The bids may include Utility-side costs in a single bundled invoice amount. Customers are unaware of the Rule 16[2] allowance covered by the Utility.

2. Contractors reported that it is uncommon for the Rule 16 allowance amount to cover the full cost of the customer's Service Upgrade. PG&E reported in a data request response that typically any Service Upgrade job that is more than just a line replacement will exceed the $2,154 allowance.

3. Customer costs can be organized into three categories, (1) the Service Upgrade paid to the Utility, (2) the customer-owned electrical panel upgrade paid to the contractor such as an electrician or solar company, and (3) other customer costs such as trenching that are often paid to a separate contractor. Each of these categories includes three items: labor, materials, and permit costs. The total cost for all three categories was reported to range between approximately **$2,000 to $30,000**.

    - **Service Upgrade.** Rules 15 and 16 govern the allowance for Service Upgrades totaling $2,154 for PG&E and $3,241 for SDG&E.[3] Utility contractors reported customers may pay between $300 and $16,000 or more to the Utility for costs that exceed the allowance. The factors that determine costs are meter and pole location, construction requirements, trenching requirements, and distance to the distribution infrastructure.
    - **Customer-owned electrical panel upgrade.** Customers are always fully responsible for an electrical panel with costs ranging between $2,000 and $4,500 with an average cost of $2,780. This cost does not include additional customer costs incurred if they are responsible for any portion of Utility infrastructure, or other costs such as trenching, excessive run distances, or higher labor prices in affluent areas.
    - **Other costs**. Other Service Upgrade related costs the customer may typically be responsible for, but not limited to, include trenching, permits, easement costs, conduit replacements, and potential pole and transformer partial cost replacements. Permit costs ranged between $130 to $170, depending on the jurisdiction. PG&E reported the cost of a new transformer is between $6,000 to $8,000. If there are three or more customers on the transformer, the **transformer** and pole upgrade cost is covered by the Utility. But if there are less than three customers on the transformer, the customers are required to cover a portion of the cost of the transformer and pole upgrade. If there is only one customer on the transformer, the customer requesting the upgrade is required to cover the costs of the transformer upgrade and pole upgrade, if needed. Contractors reported these additional costs range between $2,850 to $30,000 or more.

[2] See sections 1.3.1 and 4.3.1

[3] Authors' Note: The allowances presented here and referenced throughout this document are in scope of the Study. Please note that the allowances are subject to change.

KEY RECOMMENDATIONS

Based on the key findings, the Study team recommends that the Utilities consider the following recommendations:

Service Upgrade Triggers

Service Upgrades are triggered by electrical panel upgrades that are often avoidable due to a lack of contractor education and incentives.

1. **Leverage Workforce, Education, & Training (WE&T) programs** to integrate education on the options to mitigate the need for a panel upgrade. Electricians drive the decision to upgrade in the face of the cost. Increase contractor awareness of the existing Utility Electric and Gas Requirements Manual.
2. **Incentives to avoid panel upgrade.** Consider nonfinancial and financial program incentives that encourage mitigating the need for upgrading a customer's electrical panel that will trigger a Service Upgrade.
3. **Require inspectors to assess the need for a panel upgrade and provide a report to the customer.** In addition to contractor education, Utility and Building Department inspectors should be trained to assess the need for a panel upgrade and provide the customer with a panel report and a leave-behind pamphlet explaining options to avoid the need for a panel upgrade and potential cost savings. This recommendation also supports decreasing the Service Upgrade cost category below.

Service Upgrade Process

To improve the Service Upgrade process, Utilities must improve the timeline, improve communication with the customer, and right-size resources to meet the customer's increasing demands.

1. **Expand existing software platform for Service Upgrades** to reduce customer confusion, set timeline expectations, and reduce time spent by Utility staff communicating with customers. Improve upon and expand the Utilities' existing customer-facing software platform to enhance the customer experience and "at will" information exchange. The system should focus on the timeline and cost expectations, frequently asked questions, and provide customers and contractors with automated status updates with important notifications to understand steps completed and upcoming requirements. The system must identify and track issues with applications reported by Utility SMEs during any stage of the application to reduce the administrative burden on Utility staff. It must allow more detailed customer project tracking than currently available.
2. **Develop a system for Utility staff to visualize capacity constraint.** Utilities should consider tracking the location of Service Upgrades on a neighborhood or multi-group level and flag those areas as potentially requiring more extensive distribution level upgrades as electrification adoption increases.
3. **Leverage existing resources**. Consider leveraging internal Utility continuous process improvement resources that will assess and report on the Service Upgrade timeline, process automation and system upgrades.

4. **Develop and share Utility-specific best practices**. There are differences between the PG&E and SDG&E Service Upgrade process. The Utilities will benefit from sharing best practices and lessons learned for processes and customer application intake, requirements, and scheduling.

Service Upgrade Costs

The customer pays a contractor for the home upgrades but, in addition, must pay the Utility up to $30,000 or more to upgrade the Utility's infrastructure from the customer's meter to the pole. These are recommendations to decrease the cost impact.

1. **Leverage industry best practices to conduct education and training for contractors and inspectors** on the options to mitigate the need for a Service Upgrade, Service Upgrade processes, and all costs associated with a panel upgrade and Service Upgrade.
2. **Decreased cost.** Increase the Rule 16 allowances to reduce the cost burden on the customer. Identify other incentive mechanisms to offer incentives to customers to further reduce the cost burden of the Service Upgrade, particularly during electrification retrofits. These incentives could be included in parallel to statewide decarbonization, demand response, energy efficiency third-party, EV charging, or self-generation incentive programs.

1.0 INTRODUCTION

The Study team conducted a variety of data collection and literature review activities focused on assessing the processes and costs required for residential Service Upgrades. The simplified objectives of the Study are listed below, the full Study objectives are listed out in Section 1.1.

1. Map out existing process for completing Service Upgrades in residential retrofits.
2. Understand the costs incurred by all parties when upgrading electric service to residential sites.
3. Make recommendations to the Utilities and future program implementers to address the challenges to integrating Service Upgrades into electrification projects.

Beginning in August 2021, homeowners, contractors, building department staff, Utility staff and CPUC staff were contacted to participate in either an online survey or in-depth interview. A literature review of the Utility's existing documentation and online data available on cost was conducted to supplement the Study team's understanding of Service Upgrades, in parallel with conducting interviews, and supported the Study findings. In addition, the review of the Utility's Rules informed the interview and survey questions for homeowners, contractors, building departments and Utility staff.

Due to the increasing electrification of the residential sector, the goal of this Study is to provide the Utilities with actionable recommendations and strategies to support California's decarbonization initiatives. The Study objectives and associated activities focused on uncovering ways the Utilities and future program implementers can facilitate an improved Service Upgrade process for homeowners and contractors.

1.1 OBJECTIVES

The objectives of the Study were to map out the existing process for Service Upgrades, understand the costs incurred by all parties and make recommendations for the Utilities and future program implementers.

1.1.1 OBJECTIVE 1: MAP OUT EXISTING PROCESSES FOR COMPLETING ELECTRICAL SERVICE UPGRADES IN RESIDENTIAL RETROFITS

Activity 1: Identify common scenarios when Service Upgrades are required to complete electrification upgrades in residential retrofits and develop several representative examples.

- What set of information is required to determine whether a Service Upgrade is required?
- What alternatives are considered to alleviate the need for these upgrades?
- What set of conditions typically trigger the need for Service Upgrades? May include:
    - Building characteristics, like type, vintage, etc.
    - Specific appliance installation or combination of domestic hot water, Heating Ventilation Air Conditioning (HVAC), cooktops, dryers, electric vehicles, etc.

- Interaction with solar and battery storage systems
- How is the California Title 24 – Administrative (Part 1), Energy (Part 6), Electric (Part 3) and Fire (Part 9) Codes addressed in the common requirements for a Service Upgrade?

Activity 2: Identify current processes in place to complete the Service Upgrades and develop process flow charts.

- What are the various steps required to complete a Service Upgrade, from conceptualization through implementation? Include details on:
    - Electrical upgrades required for service panels, electric panels, and branch circuits
    - Infrastructure requirements if gas end uses are removed from the building, such as capping gas lines
    - Required expertise
    - Permitting requirements
- Who is responsible for the execution of each component of the Service Upgrade process such as the Utility, electrician, homeowner, etc.?
- What is the typical timeframe required to execute each step?
- What are potential barriers that exist at each step?
- Under which scenarios do customers abandon electrification retrofits due to Service Upgrade challenges?

1.1.2 OBJECTIVE 2: UNDERSTAND THE COSTS INCURRED BY ALL PARTIES WHEN UPGRADING ELECTRICAL SERVICE TO RESIDENTIAL SITES

Activity 1: Identify typical costs associated with increasing electrical capacity for residential electrification retrofit projects and the parties responsible for these costs.

- What are the costs or cost ranges associated with electrical capacity upgrades, which may include, but not limited to:
    - Professional service fees from electrical engineers, electricians, contractors, plumbers, etc.
    - Branch circuit costs
    - Electric panel costs
    - Utility fees, e.g., Service Upgrades, gas service termination
    - Costs associated with capping or removing existing gas plumbing
    - Permitting and inspection costs
- Who is responsible for the cost of each component of the Service Upgrade process such as the Utility, homeowner, etc.?

Activity 2: Identify and explain factors that may impact these costs.

- What factors may cause these costs to be higher or lower, including:
    - Building location
    - Building characteristics such as type, vintage, etc.
    - Physical constraints such as distance to line, etc.
- Are these costs expected to change over time? If yes, why?

1.1.3 OBJECTIVE 3: MAKE RECOMMENDATIONS TO THE UTILITIES AND FUTURE PROGRAM IMPLEMENTERS TO ADDRESS THE CHALLENGES TO INTEGRATING SERVICE UPGRADES INTO ELECTRIFICATION PROJECTS

Activity 1: Identify ways that Utilities can improve Service Upgrade processes.

- What are the biggest hurdles to Service Upgrades, and how can Utilities help customers overcome them?
- What strategies would improve the process for successful Service Upgrades? Recommended strategies may include (but are not limited to) those listed in *Strategies and Approaches for Building Decarbonization* (Building Decarbonization Coalition 2019).
    - Ensuring Affordability and Equity
    - Workforce Training and Development
    - Developing Markets: Upstream and Midstream Programs
    - Deploying Rate Design with Demand Management
    - Harnessing Consumer Investment: Downstream Programs
    - Financing Building Electrification
    - Local Government Initiatives

Activity 2: Develop recommendations to potential program implementers on incorporating Service Upgrades into electrification programs.

- What pitfalls associated with Service Upgrades should implementers look out for when designing electrification programs?
- What other considerations should implementers be aware of?

Activity 3: Identify future research needs

- What support can the California Public Utilities Commission (CPUC) provide to streamline electrical service upgrades? How can the CPUC value the avoided costs of electrical service upgrades when low-amp alternative appliances are pursued?
- What is the current customer demand for electrification retrofits?

1.2 METHODOLOGY

A high-level approach to the methods and strategies for data collection and analysis are listed below, including in Table 1 which addresses the three Study objectives. Refer to Section 4.4 for the complete research plan and interview study guides.

1. **Online Surveys:** These were conducted with homeowners who recently completed Service Upgrades with their Utility. Additionally, a follow-up phone call was attempted with homeowners who opted-in to a phone call to discuss the responses.

2. **In-Depth Interviews:** Telephone interviews were conducted with contractors, Utility SMEs and building department staff who were involved with Service Upgrades. The building department staff interviewed worked on building permits for residential Service Upgrades. In addition, CPUC staffers were interviewed to gain additional knowledge on how the Utility's tariff Rules are developed and reviewed for rate case approvals.

3. **Literature Review:** The Study team reviewed existing Service Upgrade data and studies to inform the interview and survey questions and analysis for recommendations.

Table 1: Research Methods, Sample Size, Target Audience, and Incentives

RESEARCH METHOD	STUDY TARGETS AND ACTUALS			
	TARGET	ACTUAL COMPLETED	TARGET AUDIENCE	INCENTIVES
Online Surveys	50	34* PG&E: 15 SDG&E: 19	Homeowners	$50
In-depth Interviews	40	23** PG&E: 12 SDG&E: 11	Contractors/Trade Professionals	$150
	10	3 PG&E: 2 SDG&E: 1	Building Department Staff	None
		3	CPUC Commissioners	
		6 PG&E: 3 SDG&E: 3	Utility SMEs	

* 11 of the 34 homeowners provided partial responses to the survey and/ or did not fully complete it.
**Three of the 23 contractors provided partial responses to the interview questions and/or did not fully complete it.

1.2.1 Recruitment Plan

The Study team utilized several methods to recruit participants in the surveys and interviews.

Homeowner Recruitment: The Study team submitted a data request for a list of customers from both PG&E and SDG&E who completed a Service Upgrade within the last 24-months from the respective Utility. The Utilities sent a notification email to the customers informing them that a survey was being conducted. Then the Study team followed up with regular reminder emails.

Contractor Recruitment: For the contractor recruitment, recruiting electricians to participate in the study was prioritized over other building trades because they are the most involved in the Service Upgrade process. Most of the interviews came from calling contractors and trade professionals identified by the Study team as good candidates for interviews. The Study team developed a list of contractors from various sources: (1) Energy Connection's "Find a Contractor," an online tool for homeowners to find contractors that are knowledgeable in high performance buildings and building electrification, (2) top-rated trade professionals in major cities, and (3) the Decarbonization Working Group listserv of electrification focused professionals in California. In addition, the Study team leveraged existing contractor relationships to obtain interviews and bid information. The PG&E team also sent an outreach email to a list of verified contractors requesting their assistance in Study participation after an initial round of contractor outreach resulted in lower participation than expected.

Utility Subject Matter Experts and CPUC Staff: This group was reached by utilizing the Study team's professional contacts to find the most applicable interviewees.

Building Department Recruitment: The Study team called permit offices of major cities to interview building department representatives.

1.2.2 Cost Analysis

Cost data was collected from customers and contractors. Because customers are the entity that incur the costs, directly or indirectly, valuable cost data came from the customers' input. However, as customers are less able to report background costs such as traffic permits, and they are less likely to be aware of the effects of incentives under Rule 16, the collected data includes only what costs the customer incurs. For that reason, cost data was collected from electrical contractors who performed the homeowner's service panel replacement, and Utility contractors who perform Utility work on the Service Upgrade. Cost implications can be better understood with input from all three of these market actors.

For data collected on Service Upgrade triggers, processes, and timelines, the primary mode of analysis was qualitative —gathering information including the pain points and successes of customers, contractors, and Utility staff allows the Study team to refine recommendations that benefit all parties and improve the process for the customer. Quantitative analysis, where required, took the form of taking the average, range, or comparing the relative quantities of various responses to determine the major factors impacting Service Upgrades and costs.

1.2.3 Limitations

The Study's findings are from a relatively small pool of Utility customers and contractors. The Study is primarily qualitative and more robust quantitative analysis is needed to validate the findings in this Study, assuming the Utility data system and confidentiality issues can be resolved.

Response Rate. The Study team requested 100 verified customers from each Utility. There was a lower-than-expected response rate so the request should have been doubled to increase the sample size.

Cost Detail. The Study team leveraged industry relationships to gather cost details available. There are two cost components: (1) Project costs customers pay to contractors and (2) Service Upgrade costs the customer pays to the Utility. There were a few full-service electrification contractors that shared detailed bid data. Three Utility-side contractors shared high-level Service Upgrade cost information during the interview process.

Incentive Amount. The contractor incentive amount of $150 may have been insufficient for the requested amount of time required to participate in the Study. Although contractors were compensated for their time, some contractors reported that time as a potential "lost job" which could have had the opportunity for more revenue. Increasing the contractor incentive would have increased participation.

1.3 BACKGROUND

The relevant Tariffs and protocols of the Utilities regarding Service Upgrades follow a predetermined set of requirements and regulations. This includes Rule 2: Description of Service, Rule 15: Distribution Line Extensions, Rule 16: Service Extensions and the Utility Electric Design Manual, and Rule 20: Replacement of Overhead with Underground Electric Facilities. The Rules or Tariffs are developed by the California Public Utilities Commission and are followed by the Investor-Owned Utilities in California.

1.3.1 Tariff Rules

Rules 15 and 16 are the main rules that govern the requirements for a Service Upgrade. In **Rule 15** for distribution line extensions, it outlines: general requirements, installation responsibilities of the customer (Applicant) and the Utility, distribution line allowances, advances by the Applicant, refundable and nonrefundable payments, Applicant design and installation options, and special conditions. In **Rule 16** for service extensions, it outlines: general requirements, metering facilities, service extensions requirements, responsibilities for service extensions by the Applicant and the Utility, allowances and payments by Applicant, and exceptional cases.

1.3.2 Distribution Line and Service Extension Allowance

For a residential Service Upgrade, there is a cost allowance for the upgrade, which seeks to establish an "average" cost paid by the Utility for service extension costs. Each Utility estimates the average project costs that are typically covered by the allowance during rate filings, and results in the amount that is covered by the Utility. However, if the individual Applicant project is estimated to cost more than the allowance, the Applicant is required to pay the difference before the project begins. As shown in Table 2, the allowance for PG&E is $2,154 and $3,241 for SDG&E. This allowance is first applied to the residential service, then what is left over is applied to the distribution line extension.

Table 2: Extension allowance and Cost of Service Factor for PG&E and SDG&E.

	PG&E	SDG&E
Allowance*	$2,154	$3,241
Cost of Service Factor**	14.64%	14.63%

* Allowances are set as the distribution line and service extension portion of the (Utility Net Revenue) divided by the (Cost of Service Factor). *Defined in Rule 15 Section C.3*

*** The Cost of Service Factor includes depreciation, return, income taxes, property taxes, Operating and Maintenance (O&M), Administrative and General (A&G), Franchise Fees and Uncollectible Expenses (FF&U) and replacement of facilities for 60 years at no additional cost to customer. Defined in Rule 15 Section J for SDG&E and Rule 2 Section 1.3.b for PG&E*

1.3.3 Utility and Customer Responsibilities

The most pertinent information for this Study outlined in Rule 16 describes the responsibilities of the Applicant and the Utility. This describes which party is responsible for costs of different parts of the Service Upgrade. The Utility is responsible for planning, designing, and engineering the service extension and/or distribution line extension, using their standards for materials, design, and construction. However, the Applicant may use the Applicant Design Option, where instead they can select competitive bidding and the service extension may be designed by a qualified contractor (the requirements for this design option are described in Rule 15 Section F). In addition, the Utility is responsible for the **electric service**, **meter,** and **transformer** — extending from the distribution line to the **service delivery point.**

The Applicant is responsible for providing a **clear route** on private property (or paying for one to be established) and **excavation**: all necessary trenching, back filling, and other digging required including permitting fees. In addition, the Applicant is responsible for furnishing, installing, owning, and maintaining all **conduit and substructures** and **protective structures.** Beyond the service delivery point, the Applicant is responsible for planning, design, installing, owning, maintaining, and operating the service facilities, except for the meter itself.

In addition, Rules 15 and 16 reference **Rules 2 and 20**. **Rule 2** is the Description of Service and outlines the service voltages to be distributed to customers, voltage frequency control requirements, load limitations, and interferences with service, but as it relates to Service Upgrades – Section I on Special Facilities. If a Service Upgrade project is deemed above what is standard as a "Special Facility," then the Applicant is responsible for additional costs above the standard for this project.

Rule 20 describes the requirements for the conversion of overhead to underground distribution lines. The Utility (at its expense) will underground their overhead electrical lines along public streets and roads, public lands, and private property when rights-of-ways have been obtained. As it pertains to residential retrofits, (if a jurisdiction decides it wants to underground their electric distributions and following the Utilities requirements) the Utility will pay for no more than 100 feet of each customer's underground electrical service lateral and will pay up to $1,500 per service entrance (excluding permit fees). However, the governing body may limit these for a particular project.

1.3.4 Utility Electric and Gas Service Requirements

The Utility's Electric and Gas Service Requirements[4] document is a guide for contractors and project planners describing the technical and procedural requirements for completing a Service Upgrade. For example, Section 3: "Electric Service Underground" provides information to help applicants, their engineers and contractors select appropriate locations for an underground electric distribution system. Section 4: "Electric Service Overhead" provides instructions and minimum clearance requirements for overhead electrical service. This document references the Tariff Rules frequently and

4 Green Book Manual. Accessed February 2022. PG&E Website. https://www.pge.com/en_US/large-business/services/building-and-renovation/greenbook-manual-online/greenbook-manual-online.page

offers a more detailed manual on how to complete a Service Upgrade project, along with specific material requirements to be used for electric service facilities.

2.0 STUDY FINDINGS

This section discusses the findings of the Study by first discussing the existing process including common scenarios and triggers for a Service Upgrade. This is followed by a discussion on the costs incurred by each party.

2.1 MAP OUT EXISTING PROCESS

2.1.1 Identify common scenarios when Service Upgrades are required to complete electrification upgrades in residential retrofits

The common scenarios when Service Upgrades are required to complete electrification upgrades in residential retrofits fall into two categories. Beyond these two categories, there are several other items that are common on Service Upgrades.

Category 1: Electric load requiring more service capacity

A home's vintage. Homes built prior to 1965 are the most likely to have panel sizes below 100-amps. Customers completing electrification retrofits, installing an EV Charger and solar or other improvements that require more service capacity will require a panel upgrade that will trigger an unavoidable Service Upgrade.

A home's size. A good indicator for the need for a home's electrical panel upgrade is often the size of the home. A home electrical panel upgrade from 100-amps is only necessary in most of California for single-family homes that are over approximately 2,000 square feet. A brand new, appropriately sized gas-fired heating only system in homes over 2,000 square feet with no air conditioner (A/C) would result in an equivalent electric heat pump system when converting to an all-electric HVAC system — which would likely exceed the remaining capacity of the existing panel circuits due to the fuel switch for heating. However, if central air conditioning is already present, a new electric heat pump is typically sized the same - requiring only the same circuit size as the original A/C installed, so the A/C circuits can generally be reused. Recent construction homes larger than 2,000 square feet typically already have 200-amp service, rather than 100-amp service, and a 200-amp service panel is the Title 24 code requirement as of 2019.

Electric load increases requiring more service capacity. This is the case with electrification retrofits such as solar, EV charging, new HVAC equipment, pool pumps, induction ranges, or heat pumps for water or space heating.

Multiple units and meters on a property. If a single-family home is subdivided into multiple units, it would be expected that the added appliances at the lot (new electric stoves, water heaters, clothes dryers, HVAC) would add to the overall potential "coincident" load at the site, and more service capacity would be required as per the electrical code requirements for service panels and feeders.

Accessory Dwelling Units (ADU), workshops, barns, and other additions to a home can trigger a Service Upgrade if the service wires are below the newly required capacity. An ADU may also have a separate meter if it has a separate address to the main house.

Type of Panel Upgrade. It is common for contractors to recommend replacing an existing electrical panel with a panel of a greater amperage. This will require the Utility to provide an increased service drop, which will increase the level of review to a new service of which a Service Upgrade is the sub-category. It is less common for customers to replace an electrical panel with a panel of the same amperage for fire safety reasons or improved functionality such as a smart panel.[5] Smart panels include only those electrical panels that are able, via Wi-Fi, internet, algorithms, or other methods, to control energy loads at a given home on a basis of timing and usage, and that distribute power according to the circuits added to reduce power to loads that are not in use and to increase available power to loads that are able to be used. This is defined in this Study as a like-for-like panel upgrade (Like-For-Like Panel Upgrade). Like-For-Like Panel Upgrades require less Utility review because the size of the service drop and size of the panel does not change, and no upstream infrastructure will be impacted.

Category 2: Codes and Standards.

Historically, some homes had the Utility meter in garages or other publicly inaccessible space, and to be brought up to code, a cascade of electrical work including a possible Service Upgrade can be triggered by something as simple as a new circuit box being added. When a meter is inaccessible to the Utility, it must be moved to a publicly accessible location.

Other Common Factors

A customer's service panel sizing determines the capacity of the needed electrical equipment on the pole or from the transformer, as well as the size of wires in the "service feeder," which is the line connecting the Utility to the customer. If the service feeder and transformer, are not rated for the capacity the customer requests, it must be upgraded in accordance with Utility rules, the "Green Book" requirements, and the electrical code requirements of the authority having jurisdiction (AHJ). On the customer side, the electrical panel Load Calculation process that is outlined by the 20197 California Electrical Code (CEC) Article 220.82(A), is the primary set of code requirements that determine the size of the customer's electrical panel, which in turn determines the size of the required service feeder line from the Utility under Article 220.61. This was a consistent answer from our electrician respondents; "the result of the panel calculations tells me that I have to install a bigger panel, so I do, which means talking to the Utility about upgrading the service feeder." The homeowner's panel sizing is important to recognize because there are alternatives to panel upgrades that are almost always left unexplored, and they can help reduce the load on the panel which can help to avoid a panel upgrade.

Electrical upgrades required for service panels and branch circuits. The CEC Article 220 indicates the electrical sizing of the service panel that the customer owns determines the requirements under the Green Book for the meter size and the service feeder size. Appliances on various branch circuits of the

[5] Span.io Website. Accessed February 2022. https://www.span.io/

panel determine the required capacity of the busbar and main breaker. This relationship creates a dynamic in which, potentially, a customer who wants to install just one new appliance triggers a stream of events that leads to that customer requesting a Service Upgrade from the Utility. There is an anticipated increase in Service Upgrade requests for customers who are completing electrification upgrades and retrofits, but there are methods available to help customers avoid a service panel upgrade and avoid needing a Service Upgrade request to the Utility. There is already an increase in Service Upgrade applications due to other factors, including Solar PV.

Infrastructure requirements if gas end uses are removed from the building. Utility staff and contractor respondents indicated that capping a gas line at the meter is a job that is often done for free, although there have been anecdotal reports of costs associated with removing the meter, the respondents in interviews and surveys did not indicate an occurrence of costs. Infrastructure requirements include shutting off the gas line to the meter, removing the meter, and capping the gas line from the transmission line in the street or elsewhere.

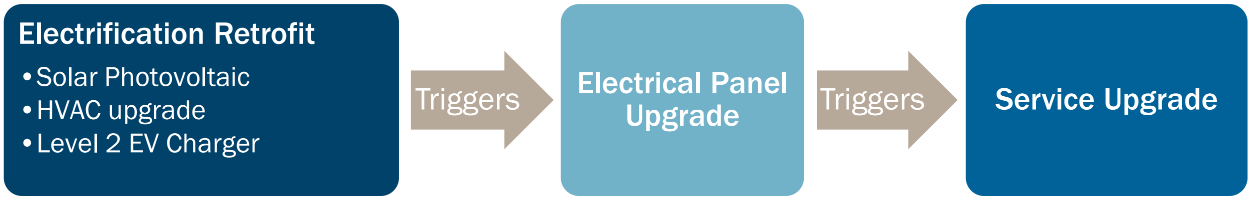
Required expertise. For Service Upgrades, a lineworker is required, as well as a general contractor or a C-10 electrical contractor license. In California, these skills can be obtained from several technical colleges, IBEW Union Locals, and other accredited training programs. For removing a gas line, a Utility certified gas contractor is required. This required expertise was considered by some Utility staff interviewed to be in short supply, especially in the areas of lineworkers and Utility-side electrical contractors.

Permitting requirements. For a Service Upgrade, an electrical permit is not the only requirement. The Utility contractor is responsible for obtaining a traffic control permit from most local authorities, and this can represent a considerable time step in some jurisdictions and in high traffic areas. The Utility contractor usually absorbs this cost, and indirectly passes it to the customer.

2.1.1.1 What set of conditions typically triggers the need for Service Upgrades?

When a Service Upgrade is required, it is most often a direct result of an electrical panel upgrade triggered by insufficient service capacity required to meet a customer's potential increase in electrical load. The conditions that trigger an electrical panel upgrade are also triggers for the Service Upgrade as illustrated (Figure 2).

Figure 2 - Service Upgrade triggers



Most common triggers reported by Utilities data. The Utility's Service Upgrade data request response indicated that the most common trigger for a Service Upgrade is a **solar PV installation (43%)**, followed by **Level 2 EV Chargers (12%).** The two leading triggers accounts for 55% of all Service Upgrades. The remaining Service Upgrades are noted as wiring upgrades which is assumed to be associated with home renovations and underground or overhead conversions.

Most common triggers reported by contractors. From the contractor's perspective, they reported the top three triggers for an electrical panel upgrade that will trigger a Service Upgrade are:

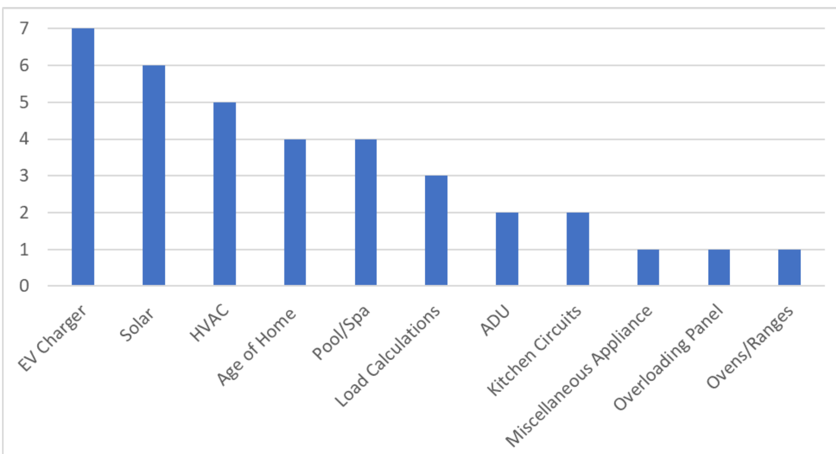
Level 2 EV Charging

Solar Photovoltaic

HVAC Upgrade

The other factors that can lead the contractors to pursue a Service Upgrade include the age of the home, installing a pool or spa, adding an accessory dwelling unit (ADU), adding appliances, ovens, ranges and upgrading the kitchen circuits during a home renovation project (Figure 3).

Figure 3: Electrician-reported reasons for service panel upgrades that trigger a Service Upgrade (N=36).



Electrical contractors consider if the home's panel has breaker space to accommodate additional circuits, even though the calculations are under 100-amps. Spare breakers may be needed to increase a circuit from 120 to 240 volts. The contractor considers numerous factors in conjunction with the homeowner when determining the necessary panel capacity. One overarching consideration is the future intentions of the homeowner. If the homeowner plans to install an electric vehicle charging, solar PV, pool pumps and/or pool heat pump, new HVAC equipment, induction range, tankless water heater, home additions or ADUs, they are often culprits in causing an electrical panel to be upsized, and thus, the Service Upgrade.

Load Calculations are the fundamental factor that cause Service Upgrades. These are determined by the electrical code, but not all professionals or jurisdictions are in the habit of doing them with the goal of preserving the existing service capacity. Electricians must perform **load calculations** and commonly use the National Electrical Code (NEC) Section 220.83, or as per local jurisdiction requirements in the **30-Day load study** per NEC 220.87. When adding only one appliance, the observed demand over a 30-day load study or a yearlong study is generally even lower than rigorous and accurate panel sizing calculations that Section 220.83 suggests. This is a more favorable estimate of peak load than the Load Calculations method or the Watt Diet, which is a streamlined Load Minimizer[6]. When doing a full electrification retrofit with two or more appliances to fuel-switch, the NEC Section 220.83 method is often more favorable to keeping the existing panel.

In the case of EV chargers, some tankless water heaters and new HVAC installations, spare breakers may be needed to increase a circuit from 120 to 240-volts. Often, the need to upgrade to a panel with more breaker space leads to the homeowner or electrician suggesting the idea of increasing their service capacity at the same time to save time or expense later or improve home value.

For solar PV, the electrician considers the size of the planned solar installation. Busbars are commonly the limiting factor in a PV array size. If a customer wants more PV than the busbar can accommodate alongside the service panel, they go for a Service Upgrade. 5 kW DC is the average total residential solar installation size[7], and size is limited by available roof area and shape.

PV installers will often recommend a panel upgrade while onsite, and SDG&E staff reported that it is common for PV sales teams to submit applications for whole neighborhoods that they canvass prior to signing an agreement to initiate the Service Upgrade process. This results in Utility staff working on applications that will never become projects. Under these circumstances, a small percentage of these homeowners sign solar PV agreements.

HVAC upgrades are a common reason to upgrade a service panel when a home only has a gas furnace. This is common in many temperate climates in California where air conditioning is seldom needed, and in lower-income homes upgrading from window air conditioning units. If an air conditioning unit is present, a heat pump is normally able to utilize the same breaker as the existing unit.

Kitchen circuitry Changes to kitchen circuitry can be a simple, $500 job of installing a new circuit and wire, but the existing breaker spaces on the panel can mean that a Like-For-Like Panel Upgrade or even a Service Upgrade is necessary, especially in older homes.

Service Upgrades do not always happen because they are immediately required by the code, rather the contractor is trying to set the homeowner up for success later and avoid future roadblocks.

2.1.1.2 What alternatives are considered to alleviate the need for these upgrades?

Service Upgrades are triggered by a customer's electric load requiring more service capacity. Alleviating the need for an electrical panel upgrade also alleviates the need for Service Upgrades. This section discusses the most effective alternatives to alleviate the need for an upgrade for the most common Service Upgrade triggers reported by the Utilities and contractors.

---

6 Redwood Energy Website. "Watt Diet Calculator." Accessed February 2022. https://redwoodenergy.net/watt-diet-calculator/

7 SEIA Website. Accessed February 2022. https://www.seia.org/research-resources/solar-photovoltaic-technology

Avoid a Service Upgrade triggered by solar photovoltaics (PV) installation. One of the leading drivers for Service Upgrades in California is solar PV. Much of this category is driven by customer desire for a certain amount of energy offset along with available roof space and shape. Although the average residential solar installation size in California is 5 kW DC[8], cost-effective energy efficiency measures can help reduce the overall size of a customer's PV offset. That in turn may allow more customers to size a PV system under the code limits of their existing panel, from 3.8 kW for 100-amp busbars, up to a maximum of 13.4 kW for 225-amp service busbars with a 200A main breaker. The electrical code (Section 705) prescribes that when a customer's busbar rating is higher than their main panel rating, they can install more solar than if the panel rating and busbar rating were matched.

Another consideration is some solar inverters enable more PV capacity than the inverter outputs to the grid, meaning more capacity is available across the day. This is known in the industry as "clipping"[9] and may reduce the AC nameplate size needed for the solar installation.

Avoid a Service Upgrade triggered by the installation of a 240-volt or level 2 EV charger. As discussed in Section 2.1.1, electricians reported installing a 240-volt EV charger as one of the most common reasons for a panel upgrade and a resulting Service Upgrade, but it is one of the most avoidable. Many EV adopters overestimate the size of the EV charger they require. Customers who travel less than 20,000 miles per year in their commute can charge effectively from a 120-volt charger with the electrical outlets already found in the customer's garage. A 240-volt charger is generally unnecessary. Avoiding the need to add a new 240-volt circuit can alleviate the need for a panel upgrade that triggers a Service Upgrade.

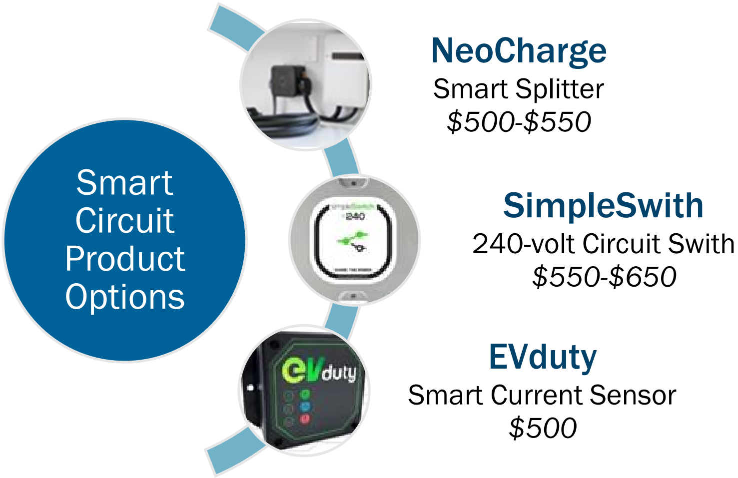
Several options existing on the market today that can share power between an EV and another device on the panel, such as the devices in Figure 4, which are all Underwriters Laboratory (UL) Listed. If the EV is the trigger for the upgrade, selecting one of these options would be much less expensive for customers than upgrading their panel.

---

[8] SEIA Website. Accessed February 2022. https://www.seia.org/research-resources/solar-photovoltaic-technology

[9] PVPMC Website "Inverter Saturation or 'Clipping'". Accessed February 2022. https://pvpmc.sandia.gov/modeling-steps/dc-to-ac-conversion/inverter-saturation/

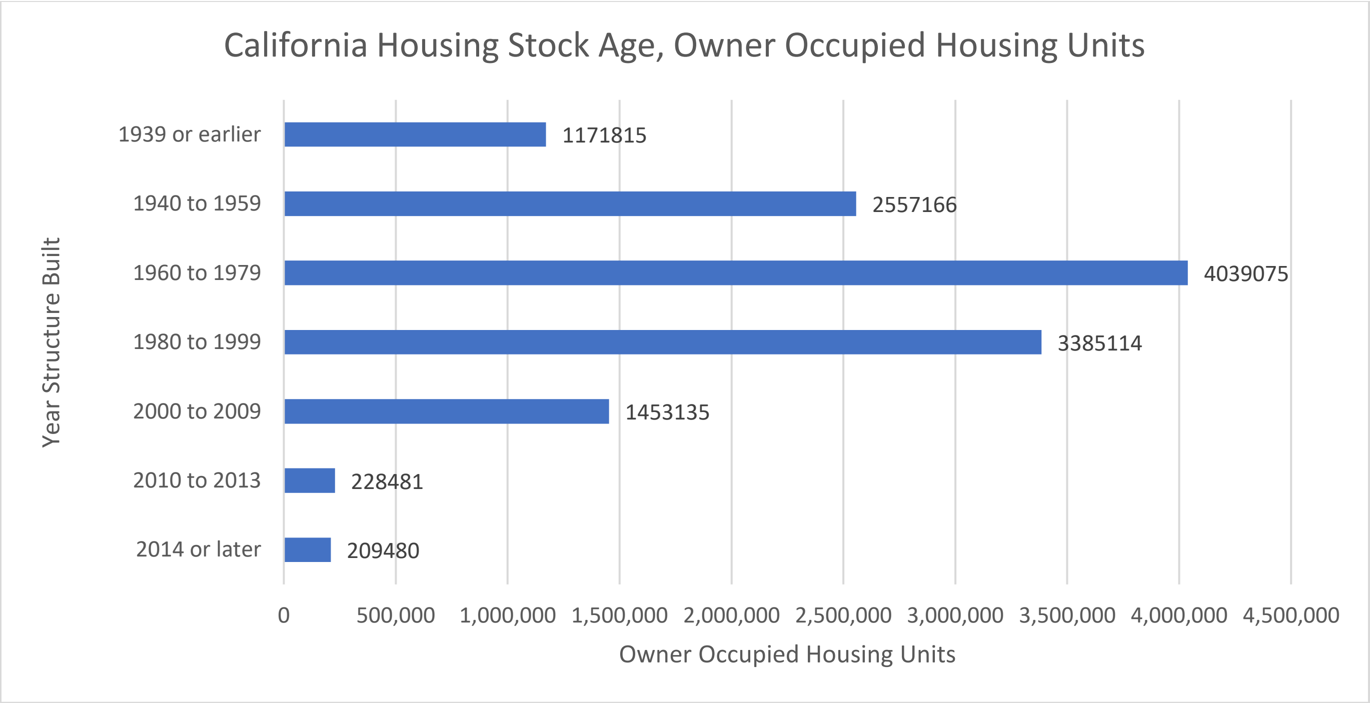
Figure 4: Smart Circuit Products and Sharing Devices



Homeowners and contractors are unaware of alternatives. In general, electricians do not consider alternatives to alleviate the need for Service Upgrades, and homeowners are unaware of the possibility of doing so. Some electricians, especially if they are electrification professionals or if the customer is an electrification early adopter, will make the customer aware of some of the options available. Electricians who are not following emerging trends may be unaware of the options on the market.

Since most homes built after 1968 have 100-amp service, a panel upgrade is unnecessary. From 1965 to 1967, single family homes in California began to be require 100-amp electrical service, regardless of load calculations required. This means that there is a subset of older homes on less than 100-amp service, but there is also a high level of confidence that a home built after 1968 has at least 100-amp service already. If a 100-amp service is the baseline for an electrification retrofit, and it is possible to electrify the home on 100-amps, this means that those homes are already prepared without an upgrade. In some areas of the state, especially San Francisco, meters are being required to be moved out of garages and into publicly accessible space, which creates the need for a full review process whenever an electrical project needs to pull a permit. Figure 5 illustrates the relative age of the owner-occupied housing stock in California. Approximately 71% of homes should have at least 100-amp panels based on the year the home was built, and of the remaining 29% that were not required, any that added air conditioning would have since upgraded to 100A.

Figure 5: 2020 US Census data on the age of housing stock in California



Heat pump water heaters that will alleviate the need for a Service Upgrade. Almost all gas water heaters currently have a 120-volt circuit to the appliance, and this can either be upgraded to 240-volts or it can be kept on a 120-volt circuit to avoid some Service Upgrades due to insufficient breaker space. Almost all Heat Pump Water Heaters on the market are currently 240/208 volts, but the major manufacturers including Rheem[10] and Haier are bringing 120-volt water heaters to hardware stores and plumbing distributors. These 120-volt standalone units are intended to be a near drop-in replacement for a standard gas-fired storage tank water heater, without requiring expensive 240-volt circuit upgrades from the currently available heat pump water heaters. The Nyle recently came out with the E-8 which is available for purchase at the time of writing in late 2021[11], uses low-GWP refrigerant, and makes use of the existing 120-volt line and tank from the gas water heater, drawing only a nameplate rating of 900 Watts.

Electrical panel sizing for a customer. To help prevent the need for some panel upgrades, a helpful tool is the "Watt Diet" Calculator[12] which determines the size of a home's electrical panel according to the code requirements. It does the load calculations that an electrician would do, with the goal in mind being to reduce the required panel size, which reduces the

10 CleanTechnica Website. Accessed February 2022 "120 Volt Heat Pump Water Heaters Hit The Market & Make Gas Replacements Even Easier." https://cleantechnica.com/2021/11/29/120-volt-heat-pump-water-heaters-hit-the-market-make-gas-replacements-even-easier/
11 Nyle Technologies "E8 Product" Accessed February 2022. https://www.nyle.com/water-heating-systems/units/e8/
12 Redwood Energy Website. "Watt Diet Calculator." Accessed February 2022. https://redwoodenergy.net/watt-diet-calculator/

required service feeder size. An all-electric home with an EV charger can be as big as 2,000 square feet in most of California and fit on a 100-amp panel- so some electrification retrofits do not necessarily need a Service Upgrade. The biggest load impacts on a home's electrical panel result from HVAC systems, pool pumps, and EV charging. However, methods exist to reduce these loads, like choosing high-efficiency appropriately sized HVAC equipment and utilizing power sharing devices that share a 240-volt circuit between an EV charger and dryer for example.

2.1.1.3 California Title 24 impacts in the common requirements for a Service Upgrade

California Building Code, Title 24, Part 3, is the electrical code for the state of California (also called the California Electrical Code, or CEC), and its current iteration is adopted from the National Fire Protection Association (NFPA), Section 70, National Electric Code — also known as the 2017 National Electrical Code (NEC), which is adopted by all 50 states.

The requirements include the primary set of panel load calculations that are part of the electrical code administered by the state, however, the load calculations are generally performed by the electrician in accordance with the city or county to get the permit to install the new or upgraded service panel. These calculations impact the Service Upgrade process by initiating the need for a Service Upgrade, and Title 24 Part 3.

California Building Code, Title 24 Part 6 — also known as the California Energy Code — is not addressed or included in the requirements for a Service Upgrade. **However, Title 24 Part 6 began to require 200-amp main service for single-family buildings in the 2019 standards** (Title 24 Part 6, §110.10(e))[13].

California Building Code, Title 24, Part 9 — also known as the California Fire Code — includes the following related to panel circuits or retrofits: If the electrician notices missing smoke or Carbon monoxide detectors, the electrician is required to install these. If there are outlets required to be Arc Fault Circuit Interruptible (AFCI) or Ground Fault Circuit Interruptible (GFCI) and the electrician notices they are not already, the electrician must install these as well.

2.1.2 Identify current processes in place to complete the Service Upgrades

This section discusses the current processes in place to complete the Service Upgrades for both SDG&E and PG&E from both the Utility's perspective and the contractors. SDG&E, PG&E and contractors from both service territories provided processes, responsible parties, and timelines from their perspective. Although there are many similarities, the distinct differences are discussed.

2.1.2.1 SDG&E Service Upgrade Process, Responsible Parties, and Timeframe

SDG&E's data request response provided a detailed 11-step process, responsible parties, and the timeline for the Service Upgrade process illustrated in Figure 7 totaling up to 17 weeks.

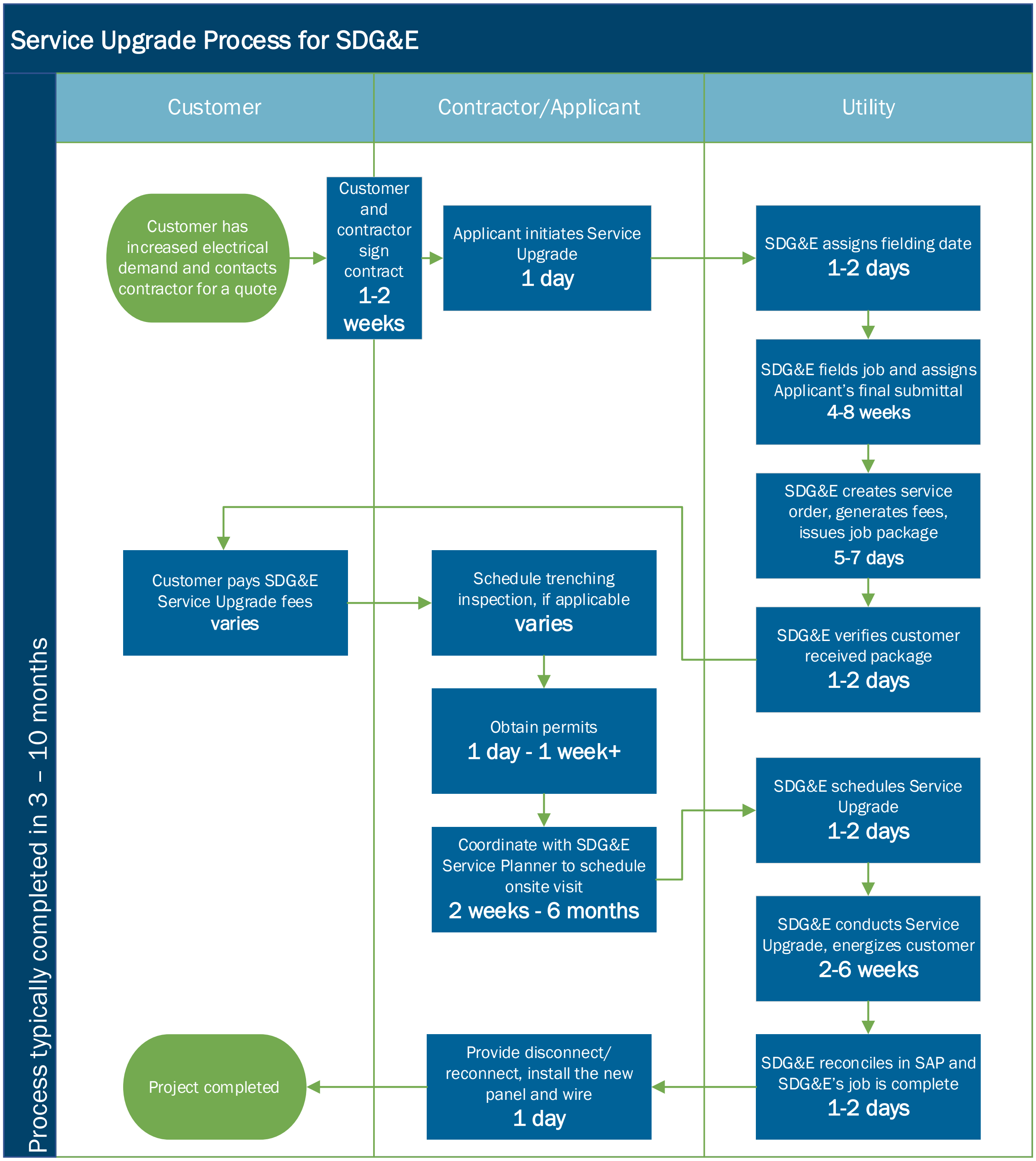
13 EnergyCodeAce Website. Accessed January 2022. https://energycodeace.com/site/custom/public/reference-ace-2019/index.html#!Documents/section11010mandatoryrequirementsforsolarreadybuildings.htm

- From SDG&E's perspective, the process starts when the customer applies for the Service Upgrade. The customer can call SDG&E to initiate the process or complete the process online. SDG&E creates a job package and assigns a fielding date which will take one to two days to complete.
- Over the next four to eight weeks, SDG&E fields the job and assigns the customer's final submittal date,
- SDG&E then creates a service order which generates the Utility fees to complete the Service Upgrade and provides the job package to the customer in five to seven business days.
- SDG&E then contacts the customer over the next one to two days to verify they received the job package. The customer must then pay the Utility the fee and obtain a permit. Contractors reported this step takes between one day and a week or more to complete. If a right-of-way is required, it must be obtained at this point in the process. The customer must also schedule trench inspections as the trenching is fully the responsibility of the customer. SDG&E reported that these customer steps have timeframes that vary by project.
- Once all the requirements are met, SDG&E will take one to two days to schedule crews.
- Over the next two to six weeks, SDG&E completes the Service Upgrade work, the customer is energized, and the meter set is completed. Over the next one to three days, SDG&E completes their last step to reconcile the job in SAP and the job is considered complete.

Contractors that participated in the Study reported the Service Upgrade process from their perspective, which somewhat aligned with SDG&E's reported process. The contractors reported a process with fewer steps and a shorter timeframe. Contractors reported the process commencing before SDG&E's starting point, which is when the customer calls the contractor for a quote to complete the home improvements. The contractor will gather information to develop a bid and the customer signs a contract in between one to two weeks. The next step is the Utility issues a service order in the next two days to two months. The contractor then reports spending the next two weeks to six months coordinating with SDG&E to get a planner onsite. Contractors then obtain permits that typically can be done between one day and one week or more. The last step that the contractor reported is that they disconnect/reconnect and install the new panel with wiring and complete the job, which takes one day.

Error! Reference source not found. combines the information from SDG&E and the process and timeline data gathered during contractor interviews. Overall, the total Service Upgrade process is typically completed in up to ten months.

Figure 6: Overall Service Upgrade Process for SDG&E



2.1.2.2 PG&E Service Upgrade Process, Responsible Parties, and Timeframe

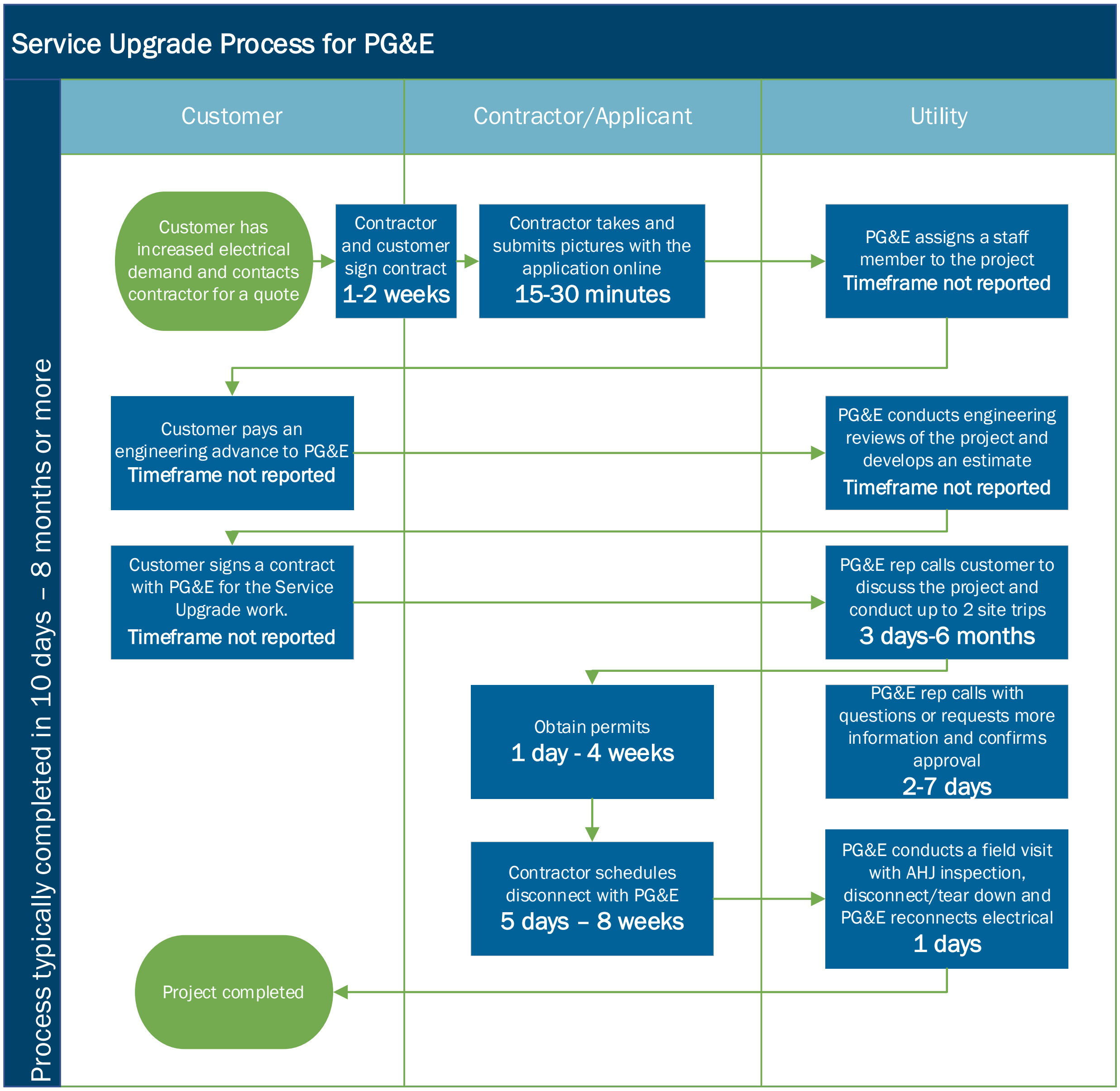
PG&E's data response indicated a list of steps with the process and responsible parties with an overall timeline that is reported to be highly variable depending on circumstances. A job that requires no transformer upgrade can be completed in less than two weeks, whereas jobs that require a transformer upgrade and underground trenching could take four months or more.

PG&E's Service Upgrade process is initiated when the customer submits a request online or over the phone. PG&E assigns a staff member (Job Owner) who has a conversation with the customer to understand the basic parameters of the project. The customer is then required to submit an engineering advance to begin PG&E's engineering reviews of the project to begin. An engineer develops an estimate, and the customer signs a contract with PG&E for the work. The customer completes any work on their end such as trenching that must be completed and then PG&E inspects. The last step reported by PG&E is completion of the Service Upgrade.

Contractors report the Service Upgrade process starting with the homeowner calling the contractor for a quote. Over the next one to two weeks, the contractor gathers information, and they sign a contract. The contractor takes photos and submits them to PG&E as part of the online Service Upgrade application. Contractors reported the ease of using the online system, the time and effort saved by PG&E requiring photos to be submitted with the application and the time necessary to complete the application which is only 15 to 30 minutes. The contractor waits to hear from the PG&E representative over the next three days. The lead time up to 6 months was reported by contractors because two site trips are required. The PG&E rep will then call the contractor with questions if more information is needed. PG&E confirms approval over the next two to seven days. The contractor obtains the permit from the authority having jurisdiction (AHJ) which is reported to take between one day and four weeks. The contractor schedules a disconnect with PG&E that will be over the next five days to eight weeks. After a field visit to complete the AHJ inspection and a disconnect/tear down, PG&E reconnects the electrical, and the installation is complete. From the contractor's perspective, the Service Upgrade process can be as little as two days and upwards of eight months from start to finish.

Error! Reference source not found.7 combines the information from PG&E's data request response on the Service Upgrade process along with the process and timeline data reported by contractor working in the PG&E service territory. Overall, the total Service Upgrade process is typically completed within ten to 30 days but projects up to eight months were reported.

Figure 7: Overall Service Upgrade Process for PG&E



2.1.2.3 PG&E and SDG&E Process Differences

There are two significant process differences between the PG&E and SDG&E Service Upgrades that may contribute to a more streamlined process for SDG&E. These include: (1) requiring load calculations to be submitted in the initial application and (2) having an online system that requires photographing the site in the initial application.

For PG&E Service Upgrades, the Applicant, either the customer or the contractor, are required to upload site photos as part of the initial application. However, SDG&E requires a planner to physically visit the site to create a permit number. PG&E contractors reported it took 15 to 20 minutes to take and upload photos into the PG&E application system. Conversely, contractors reported that coordinating with SDG&E to schedule an on-site visit with a Utility planner can add weeks to the process. The required physical site visit adds time to the process and cost for the Utility and customer.

PG&E staff and contractors reported that applications have a 30-day clock reset. If a period of 30 days passes without further customer documentation being received by PG&E, the Service Upgrade application is closed and canceled. This means that in some cases where permit acquisition or design work takes longer than 30 days, a customer must resubmit a new application. Utility staff and customer time and money is lost. Utility staff indicated that customers are frustrated by this outcome. No customer survey respondents reported this specific issue. This is a distinct difference by PG&E and SDG&E.

SDG&E requires the contactor to coordinate the entire process with SDG&E and the city, including the disconnect and reconnect. It is the contractor’s responsibility to make sure the city inspector and SDG&E crew are available at the same time. One contractor reported that SDG&E only has two crews in their area for this process which makes coordinating even more difficult. The contractor coordinates with city inspectors to inspect the panel after the grounding is done. Then the inspector calls SDG&E to reconnect the panel, but if the inspector cancels that day SDG&E charges the customer $750.

PG&E contractors reported coordinating issues with the application process rather than the onsite process of waiting for the installation date that takes about four to eight weeks. It was noted the PG&E delay was due to rescheduling due to weather. PG&E contractors reported if erroneous information were provided, or PG&E wants different information for the application it would take the PG&E rep five to seven days to respond instead of 24 to 48 hours. Another contractor reported not hearing back for over a week, and has lost jobs due to the time it can take to coordinate with PG&E.

2.1.2.4 Customer feedback on the Service Upgrade process

Customers reported on their experiences, education throughout the process, and challenges they encountered. **Approximately 54% indicated some major challenge, with the majority reporting significant delays from the Utility and some delays with the local permitting office.** Most delays revolved around the initial Utility inspections and Utility staff response time, with some customers receiving responses weeks after they reached out to the Utility.

Many of the customer responses indicated that the entire process was very confusing and took months longer than estimated by the Utilities, which also increased the financial impact related to the Service Upgrade due to the duration.

The Utilities report consistently looking for ways to improve the customer experience. This is certainly an area worthy of the Utilities’ time and effort to streamline and improve upon.

2.2 UNDERSTAND COSTS INCURRED BY ALL PARTIES

2.2.1 Identify typical costs associated with increasing electrical capacity for residential electrification retrofit projects and the parties responsible

The typical costs associated with increasing electrical capacity in residential retrofits fall into three categories – Utility Service Upgrade costs, customer-owned equipment costs, and other miscellaneous project costs which may apply. The total cost for all three categories was reported to range between approximately $2,000 to well over $30,000 or more.

2.2.1.1 Utility Service Upgrade Costs

Rules 15 and 16 govern the allowance for Service Upgrades totaling $2,154 for PG&E and $3,241 for SDG&E, which is the amount the utility initially covers on behalf of the customer, as filed in rate case proceedings. However, a Utility contractor reported that despite the Utility supplying the materials for service upgrades — wire, conduit, pole changeouts, and transformer upgrades, etc. potentially paid by the customer to the Utility — the cost the contractor would bill the Utility may still range between $2,000 and $30,000 for the labor, excluding any customer owned equipment.

Those material costs may also be passed onto the customer in certain circumstances, such as in the case of a transformer replacement. Utility SMEs and data request responses reported that if the transformer needs to be replaced and upgraded, the homeowner bears:

- 100% of the cost if they are the only home on the transformer
- 50% of the cost if the transformer is shared with another property
- 0% of the cost if it is shared between three or more properties. In this case the Utility bears 100% of the transformer upgrade cost.

The average costs reported by the contractors is shown in Table 3 below. However, as the Utilities did not provide their actual contractual Service Upgrade costs due to privacy reasons, these costs were reported by electrical contractors who have performed work on behalf of the utilities in the past.

Table 3: Utility Service Upgrade Costs for Utility/Public Right-of-Way Property

Cost Description	Average cost	Transaction
Transformer Upgrade	$6,000 - $8,000	Homeowner → Utility
Pole Replacement	$9,000 - $11,000	Homeowner → Utility
Total New or Upgraded Utility Equipment Service	$10,000 - $30,000	Utility → Contractor
Overhead line, service line only	$2,850 - $4,500 (Utility supplies materials)	Utility → Contractor
Overhead line with a new Utility pole	$11,000 - $13,000 (Utility supplies materials)	Utility → Contractor
Overhead to underground conversion	$13,000 - $18,000 (Utility supplies materials)	Utility → Contractor
Trenching for underground upgrades	$180 to $200 per llinear foot (Utility/Public Property)	Utility → Contractor

2.2.1.2 Customer-owned Equipment Costs

Customers are responsible for electrical panel upgrades with costs ranging between $2,000 and $4,500 with an average cost of $2,780 as reported by electricians. This cost does not include additional customer costs incurred if they are responsible for any portion of Utility infrastructure — pole changeouts, transformer upgrades, conduit replacement — or other costs such as sub-panels, excessive run distances, new breakers, trenching, etc. All together, these costs can range from $3,000 to more than $18,000.

Overhead to underground conversions or panel relocations on the homeowner's property typically resulted in costs ranging between $3,000 and $10,000 on average, compared with the average overhead service upgrade cost range between $2,000 and $4,500.

Table 4: Customer-Owned Equipment Service Upgrade Costs

Cost Description	Average cost	Transaction
Homeowner Equipment Service Upgrade Fee	$1,300 - $5,000	Homeowner → Contractor
Breaker Panel Upgrade	$1,300 - $5,000	Homeowner → Contractor
Upgrade/New Branch Circuits	$250 - $700 per circuit	Homeowner → Contractor

2.2.1.3 Other Miscellaneous Costs

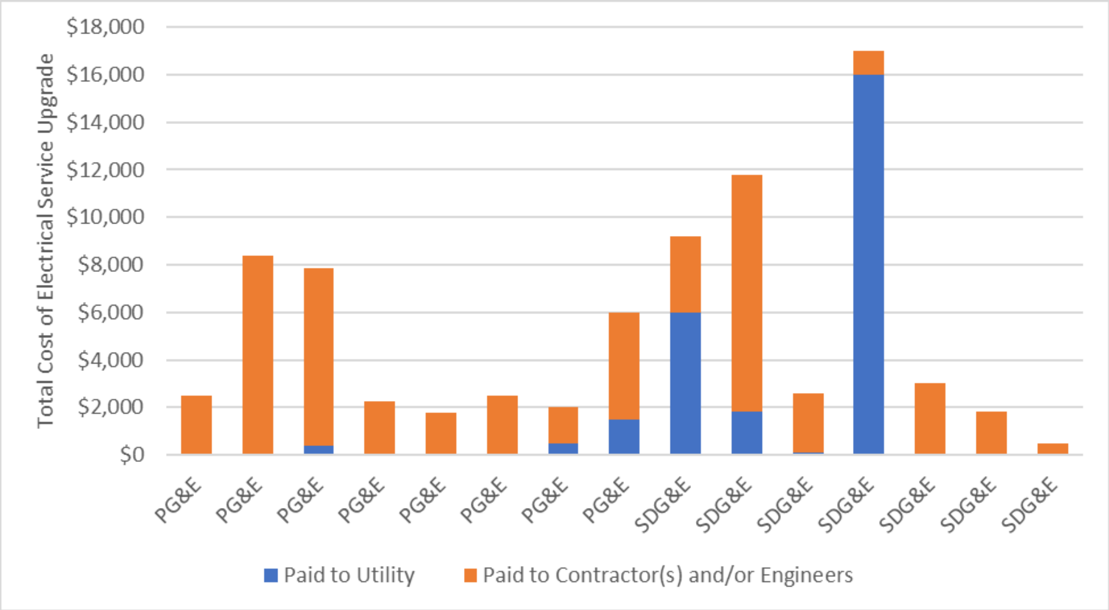
Other Service Upgrade related costs the customer may typically be responsible for, but not limited to, include trenching, permits, easement costs, conduit replacements, grounding, taxes, and other design or application fees. Additionally, costs may be incurred due to errors in the process, as reported by one homeowner who was instructed to relocate the gas meter, then once that was paid for, was told that it had to be moved to yet a different location, resulting in more expenses incurred.

Table 5: Miscellaneous Service Upgrade Costs

Cost Description	Average cost	Transaction
Permit Costs	**PG&E Territory**: $125 - $500 **Arcata, CA**: $129 **Humboldt County**: $132 **Other Northern Counties**: $125 - $140 **SDG&E Territory**: City $128, County $136	Homeowner → Contractor — OR — ↓ Homeowner → City/County
	Contractor "Bundled" Fee: $500 (All Permit + Labor Fees in one)	Homeowner → City/County
Upgrade/New Branch Circuits	$250 - $700 per circuit	Homeowner → Contractor
Trenching & Conduit	$5 - $15 per linear foot (Homeowner Property)	Homeowner → Contractor

The total cost for a Service Upgrade as reported by homeowners in the survey results is shown in Table 6 below.

Table 6: Total Cost of Electrical Service Upgrades as Reported by PG&E and SDG&E Homeowners



The outlying respondent in Table 6 that reported a $16,000 total cost for the Service Upgrade had the following statement about the major challenges faced during the Service Upgrade:

"Inspection prior to start by SDGE was flawed. She told me I had to move the gas line prior to being able to upgrade my power panel. I paid *$1,002 dollars*[14] to move the gas line and when she came back, she said there was another issue with the gas line, and it would have to be moved again. She had a person with her who was 'in training' and she was supposed to be the trainer? Completely unnecessary and additional cost on the project (along with delays)"

2.2.2 Identify and explain factors that may impact these costs

Several single-family home contractors noted that their long-standing price estimates are far different now since the COVID-19 pandemic has impacted the economy. Due to supply chain disruptions and manufacturing and shipping delays from the pandemic, material costs have increased significantly, which has resulted in material costs becoming the dominant cost in Service Upgrades. A contractor stated that "Labor used to be the main cost with materials nearly insignificant, but with the cost of wire and materials increasing in the last 12-18 months that percent has changed dramatically."

Contractors reported the top variables that increase or decrease the cost of a Service Upgrade or upgrading a customer's breaker panel: (1) panel location and its distance from the electrical pole, (2) street line connection, and (3) transformer. Additionally, contractors reported other variables including

[14] Authors' note: This may indicate an error in the respondents' data entry: it is very possible that they paid $16,000 to their solar contractor or electrician, and only $1002 to the utility. Study administrators were unable to reach the homeowner at their provided phone.

the proximity to gas lines that must be six feet away, material costs and lead times, labor costs such as local cost of living, façade work such as stucco or brick, trenching, and amperage of panel upgrade.

When asked about the barriers typically resulting in additional cost to complete a Service Upgrade, contractors indicated the size of the panel. The larger the panel, the more time and cost barriers. Another barrier is if a gas riser is too close to the panel, it cannot be upgraded to 200-amp. This will require a mechanical contractor to move the gas line. Finally, underground conduits and Utility representatives taking five to seven days to respond instead of 24 to 48 hours as indicated is a barrier.

3.0 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the conclusions from the Study and recommendations for future activities.

3.1 CONCLUSIONS

3.1.1 Current State of Service Upgrades

3.1.1.1 Customers lack education and support during the process

General customer responses indicated the process takes longer than expected and requires a lot of Utility review. Customers are often surprised to learn that they must pay a fee to the Utility for a Utility infrastructure upgrade. Furthermore, they are typically unaware of the Rule 16 allowance. Customers that complete Service Upgrades are confused about why the process is longer than expected and there seems to be a lack of clear expectations.

Successful customers often have an advisor explaining the process and requirements prior to submitting the application. Reliable advisor sources are experienced electricians, Utility staff members, and Utility contractors.

Like-For-Like Panel Upgrades do not increase service capacity and, therefore, do not require a Service Upgrade. The most successful customer applicants have a Like-For-Like Panel Upgrade. Customers that are increasing service capacity require a higher level of review.

<u>Conclusion:</u> Customers who successfully complete a Service Upgrade quickly tend to have an educated advisor or educational support, such as experienced contractor, Utility staff member, or Utility contractor who can explain and support the complete process. More effective initial education for contractors and setting clear expectations early with customers will result in a significant reduction in the time required to complete a Service Upgrade.

3.1.1.2 Timely project communication can be improved

There are various customer touchpoints in the Service Upgrade process that require Utility communication with the applicant that can improve the overall timeline.

Utility Communication with Applicants. Communication with applicants is the number one use of staff time, as opposed to project review. This is due in part to the Utility staff practice of contacting each customer by phone call with updates to their application throughout the process. Customer-facing project tracking software can be leveraged instead, to notify customers of the stages and progress on their application automatically. Status calls take time away from processing applications, resulting in unnecessary project delays.

Incorrect Submission Applications. Staff respondents indicated that there were more issues with applicants seeking to have a new service installed compared to those who indicated that they were having a Like-For-Like Panel Upgrade. This occurs because there is more engineering and design work required whenever a customer increases their panel capacity — the service line and transformer must be inspected and a determination about whether there is capacity to service the higher load. These are different categories with different departments serving the request, and a new service request is categorized as either an increase in service or a new service drop. That means that the initial information that the customer provides is sometimes insufficient or incorrect and the Utility staff member must spend extra time obtaining that missing or incorrect information in initial application if it has been misrepresented as a Like-for-Like Panel Upgrade.

If the homeowner is submitting the incorrect type of application, in many cases, when the application needs to be rejected due to missing information after initial review, the homeowner is unprepared for the follow up paperwork that is required and is unprepared to play the role of Project Manager.

Conclusion: Clear communication and setting expectations with the customer early in the process has been a successful method of improving application processing time and increased initial education for customers with what they need to succeed will improve timeframes and outcomes.

3.1.1.3 Residential solar contractors are prematurely submitting Service Upgrade applications to SDG&E

Some SDG&E SMEs reported that solar companies are submitting Service Upgrade applications on behalf of customers that the solar companies have not spoken to, or who may have indicated a passing level of interest in a PV system. These solar companies are drastically increasing the workload of Service Upgrade Utility staff for a relatively small proportion of actual applications. Utility staff must then take the time to investigate each application as if it was a genuine submission, taking away resources from actual applications with serious customers.

Conclusion: SDG&E's application requirements need to be enhanced to prevent solar companies from prematurely submitting Service Upgrade applications to ensure Utility staff is processing contracted projects.

3.1.1.4 Contractor workload increasing from electrification without efficiency education

Electrical contractors who work with Utility customers, are primarily seeing an increase in work from EV charging and solar PV installations, while electrification/decarbonization and whole home improvement contractors who work with Utility customers are seeing a larger increase in work from heat pump space conditioners, heat pump water heaters, and EV charger installations.

Electrical contractors have limited awareness of electrification and decarbonization as a market trend or a source of work for them. Electrical contractors are less likely to suggest alternatives to Service Upgrades or appliance retrofits for electrification purposes when focused primarily on PV or EV charging work.

Conclusion: Electricians, who work primarily with customers, are unaware of the efficiency or load-sharing options available to mitigate Service Upgrades during retrofits, and instead resort to upgrading a panel capacity, and thus a resulting service.

3.1.1.5 Utilities need more resources

Contractors and customers reported that the long timeline for Service Upgrade completions due to Utility delays and customers are generally dissatisfied with the current project durations. Increasing the quantity of Utility staff available to do inspections and field work, application reviews, and engineering designs will substantially reduce the current length of time.

> *"Before solar: The [Utility] had good, staffed crews. Post solar: now one [Utility] crew has all new solar projects and all panel upgrades, and panel upgrades get delayed; Need two different crews or crew types: one for solar installations and one for panel upgrades."*
>
> *"About 10 years ago (before the increase of solar) it took 3 days to obtain a workorder."*

Utility staff also reported that construction resources are retiring faster than new crew members can be hired, so there is an increasing bottleneck factor due to the labor market for Utility crews and contractors. PV/Solar rooftop installations are increasing and are almost always associated with a service upgrade request – even if the specific project does not technically require one, the solar contractor applies anyway.

Conclusion: The number of solar photovoltaic installations has continued to rise over the years and there are now many more factors triggering Service Upgrades that require Utility staff time for application processing, inspections, and connection. The Service Upgrade department is likely understaffed and even more likely under-equipped to meet the demand for Service Upgrades, which will continue to increase as customers move to the increasingly required or simply desirable electric equipment.

3.1.2 Electrification Upgrades

3.1.2.1 Electrification retrofits and mitigation of potential Service Upgrades

An electrification retrofit does not necessitate a Service Upgrade in many homes. Products such as 240-volt consumer-grade devices like the "Simple Switch" and "Neocharge" may be options to avoid Service Upgrades while adding 240-volt loads. In homes with a lack of spare circuit breakers, the UL-listed circuit sharing devices, smart panels, and UL-listed smart circuit breakers can be deployed to share power between devices. These devices that do not typically have coincident load, such as EV chargers and washing machines, can avoid the need for a Service Upgrade. However, of the contractors interviewed, none were aware of these options other than those who specified that they were "electrification contractors" who indicated that they were pursuing ways to avoid Service Upgrades for their customers.

Conclusion: While whole home electrification contractors may be aware, most other contractors and customers are unaware of options to mitigate the need for a Service Upgrade entirely.

3.1.3 Continuing and Future Trends in Service Upgrades of all Types

3.1.3.1 Continuing Trends

Increase in Applications as Electrification Adoption Grows

Residential electrification upgrades and Service Upgrades typically run a similar course to many home improvements from the customer and contractor perspective. They will work with the Utility to shut off power to the panel if it needs to be replaced, and if it needs to be moved or upgraded, they will work with the Utility to increase the size or move the service drop.

Electrification retrofits will most likely lead to an increase in Service Upgrade applications for the Utilities in the future, as more jurisdictions investigate all-electric code options.

Utilities can help reduce confusion by educating customers and contractors about ways to mitigate the need for a Service Upgrade, and the benefits of electrification seen by early adopters currently. The Utilities can also prepare for the change internally to streamline the Service Upgrade process along with options to increase customer education, costs involved, and ongoing status reports.

Conclusion: As electrification adoption increases across California, the need for increased customer and contractor education on the Service Upgrade process, including ways to mitigate the need for an upgrade, is imperative.

Utility Contractor Availability

There is a reported lack of Utility lineman in California according to Utility staff and contractors, which is projected to increase as the existing workforce retires.

Utilities contract with private entities to complete the Service Upgrade work. Utility staff and contractors reported that Utility contractor crews' schedules have been mismanaged. As an example, one crew had no work for over a month, even though the crew was available to work and there was a project backlog. When contractors have inconsistent work, lineworkers must seek employment elsewhere. In a competitive job environment, the Utilities lose resources.

Conclusion: More effectively managing the workloads of qualified contractors will continue to be essential to meet the increasing demand for Service Upgrades.

3.1.3.2 Future Trends

Utility staff had mixed thoughts future trends for Service Upgrades. Some felt that there is an issue of pent-up demand for Service Upgrades, while others felt that solar will increasingly lead to Service Upgrades. They are not seeing a rise in applications due electrification but are seeing a rise in applications due to additions, ADU's, and Solar PV.

Residential buildings do not need a 200-amp panel to install solar, however, solar contractors upgrade service panels on most projects. The customers that need a PV array above 3.8 kW DC are also likely to be the customers that install a 200-amp panel regardless of the cost.

Conclusion: Utility staff are not seeing a rise in application quantities due to electrification but are already seeing a rise in Service Upgrade applications for other reasons.

3.2 RECOMMENDATIONS

Based on the findings of this Study, the Study team recommends the Utilities, CPUC, and future program implementers consider the following recommendations.

3.2.1 Recommendations for Utilities

Utilities should investigate leveraging the overhead to underground conversion allowance for Service Upgrades that are required to convert overhead to underground lines.

This allowance would mitigate the increased costs faced by customers who are upgrading their electrical equipment with existing tariffs and budgets for fire hardening programs. The overhead to underground conversion provides a fire hardening benefit for existing customers not currently scheduled.

Utilities should continue to assess ways to reduce the need for Service Upgrades.

Increasing customer and contractor education on ways to mitigate Service Upgrades, may increase electrification adoption due to less risk of a costly Service Upgrade during the project. It will decrease the demand for Service Upgrades for the line to the customer. Many single-family homes in California can go all-electric with a standard 100-amp service drop, and it would be in the customer's best interest to investigate ways to prevent the need for a Service Upgrade entirely. The cost of an upgrade can be upwards of $5,000 depending solely on materials and labor costs, and over $18,000 if transformer, pole, and line upgrades are needed. For instance, adding a high amperage heat pump water heater can be avoided with a lower amperage model – and the existing service drop can be used to deliver the needed power. Because the cost of a Service Upgrade is high to the individual and the ratepayer, it is worth a basic inquiry to determine if a Service Upgrade is necessary in all cases.

A key factor is assisting the homeowner and contractors to make informed choices dependent on their personal situation. Approximately 71% of California Single Family homes have at least 100-amp service entrances based on California electrical code changes in the mid-1960s and the 2020 US Census data and historical building codes.

Continue to educate contractors and customers on the availability of both energy efficient and low-amperage products.

There is a knowledge gap and an awareness gap around efficient low-amperage products and panel size suitable retrofit options, however, not necessarily a product gap. The Utilities have been doing a great job promoting energy efficiency and education among customers and contractors, so it is crucial to continue those efforts while also increasing awareness of new products which may alleviate the need for a Service Upgrade during a retrofit.

Consider offering a bonus incentive to customers completing electrification retrofits that do not significantly increase their amperage.

Although the focus on lower amperage units instead of simply "efficient" units may be untraditional, it will be more cost effective in the future with new avoided costs, increased natural gas costs, and total system benefit inclusions into cost effectiveness.

Develop and share Utility-specific best practices.

There are differences between the PG&E and SDG&E Service Upgrade processes that drive efficiencies such as requiring load calculations and site photos as part of the initial Service Upgrade application. The Utilities will benefit from developing and sharing best practices and lessons learned for the customer application intake, requirements, and scheduling that will support process improvements. The goal of the process improvements is to support Utility staff to more efficiently complete Service Upgrades, reduce the overall timeline, improve customer communication, and reduce costs.

Streamlining Utility software, including providing automatic notifications to the customer and staff would improve Service Upgrade review time.

If Utility software can show Utility staff the stages which an application has passed through, it should be able to provide updates to the customer applicant in the form of an email or a text, customer preference depending. This would save staff time spent reaching out to customers, sometimes in a redundant fashion because the customer has already seen the update in their portal.

Service Upgrade applications should continue to have one central, Utility-facing portal or document hub for each applicant that is accessible by the key staff for the application including: the planner, the inspector, and the design team. This saves staff time spent corresponding about documentation.

Educating the customer on the steps that the Service Upgrade process will take is crucial prior to submitting the initial Service Upgrade application to the Utility.

Customers that received early guidance with clear expectations of costs and fees are much more likely to complete their Service Upgrade in a timely manner and reduce Utility staff time involved in sending applications back for review or corrections.

Utilities should investigate the potential for customers to receive educational materials such as a guide, video explanation, or infographic explaining the steps and documentation they will need to get an upgrade prior to submitting an application. These should remain accessible in their applicant portal and on the Utility website. It should set realistic expectations and clearly state common issues or process delays that may result, such as the fact that misrepresenting their installation of a larger panel as a Like-For-Like Panel Upgrade will create delays in their application.

Contractors should go through a separate training path of materials and available online education resources that goes into more depth — they are often the entity submitting the application on behalf of the customer. Educational materials for contractors on this topic should remain available in the Utility education as an On Demand module and updated if there is a major change.

Assess customer touchpoints early in the Service Upgrade customer journey to identify ways to educate the customer on ways to mitigate the need for a Service Upgrade.

The first customer touchpoint is the Utility website. This is a good opportunity to provide customers with information on how to avoid a Service Upgrade. Another customer touchpoint early in the process is the onsite Utility inspection. Utility inspectors can assess the need for a panel upgrade and provide a report to the customer. Utility and Building Department inspectors will need additional training to assess the need for a panel upgrade and provide the customer with a panel report. A leave-behind informational brochure may be another way to provide customers with information about their options to avoid the need for a panel upgrade and save the customer money.

Applications should not lose all submitted documentation and have the "clock reset" after not hearing back from the applicant for time periods longer than 30 days.

According to our interviews with staff, applications submitted to PG&E void after 30 days have passed from initial submission if the application is incomplete and the applicant has not followed up. Until all documents are submitted correctly, the application isn't in the queue. This often results in Utility staff spending additional time reviewing documentation that has already been reviewed by someone else simply because some parts of the customer's application were incomplete or incorrect. The study team does not believe that the current practice, which is to create a 30-day period in which all documents must be submitted, is as effective as using a two-track system. Creating an option to "freeze" and extend the documentation retention period, after the 30 days expire, for some period approximately six to nine months -- while allowing the applicant to pick up where they left off — may be a more efficient method to ensure eventual customer follow-through and completion. It also means that staff time spent processing the application is an effective use of time if the customer picks up where they left off later.

A lack of customer response may be due to unforeseen factors limiting their ability to respond within 30 days. Currently, the application restarts from scratch, which expends both staff and applicant time at no benefit to the customer.

Assess and leverage existing resources.

Utilities have Lean Six Sigma or other internal organizations tasked with identifying process improvements. Consider leveraging these continuous process improvement resources to assess and report on the Service Upgrade timeline, process automation and system upgrades.

3.2.1.1 Incorporating Service Upgrades and recommendations into electrification programs

Low amperage products have load profiles comparable to baseload profiles than high amperage products.

These products run longer at a lower amperage and may have potential to reduce the "duck curve"[15] impact as more electronics and electrification alternatives are installed in homes. Well-chosen low amperage appliances, especially in HVAC and domestic hot water, do the same work as a high amperage at similar or greater efficiency, but at a demand that is more predictable as baseload power as opposed to peak power.

Leverage demand response (DR) programs to include an incentive for avoided upgrades, or the increased use of low-power appliances.

Options exist in the market which already provide a distributed incentive structure for customers to turn off high-amperage appliances and save power during DR and high-load events. This platform could be leveraged to educate and provide non-rate-based incentives for customers looking to electrify their appliances. Typically, marketplace DR options may compete with Utility run DR programs, which adds confusion among customers and would have to be coordinated.

Time-of-Use (TOU) rates can provide a market incentive to choose a low-amperage device, but for many customers, an education and knowledge gap exists around the problem caused by choosing energy efficient appliances which are "high-amperage," or "power inefficient." Despite customers focusing on efficiency, it may result in a relative increase in DR events as customers opt to electrify, as opposed to a market where customers have a signal to purchase devices that are both energy efficient and low-amperage. This lack of education and signals also may result in customers dissatisfaction from considering themselves "energy efficient" while still utilizing high-amperage appliances at peak times, resulting in increased Utility bills relative to a low-power energy efficient customer.

Incentives for low-amperage appliances and/or circuit sharing devices may be a beneficial intersection of equity and keeping ratepayer costs low.

The following list of potential opportunities should be considered as initial options for inclusion into future program or incentivized offerings:

- 120-volt heat pump water heaters
- 120-volt stovetops and ranges
- 120-volt ductless mini-split heat pumps (HVAC)

[15] DOE Website. "Confronting the Duck Curve." Accessed February 2022. https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

- EV, circuit sharing devices and smart circuit breakers
- "Smart" electrical panel upgrades

Pilot programs for a gas to electric conversion should be investigated by the Utilities as a non-resource option, with the future conversion to a resource program based on changes to total system benefit calculations.

The Study team understands the next round of ratepayer funded and CPUC approved third-party programs is already anticipated to provide incentives in this area of concern, and pilot programs would increase visibility and awareness on the issue.

3.2.2 Recommendations for CPUC

Investigate reallocating the existing incentives and allowances in Rules 15 and 16 for new natural gas connections to Service Upgrades. The CPUC has already begun to address this topic via Rulemaking 19-01-011, while also increasing the Rule 15 and 16 allowances to provide some incentive for overhead to underground conversions, which are becoming more often unavoidable under Rule 2.

Consider creating an incentive for Like-For-Like Panel Upgrades. The CPUC should consider Peninsula Clean Energy's rebate structure[16] which financially incentivizes everyone to have 100-amp service but reduces the existing incentive available for upgrading to 200-amp at a progressively decreasing level based on customer income, while increasing customer education about "power efficient" appliances, load balancing devices and smart panels for 240-volt appliances.

This is a strategy that would help lower income homeowners and provides for the fact that "smart" electrical panels and UL-listed devices such "smart devices" can mitigate the power requirements that could otherwise drive a major shift towards 200-amp service in all residences. Smart panels could be incentivized, but a manufacturer requirement is that the security of the equipment's firmware must be maintained for the life of the device.

The CPUC should highlight Utility efforts and best practices related to completing home upgrades without significant capacity increases, a panel upgrade, and Service Upgrades, including educational resources and support provided by the Utilities. These efforts will help motivate customers who may be reluctant to pursue an electrification upgrade, while also educating other Utility staff on best practices across the state.

3.2.3 Recommendations for Future Studies

Future studies of this topic are recommended as study targets:

This Study gathered data from electricians and contractors contracted directly with the customer for the electrification retrofits. The Study team assumed these electricians and customer-contracted firms

[16] Peninsula Clean Energy. "Heat Pump Water Heater Rebates." Accessed April 2022. https://www.peninsulacleanenergy.com/heat-pump-water-heater/

would have detailed cost data on the Utility costs associated with the Service Upgrade. The customer pays the Utility directly for the Service Upgrade costs that exceed the allowance. A future study must determine a way for Utilities to anonymize the Service Upgrade cost data so that their verified Service Upgrade cost data can be released. Future studies should consider allocating four to six months for the Utilities to respond to data requests to obtain actual Service Upgrade cost data.

In lieu of the Utilities' actual Service Upgrade cost data, a future study could offer an increased incentive amount to several key Utility contractors to obtain several "sample bids" or hypothetical full project scenarios and cost breakdown. This would include example projects including both 100A to 200A upgrades and 200A to 400A upgrades, as well as overhead and underground projects. The contractors interviewed included both customer-facing and Utility-facing contractors, but only Utility contractors are able to provide data on the Utility infrastructure costs that customers may be responsible for, and their data is proprietary but not inaccessible.

None of the participating contractors shared Service Upgrade cost data in the form of bids. The Study team received bids from full-service electrification professionals with panel upgrade costs, but they excluded the Service Upgrade cost data needed for this Study. The Study relied entirely on the Service Upgrade cost data reported by customers and a few contractor interviews that provided high-level Service Upgrade costs.

PG&E and SDG&E sent emails notifying customers of the upcoming Study before the survey and interview invitations were sent. A second round of emails was distributed to customers which provided an initial boost to response rate due to the customers' familiarity with the Utility vs the Study team. A later email was distributed to PG&E contractors and provided a significant boost in response rate compared to cold calling alone. Our dataset was smaller than expected for the number of homeowners because the initial list was reduced by more than half due to Do Not Call lists and incorrect contact information. A 25% response rate to an email survey would be an ambitious goal to a future study without this support from the Utilities.

A future study could look more closely at the housing market and develop a statistical model of the number of homes that cannot avoid a panel upgrade from 200-amps or 400-amps.

- Much of this data already exists in the form of US Census Bureau data on the age and size of homes. From there, classifications of homes based on size, climate, and age can be compared to an extensive database of electrification retrofits. Determinations can then be made about the number and types of homes within study territories that the Utilities can expect to need an unavoidable Service Upgrade.

The Study team was able to get a higher response rate from its network of professional contacts, including many electrification professionals who are working on moving customers away from gas, than it got from cold calls to electricians or customers.

4.0 APPENDIX A

4.1 CUSTOMER ONLINE SURVEYS

Full datasets were made available to the Utilities, and selected questions are displayed below to protect customer privacy and PII.

Figure 8 - Customer Survey Q1

Question 1: What triggered your Utility electrical Service Upgrade? Check all that apply:

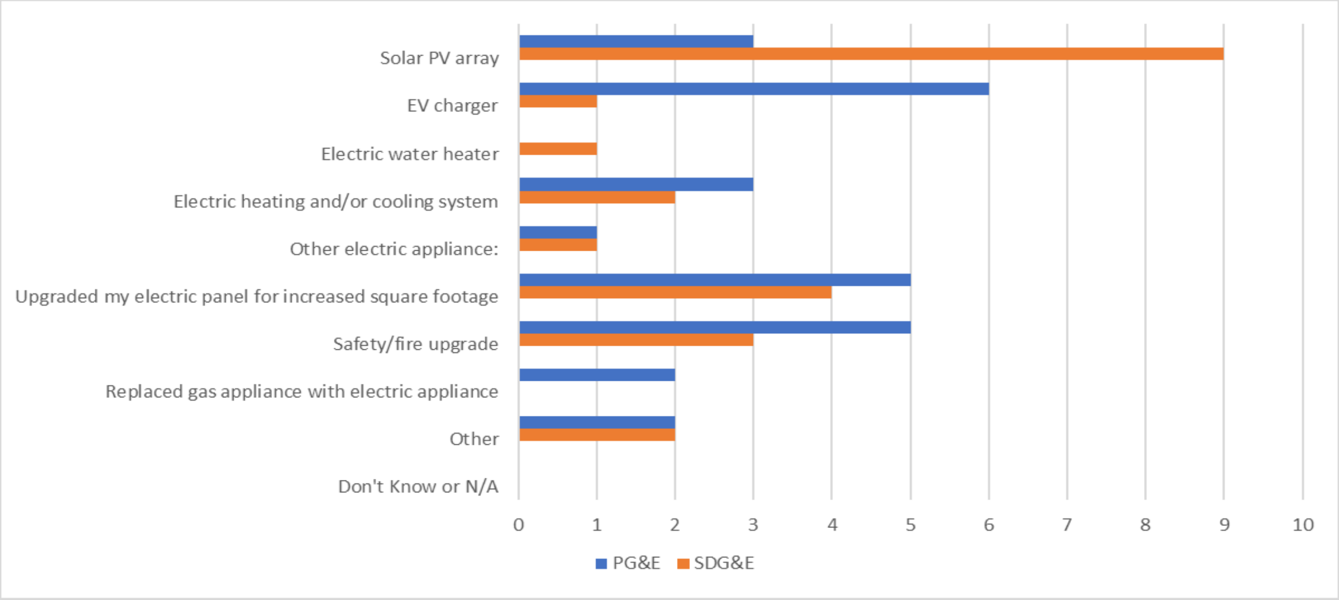


Figure 9 - Customer Survey Q2

Question 2: Did you consider any alternatives to alleviate the need for your Service Upgrade?

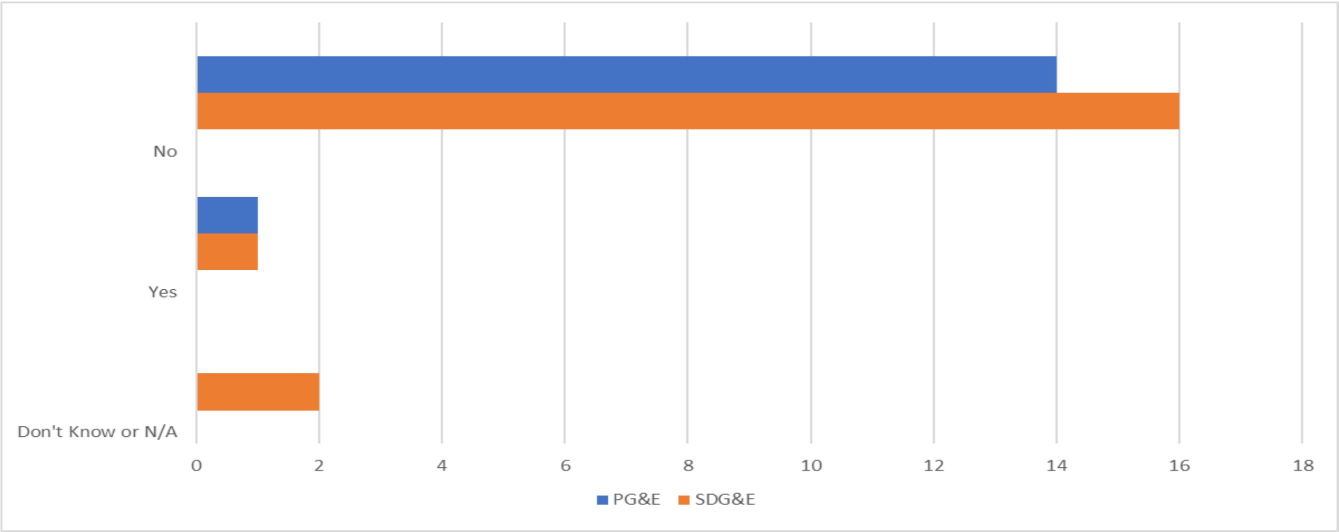


Figure 10 - Customer Survey Q9

Question 9: Approximately how long did it take from when you or your contractor first contacted your Utility to when you had the Utility electrical Service Upgrade completed?

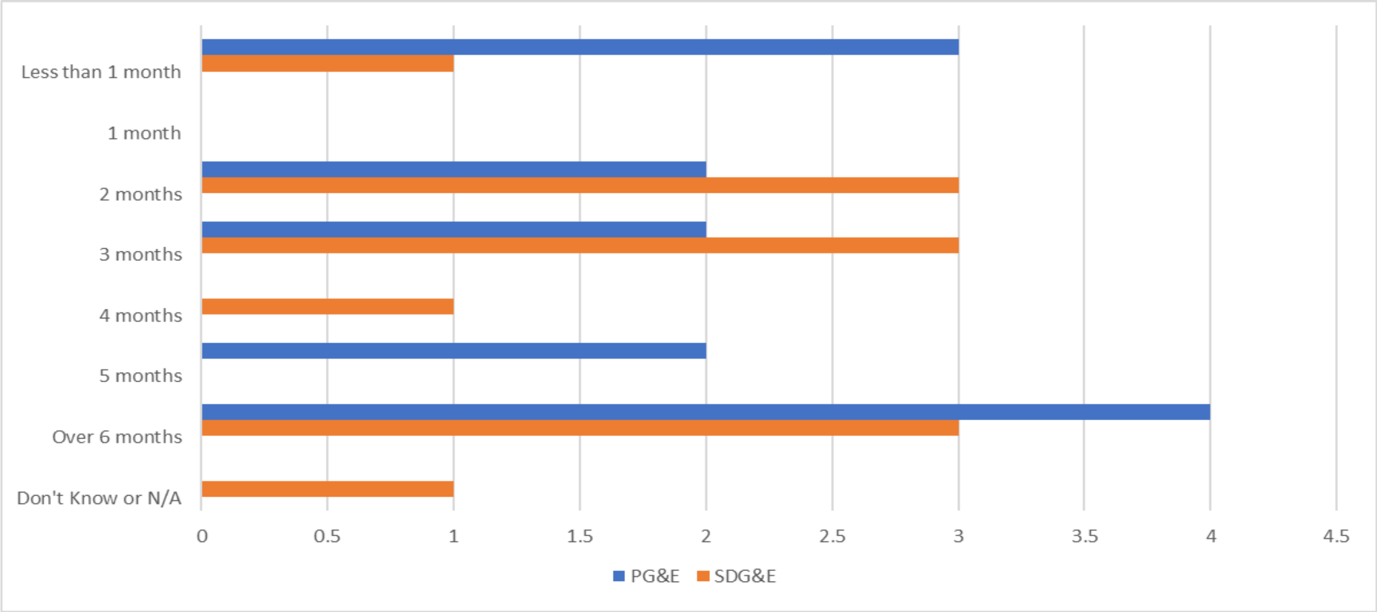
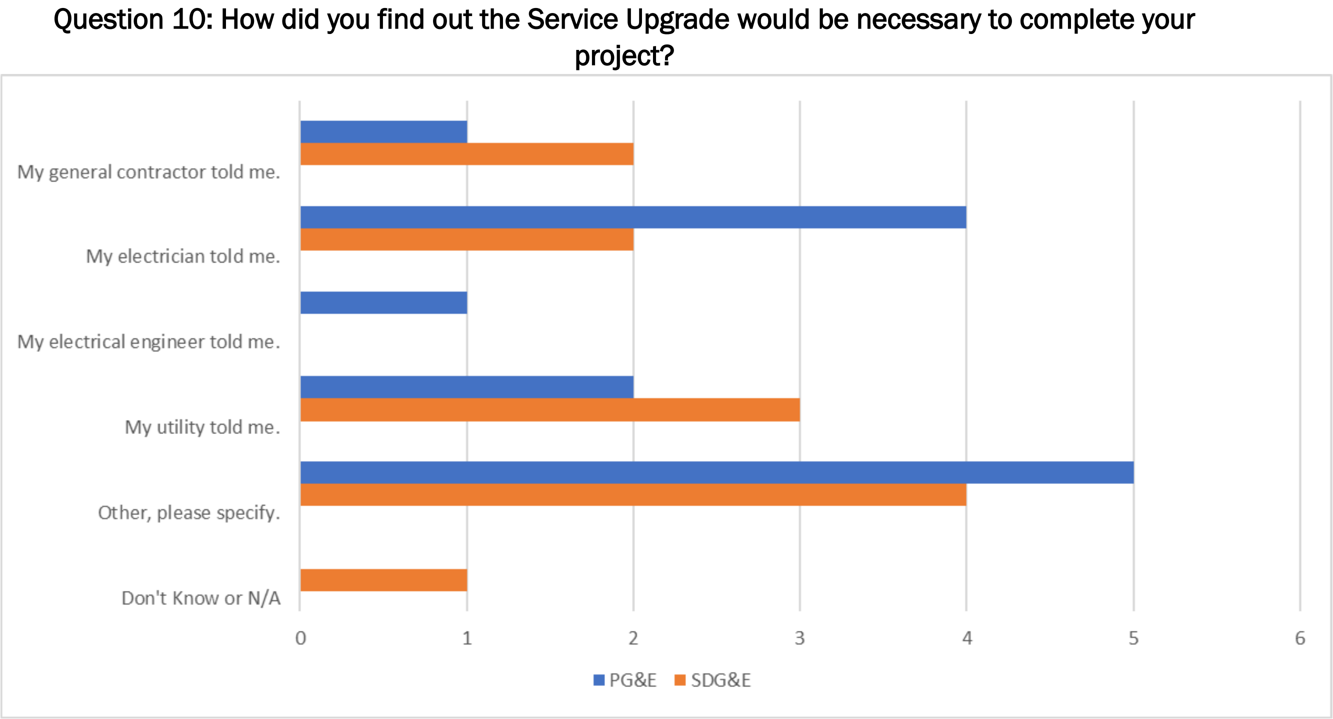


Figure 11 - Customer Survey Q10



4.2 CONTRACTOR INTERVIEWS

4.2.1 Case Studies with Electricians and Electrification Professionals

Case studies have been anonymized prior to public-facing publishing.

Case Study 1: California Electrician and Company Owner A

This electrician serves all of San Diego County and takes large jobs elsewhere in California and Arizona. The owner kindly agreed to an interview and explained Service Upgrade pricing, which is condensed below:

Q1: What is the range of prices you charge for Service Upgrades, and how do you price the tasks?

Company Owner A: "The upgrade of an existing 100-amp overhead service to 200-amp service is around $3,200. Of that total cost, $1,800 to $2,200 is just the service panel, and that if it's just stucco siding, but this number goes up exponentially if there is brick, wood, or trim repair work around a panel. The riser may also need work.

While every city is different, roughly $700 of the $3,200 is costs related to permitting. The permit itself in this example is $250, plus $150 for two hours of labor at City, so $400 total. When the City comes out to inspect, we must set aside a 4-hour window, so at $75 an hour that waiting around costs $300. That's where the $700 cost comes from."

Q2: In your experience, what are the most common home improvements (or combination of home improvements) that trigger a Utility electrical Service Upgrade?

Company Owner A: "Adding a solar array, enlarging the house, building an accessory dwelling, or installing a pool or hot tub."

Q3: What is the process for working with the Utility when upgrading a service?

Company Owner A : "Fill out the application, call the coordinator, check with project manager to set dates, call the City, pay for permits, align the dates that SDG&E is available, call in to the City Inspector 2 days before my disconnect date and let him know its urgent (it's a disconnect reconnect), have Inspector online with SDG&E, then give SDG&E the OK the morning of the disconnect/reconnect. Arrange everything with inspector to be complete before 2pm. Have him release the meter to SDG&E. Then SDG&E has their crew out before 4pm to reconnect.

10 years ago, this would have taken roughly three days with an SDG&E project manager to arrange for a work order and disconnect date. Today it takes up to 25 days with the project coordinator, and another ten business days for the workorder."

Q4: Do you feel that there are ways to streamline the Service Upgrade process for the customer's benefit?

Company Owner A: "Before solar, about 10 years ago, SDG&E had good crews. Post solar, the same crew also has all the new solar rooftop projects, and crews are not coming out to reconnect services as quickly. The solution could be assigning Lineman just for solar, and [a] different crew for panel upgrades."

Case Study 2: California Electrician and Company Owner B

Q1: How do you price Service Upgrades?

Company Owner B: "Each service must be looked at separately as each one, depending on age, will present different challenges. Some have panels recessed in the wall, some have panels under the residence, others may have multiple non-code complying wiring attached that must be corrected while doing the service change. Costs [in Humboldt County] can range from a super simple [panel] replacement at $750 all the way up to $2,000 for a 200-amp complex service."

Q2: What is the split between labor and materials?

Company Owner B: "With material prices escalating so rapidly over the past year due to shortages, [2021] pricing may not reflect actual costs of service changes in the future once we emerge from the pandemic. Every service presents different scenarios that will affect labor and materials required to complete the installation."

Case Study 3: Former California Utility Employee

A Former California Utility Employee avoided a $16,000 underground Service Upgrade bill from the Palo Alto municipal electric Utility while electrifying their 2,200 square feet, two story home. The Service Upgrade was avoided by using "power-efficient appliances, on a budget, in little experimental stages." Company Owner C previously provided a training at the PG&E Energy Education Center on methods they used to achieve full electrification retrofits on 100-amp service, in dozens of stellar homes.

Former California Utility Employee's first project, an original 1940's home, had a previous Service Upgrade in the 1990's, so the existing service's "power budget" was 150-amps. By performing the electrification work themselves, and with the help of "buddies," they spent only $6,400 to replace their gas water heater, furnace, stove, and laundry dryer. Had they installed new gas appliances, instead of electric, the budget would have been $1,400 cheaper, at $5,000.

The additional cost of new all-electric appliances was $1,400, but had they also performed a $16,000 Service Upgrade the additional cost would have been $17,400*. So, by avoiding a Service Upgrade even though they wanted to go all-electric, the Former California Utility Employee was able to save $16,000.* The electrification measures and costs are itemized in Table 7 below.

Table 7: Example Electrification Measures at an example home

Appliance	Type of Cost	Cost	DIY Labor Hours	Specifications
Heat Pump Water Heater	Appliance	$1,200	4	50 Gal. HPWH from Lowe's
	Electrical	$150	5	New 240-volt 30-amp circuit in flexible armored conduit
	Pipes and fittings	$190 for materials & lunch for my friend	10	Connectors and ball valves for future hydronic heating coil plus condensate pump and line
Window Heat Pump	Appliance, plug in	$390	1/2	Frigidaire 8,000 BTU/h 120-volt plug-in window heat pump # FFRH0822R1
Mini-Split Heat Pump	Appliance + shipping	$1,600	1	Mr. Cool DIY 12,000 BTU/h variable speed 120-volt
	Electrical	$120	5	New dedicated 120-volt 20-amp outdoor outlet serving as "disconnecting means"

	Head Installation	Free with my friend	9	Watch video, mount bracket, drill hole, pass line-set through it
	Compressor Installation	$40	3	Bolt to plastic base on gravel bed
Induction Cooktop	Appliance	$900	1	Frigidaire Gallery 36" width
	Electrical	$190	5	Crawling under house to run new 240-volt 40-amp circuit
Combined Washer/Condensing Dryer	Appliance	$1,600	1	It just plugs in where the prior washer was and replaces washer and dryer.
Total	Gross Cost	$6,400	45	Net Incremental Cost $1,400 if we subtract the cost of new gas machines.

4.3 LITERATURE REVIEW

A Literature review was conducted throughout the Study to provide background information to answer the Study objectives as well as help to form the interview and survey questions. The sections below outline the Tariff documents from the Utilities: Rule 15 and 16, a historical code book review to understand how the age of home effects its circuits and thus the cost of a Service Upgrade, and a review of the cost data for Service Upgrades that exist online.

4.3.1 Tariff Rules Documentation

The following section summarizes the most relevant portions of the Utility Rules 15: Distribution Line Extensions (Distribution Line Extensions) and Rule 16: Service Extensions (Service Extensions). A detailed review of these documents was conducted to understand the Utility's allowance for Service Upgrades as well as to understand the responsibilities of the Utility and the homeowner for the different portions of a Service Upgrade.

4.3.1.1 Rule 15: Distribution Line Extensions

Rule 15[17,18] summarizes the Utility's construction and design specifications, standards, terms, and conditions of a new extension of an electric distribution line (under 69 kV for SDG&E and under 50 kV for PG&E), used to provide permanent electric service to their customers.

Distribution Line Extension Allowance

Customers do not have to pay for a Service Upgrade for permanent electrical loads if the cost of the upgrade does not exceed the allowance. The allowances for both PG&E and SDG&E are based on this formula:

17 PG&E Website. "PG&E Rule 15". Accessed February 2022 https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_RULES_15.pdf
18 SDG&E Website. "SDG&E Rule 15" Accessed February 2022 https://www.sdge.com/sites/default/files/elec_elec-rules_erule15.pdf

$$Allowance = \frac{Net\ Revenue}{Cost\ of\ Service\ Factor}$$

The Cost of Service Factor is the "depreciation, return, income taxes, property taxes, operating and maintenance (O&M), administrative and general (A&G), franchise fees and uncollectible expenses (FF&U) and replacement of facilities for 60 years at no additional cost to customer." The residential distribution line extension, service extension, (or combination of both) for permanent service allowance for PG&E is $2,154 and $3,241 for SDG&E. The residential allowance will first be applied to the service facilities and any excess will be applied to the distribution line extension.

Table 8: Extension allowance and cost of service factor for PG&E and SDG&E.

	PG&E	SDG&E
Cost of Service Factor	Distribution: 14.64% *(Defined in Rule 2 Section 1.3.b)*	14.63% *(Defined in Rule 15 Section J)*
Allowance	$2,154 *(Defined in Rule 15 Section C.3)*	$3,241 *(Defined in Rule 15 Section C.3)*

The Utility periodically reviews the factors used to determine its residential allowances, if the review results in a change more than 5%, the Utility will submit a tariff revision proposal to the CPUC for review and approval.

4.3.1.2 Rule 16: Service Extensions

Rule 16[19,20] outlines the requirements of service extensions for both the Utility and the customer or contractor applying for the Service Upgrade (Applicant). A Service Upgrade includes the **Utility's service facilities** that extend from the Utility's distribution line facilities to the service delivery point. And the **Applicant's service facilities** are any other service-related equipment required of Applicant on Applicant's premises to receive electrical service. **The Utility's service facilities include** primary or secondary underground or overhead service conductors, poles to support overhead service conductors, service transformers, Utility owned metering equipment, and other Utility-owned service-related equipment.

The Utility will be responsible for planning, designing, and engineering the distribution line extensions, using their standards for materials, design, and construction. However, the applicant may choose the Applicant design option, described in Rule 15, to design the service extension. **PG&E Only** (and not SDG&E): the Utility will only support the design for the 18 months following the date of application. Where requested by Applicant and mutually agreed upon, the Utility may perform work on the portion of the service extension that the Applicant is normally responsible for, so long as the Applicant pays the Utility its estimated installed cost. Also, for the **Applicant design option**, the Applicant can use

19 PG&E Website. "PG&E Rule 16". Accessed February 2022: https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_RULES_16.pdf
20 SDG&E Website. "SDG&E Rule 16" Accessed February 2022: https://www.sdge.com/sites/default/files/elec_elec-rules_erule16.pdf

competitive bidding to install the portion of the service extension normally installed and owned by Utility, in accordance with Rule 15.

"Special" or "added facilities" will be installed at Applicant's expense in accordance with **Rule 2** Description of Service (Description of Service). In Rule 2 it summarizes that the Utility will only install what is standard and what it deems necessary to provide regular service. When the customer and the Utility agree to install special facilities, additional costs will be paid by the applicant.

Rights-of-way or easements may be required by Utility to install service facilities on Applicant's property. If **service facilities** pass through property owned by a third party, Utility may need to get appropriate rights-of-way or easements, before installation without cost to the Utility. If facilities are installed on applicants' property or third-party property and will serve the adjacent property, Utility may need to get appropriate rights-of-way or easements before installation for **Distribution Line Extensions** as well. Rights-of-way and easements shall have appropriate **clearances** in them to maintain legal distance form adjacent structures.

Service Extensions

The **general location** requirements of a Service Extension are as follows. The Service Extension will extend either in a **franchise area** *("public streets, roads, highways, and other public ways and places where PG&E has a legal right to occupy under franchise agreements with governmental bodies having jurisdiction")* from the point of connection at the distribution line to Applicant's nearest property line, or on **private property** that follows along the shortest, most practical, and available route as necessary to reach a Service Delivery Point.

Underground installations are required where required to comply with applicable tariff schedules, laws, and ordinances. They may be necessary as determined by the Utility where Applicant's load requires a separate transformer installation of 75 kVa or greater. Underground installations are optional when requested by the Applicant. **Overhead installations** are permitted except under the circumstances specified in items 1 through 3 above.

Underground Installations will be installed for:

1. **New construction** on any property except public property and public rights-of-way
2. Circumstances in which **capacity upgrades, conversions, and relocations are required due to customer-driven renovations of existing structures** or other building activities resulting in a change of use or occupancy as defined in state or local law
3. Except for situations on a case-by-case basis in which the local authority and the Utility agree to locate Equipment above ground because the above-ground location is technically feasible for the installation.

When Applicant's building is located a considerable distance from the distribution line, or if there is an obstruction or hazard, this is considered an **unusual site condition**, and the Utility may waive the normal service delivery point and will be located at another point on the Applicant's property or property line.

<u>Applicant Responsibilities</u>

Per Rule 16, The Applicant is responsible for in summary- **Service lateral facilities** that include: providing (or paying for) a **clear route** on private property, **excavation** which includes all necessary trenching, backfilling, and other digging as required including permitting fees and **conduit and substructures.**

The Applicant is responsible for furnishing, installing, owning, and maintaining all conduits including pull wires and substructures on Applicant's premises. **Conduits** are defined as**:** *"ducts, pipes, or tubes of certain metals, plastics or other materials acceptable to PG&E (including pull wires and concrete encasement where required) for the installation and protection of electric wires and cables."* In addition, the applicant is responsible for - installing (or paying for) any conduits and substructures in Utility's Franchise Area (or rights-of-way, if applicable) as necessary to install the service extension. **Substructures** are defined as *"the surface and subsurface structures which are necessary to contain or support PG&E's electric facilities. This includes, but is not limited to, splice boxes, pull boxes, equipment vaults and enclosures, foundations or pads for surface mounted equipment."* The Applicant is also responsible for furnishing, installing, owning, and maintaining all necessary **Protective Structures** on Applicant's premises.

Beyond the service delivery point, the Applicant is responsible for planning, design, installing, owning, maintaining, and operating the service facilities (except metering facilities). *"**Service delivery point:** Where PG&E's service facilities are connected to either Applicant's conductors or other service termination facility designated and approved by PG&E."* **Rule 2** further defines requirements of electrical services, including but not limited to: available service voltages, load balancing requirements, requirements for installing electrical protective devices, loads that may cause service interruptions and motor starting limitations. Applicants are required to follow all requirements in Rule 2 for their portions of the Service Upgrade.

In addition, the Applicant shall be responsible for furnishing, installing, owning, maintaining, inspecting, and keeping in good and safe condition all facilities on Applicant's premises, that are not owned by the Utility but are required to receive service. Such facilities include but are not limited to: overhead or underground termination equipment, conduits, service entrance conductors from the service delivery point to the location of the Utility's meter, connectors, meter sockets, meter and instrument transformer housing, service switches, circuit breakers, fuses, relays, wireways, metered conductors, machinery, and apparatus. When the Utility determines that the Applicant's load is of sufficient size, it is the Applicant's responsibility to coordinate response time characteristics between the Applicant's protective devices (circuit breakers, fuses, relays, etc.) and those of the Utility. The Applicant may also be required to install a **transformer** on their premises, more requirements for these installations are in Rule 16.

The Applicant is responsible to pay for, in advanced of Utility performing work: the Utility's estimate installed costs of any **pole riser** materials, the Utility's total estimated installed cost (including relevant facilities, such as connectors, service conductor, service transformers, metering equipment, and the conduit portion of CIC cable) for any **excessive service** that exceed the allowance and any **tax**.

Utility Responsibility

Per Rule 16, The Utility is responsible for the **service** itself**,** the **meter,** and the **transformer:** The Utility will furnish, install, own, and maintain the follow service facilities. Any necessary pole **riser material** for connecting underground services to an overhead distribution line. For underground and overhead, the Utility will provide **service conductors** to supply permanent service from the distribution line source to the service delivery point. When the **meter** is owned by the Utility, the Utility will be responsible for the necessary instrument transformers where required, test facilities, meters, associated metering equipment, and the metering enclosures (only when PG&E elects to locate metering equipment at a point that is not accessible to Applicant). The **transformer** where required, including any necessary switches, capacitors, electrical protective equipment, etc. When either a pad mounted or overhead transformer is installed on Applicant's premises, the service extension shall include the primary conductors from the connection point at the distribution supply line to the transformer and the secondary conductors, if any, from the transformer to the service delivery point. Utility will own and maintain conduits only under special circumstances: when they are in the same trench with the distribution facilities and when necessary to located conduits on a property other than owned by the Applicant. When the Utility installs service conductors using pre-assembled **cable-in-conduit**, will be considered part of the conductor installation. Utility will start service, after there has been a **government inspection**.

Existing Service Facilities

When an existing service facility requires replacement, it will be replaced as a new service extension (the same responsibilities apply from the above sections). If a service needs to be relocated (necessary for maintenance or operative convenience) the Utility will perform this work at its own expense. Except for the following: if the Applicant requests a relocation or rearrangement for aesthetics, remodeling, additions, etc., will be performed with the normal responsibilities, except that Applicant shall pay the Utility its total estimated costs. If facilities are damaged, repair will be made at the expense of the party responsible for the damage. Applicants are responsible for repairing their own facilities.

If there is not proper access or clearances for a Service, then the Applicant or owner shall, at Applicant's or owner's expense, either correct the access or clearance infractions or pay PG&E its total estimated cost to relocate its facilities to a new location.

For **Overhead to Underground Service Conversions**- this is where Rule 16 connects to **Rule 20:** which describes where an existing overhead distribution line is replaced by an underground distribution system in accordance with Rule 20, these new underground services will be installed following the requirements of Rule 16. When the applicant requests and undergrounding, the Applicant shall perform all excavation, furnish, and install all substructures, and pay PG&E its total estimated installed cost to complete the new service and remove the overhead facilities.

4.3.2 Historical Code Book Review

Historical electrical code requirements were assessed by the Study team for changes that pinpoint inflection points in time where building practices may benefit or hinder homeowners today in terms of electrical service and circuitry in the home.

When was 100-amp Service first required?

The majority of single-family homes in were built to call for 100-amp service to the lot as of the 1962 changes to the National Electrical Code (NEC). Ever since that code revision, this has been a stringent recommendation in Article 230 of the NEC. **The City of San Diego adopted this on January 20th 1966**, as part of the Uniform Building Code (UBC) of 1964. Most localities in today's PG&E service territory would have adopted this requirement as part of the UBC between **1965 and 1967**. Localities that adopted their own code since 1962 would have most likely adapted their version from the National Electrical Code recommendations. **In the 1959 code and prior through at least 1947, 100-amp service was only required when the home's load calculations reached beyond 10 kW.**

What size of house in 1959 crossed the 10-kW threshold?

Most 1 or 2-story homes in PG&E and SDG&E territories would have crossed 10 kW in their load calculations as of code year 1959 due to lighting calculations, electric stoves, and electric heating.

A single-story home may not have upgraded from a 60-amp service if the home already had gas services at that time. It is expected that most homes with central air conditioning have already upgraded from a 60-amp service to at least 100-amp service. A home with an Accessory Dwelling Unit (ADU), (often what is referred to as a mother-in-law's unit), or a barn or another structure, would have been required to use 100-amps for service in 1959.

4.3.2.1 Recommendations and Findings Regarding Keeping 100-amp Service Viable in Older Homes

Upgrading kitchen circuits as part of converting a home from using a gas stove will increasingly be a reason that electricians come to homeowners and ask them to upgrade their service line. **Localities with a propensity towards older homes, wood stoves, and/or no air conditioning are likely to see more unavoidable Service Upgrades.** These homes are found more often in rural areas, lower-income areas, and coastal areas. Older kitchen wiring can also be a common secondary trigger for panel upgrades from an electrician's perspective.

Kitchen Circuit Requirements since 1937 National Electrical Code from NFPA

As early as 1937, Wiring Simplified[21] (H.P. Richter) was recommending upwards of four outlets (including light fixtures) to the kitchen. Now, that does not mean circuits, but **outlets.** They would all be on one kitchen circuit, unless a full-size fuse box rated 240-volt, 60-amp, with six circuits was installed, in which case there would generally be at least two circuits to the kitchen. No mention is made of specific amperage requirements for the electrical service. This at a time when homes might only get 120-volt service.

If, in **1937** they wanted to run an electric stove, they would have had 240-volt service, which was the commonplace recommendation. Wood-burning stoves were common at this time, but we can assume for wood stove homes that at some point in the 50's, 60's, or 70's someone must have upgraded to 240-volt service to the home, to accommodate either an electric dryer or water heater, most often the service would have been 100-amps. So, they could have two kitchen circuits as early as 1937, but if the wiring has not been upgraded the kitchen outlets and wires would probably only be 15-amp.

In 1947 one circuit was required at bare minimum for every 867 sq. ft. Two **outlets** are a minimum in the kitchen. However, that says nothing about the required number of circuits to the kitchen. Additionally, for the 1947 code, Richter[22] recommends at least four outlets, one for the fridge, for the toaster, for the ironing area, and for any floor lamps.

In 1956 Richter mentions that the 1951, 1953, and 1956 revisions have contained little changes, except for the required number of circuits in a panel overall but does not mention the number of circuits to the kitchen.

At least by 1959 the code[23] started requiring the two special appliance circuits we still require today, but **even in 1959** they were not **required** to be 20-amp, only recommended. However, in the year 1962, some localities did begin to require 20-amp circuits in the kitchen.

In 1962, the NFPA revised their National Electrical Code recommendations[24] to become a requirement – the kitchen should have two, specifically 20-amp small appliance circuits, each with only one outlet. Most California localities which chose to adopt would have adopted it between 1962 and 1967, alongside of Uniform Building Code updates.

By 1975, while the two 120-volt small kitchen appliances circuits had to be rated 20-amp, at that time the **outlets** were only required to be **15-amp.** If the home was up to code, we can state with confidence that the wires should be good for that amperage, but **the outlets may need to be upgraded**, as well as the breaker, **to 20-amps.** It would be important to do this upgrade because for a range they are usually hidden away behind cupboards or along baseboards, and it would not necessarily trip the breaker if it did start to overheat, and the breaker was not matched to the outlet.

---

21 Richter, H. P., Hartwell, F. P., & Schwan, W. C. (1962). *Wiring simplified: Based on the ... National Electrical Code*. Minneapolis, MN: Park Pub. https://www.worldcat.org/title/wiring-simplified/oclc/5636171

22 Richter, H. P., Schwan, W. C. (1947). *Wiring simplified: Based on the ... National Electrical Code*. Minneapolis, MN: Park Pub.

23 National Electrical Code, 1959. (1959). United States: National Fire Protection Association. https://www.google.com/books/edition/National_Electrical_Code_1959/KxgBngEACAAJ?hl=en

24 National Fire Protection Association Advance Reports (1962) https://www.nfpa.org/Assets/files/AboutTheCodes/70/NEC-Advanced%20Repotrt-1962.pdf

Table 9: The required kitchen and electrical service wiring for homes built under various NEC code years.

NEC Code Year	Kitchen Wiring	Electrical Service Only	Electric and Gas
1937 to 1959	1 Circuit, 15 -amps	60 -amps	60-amps
1959	1 Circuit, 15-amps	100-amps, 60-amps with Wood Stove	60-amps
1962 Code Adopted	2 Circuits, 20-amps, 2 Outlets	100-amps	100-amps

Table 10: Cost to replace or upgrade an electrical panel from various online sources.

Source	Cost to replace or upgrade electrical panel	
HomeAdvisor.com[25]	National average: $1,186 Typical range: $532 - $1,941 Low end to high end: $125 - $3,500	100-amps - $500 - $1,500 150-amps - $500 - $1,700 200-amps - $750 - $2,000 400-amps - $1,500 - $4,000
HomeGuide.com[26]	Average: $850 - $2,500 Upgrade from 60 to 100-amps: $850 - $1,100	Upgrade from 100 to 200-amps: $1,300 - $1,600 Upgrade from 200 to 400-amps: $2,000 - $4,000
Angi.com[27]	200 amp: $750 - $2,000	
Fixr.com[28]	Average: $1,500 - $4,000 Low: $800 Average: $2,500 High: $4,500	100-amps: $800 - $1,200 200-amps: $1,300 - $3,000 400-amps: $2,000 - $4,000
PennaElectric.com[29]	$2,500 - $4,500	

25 HomeAdvisor.com "Electrical Panel Upgrades" (Accessed December 2021) https://www.homeadvisor.com/cost/electrical/upgrade-an-electrical-panel/
26 HomeGuide Website. "Costs to Replace and Electrical Panel" (Accessed December 2021) https://homeguide.com/costs/cost-to-replace-electrical-panel
27 Angi.com (Formerly Angie's List) "Cost to Upgrade to 200-Amp Service (Accessed October 2021) https://www.angi.com/articles/ask-angie-what-does-it-cost-upgrade-200-amps.htm
28 Fixr.com Cost to Upgrade and Electrical Panel (Accessed December 2021) https://www.fixr.com/costs/install-electrical-circuit-panel-upgrade
29 Penna Electric Website. (Accessed December 2021) "Why An Electrical Panel Upgrade Is Costly & 3 Reasons It's Worth It" https://pennaelectric.com/electrician-blog/why-an-electrical-panel-upgrade-is-costly-3-reasons-its-worth-it/

HomeServe.com[30]	200 amp: $3,500 - $4,500	
RemodelingCalculator.org[31]	Average cost to replace electrical panel: $1,200 - $3,000	200-amps - $850 - $1,150 400-amps - $2,000 - $4,000
Home.costhelper.com[32]	Upgrading an electrical panel Typical cost: $800 - $1,200	100-amps: $1,500 - $2,500 200-amps: $1,300 - $3,000 400-amps: $2,000 - $4,000

Costs cited above generally include national data in their averages. Additional costs for residential Service Upgrades were found online from studies focused on electrification. Considering the below estimates are higher than the other online cost estimators, it is assumed that these cost estimates include the potential costs to the Utility, but it is not explicitly stated in any of the studies.

Table 11: Studies focused on electrification that referenced electrical Service Upgrade costs.

Study Title	Service Upgrade Cost
City of Palo Alto 2019 Title 24 Energy Reach Code Cost Effectiveness Analysis (2018)[33]	$2,480
Electrification of buildings and industry in the United States (2018)[34]	$4,700
Local Government Programs and Policies for Existing Building Decarbonization (2021)[35]	$3,904

4.4 RESEARCH PLAN AND INTERVIEW STUDY GUIDES

The interview guides have been provided in a separate PDF along with the final report.

30 HomeServe.com (Blog). (Accessed December 2021) Post: "How Much Does It Cost to Replace an Electrical Panel?" https://www.homeserve.com/en-us/blog/cost-guide/replace-electrical-panel/
31 RemodelingCalculator.com (Accessed February 2022) "2022 Cost To Replace An Electrical Panel" https://www.remodelingcalculator.org/cost-upgrade-electrical-panel/
32 CostHelper Website. (Accessed December 2021) https://home.costhelper.com/electrical-upgrading-electrical-service.html
33 TRC (2018) "City of Palo Alto 2019 Title 24 Energy Reach Code Cost Effectiveness Analysis" https://www.cityofpaloalto.org/files/assets/public/development-services/green-building-files/2019-palo-alto-reach-code-cost-effectiveness-20180914.pdf
34 LBNL (2018) "Electrification of buildings and industry in the United States" https://ipu.msu.edu/wp-content/uploads/2018/04/LBNL-Electrification-of-Buildings-2018.pdf
35 Electrify Marin (2021) "Local Government Programs and Policies for Existing Building Decarbonization" https://www.marincounty.org/-/media/files/departments/cd/planning/sustainability/electrify-marin/531-lessons-learned-report.pdf?la=en

5.0 APPENDIX B

This Study did not evaluate program measures and will be left intentionally blank.

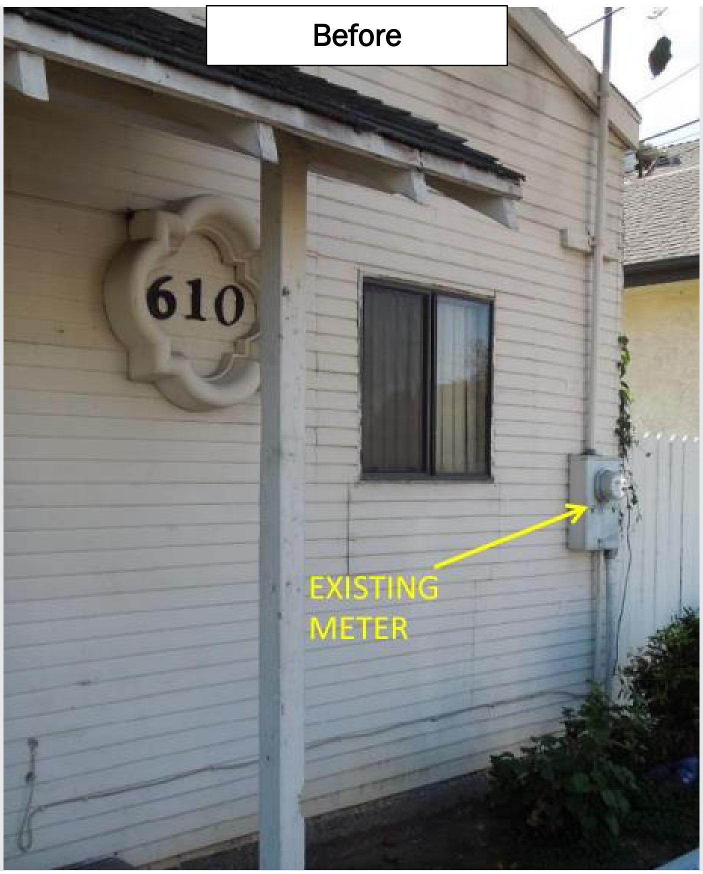
6.0 APPENDIX C – STANDARDIZED CATALOG OF RECOMMENDATIONS

Study ID	Study Type	Study Title	Study Manager
PG&E0467.01	Other	Service Upgrades for Electrification Retrofits	PG&E

No.	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendation	Recommendation Recipient	Affected Workpaper or DEER
1	N/A	Service Upgrades are triggered by electrical panel upgrades that are often avoidable.	Appendix A	Offer nonfinancial and financial program incentives to avoid panel upgrades.	Third-Party Program Implementers	N/A
2	N/A	Customers and contractors would benefit from having access to increased educational information on the process, requirements, and costs associated with Service Upgrades. There are manuals and guidance documents available such as Utility's Electric and Gas Service Requirements, but contractors were unaware of them.	Appendix A	Leverage Workforce, Education, & Training (WE&T) programs to integrate education on the options to mitigate the need for a panel upgrade.	Third-Party Program Implementers	N/A
3	N/A	Most customers and contractors are unaware of available options to mitigate the need for a panel upgrade that would trigger a Service Upgrade. Customer touchpoints include the Utility website, the onsite Utility inspection, and Building Department inspectors. Utility inspectors can assess the need for a panel upgrade and provide a report to the customer.	Appendix A	Leverage customer touchpoints to support customer education. Require inspectors to assess the need for a panel upgrade and provide a report to the customer. A leave-behind informational brochure may be another way to provide customers with information about their options to avoid the need for a panel upgrade and save the customer money.	Building Departments, IOUs, CPUC, Third-Party Implementers	N/A
4	N/A	Some Utility staff Subject Matter Experts reported a perception that a lot of time is spent communicating with customers as opposed to reviewing and processing Service Upgrade applications. This may be due to a variety of issues including time spent addressing customer response accuracy, a lack of automated updates to customers through SAP, time needed to fully address customer questions and concerns, and time spent educating customers on the process. Customers are also typically unaware of the full cost of a Service Upgrade.	Appendix A	Expand existing software platform to reduce customer confusion, set timeline expectations, and reduce time spent by Utility staff communicating with customers.	IOU	N/A

No.	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendation	Recommendation Recipient	Affected Workpaper or DEER
5	N/A	The number of solar photovoltaic installations has continued to rise over the years and there are now many more factors triggering Service Upgrades that require Utility staff time for application processing, inspections, and connection. The Service Upgrade department is likely understaffed and even more likely under-equipped to meet the demand for Service Upgrades, which will continue to increase as customers move to the increasingly required or desirable electric equipment.	Appendix A	Develop a system for Utility staff to visualize capacity constraint.	IOU	N/A
6	N/A	Applications with missing or erroneous information may be voided by one Utility after 30 days of no applicant update, requiring a full application restart despite any work previously reviewed. Some customers reported that the overall Service Upgrade process is confusing, and it took longer than expected, often exceeding six to nine months.	Appendix A	Leverage existing Utility continuous process improvement resources.	IOU	N/A
7	N/A	Solar photovoltaic sales teams in SDG&E territory submit Service Upgrade applications for a batch of customers in a neighborhood that they canvass prior to signing an agreement. PG&E did not report this issue which may be due to its requirement to submit load calculations and onsite photos as part of the application.	Appendix A	Develop and share Utility-specific best practices.	IOU	N/A
8	N/A	Rules 15 and 16 govern the allowance for Service Upgrades. Contractors reported that it is uncommon for the Rule 16 allowance amount to cover the full cost of the customer's Service Upgrade. The total Service Upgrade cost to customers is $2,000 to $30,000.	Appendix A	Increase the Rule 16 allowances to reduce the cost burden on the customer.	CPUC, IOU	N/A

Before



After

NV5

Delivering Solutions
Improving Lives

Attachment to Question 8c: Pocket Guide to All Electric Retrofits of Single Family Homes

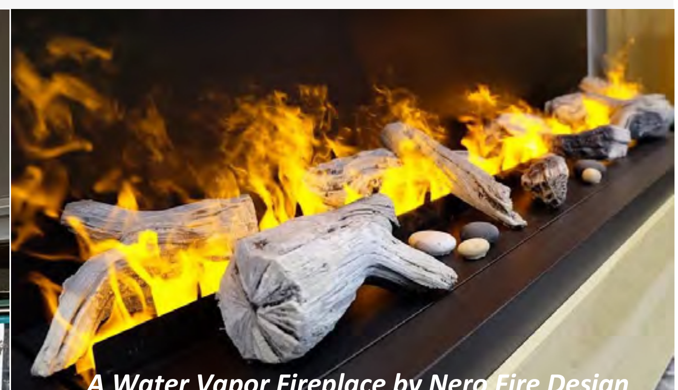
Sean Armstrong's House in Arcata, CA

The Heat Pump Store in Portland, Oregon

Jon and Kelly's Electrified Home in Cleveland, OH

A Pocket Guide to All-Electric *Retrofits* of Single-Family Homes

A Big Chill Retro Induction Range



A Water Vapor Fireplace by Nero Fire Design

A NeoCharge Smart Circuit Splitter

REDWOOD ENERGY

February 2021

Contributing Authors

Redwood Energy

Sean Armstrong, Emily Higbee, Dylan Anderson

Anissa Stull, Cassidy Fosdick, Cheyenna Burrows, Hannah Cantrell, Harlo Pippenger, Isabella Barrios Silva, Jade Dodley, Jason Chauvin, Jonathan Sander, Kathrine Sanguinetti, Rebecca Hueckel, Roger Hess, Lynn Brown, Nicholas Brandi, Richard Thompson III, Romero Perez, Wyatt Kozelka

Menlo Spark

Diane Bailey, Tom Kabat

Thank you to:

The many generous people discussed in the booklet who opened their homes up for public scrutiny, as well as:

Li Ling Young of VEIC
Rhys David of SMUD
Nate Adams of Energy Smart Ohio
Jonathan and Sarah Moscatello of The Heat Pump Store
The Bay Area Air Quality Management for their contribution in support of this guide
Erika Reinhardt

Thank you for contributing images of your beautiful homes and projects!

Barry Cinnamon, Diane Sweet of EmeraldECO, Dick Swanson, Eva Markiewicz and Spencer Ahrens, Indra Ghosh, Jeff and Debbie Byron, Mary Dateo, Pierre Delforge

And thank you to those who reviewed and edited!

Bruce Naegel, David Coale, David Moller, Edwin Orrett, Nick Carter, Reuben Veek, Robert Robey, Rob Koslowsky, Sara Zimmerman, Sean Denniston, Steve Pierce

Contact

Sean Armstrong, Redwood Energy
(707) 826-1450
sean@redwoodenergy.net

Check out Redwood Energy's Commercial, Multifamily and Single-Family Home Zero Carbon All-Electric Guides at their website: https://www.redwoodenergy.research/

This report was produced for Menlo Spark, a non-profit, community-based organization that unites businesses, residents, and government partners to achieve a climate-neutral Menlo Park by 2025. Menlo Spark weaves together transformational energy, transportation, land use and building policies that promote community prosperity, bolster economic vitality, and protect civic heritage. The intent of this report is to help cities and developers everywhere embrace healthier, lower cost all-electric building construction practices.

Table of Contents

INTRODUCTION **5**
THE BUSINESS OF ELECTRIFYING HOMES **6**
Clean Energy Company Highlight: BlocPower 6
A List of California Contractors who Perform Building Electrification 6
Electrification Technical Assistance Program 6
THE BENEFITS OF AN ALL-ELECTRIC HOME RETROFIT **7**
Health 7
Safety 7
Wealth 7
Comfort 7
Climate 7
DESIGN FACTORS WHEN ELECTRIFYING YOUR HOME **8**
ELECTRIFYING ON A TIGHT BUDGET **9**
Plug-In Cooktops 9
Plug-In Cooking Appliances 9
Plug-In Space Heaters 10
Water Heaters 10
WHAT DOES IT COST TO ELECTRIFY YOUR ENTIRE HOME? **11**
What Does It Cost to Electrify Your Home's Kitchen? 12
What Does It Cost to Electrify Your Home's Laundry Dryer? 13
What Does It Cost to Electrify Your Home's Water Heating? 14
California: The Sacramento Municipal Utility District (SMUD) *14*
What Does It Cost to Electrify Your Space Heating? 15
California: The Sacramento Municipal Utility District (SMUD) *15*
Oregon: The Heat Pump Store *16*
Ohio: Energy Smart Home Performance *17*
Vermont and New York: The Vermont Energy Investment Corporation (VEIC) *18*
Massachusetts: State-Wide Rebate Data *18*
THE "WATT DIET" - AVOID A NEW ELECTRICAL PANEL AND REDUCE WIRING **19**
A 100-Amp panel has enough power for complete electrification of a 3,000 square foot home 19
How Insulating and Air Sealing Reduce the Necessary Space Heating Power 21
Power Trade-Offs for the Watt Diet 22
SIMPLE "BOX-SWAPPING" RETROFITS **25**
Box Swapping the Heating, Ventilation and Air Conditioning (HVAC) System 25
Box Swapping a Ducted HVAC System *25*
Box Swapping a Ductless System *25*
Box Swapping a Water Heater 26
Gas Tank Water Heater to Heat Pump Water Heater (HPWH) *26*
Three ways to get more hot water – which one is right for you? 27
Box Swapping a Stove 28
Box Swapping a Gas Clothes Dryer 28
Box Swapping a Gas Generator 29
Box Swapping a Gas Generator with an Electric Car 30
ELECTRIC RETROFIT INCENTIVES AND REBATES **31**
CASE STUDIES OF COMPLETE ELECTRIFICATION RETROFITS **32**
1890 Ranch, Ravenna, OH 32
Ben and Sara Shalva's Home, Baltimore, MD 32
Steve and Lisa Schmidt's Home, Los Altos, CA: Electrifying Without Increasing the Power Supply 33
Wei-Tai Kwok's Home, Lafayette, CA 34
Peter and Margaret Darby's Home in Hamilton, NY 34
Campus Center for Appropriate Technology (CCAT) at Humboldt State University, Arcata, CA 35

Perlita Passive House, Los Angeles, CA 35
Jon and Kelly's Home, Cleveland Heights, OH 36
Colonial Solar House, Urbana, IL 36
The Bindley Carbon Neutral Renovation, Holderness, NH 37
Ross Residence, Amherst, MA 37
Erika Reinhardt's Family Residence, Bay Area, CA 38
Modest Manor, San Francisco, CA 38
ADDITIONAL ALL-ELECTRIC CASE STUDIES 40
ALL-ELECTRIC PRODUCT GUIDES 41
Domestic Hot Water 42
Individual Heat Pump Water Heaters (240V and 120V) 42
Heat Pump Water Heaters on US Market (240V) 42
Retrofit Ready Heat Pump Water Heaters (120V) 43
Product Highlight – Eco2 Heat Pump Water Heater 43
On-Demand Water Heaters (120V and 240V) 44
Small Demand and Low Power Applications (120V) 44
Hybrid Heat Pump and Electric Resistance On-Demand Water Heaters 44
Three ways to get more hot water – which one is right for you? 45
Heat Pumps for Swimming Pools and Hot Tubs 46
Heating, Ventilation and Air Conditioning 47
Overview of Single-Family HVAC 47
Air Source Heat Pumps (Air-to-Air) 48
Central Ducted Heat Pumps (240V) 48
120V Air Handlers 49
Mini-Split Heat Pumps (240V) 50
The Complete Cost of Mini-Split Systems 50
Ductless Mini-Split Heat Pumps (120V) 53
Ductless Mini-Split Heat Pumps (240V) 53
Ducted Mini-Split Heat Pumps 54
Packaged Terminal Heat Pumps (240V and 120V) 55
(120V) Packaged Terminal Heat Pumps 55
(240V) Packaged Terminal Heat Pumps 55
Portable Air Source Heat Pumps (120V) 56
Hydronic Heat Pumps (Air-to-Water) (240V) 57
Geothermal Heat Pumps (Ground/Water-to-Air/Water) (240V) 58
Heat and Energy Recovery Ventilation (HRV and ERVs) 59
ERV, HRV, and Heat Pump Combined Products 60
Electric Cooking 61
Glass Top Radiant Range ($550 or less) 61
Glass Top Radiant Range (Greater than $500) (240V using a 40amp circuit) 61
Slide-In Induction Ranges (240V, 40 amp) 62
Slide-In Induction Range (240V, 40 amp) 62
Retro Induction Ranges 62
Single Burner Countertop Induction (1800W, 120V and using a 15amp circuit) 62
Single Burner Drop-In Induction (1800W, 120V and using a 15amp circuit) 63
Double and Triple Burner Countertop Induction (1800W, 120V and using a 15amp circuit) 63
Four+ Burner Induction Stovetops (9600W, 240V using a 40amp circuit) 63
Cooking Energy Use with High Efficiency Cookware 63
Countertop Ovens (120V) 64
Kitchen Hoods (Low Sound, High Air Flow) 65
Quiet Kitchen Hoods 65
Quiet Low-Cost Hoods Compliant with 2022 Code 65
Electric Laundry Dryers 66
Condensing Washer & Dryer—A combined appliance 66

Heat Pump Dryers *67*
Standard Electric Dryers *67*
ENERGY MANAGEMENT SYSTEMS 68
Whole House Panels *68*
Subpanels *68*
Smart Circuit Splitters (EV Charging and Appliances) *69*
SOLAR PHOTOVOLTAIC PANELS 70
SOLAR INVERTERS AND SOLAR ARRAY SIZING 71
String Inverters *71*
Power Optimizers *71*
Microinverters *71*
Solar Array Size and the Watt Diet *72*
Enphase - Microinverters *72*
Solar Edge – Single Phase Inverters *72*
Solar Edge – Combined EV Charger and Solar Inverter *72*
ELECTRIC BATTERY STORAGE 73
LOW-COST RESILIENCE 74
Electric Generators *74*
Electric Cooking on Small Batteries *74*
Back-up Battery Light Bulbs *75*
Electric Camp Stoves and Grills *75*
ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) CHARGING LEVELS 76
ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) LEVEL 2 EV CHARGERS 76
VEHICLE TO HOME AND VEHICLE TO GRID CHARGING 77
Available Soon in the United States *77*
Not Available in the United States *77*
ELECTRIC VEHICLES 78
EVs and Outdoor Recreation Inspiration *79*
ELECTRIC FIREPLACES 80
What is a water vapor fireplace? *80*
Why buy an LED fireplace? *80*
ELECTRIC SAUNA HEATERS 81
(240V) Electric Resistance, heater unit only *81*
(120V) Infrared, Full Room *81*
ELECTRIC OUTDOOR HEATERS 82
Wall Mounted *82*
Free Standing *82*
ELECTRIC BARBEQUES 83
ELECTRIC LANDSCAPING 84
Residential Grade *84*
Commercial Grade *85*
ELECTRIC SNOWBLOWERS 86
ELECTRIC SNOWMOBILES 87
REFERENCES 88

Product Guide Quick Reference

Electric Cooking	Heat Pump Water Heaters	Electric Dryers	Heat Pump Space Heating and Cooling	Electric Vehicles	Energy Management Systems	Solar PV Panels	Back-up Batteries
p. 61	p. 42	p. 66	p. 47	p. 78	p. 68	p. 70	p. 73

Heat Pump Pool and Spa Heating	Electric Saunas	Electric Fireplaces	Electric Outdoor Heating	Electric Landscaping	Electric Barbeques
p. 46	p. 81	p. 80	p. 82	p. 84	p. 83

Introduction

Welcome! This booklet is intended to be a simple "how-to" guide to help homeowners, home renters, utilities and policy makers who want to replace existing gas appliances with efficient electric alternatives, many of which are simple and require no home modifications (e.g., countertop induction ranges, condensing washer/dryers, portable space conditioning heat pumps). This booklet has three sections, the first to explain the costs, benefits and strategies for electrifying a home, the second section is lessons learned from case studies of retrofitted homes, and the third section is an extensive product guide to help choose your electrification appliances.

You are not alone in this project of electrifying your home! And it can be affordable and easy—see our discussion of the Watt Diet and how one can avoid electrical upgrades. Since 1993 Americans have been progressively using more electric appliances, and 1 in 4 homes nationwide are now all-electric[1]: electric stoves are now 61% of annual sales in the U.S.[2] and electric laundry dryers are 88% of annual sales,[3] while the majority of homes built since 1950 have been built with electric water heaters, and since 1970 the majority of homes have been built with electric space heating.[4] Electrifying existing buildings, often paired with low-cost solar power, is a growing industry nation-wide.

This guide was written to accelerate this existing trend to use electric appliances because the global scientific community says that fossil fuels burned in our buildings are causing 28% of climate change[5], with natural gas leaks upstream of our appliances responsible for another 25% of global climate change.[6] As our grid power grows cleaner by including more clean, renewable energy, a concerted effort is underway globally to use cleaner grid electricity to replace polluting fossil fuel appliances.[7]

The Business of Electrifying Homes

This section is just a sampling of the thousands of clean energy companies that are making buildings better for people and the planet with heat pumps, electric appliances, and solar arrays.

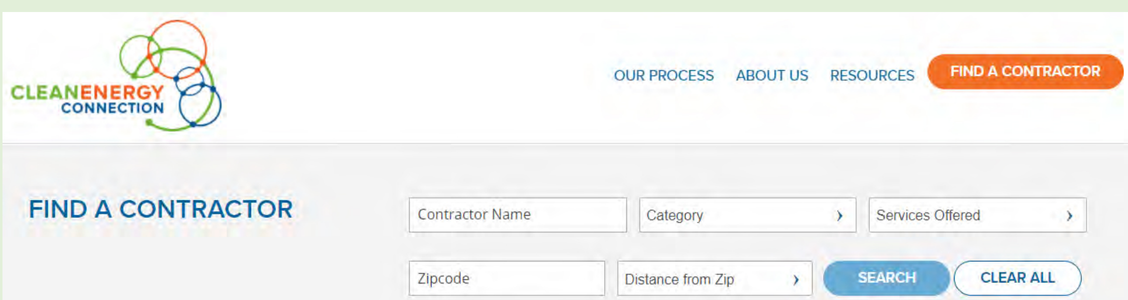
Clean Energy Company Highlight: BlocPower

Figure 1: Cornerstone Baptist Parsonage and BlocPower CEO Donnel Baird.

Cornerstone Baptist Church, a historic Black Church in Brooklyn, NY, owns a landmark parsonage on President Street. Until 2020 the Reverend Lawrence Aker and his family suffered from a common fuel oil (aka diesel) boiler problem: dramatic overheating, requiring AC use even in the winter.[8] The solution, a heat pump system, was designed, financed and installed by **BlocPower**, founded by CEO Donnel Baird. Like a growing number of businesses nation-wide, BlocPower installs efficient heat pumps, often paired with solar arrays, to dramatically increase comfort, reduce energy bills, and stop contributing to smog and asthma. BlocPower's CEO, Donnel Baird, speaks movingly about how in 2012 he channeled his opposition to racial unfairness into a business model for clean energy that benefitted communities of color. As a Black founder, Donnel was turned down 200 times before any venture firms were willing to back his vision, but BlocPower is now funded by some of the world's largest investors.[9] Other contractors who were early adopters of heat pump + solar retrofits in the U.S. include Building Doctors in Los Angeles, Electrify My Home and emeraldECO serving the San Francisco Bay Area, Energy Smart Ohio, and The Heat Pump Store in Oregon.

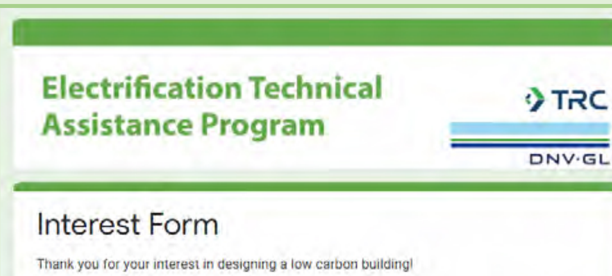
A List of California Contractors who Perform Building Electrification

When electrifying your home, it is important to find a skilled and knowledgeable contractor. The Clean Energy Connection has put together an online searchable database of California contractors with positive customer references and at least 2.5 Stars on Yelp that is free to use for all.[10] The contractors are experts in heat pump water heaters, heat pumps for space heating, electric appliances, electric vehicle chargers, solar arrays, and battery storage. In addition, The Switch is On has a contractor look up tool on their website.



Electrification Technical Assistance Program

An example for utilities nation-wide, Silicon Valley Clean Energy has free technical experts on-call in their Electrification Technical Assistance Program. Any architect, engineer, builder or developer is eligible for all-electric design assistance that would usually cost thousands of dollars, for buildings of any type or size. The reports are then shared for free to accelerate community competence in all-electric design.[11]



The Benefits of an All-Electric Home Retrofit

Health

Children in homes with gas stoves are 42% more likely to develop asthma[12] than those with electric stoves and asthma kills ten Americans a day[13] and costs on average $3,266 per year for medications. The health impacts of air pollution from fossil fuels fall disproportionately on people of color - African Americans are three times more likely to suffer from asthma than the general population.[14] In addition, home chefs using gas stoves have twice the risk of lung and heart disease, and are three times as likely to need asthma medication as people cooking on electric stoves.[15] These health impacts are tied to the many pollutants released when gas is burned, such as nitrogen dioxide, cancer-causing formaldehyde and acetaldehyde, and ultra-fine particulates.[16] Gas stoves and other gas appliances are also dangerous due to carbon monoxide, an odorless gas that kills 500 people a year in the U.S. and sends 15,000 people to the emergency room.[17]

Safety

Electric cooktops, water heating, space heating and clothes drying all present lower fire risks and lower explosion risks than their gas fired alternatives. Just having electricity as the one utility service eliminates the risk of having both gas and electric services – and reduces the dangers that come with a pressurized and combustible network of fuel going to homes. Nationwide since 2010 the natural gas system has caused 236 public safety incidents and $198 million in damages per year.[18] Natural gas accidents have killed 548 people and broken more than 9,000 pipelines between 1986 and 2016 in the U.S. (nearly one a day).[19] Additionally, construction risks are reduced by not having the threat of hitting gas pipelines when digging trenches, doing road work, etc. For instance, in Ohio construction workers hit gas mainlines 410 times in 2015 alone.[20]

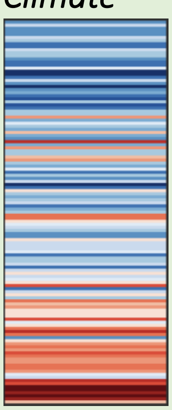
Wealth

Utility bills for efficient all-electric homes can be up to $800/year less than for comparable homes using fossil fuels due to recent rapid gains in electric appliance efficiency and the low cost electricity available in most of the U.S.[21,22] Utility bills are the #1 use of payday loans in the U.S., with annual interest rates as high as 400% and an average repayment period of five months.[23] Replacing gas appliances with electric appliances also allows homeowners to lowers bills with solar power—in the U.S. the average repayment period is 8 years[24] into the warrantied 25 year lifespan of the solar panels and inverter, producing a net profit three times greater than the installation cost. (e.g. producing power at 1/3 the average retail electric rate.)

Comfort

Heating your home with a heat pump can dramatically improve comfort due to quieter and more consistent warmth. While a furnace continuously turns off-and-on, blowing heat noisily through the ductwork at high speed, a heat pump fan stays always on continuously at a lower, quieter speed and evenly heats your home. Cooking with electric equipment can also be much more comfortable, especially during warm weather since electric stoves produce half as much waste heat in the kitchen. In 2020, Consumer Reports ranked the top 8 stoves, and the best stoves were electric induction stoves, ranked #1-2, #4-5, and #8, with a smooth top electric resistance stove at #6. Cooking with electricity means one has access to the best stoves on the market—the fastest, easiest to clean and most controllable stoves made.

Climate



A recent analysis found big climate and clean air benefits from replacing gas appliances with electric in every state across the U.S.[25] This is due to two key factors: Heat pump appliances are three to four times more efficient than gas, and also because grid electricity is sourced with more renewable energy every year. The global community of cities, states and nations have identified building electrification as the fastest, least expensive, and most likely to succeed solution to the building sector's 28% of global greenhouse gases.[26] One of the largest sources of greenhouse gases is not from burning gas, but instead its leaking Methane ("natural gas"), which is an exceptionally strong greenhouse gas. Methane leaks at each stage--fracking, storage, delivery piping and in the appliance--and "about 25% of the human-made global warming we're experiencing is caused by methane emissions,"[27] according to the Environmental Defense Fund. Differently put, eliminating gas service to one's home doubles the positive impact of not burning gas.

Design Factors When Electrifying Your Home

This guide organizes the discussion of retrofits in two main categories, “box swapping” when only the appliances themselves are upgraded and there’s enough power to replace a gas appliance with an electric one, and “deep retrofits” when additional building shell improvements, duct and air sealing improvements are combined for added comfort. Either of these types of retrofits can be done quickly, or phased in over the course of years, depending on the owner’s needs. Below are questions to consider, when considering electric retrofits for your home.

Up-Front Costs and available funds	What is your budget for electric retrofit? While there can be savings from electrifying all at once, most people can only afford retrofitting in steps. Consider the most pressing needs first, like an old water heater that may soon give out; and the least expensive options, like a two-burner induction range which can plug into existing 120V wiring and provides immediate health benefits of avoided combustion in your kitchen.
Utility Bills	Do you want lower utility bills? Heat pump space heaters are at least four times more efficient than comparable gas models and can now operate at –30°F. Avoiding electric resistance, which is not very efficient, and the use heat pumps for laundry drying, hot water and space heating will keep electric bills low.
Solar Power	Would you like to generate your own clean power? Solar power in the U.S. has an average payback of 8 years[28], and the cost of solar panels has dropped by 89% since 2006[29]. Electrifying your home and installing a solar array can eliminate your utility bills.
Location	What climate are you in, and how old is your home? Weather, existing insulation and regional building practices (e.g., radiators vs. ducts) will influence what type and size of heating and cooling equipment best meets your needs.
Power Supply	How much power is supplied to your home? Electrifying all the gas loads in an older home may require more power from the utility, but you can likely avoid this by choosing power-efficient appliances and using power sharing plugs (*See the **Home Watt Diet** Section for more information)*. Many modern homes already have enough power to support an all-electric transition, especially if you already have air conditioning—that same power can be used for space heating in the winter.
Electric Vehicle Charging	How much power do you need for electric vehicles? Investing in efficiency in the home can free-up capacity for faster charging and more car chargers. Also, power-sharing chargers can eliminate the need for upgrades, by sharing a circuit with things like laundry, car charging automatically resumes when the dryer is finished.
Product Choice	What do you value? As you review the product guides in this booklet, note the differences in efficiency, aesthetics, cleanability, cost, and comfort.
Health and Environment	How concerned are you about indoor air pollution and health? Gas stove release pollution that contributes to asthma and other respiratory and cardiac health impacts, but they use relatively little gas compared to a furnace or water heater that “only” pollutes outdoor air. If you are going to electrify your home in steps, consider your health when prioritizing retrofits.

Electrifying on a Tight Budget

Many of the co-authors of this booklet have limited means--we have young families, or graduated from college with student loans, or are living in rental homes, and found these electrification options out of necessity, but we use them because they're satisfying and effective. All of these products allow DIY/self-installation, which cuts total costs by half or more. For example, **a comfortable, high-quality electric lifestyle can cost less than $2000** with a True Induction range ($140), an Oster oven ($160), a Whynter portable heat pump ($440) and a DIY "retrofit ready" heat pump water heater from Rheem ($1200).

Plug-In Cooktops

These 120V cooktops can plug into any outlet in your home. Countertop resistance ranges cost less than $20 for one burner and $30 for two burners. A countertop induction range can cost as little as $50 for one burner and $140 for two burners.

			
Brentwood resistance plate	Brentwood resistance plates	IKEA induction	DrinkPod True Induction
$18	**$30**	**$50**	**$140**

Plug-In Cooking Appliances

These 120V models can plug into any outlet in your home and can fry, stew, bake, roast, rotisserie, steam and air fry, using the versatility and controllability of electricity to provide more services than larger, standard ovens. The largest models can accommodate a small-medium size turkey.

				
Crockpot 2 Quart Insulated Slow Cooker	Instant Pot 3 Quart Insulated Multi-Function Cooker	Presto Stainless Steel Electric Wok	Elite Combination Oven/Griddle/ Steamer	Oster French Doors, XL Capacity Convection Oven *(Staff Favorite)*
$10	**$60**	**$80**	**$40**	**$160**
Insulated cookware uses 1/4th as much electricity to get the same job done, regardless of whether it's slow or fast.	This insulated multi-function vessel can slowly make yogurt, pressure cook beans and rice, steam vegetables and stew meats.	Electric woks can steam, bake and stir-fry, spreading heat evenly through the wok.	Many small oven appliances are multi-function—this one is unusual in having a griddle/steamer on top.	This oven can bake a modest Thanksgiving turkey and is controllable for high performance baking.

Plug-In Space Heaters

An electric resistance heater is silent and low-cost for a bedroom, but a heat pump produces 2-4 times as much heat with the same amount of electricity, enough to heat and cool multiple rooms.

			
Electric Resistance Heaters	Whynter ARC-122DHP Mobile Heat Pump	Mr. Cool DIY-12-HP-115B Ductless Minisplit	Innova HPAC 2.0 Through-wall heat pump via two 6” ducts
$50+	**$440**	**$1450**	**$2000**
For one room. Enclosed heating elements are safest.	10,000 BTUs/Hr is enough for a big living room down to ~20F. 120V, audible fan, for a warmer climate.	12,000 BTUs/Hr heat pump works down to 5F. 120V, quiet, designed for self-installation, but needs dedicated circuit. *(Note that the ugly fan coil box sits outside, just like an A/C unit.)*	10,000 BTUs/Hr heat pump works down to -5F, has supplemental resistance heating. 120V, can plug into any circuit (doesn’t require a dedicated circuit), quiet, designed for self-installation.

Water Heaters

An electric resistance model can come in smaller sizes and fits the smallest construction budgets. Heat pump water heaters start at 40 gallons (although 20-gallon models in Eurasia are coming to the U.S. market), cost 3x as much to buy but use only 1/3rd as much electricity as a resistance water heater.

			
Bosch ES8 **Resistance** 7 Gallons	Reliance **Resistance** 19 Gallons	Rheem **Resistance** 30 Gallons	120V Rheem **Heat Pump** 40 Gallons
$215	**$380**	**$380**	**$1200**
This 7-gallon tank is right sized for a **single** 6-8 min showers with a 1.5gpm showerhead. 120V wiring, but 1440W still requires a dedicated circuit. 17” square, 15” deep, stores at up to 145F to provide a longer shower.	This 19-gallon tank is right sized for **two** consecutive 6-8 min showers with a 1.5gpm showerhead. 18” round, 24” high. 120V, but 1650W element requires a dedicated circuit.	This 30-gallon tank is right sized for **three** consecutive 6-8 min showers with a 1.5gpm showerhead. 19” round and 48” high. 240V wiring, 16Amp draw goes on a 20Amp circuit.	This “retrofit ready” 40-gallon tank is right sized for **four** consecutive 6-8 min showers with a 1.5gpm showerhead, more if stored at 130F-140F. Comes in 120V, 900W for plugging into a shared circuit, and 240V using 2250W or 4500W requiring a dedicated circuit.

What Does it Cost to Electrify Your Entire Home?

This section is intended to help you make a realistic budget for electrifying your house. One way to approach home electrification is incrementally, when an appliance is ready for replacement. Often there is no cost difference between gas and electric appliances, just a one-time wiring cost, and some of those can be avoided (see Lisa and Steve Schmidt's case study).

Electrifying your house with new appliances can cost **$2,000** if you self-install, as you saw in the above "Electrifying on a Tight Budget**."** But if you're hiring contractors, going with higher end products and putting them in a larger home, the budget starts at $10,000. If the house is being thoroughly re-insulated for more comfort (note the grey part of the bars below) and broken ductwork is being replaced, then the cost doubles or triples. Every house is different, and people have different tastes and desires, so unsurprisingly there are a wide range of costs that you will see in the discussion below.

Figure 2: An all-electric retrofitted home in Cleveland, Ohio whose total home comfort and electrification retrofit costs were $31,000 (House 9 in the figure below).

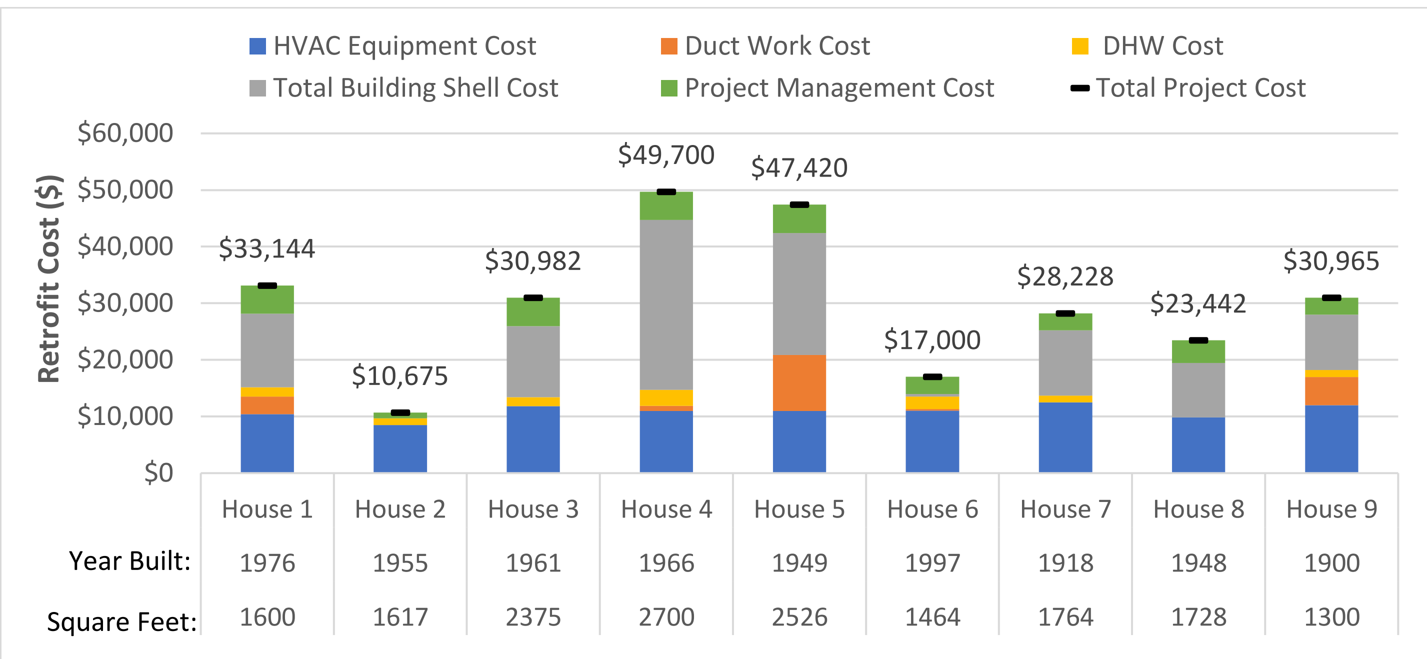


Figure 3: A summary of Energy Smart Ohio's case studies, showing the range of costs of home comfort and electrification retrofits. An important thing to note is that the heat pump cost reflects cold climate heat pumps, and the water heater costs reflect a mix of electric resistance and heat pump tanks for most homes, most of which were self-installed by the homeowners.

To help keep you on budget when hiring contractors, below you will find suggestions for **"box swapping**," what we playfully call replacing existing gas appliances with nearly identical electric appliances, which avoids retrofit costs. You can also avoid wiring costs by using **power-efficient equipment**, such as condensing washer/dryers, and/or by using **power-sharing plugs**, which can share power between two high-power appliances like electric car chargers, laundry dryers, electric ranges and electric water heaters. In the **"Watt Diet"** discussion below you will find a comprehensive set of strategies to help you avoid rewiring your house or adding more power service to your home, while still electrifying all your loads.

What Does It Cost to Electrify Your Home's Kitchen?

Cooking with electricity means one has access to the best stoves on the market—the fastest, easiest to clean and most controllable stoves made. In 2020, Consumer Reports ranked induction stoves as the #1, 2, 4, 5, and 8 best stoves for sale, with a smooth top electric resistance stove at #6 of the top 10. Replacing a gas stove with an electric one generally has two costs—wiring a new 240V plug (averaging $300[30]) and purchasing the stove ($500-$2,500).

However, one of the co-authors of this booklet happily cooks with two 120V* countertop induction units ($150-$250 each) and a Thanksgiving turkey-friendly 120V countertop oven ($150), avoiding the expense of adding a 240V** plug and adding the convenience of two cooking stations in the kitchen, so the spouses can have some elbow room when cooking at the same time.

Figure 4: An induction wok is featured in David Kaneda's kitchen in Cupertino, CA[31] and Erika Reinhardt loves that her toddler can now safely make pancakes with their new induction stove—learn more below in her case study.

Figure 5: A double oven KitchenAid induction stove; the cost of electric induction cooktops at Home Depot in August of 2020, ranging in size from 24 inch (5 products), 30 inch (14 products), 36 inch (17 products). X marks the average, the middle line is the median, the box surrounds 50% of cases, and the "whiskers" illustrate the lowest 25% and the highest 25% of cost data.

**120V electricity is delivered between 110V and 127V, and appliances are sometimes alternatively described as "115V"*
***Similarly, 240V refers to appliances that use delivered voltage that ranges between 208V and 250V, and one finds appliances are listed at 220V or 230V, depending on the whims of the manufacturer, but they all plug into the same outlet.*

What Does It Cost to Electrify Your Home's Laundry Dryer?

You likely already have an electric laundry dryer—88% of laundry dryers sold in the U.S. are electric. But when replacing a gas dryer, the simplest upgrade is to a 120V condensing washer/dryer ($800-$1600), which is a single appliance rather than two machines, and is popular world-wide. Using a 120V condensing washer/dryer avoids the expense of adding a 240V plug (averaging $300[32]), and adds the convenience of not having to move damp laundry from the washer to the dryer. Should you wish to install your own 240V plug, here is a DIY video.

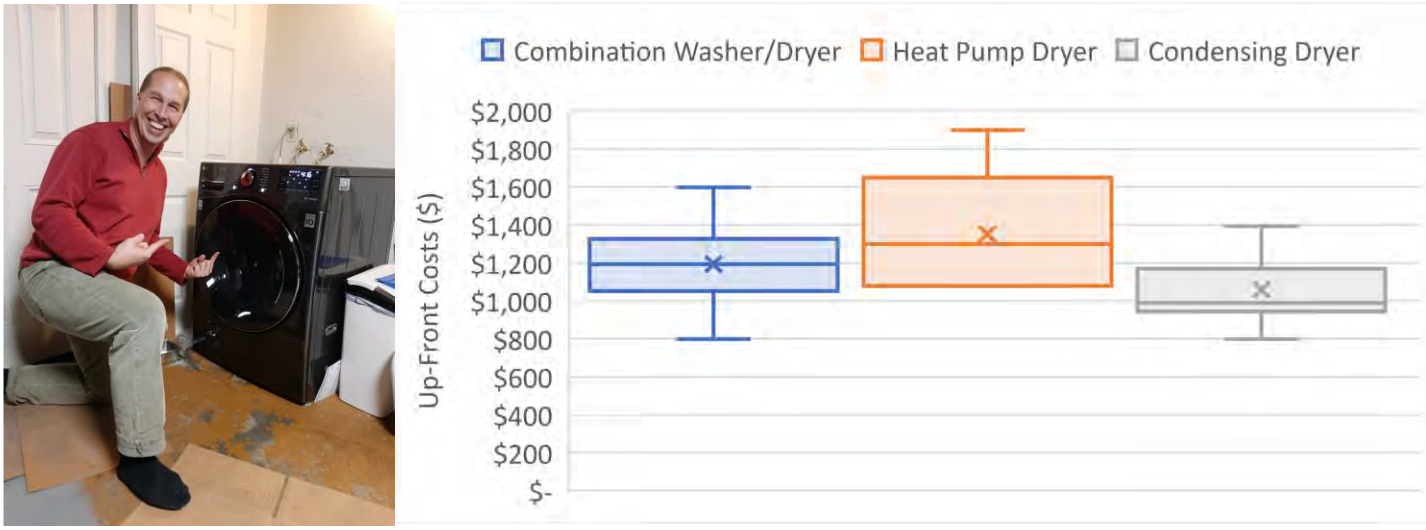


Figure 6: At left, one of the authors celebrating his first laundry load in an all-in-one, condensing washer/dryer, which he loves. At right, the cost of 22 Energy Star laundry dryers of various types at Home Depot in August of 2020.

Electric Resistance and Heat Pump dryers both use 240V power, but electric resistance dryers use roughly twice as much electricity as a heat pump or condensing dryer (figure below).[33] Also, electric resistance dryers blow out hot, lint-filled air through a vent, while heat pump and condensing dryers are ventless: the water they extract from the wet laundry goes down a drain and the lint is caught in a filter.

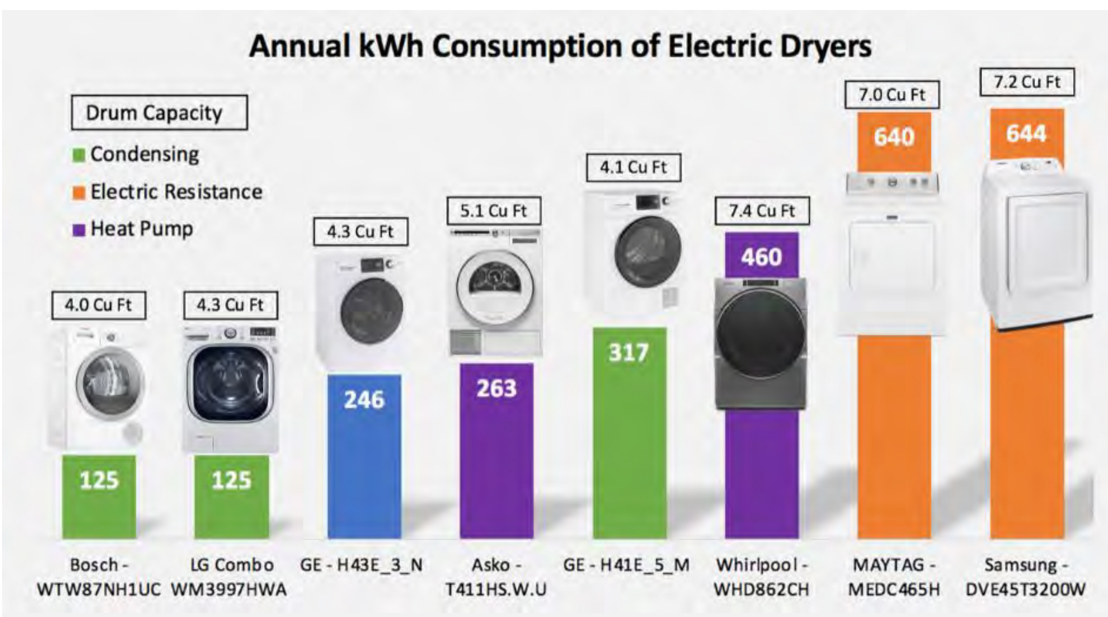


Figure 7: Relative dryer energy use, condensing dryers and heat pump dryers use roughly half the energy of a standard electric resistance dryer.

What Does It Cost to Electrify Your Home's Water Heating?

There are two common types of electric water heaters—electric resistance and heat pump. Electric resistance, what one sees happening inside of a toaster when the wires get hot, uses 3-5 times as much energy as a heat pump, which collects existing heat from the air. The energy savings of using a heat pump water heater over the course of a year is equal to the amount of energy to drive an electric car about 12,000 miles. However, a heat pump water heater is a larger investment, costing up to 3 times as much as a resistance water heater but using only 1/3 as much electricity. Resistance water heaters also come in smaller sizes: they come as small as 2 gallons for a sink, or 7 gallons for a single shower. The smallest heat pump water heater in the U.S. is a 40 gallon, while models as small as 20 gallons are sold in Eurasia.

Figure 8: Rheem heat pump water heater.

California: The Sacramento Municipal Utility District (SMUD)

The municipal utility serving Sacramento, California rebated 1650 gas-to-heat pump water heater conversions over two years. Roughly 70% of all installations ranged between $3,000 and $5,000, with another 15% below and 15% above that price range. A 50-gallon heat pump tanks cost about $1,200 before installation, so the rest is labor, materials and profit, with self-installations costing $1500-$2000.

The range of prices illustrates the value of getting multiple bids or learning to do it yourself ("DIY"). Instruction videos for DIY installation can be found [here] and [here].

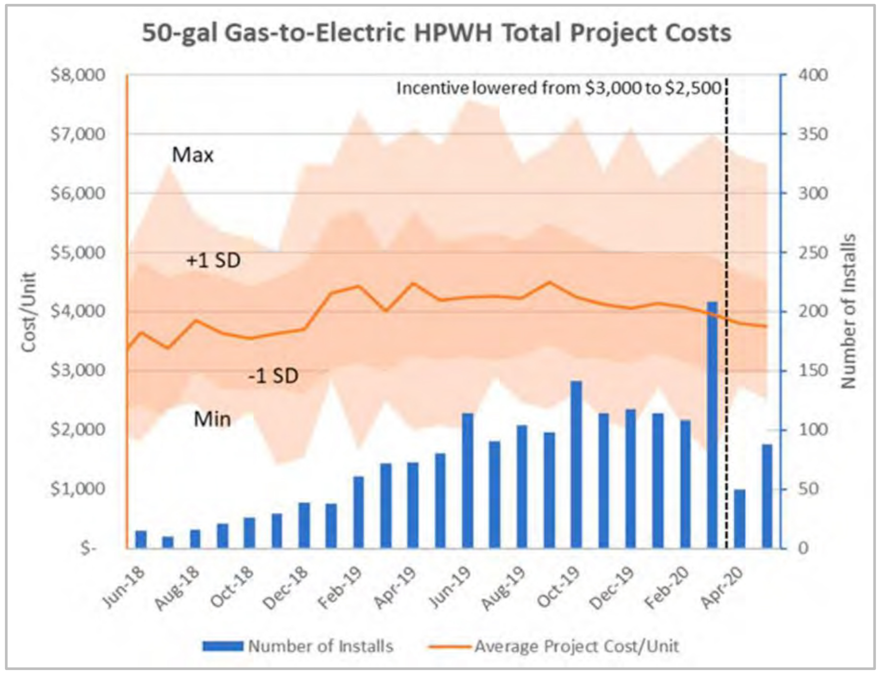


Figure 9: The retrofit pricing from 1650 installations of 50-gallon heat pump water heater replacements in Sacramento over two years.[34]

SMUD Residential Heat Pump Water Heater Total Project Costs

Technology		2018 Cost/Unit	2018 Count	2019 Cost/Unit	2019 Count	2020 Cost/Unit	2020 Count	Total Cost/Unit	Total Count
50-gal	**Gas to Electric**	**$ 3,763**	**114**	**$ 4,291**	**1,005**	**$ 3,983**	**531**	**$ 4,155**	**1,650**
	Electric to Electric	$ 3,299	51	$ 3,747	99	$ 3,769	37	$ 3,629	187
	All	$ 3,619	165	$ 4,242	1,104	$ 3,969	568	$ 4,101	1,837
65/80-gal	**Gas to Electric**	**$ 3,781**	**9**	**$ 4,578**	**25**	**$ 4,381**	**30**	**$ 4,374**	**64**
	Electric to Electric	$ 3,813	3	$ 3,806	12	$ 4,003	6	$ 3,863	21
	All	$ 3,789	12	$ 4,328	37	$ 4,318	36	$ 4,247	85

[1] Total project costs are assumed to include equipment, labor, permits, and profit, but these items are not collected by SMUD - some total costs may include additional costs or exclude some items.

[2] SMUD gas-to-electric HPWH incentive level of $3,000/unit began in May 2018 and went down to $2,500 in April 2020; the electric-to-electric incentive level is currently $500/unit.

Figure 10: The pricing of 1912 heat pump water heater replacements, both of gas and electric tanks, in Sacramento. Note that gas to electric costs about $500 more than electric to electric due to wiring costs and plumbing a condensate drain. (SMUD, 2020).

What Does It Cost to Electrify Your Space Heating?

If you have gas heat, getting rid of it will likely be the largest benefit to the environment and your utility bills. Leading contractors from different parts of the U.S. shared their bidded costs to help us write this section. Details are below, but to summarize, a house usually needs 1-3 "tons" (1 ton is 12,000 BTUs/hr) of heating capacity; each "ton" costs $3,200 to $6,000 with Energy Smart Ohio, between $4,650 to $5,950 in Sacramento, CA, and $3,100-$4,300 in Oregon for ductless mini splits installed by The Heat Pump Store in Portland and Eugene. From this cost data you can assume that your next heat pump will cost between $3,100 and $18,000, depending on how big and insulated your house is, and how good a bid you got. Fixing a furnace's ducting often isn't necessary, but we can see from Energy Smart Ohio's pricing that when there are minor problems it will cost a few hundred dollars to fix, and $3,000-$10,000 for completely replacing old ducting.

However, there are $500-$700 portable, quiet heat pumps that work when its 10F outside, and they can be self-installed in a window, which works for home renters and homeowners on a strict budget.

Figure 11: The Heat Pump Store staff installing in Portland, OR.

Figure 12: Daiken's 96-acre heat pump factory in Houston, TX.

California: The Sacramento Municipal Utility District (SMUD)

The electric utility that serves Sacramento, CA rebated almost 800 heat pumps used for space conditioning (heating and cooling) in 2020. SMUD organizes heat pump installation costs by efficiency (HSPF means "Heating Seasonal Performance Factor," and the higher the number, the more efficient) and type (Packaged, Mini Split, Standard Split), with pricing for each "ton" of heating capacity. This historical unit refers to one ton of ice melting in one day, which absorbs 12,000 British Thermal Units (BTUs) per hour. A 400-1,000 sf house likely needs only 1 ton of heating/cooling capacity ($4,650 to $5,950), while a 2,000 - 3,000 sf house might use 3 tons ($13,500 to $17,860).[35]

SMUD Residential Space Heating Heat Pump Total Project Costs/Ton

Technology		Gas-to-Electric Cost/Ton	Gas-to-Electric Count	Electric-to-Electric Cost/Ton	Electric-to-Electric Count
HSPF 8 to 10, 2-stage	Package HP	**$5,194**	**119**	$4,279	49
	Split HP	**$4,652**	**206**	$4,706	88
HSPF ≥ 10, 2-stage	Split HP	**$5,198**	**32**	$4,713	11
HSPF 8 to 10, Variable	Split HP	**$5,953**	**79**	$5,331	18
	Minisplit HP	**$5,395**	**12**	$5,007	3
HSPF ≥ 10, Variable	Split HP	**$5,691**	**78**	$6,085	12
	Minisplit HP	**$5,464**	**54**	$5,319	3

[1] SMUD HP program requirements for split/minisplit: ≥2-stage (or variable), HSPF 8.2 or greater, must service entire home. Package: ≥2-stage (or variable), HSPF 8 or greater. These exceed Title 24 standards, and thus costs may not be comparable to other program/statewide estimates.

[2] Total project costs are assumed to include equipment, labor, permits, and profit, but these items are not collected by SMUD - some total costs may include additional costs or exclude some items.

[3] Gas-to-electric rebate is $2,500 and electric-to-electric is $750. $2,000 in additional rebates for AC & airflow have been reduced to $500 as of Aug. 2020 due to COVID-19 economic considerations.

Figure 13: From the SMUD data, selecting a variable speed inverter drive over "two stage" appears to cost an extra $1,300/ton in lower efficiency units (HSPFs under 10) to select Variable Speed Inverter drive vs. "Two stage". The same up-selecting in more efficient heat pumps has a $500/ton premium. There appears to be almost no premium for selecting higher HSPF when selecting variable speed drive units. <u>HSPF = Heating Season Performance Factor (higher is better) is a seasonal energy efficiency measurement of heat delivered per kWh of electricity used.</u>

Oregon: The Heat Pump Store

Sarah and Jonathan Moscatello of The Heat Pump Store

Below are the standard installed costs for ductless mini split heat pumps kindly provided by Sarah and Jonathan Moscatello, who keep their 50 staff busy installing thousands of Heating/AC heat pumps each year from Eugene to Portland, OR. Sarah and Jonathan only install ductless mini split HVAC heat pumps, which are the most efficient type and let residents choose a comfortable temperature in each zone in the home with a remote control. A single wall-mounted fan coil will condition a 500sf-1,200sf zone, depending on the climate and how well insulated the house is.

The cost of a ductless mini split system varies by the space conditioning capacity of the system as well as by the number of zones of the system. The manufacturer's wholesale pricing also impacts retail pricing—there is a roughly 30% price difference between leading brands like Daikin, LG, Panasonic, Fujitsu, and Mitsubishi due to the manufacturer's investment in product quality and marketing. Should you wish to self-install, here is a DIY instructional video.

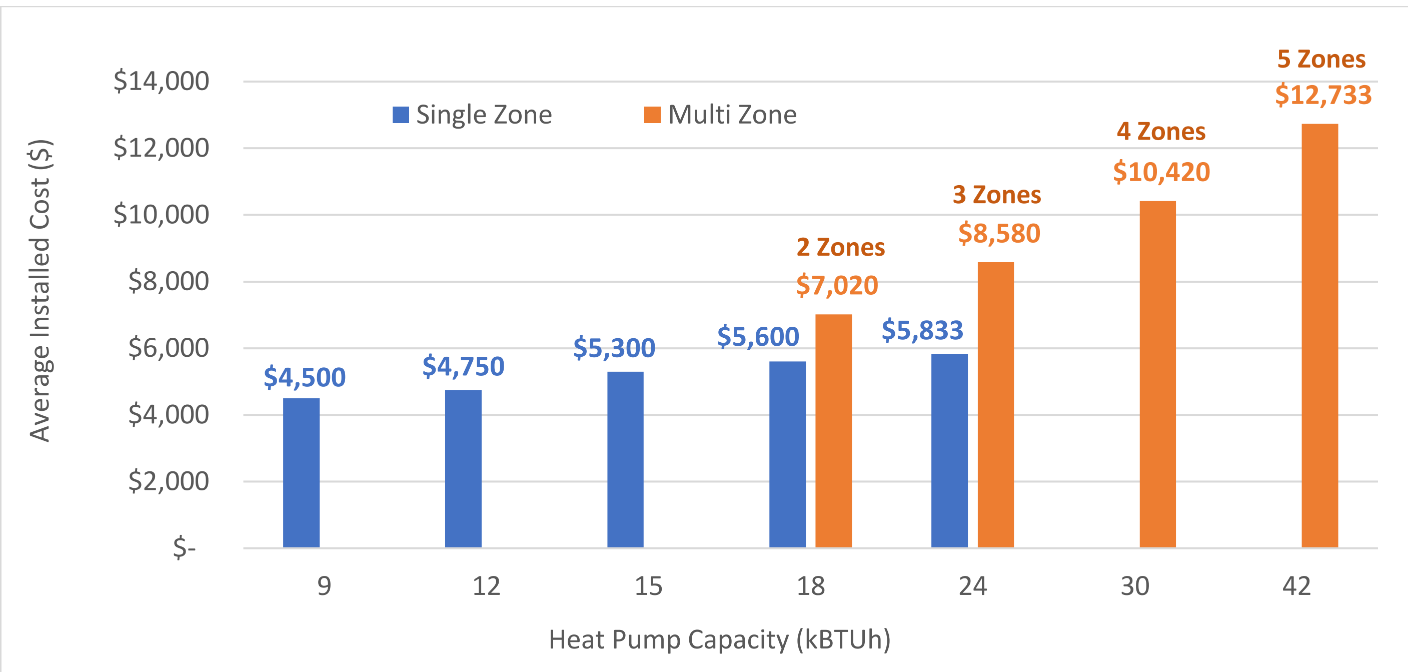


Figure 14: Average installed cost of ductless mini-split systems, the blue showing the prices for a single zone systems of different capacity sizes, and the orange shows the average costs for multi zone systems.[36] Pricing was provided under contract by The Heat Pump Store in 2019.

Note that these costs assume the outdoor and indoor components share a wall within 15' of each other, because 25' or more separation adds $500 more per zone, and placing the inside Heater/AC on an interior partition wall costs $1000 more per zone—because interior wall locations require that wiring and refrigerant lines must be installed in a crawlspace or attic, rather than inexpensively on the building's exterior.

Ohio: Energy Smart Home Performance

Nate Adams of Energy Smart Ohio

Nate Adams is an electrification consultant in Ohio, proudly removing gas lines during the day and running the Electrify Everything and HVAC 2.0 Facebook sites at night ("HVAC" stands for Heating, Ventilation and Air Conditioning). Nate's focus on client comfort to address Ohio's muggy summers and frigid winters means a ducted heat pump also comes with humidity management and a thick air filter to reduce pollen and other allergens.

Replacing the existing gas furnace and air conditioner with a ducted heat pump costs an average of $10,95, while making the homeowners more comfortable. Additional insulation and air sealing to get rid of drafts also helps provide the comfort people are seeking in Ohio's tough climate and it allows the use of smaller heat pumps and can avoid the need for large ducts. But it becomes about half of the project cost and a critical part of providing true comfort in a touch climate. Consequently, Nate considers his job to be providing "home comfort," and heat pumps simply provide the most comfort with quiet, evenly heated and cooled homes, but homeowners often also want more insulation, less draftiness and repaired ductwork to reduce energy waste.[37] The costs below were provided under contract by Nate Adams and are intended to help you set a realistic budget for both electrifying your ducted HVAC system and making your house more comfortable and efficient.

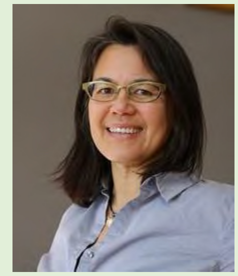
Table 1: Cost breakdown of Energy Smart's projects in Ohio.[37]

Energy Smart Ohio Comfort Upgrade Costs											
Client	Zip Code	Square Feet of House	Year Built	Job Date	Heat Pump Equipment+ Install Cost	Duct Work Cost	Insulation and Air Tightness Costs	Project Management Cost	Total Project Cost	HVAC Capacity Before (BTU/hr)	HVAC Capacity After (BTU/hr)
Peter A.	44256	1600	1976	10/19	$10,400	$3,100	$12,994	$5,000	$31,494	140,000	36,000
Ryan A.	44233	1617	1955	11/17	$8,500	$0	$0	$1,000	$9,500	100,000	24,000
Hallie B.	44313	2375	1961	12/17	$11,800	$0	$12,582	$5,000	$29,382	120,000	36,000
Brad M.	44202	2700	1966	10/16	$10,950	$950	$30,000	$5,000	$46,900	90,000	36,000
David F.	44236	2526	1949	7/19	$11,000	$9,850	$21,570	$5,000	$47,420	60,000	36,000
Cindy W.	44410	1464	1997	3/19	$11,050	$250	$500	$3,000	$14,800	57,000	24,000
Carole P.	44255	1700	2000	7/20	$11,460	$0	$300	$2,000	$13,760	10,000	36,000
Jon N.	44118	1764	1918	10/14	$12,498	$0	$11,530	$3,000	$27,028	80,000	36,000
John P.	44231	1728	1948	5/19	$9,850	$0	$9,592	$4,000	$23,442	85,000	36,000
Paul S.	44103	1300	1900	8/15	$12,000	$4,995	$9,770	$3,000	$29,765	120,000	24,000
Average Costs					**$10,951**	**$1,915**	**$10,884**	**$3,600**	**$27,349**	**86,200**	**32,400**

Figure 15: A few images from Energy Smart Ohio's retrofit project 1918 House of the Future in Cleveland Heights. Left to right: Carrier Greenspeed heat pump, air handler in the basement, blower door test, and insulating the basement.

Vermont and New York: The Vermont Energy Investment Corporation (VEIC)[38]

VEIC builds all-electric modular homes and helps low-income residents of Vermont and New York retrofit their homes with heat pumps. Li Ling Young, VEIC's Senior Energy Consultant, sees heat pump retrofits costing $7,000-$20,000, similar to what we saw in the data from nearby Ohio. Li Ling notes that many homes could use another $10,000 of insulation and air tightness work for greater comfort. VEIC found that in the milder, coastal region of New York state, even without extra insulation or sealing air leaks, HVAC contractors are installing ductless heat pumps and confidently removing the fuel fired heating systems.



Li Ling Young of the Vermont Energy Investment Corporation

Unlike standard ducted and ductless air-to-air heat pumps, the relatively uncommon air-to-water heat pumps that make hot water for radiant floors in wealthier people's homes can be quite expensive—Li Ling saw two recent installation bids for $35,000. Radiant floors don't provide air conditioning, so it can make sense to downsize the radiant floor heat pump while adding a ductless mini-split, which provides more control over heating (radiant floors can take 8-24 hours to significantly change temperature) and air conditioning during the summer.

Massachusetts: State-Wide Rebate Data[39]

The electric utilities of Massachusetts have tracked installation costs on more than 600 rebated heat pumps used for Heat and Air Conditioning between 2014 and 2019. Most retrofitted systems, including ductwork, permitting and design, cost between $10,000 and $30,000 in homes that range between 800 square feet to 2,500 square feet. Note that costs are both significantly lower or higher than the averages—getting a lower price is often the result of getting more than one bid.

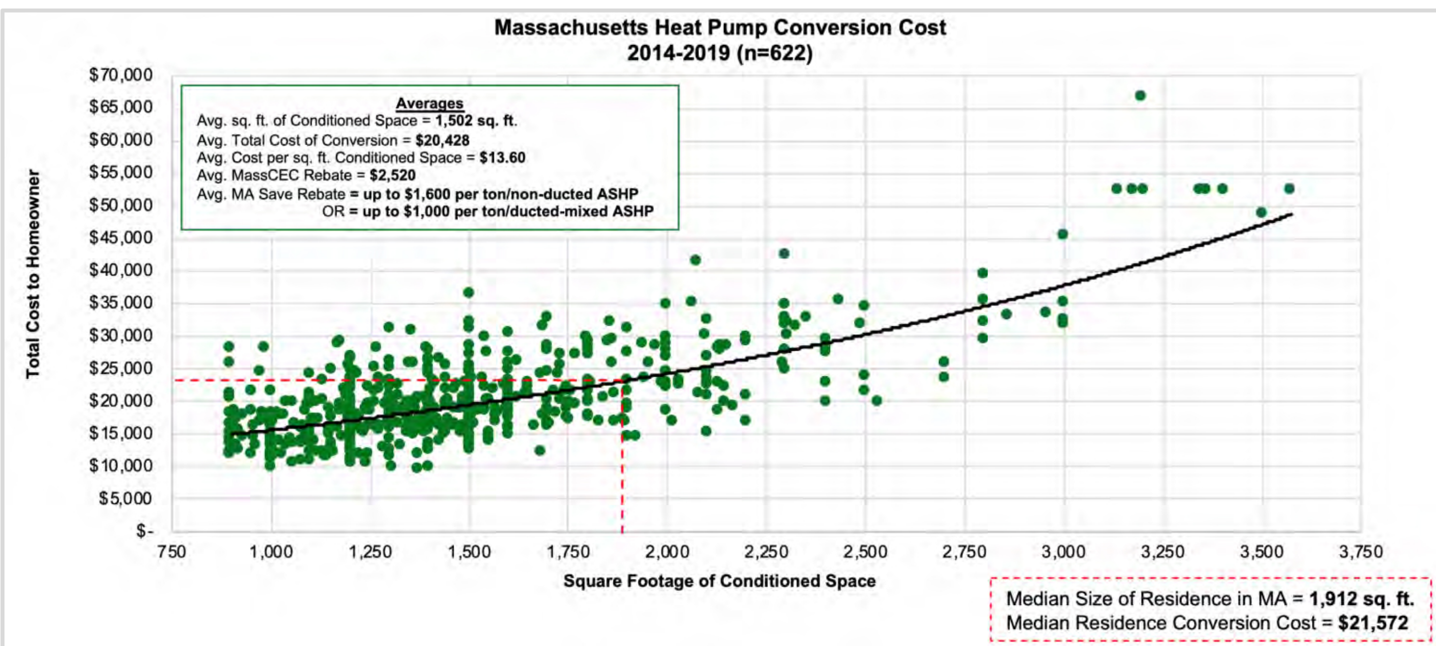


Figure 16: Heat pump conversion cost data from Massachusetts rebate program. Keep in mind the heat pump costs shown are for cold climates, meaning they are likely to have variable speed drives and high capacities, thus increasing their cost.

The "Watt Diet" - Avoid a New Electrical Panel and Reduce Wiring

Retrofitting with 240V electric stoves, water heaters, laundry dryers and space heating creates the expense of running new wires to each appliance, ranging from $85 to $600 per circuit and averaging $300[40], and sometimes all this new demand for electricity can trigger the need for a new circuit breaker panel. A new circuit breaker panel costs at least $450, averaging $1,475 and as much as $4,000.[41] However, there are many ways to stay on budget and using the existing power supply of your home by following the National Electrical Code (NEC). We call this process of avoiding power upgrades a "Watt Diet," which involves power efficient appliances and sometimes power balancing plugs. If you'd like to learn more, the authors offer a 30-minute training here.

A 100-Amp panel has enough power for complete electrification of a 3,000 square foot home

The above statement will surprise some readers, but it's true—most homes don't need more than the minimum the National Electrical Code requires, which is at least a 100 Amp, 3-wire service for every single-family home.[42] Below is an example of a set of appliances that can fit into an all-electric 100-amp home, including a "high power" 21 Amp heat pump water heater and a 3 ton [36,000 BTUs/hr] heat pump for space conditioning. These appliances pair with a 2,000 square foot home in the relatively mild climate of Northern California (e.g. Sacramento, Bay Area), but could also support a larger house or a house of a similar size in a colder climate. See the additional two full page Watt Diet examples below, the first is a "typical" 2,000 square foot home and the second is a power efficient 3,000 square foot home.

Brand and Type	Frigidaire Fridge	Waste King Garbage Disposal	Frigidaire Dishwasher	Broan Kitchen Exhaust Fan	Amana Radiant Electric Range	Heat Pump Water Heater	LG Combined Washer/ Dryer	Fujitsu Heat Pump (heating and cooling)	Plug Loads and Lighting
Cost ($)	$650	$50	$440	$350	$650	$1,300	$1,500	$11,000*	3,000W (kitchen plugs) + 6,000W (plugs and lighting)**
Power	720W	480W	1,200W	168W	9,600W	4500W	1,200W	5,760W (heat pump at design T) + 840W (air handler)	
Amps	6A	4A	10A	1.4A	40A	21A	10A		
Volts	120V	120V	120V	120V	240V	240V	120V		

* Average cost of a ducted heat pump, from Energy Smart Ohio's case studies (see What Does it Cost to Electrify Your Space Heating? section above)

** 3,000 Watts for kitchen plugs and 3 Watts per square foot for plugs and lighting as defined by the National Electrical Code, assuming a 2,000 square foot home.

Here are several more Code compliant ways to keep your house on its current panel with the Watt Diet:

1) **Use efficient heat pumps**—electric resistance uses 3-5 times as much power as heat pumps. Higher efficiency heat pumps (like those with inverter controls and omitting resistance back-up heating) use less electricity and power to heat and cool.
2) **Use a condensing, combined washer/dryer** (also called ventless washer/dryer), which are popular world-wide and designed specifically for retrofits: they use so little power they can plug into any 120V outlet in a house, while 240V dryers (resistance, heat pump and condensing) require a larger, 240V dedicated circuit.
3) **Use a combined range and oven**--the NEC requires twice as much power allocated to a separate oven and range (19,200W) as a combined range and oven (9,600W). Similarly, avoid attaching a microwave oven to the wall, which triggers an extra, dedicated circuit—just place the microwave *on* the countertop or cabinet.
4) **Insulate and air seal the home** to select smaller heat pumps for the reduced space heating power needs. Most houses do not need more than 3 tons (36,000 BTUs/hr) if they are reasonably insulated, regardless of the climate.

Keeping the heat pump capacity smaller allows the reuse of existing ducts, while ductless designs save even more energy by not losing heat through ducting.

5) **Use circuit-sharing plugs** (e.g. NeoCharge, Dryer Buddy, SplitVolt, or hard wired SimpleSwitch) so one existing high voltage (240V) outlet can power both a car charger and a laundry dryer, or a water heater and a range (See Lisa and Steve Schmidt's case study).
6) **Analyze a year of the home's history of hourly power usage**—it may be low enough to allow added electrical devices even if some NEC panel calculation methods indicate otherwise. Code allows you to multiply last year's hourly peak kW use by 1.25 and add new nameplate power (kW) loads up to the main panel rating (e.g. 24 kW for 100A panel or 48 kW for 200A panel. section 220.87). However, this option is only for homes without solar. Knowing your home's max power use can be helpful to see if you are under capacity, but also if you are at capacity - you may want to consider upsizing your panel for nuisance tripping reduction or possible safety improvement reasons.
7) **Check to see if you need to free up panel spaces for new circuits or if you can share poles.** In older homes when less efficient appliances were common; the circuits were upsized appropriately to fit these appliances. One way to utilize old wide breaker spaces is to replace them with "tandem breakers" that are thin and can serve two circuits from one breaker space (AKA single pole space) or you can combine circuits in a sub panel that then lands on only one pair of poles in the main panel. Automatic Circuit Sharing (ACS) devices also make double-use of a breaker space by serving two devices that take turns using the power. If things are really tight, gathering several small circuits onto a sub panel is a way to create more panel pole spaces. Keep in mind that a 100 Amp Sub Panel can be served by a smaller circuit like a 50 Amp circuit serving up to 80 Amps of loads because of their already counted diversity.

Below is a summary of the National Electrical Code requirements for wiring a house. General lighting and plug loads have a watts per square foot requirement, and kitchen counter circuits and bathrooms require circuits of a certain size. Various appliances require dedicated circuits as well, like exhaust hoods, garbage disposals and ranges.

Table 2: The required circuits in a single-family home.

Appliance	National Circuit Requirements and Guidelines (NEC required)[43]
Kitchen Counter Circuits	Two dedicated 20-Amp circuits NEC 210.52 (B)(1) 120V
Kitchen Small Appliances	One or more additional circuit(s) are required for small, hard wired appliances (kitchen exhaust hoods, garbage disposals, dishwashers, trash compactors and other motor loads and shall not be on the same circuit as either of the two) NEC 210.52(B)(1) 120V
Bathroom Circuits	At least one 20-Amp circuit 120V if circuits serve a single bathroom, lights may be on the same circuit. NEC 210.11(C)(3)
Range Circuit	Minimum of 40 Amps NEC 210.19 (3) 240V
General Lighting	General lighting circuit shall be provided for 3 Watts per square foot (NEC 220.12) 120V
Other Large Appliances	Required dedicated circuit of 15-50 Amps. Often 240 V

How Insulating and Air Sealing Reduce the Necessary Space Heating Power

Most climates are heating dominated, so the power required to heat your home will be higher than the power to cool your home. The difference in air leakage rates, or air changes per hour (ACH) (orange vs. blue bars) makes a large difference in the necessary heating power. We show this impact at progressively warmer heating "design temperatures," and the corresponding reduced power/amperage needs. Your house's heating "*Design Temperature"* is defined as the coldest outdoor temperature the house will see in its climate, except for 0.2% of the hours of a typical weather year, or 18 total hours a year. Example "design temperatures" in CA include: Los Angeles is 43F, Sacramento is 37F, Yosemite National Park is 20F, South Lake Tahoe is 10F, Truckee is -4F. In cooling dominated climates, window overhangs and shades, window film or low heat gain windows, heat reflective house paints or "cool roofs" may reduce heat pump sizing and power use. One author plants hop vines on his home's west side for seasonal shade and home brewing.

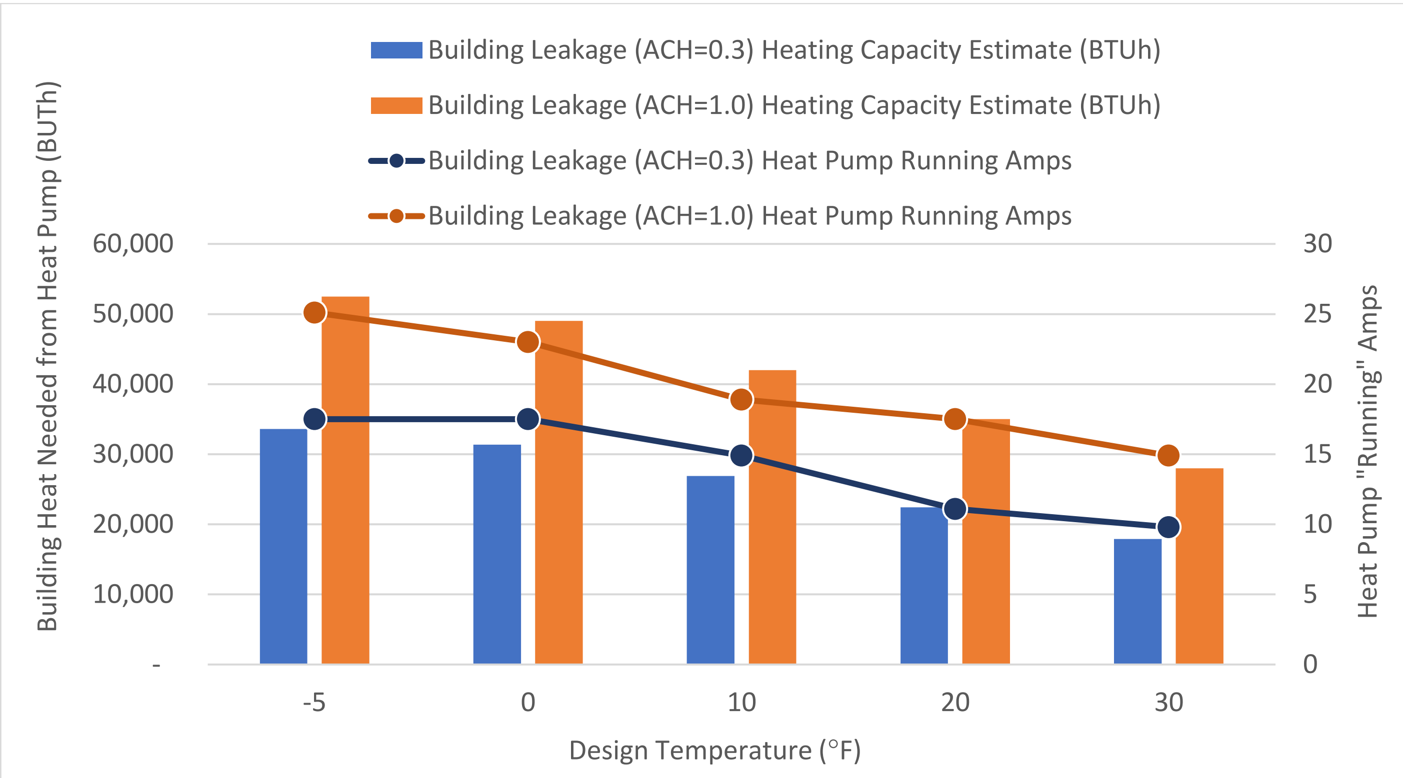


Figure 17: The heating requirements at various heating design temperatures and two leakage rates with the corresponding "running" amps for the heat pump (based on the Fujitsu FO*14R ducted heat pumps[44]) and a 2,000 square foot house with modest insulation (R13 walls, R38 attic).

Power Trade-Offs for the Watt Diet

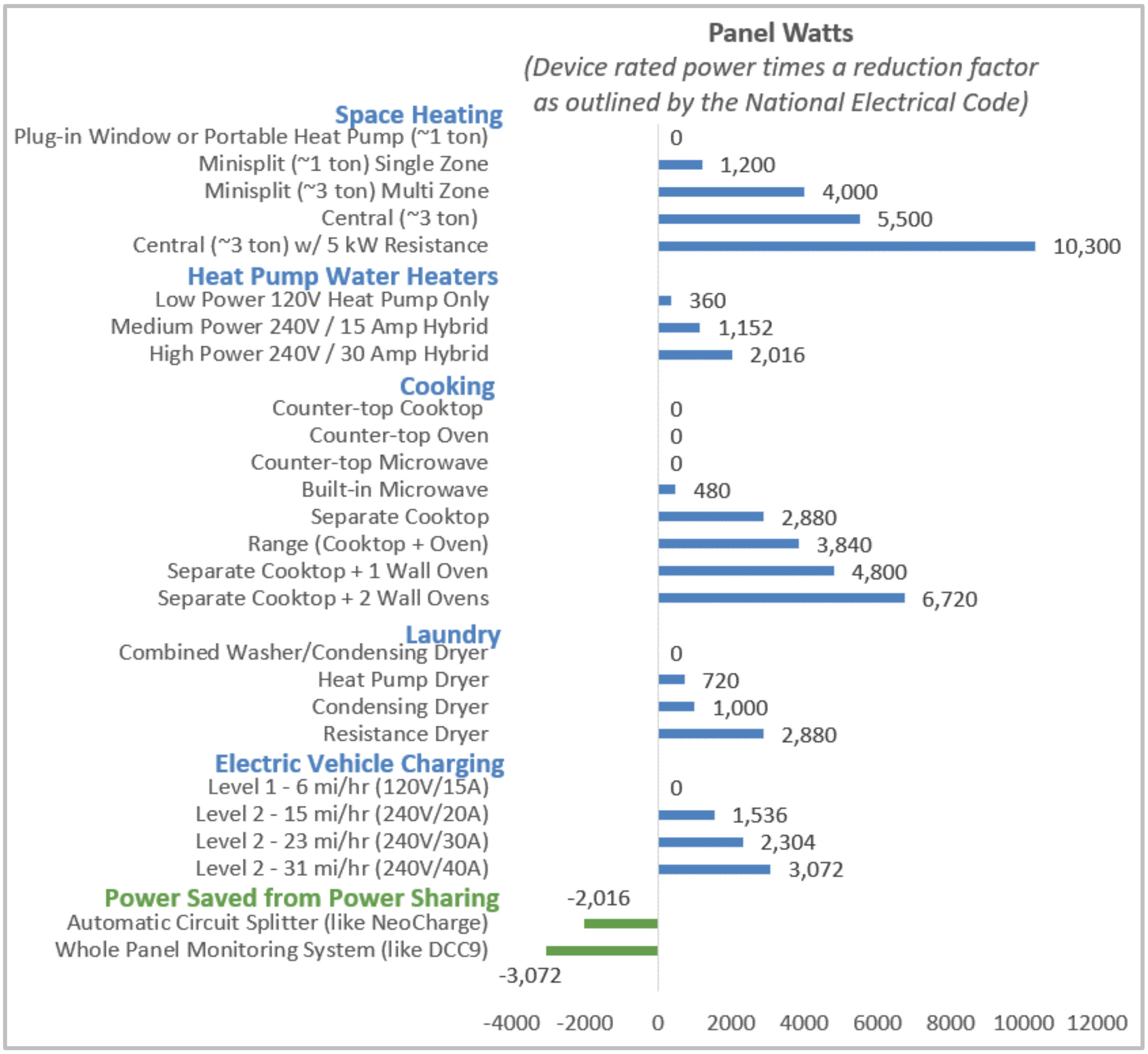


Figure 18: Panel watts of various space heating and appliances in the home.

Homes have a set amount of power access through the service wire from a nearby power pole. For example, a service wire may provide 24,000 Watts (100 Amps at 240V). This graph illustrates options to save 13,900 Watts just from choosing more efficient appliances and avoid upgrading the utility service wire and your circuit breaker panel. The graph at right compares the power demand of various appliances using the National Electrical Code (NEC) calculation method. The NEC takes an appliance's rated power use and reduces it by 50%-60%, based on the likelihood the appliance will be in use. So, a 24,000-Watt service wire might have 35,000 Watts of appliances on it and still be Code compliant.

Calculate the Watt Diet for your own home! ***Download the Watt Diet Calculator at Redwood Energy's Website:*** **https://redwoodenergy.net/research/**

Some notable power saving options in this graph are that the difference between ductless and ducted space heating (up to 6,300 W savings), different types of laundry dryers (up to 2,880 W savings), different power levels of water heaters (up to 1,650 W savings) and different level of car chargers (up to 3,072 W savings). There are also large savings (up to 3,072 W) from using Power Sharing devices (this can be achieved by sharing a circuit between the car charger and the range for example, see the Product Guide below for more information on these devices). Using this table one can count 13,900 Watts of potential savings, which equals 50 Amps at 240V—enough to power a second, smaller house (e.g. "mother-in-law" or "ADU" home) next to the main house. Or those 13,900 Watts of potential savings can prevent a house from having to upsize its service wire, breaker panel and circuits within the house. Or they can be reallocated into your favorite enhancements of devices or new amenities.

All Electric 100 Amp Home (2,000 square feet)

Ducted heat pump, medium power heat pump water heater, hybrid heat pump dryer

100 Amp Panel

Device Volts	Device Amps	Circuit	Breaker
120	12	Lights/Plug	15
120	12	Lights/Plug	15
120	14	Lights/Plug	20
120	10	Garbage Disposal	20
120	7	Refrigerator	20
240	3	Forced Air Unit	15
240	20	Heat Pump HVAC	30
240	20	EV Charger	25
240	16	Solar Input	20

Breaker	Circuit	Device Amps	Device Volts
15	Lights/Plug	12	120
15	Lights/Plug	12	120
20	Lights/Plug	14	120
20	Kitchen Outlets	15	120
20	Kitchen Outlets	15	120
20	Dishwasher	12	120
20	Clothes Washer	15	120
20	Hybrid Heat Pump Dryer	14	240
50	Range (cooktop +oven)	40	240
20	Heat Pump Water Heater	12	240

House square footage = 2000

Total Counted Panel Amps = 96.6

Additional House Information

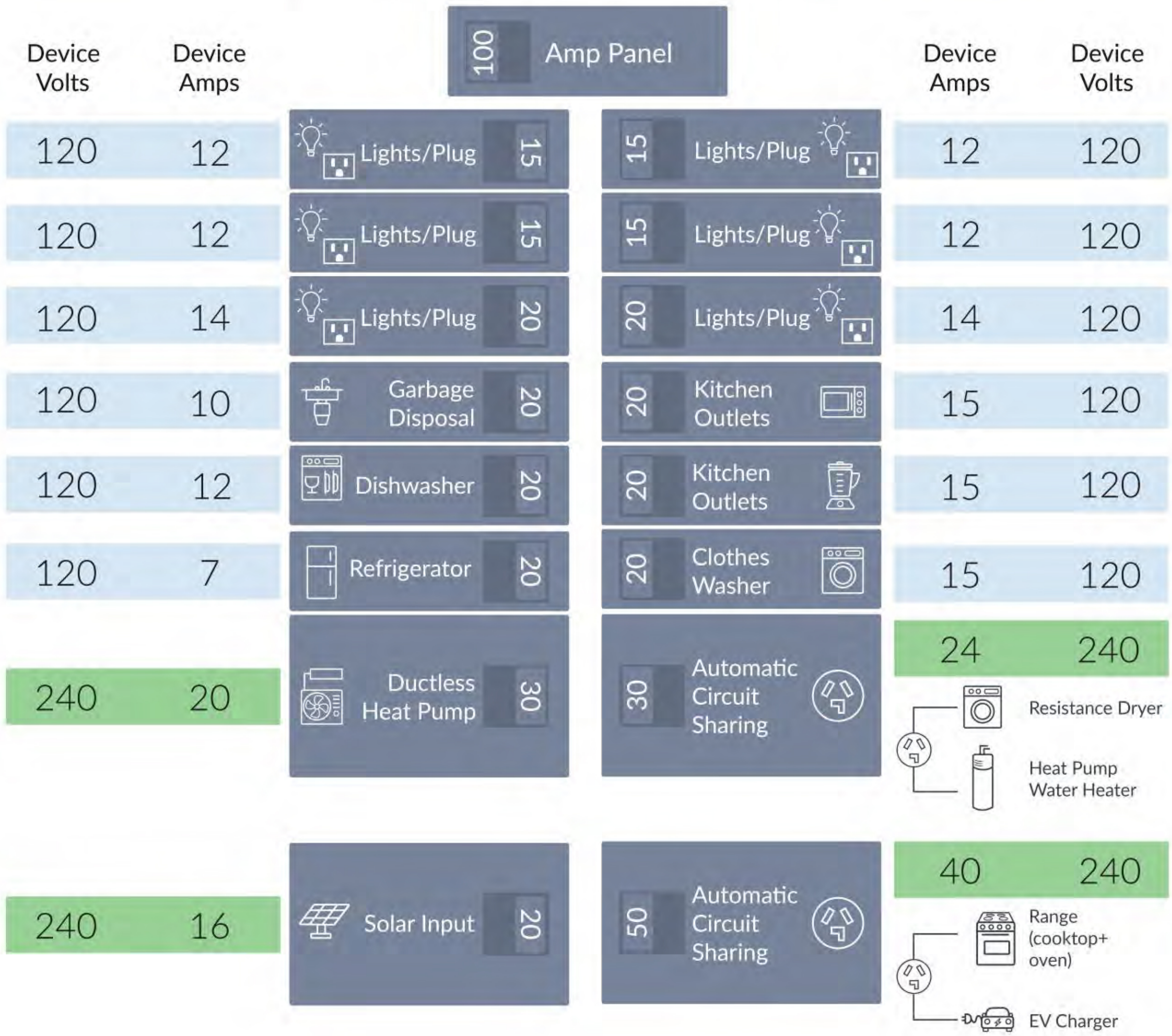
- 4 occupants
- EV charging up to 19 miles/hr
- Located in California climate zone 3 (SF Peninsula)
- Some insulation
- 38,000 Btuh heating and cooling
- 60-80 gallon heat pump water heater
- 4-burner induction or standard electric range
- 7.4 cu. foot hybrid heat pump dryer
- A 20-amp circuit will support a 3.8 kW inverter. (Many 3.8 kW inverters can support roughly a 4.6 - 5.9 kW solar array depending on inverter load ratio)

Diagram creation and design by Josie Gaillard and Courtney Beyer

February 22, 2021

All Electric 100 Amp Home (3,000 square feet)

Two "automatic sharing" circuits, ductless mini split heat pump, resistance dryer, high power heat pump water heater



House square feet = 3000

Total Counted Panel Amps = 95.6

Additional House Information

- 4-6 occupants
- EV charging up to 38 miles/hr
- Located in California climate zone 3 (SF Peninsula)
- Some insulation
- 48,000 BTU heating and cooling
- 40-80 gallon heat pump water heater
- 4-burner induction or standard electric range
- 7.4 cu. foot standard resistance dryer
- A 20-amp circuit will support a 3.8 kW inverter. (Many 3.8 kW inverters can support roughly a 4.6 - 5.9 kW solar array depending on inverter load ratio)

Diagram creation and design by Josie Gaillard and Courtney Beyer

February 22, 2021

Simple "Box-Swapping" Retrofits

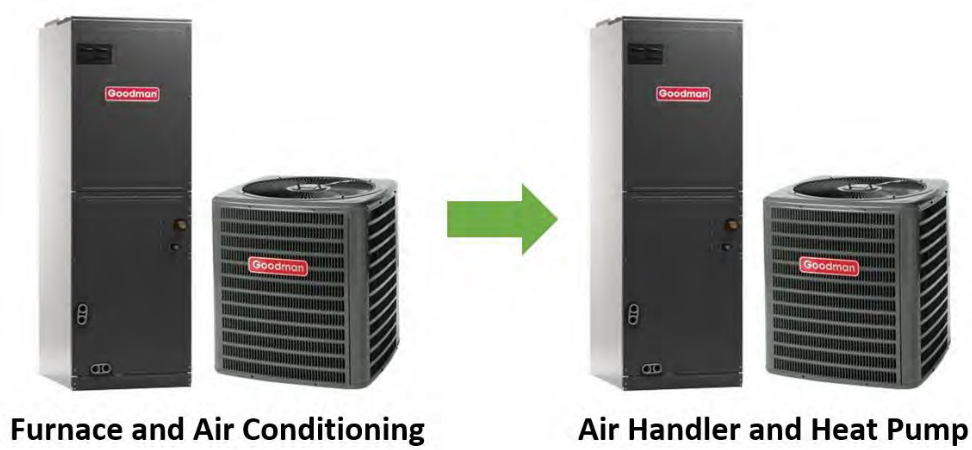
Box-swapping describes the relatively quick and painless process of switching out gas appliances with similar electric appliance, such as a ducted heat pump replacing a ducted air conditioner. An example of what is *not* box swapping is abandoning your home's ductwork and installing a radiant floor—changing systems may be more comfortable, but it is rarely the low-cost option. Each "box swap" has items to consider that are discussed below. Contact your local contractor to get specific cost estimates and design strategies.

Box Swapping the Heating, Ventilation and Air Conditioning (HVAC) System

Heating, Ventilation and Air Conditioning can come in many forms—ducted, ductless and radiant are the most common types, and each has an analogue heat pump product. There are also electric resistance products that can be swapped in place of gas space heating, but they are not discussed here in detail due to their low efficiency.

Box Swapping a Ducted HVAC System

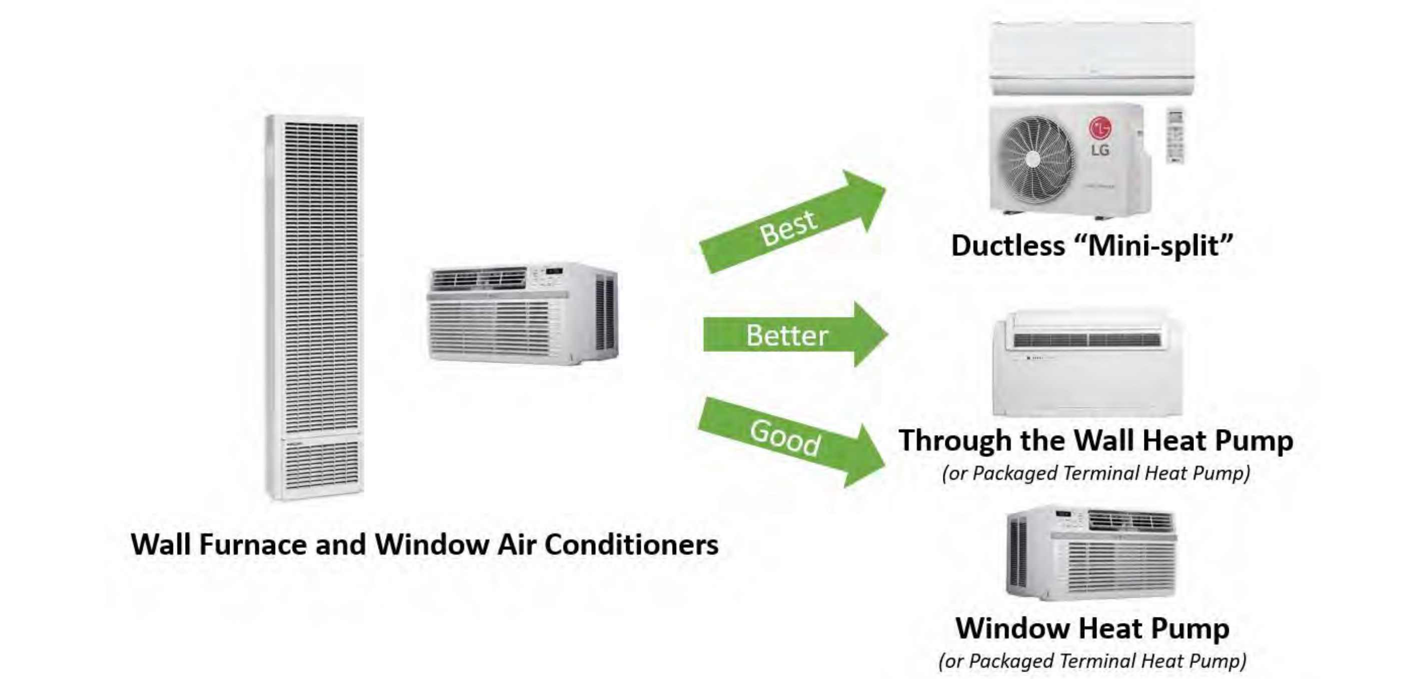
In a typical ducted heating and cooling system, there is a furnace for heating and an air conditioner for cooling. One strategy to retrofit this type of system is to replace the outdoor unit of the air conditioner with a heat pump, placed in the same location. A heat pump outdoor unit looks just like an air conditioner outdoor unit. Since a furnace typically has a large fan within it that blows hot air through the ductwork, the furnace is replaced with a similar dimension "air handler" containing a coil that is connected to the outdoor heat pump via refrigerant lines. In a furnace-only home, the same ducts can be used for a heat pump, and you get the added benefit of getting heating and cooling. One easy way to accomdate both space and water heating conversions is with an "umbilical" wire from the indoor air handler to the outdoor heat pump (this is a work around some manufacturers provide because air handlers are typically 240V, where furnaces are only 120V). This frees up the old 120V 15-20 Amp furnance blower circuit for now powering a 120V retrofit ready heat pump water heater.



Retrofit Considerations	• Typically, air handlers for heat pumps are 240 volts and air handlers for furnaces are 120 volts so it is important to note the circuit that the air handler uses. However, a common work around is to connect the heat pump and the air handler with an "umbilical cord" wire, bypassing this issue.

Box Swapping a Ductless System

In this scenario, where there is no existing ductwork, ductless heat pumps can be a good fit. Not having ducts reduces energy losses, and ductless mini splits are the most efficient heat pumps on the market. Smaller, older homes will sometimes have gas wall furnaces with the addition of window air conditioners. Even if you have one or the other, getting a mini-split or packaged terminal heat pump (reversible window air conditioner) is a great choice because they both provide heating and cooling out of just one box. If aesthetics is your strongest driver, mini-splits can also be installed to have mini-ducts (or horizontal ducts) which are shorter than typical ducts and can be packaged away in attic space out of sight.



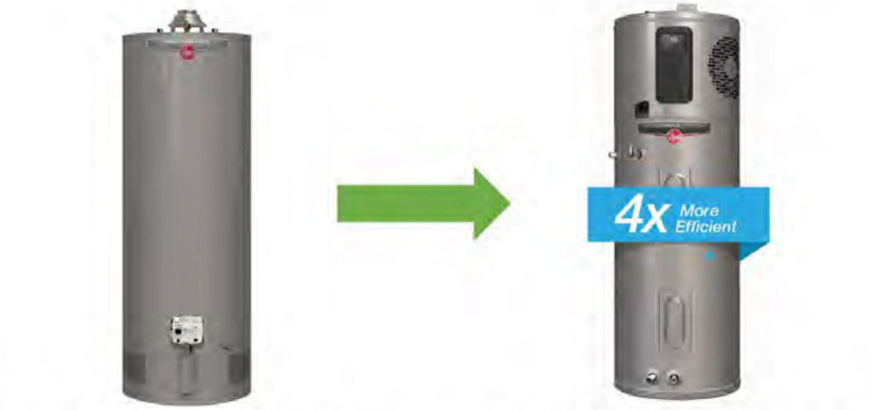
Retrofit Considerations	• Installation: Mini splits require thin copper refrigerant lines from the outside compressor to the inside fancoil. The "portable" and "window" heat pumps are very easy to install, while "through wall" types require some carpentry skills and labor. • Power: Many ductless systems have 120V versions that can use existing wall plugs, as well as more powerful (more heating and cooling) 240V versions. • Noise: Mini-splits are the quietest, followed by inverter controlled through-wall types, then single speed through-wall types, and lastly window types (which make the most noise).

Box Swapping a Water Heater

Retrofitting your gas tank water heating can be done with either an electric resistance type water heater or by using a more efficient heat pump water heater. It is not feasible yet to do a simple swap-out of an on-demand gas water heater with a heat pump water heater—wall-hung heat pump water heaters are just coming on the market in the U.S., although sold widely overseas. Note that some heat pump water heaters are referred to as "hybrid" because they have back-up electric resistance, which is needed sometimes with refrigerants (e.g. R-134a) but not others (e.g. CO_2). This is true because the refrigerant R-134a does not produce as much heat at lower outdoor temperatures, however electric resistance back up can be avoided by increasing storage volume and increasing the temperature setting of the tank.

Gas Tank Water Heater to Heat Pump Water Heater (HPWH)

Gas tank water heaters are typical in many homes. They can be box swapped with electric heat pump water heaters (HPWHs) of the same size or larger. Common heat pump water heaters come in various volumes-- 40, 50, 65 and 80 gallons--but require 240 volts of power because they were initially developed to "box swap" with 240V electric resistance water heaters.



Gas Tank Water Heater — Heat Pump Water Heater

Retrofit Considerations	• Most existing models require 240V electricity and can share the 240V outlet for the laundry dryer with a circuit-sharing plug (see product guide section for options), although a 120V version by Rheem has come out. • The heat pump water heater can use indoor heat or be vented to the outdoors • A small condensate water pipe needs to be routed either outdoors or it can be routed down an existing washer standpipe line, or into a laundry sink or floor drain • They are fairly quiet at 50 decibels of fan and electric motor noise, like that of a laundry dryer

Gas water heaters in most garages have a nearby 240-volt plug for the electric clothes dryer. One solution would be to wire a new circuit 30-amp circuit to power the HPWH, or another solution is to use a power sharing device that splits the circuit between the heat pump water heater and dryer. An example of an automatic power sharing device would be that once the dryer is done running, it automatically switches power back to the water heater. Because the power sharing device takes turns powering either the water heater or the dryer, it avoids overloading the circuit. Another solution would be to get a combined washer and dryer that can plug into a normal 120-volt socket, leaving the 240-volt plug for the heat pump water heater.

Also, currently out from Rheem and soon to be released by GE under the name Haier are "retrofit ready" heat pump water heaters, that plug into a typical 120-volt typical outlet. These new retrofit ready water heaters are expected to draw only around 7.5 amps. So, instead of wiring a new 240V circuit or replacing your standard electric dryer, you can use a 120V retrofit ready heat pump water heater.

Three ways to get more hot water – which one is right for you?
The more people in the home, the more hot water you will use. If you have two people in your home you will probably want a 40-gallon water heater, for three people would use 50 gallons, 4 people would use 65 gallons, and 5+ people use 80 gallon tanks.[45] Current (no pun intended) Heat pump water heaters are generally either 30-amp or 15-amp machines based on the Amperage of the electric resistance backup elements they use to supplement the heat pump. The 15-amp products put less power into the water during the course of the first hour test so all else being equal, they would deliver slightly less hot water in the first hour test and thereby have a lower **first hour rating**.

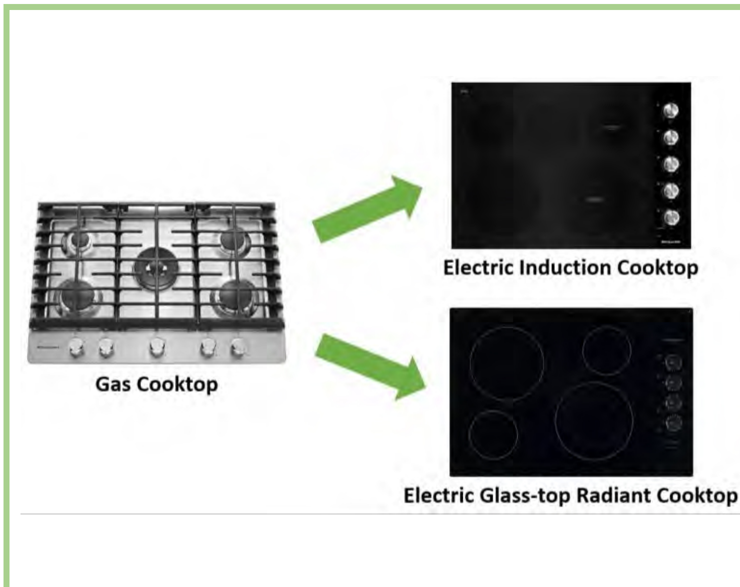
Three ways to get more hot water:

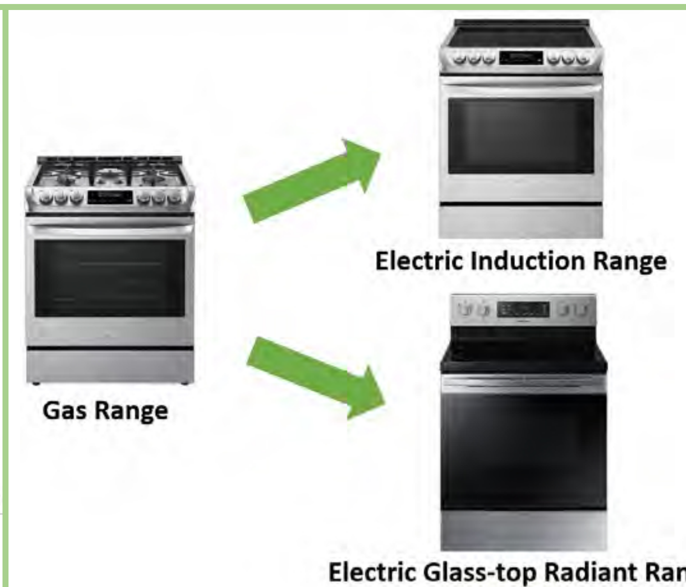
1. Set the tank to a higher temperature (and use a mixing valve to avoid scalding if you are setting it above 130F)
2. Select a larger volume tank
3. Select a higher power heat pump water heater that is 30-amps

Box Swapping a Stove

Figure 19: A stainless steel disk used to convert your favorite pan to be compatible with an induction cooktop, called a "heat diffuser" or “Induction adapter plate”.

Electric stoves use the same amount of space as gas stoves, and come in every fashion—sleek, antique or simple. Most require 240V power though, requiring a few hundred dollars of electrical work before it can plug in. Induction cooktops are favored by many professional chefs and they are easier to clean, faster to cook with, and they create less indoor air pollution. However, electric radiant stoves are roughly half as expensive, also come with easy-to-clean glass tops, but are less controllable, slower and about 10% less efficient than induction. Electric radiant cooktops allow you to use aluminum and other non-ferrous pans, while induction requires cookware with iron content, like cast iron or some types of stainless-steel pans. Any pan that a magnet can stick to works well for induction cooking. You can continue using glass and aluminum pots with induction if you put a steel disk beneath it—they are commonly sold for induction retrofits. A lower cost retrofit is to use countertop induction cooktops that are smaller (1 – 2 burners) and use 120V electricity, so they can use any of the kitchen plugs, paired with 120V countertop ovens.





Retrofit Considerations	• 240V circuit needed for higher power cooktops with more burners • Induction cooktops with 1-2 burners do not need power upgrade (120V) • Induction and Radiant cooktops use a similar amount of power	• Requires a 240V circuit • Saves power by combining oven and cooktop into one 40 amp draw • Induction and Radiant ranges use a similar amount of power and will require a similar circuit size (typically 30 or 40 amp)

If you have a gas oven and gas cooktop, then you might lack a dedicated, high power circuit required for electric stoves (40-50 Amps at 240V). The no-circuit upgrade solution would be to use one or two countertop induction cooktops. The other option is to run an additional, dedicated 240V circuit for 40-50 Amps. If the cooktop and oven are separated, they count as needing more power, and both require a dedicated circuit. Double ovens tend to need double the power of single ovens (40 amps vs. 20 amps).

Box Swapping a Gas Clothes Dryer

As discussed above, about 12% of homes have gas fired clothes dryers. You don’t need to have a high power (240V) outlet available, you can retrofit with a combined “All-in-one” condensing washer-dryer that can plug into any outlet in the home (120V). However, the washer-dryer still needs to have a supply water pipe and a drainage pipe, so its easiest to locate it where the existing washing machine was.

Standard Washer and Dryer	Combined Washer and Dryer

Retrofit Considerations	• Combinied washer/dryers can plug into a 120V / 15-amp circuit • Needs a place to drain water • Does not require venting

Heat pump dryers come in both 120V or 240V versions and are similarly as energy efficient as the combined washer/dryers. Some of them come with electric resistance back-up, so while they are more efficient they still require as much power as a standard electric dryer—30 Amps at 240V—which will necessitate a new 240V circuit to where you are replacing the gas dryer. Condensing washer/dryers come in sizes up to 4.5 cubic feet, while heat pump dryers come in sizes up to 7 cubic feet and resistance dryers can be as large as 9 cubic feet.

Box Swapping a Gas Generator

During California's planned power outages to prevent wildfire in 2019, residential back-up generators tragically became a daily source of fires.[46] Unfortunately most generators run out of fuel after two days, and more fuel is often unavailable or rationed during a major disaster—even gas stations run out or just can't pump. To replace a gas generator requires a battery, ideally paired with a solar array so it refills itself every day. Below are examples of mobile electric generators—batteries with plugs—and their price closely matches the amount of energy they can deliver without recharging. The batteries go up in cost as their capacity increases which is measured in Watt-hours. For example, the Goal Zero Yeti 500X could power a 10-Watt lightbulb for 50 hours or could charge a 12W smart phone 42 times. As another example, the Goal Zero Yeti 6000X could run an average full-sized fridge (100W) for 60 hours. Further below are miniature examples of this—single light bulbs with battery back-up, which is Code mandated for commercial new construction and is now available for homes. *(See more Low-Cost Resilience solutions in the product guide at the end of the document.)*

						
Model	S200	Rockpals	RIVER 600	Goal Zero Yeti 500X	Goal Zero Yeti 1500X	Goal Zero Yeti 6000X
Price	$170	$220	$350	$700	$2000	$5000
Solar charging	Yes	Yes	Yes	Yes	Yes	Yes
Battery Capacity (Wh)	193	288	288	500	1500	6000
Output Voltage (V)	5, 12 (VDC) 120 (VAC)	5, 12 (VDC) 120 (VAC)	5, 12 (VDC) 120 (VAC)	5, 9, 12, 20 (VDC) 120 (VAC) / 2.5A	5, 12, 20 (VDC) 120 (VAC) / 16.5A	5, 12, 20 (VDC) 120 (VAC) / 16.5A
Full charge time with 120VAC input (hrs)	6-7	6-7	1.6	4.5 (120V/1A)	7 (120V/2A)	12 (120V/5A)

Below are examples of light bulbs with a battery built into their base. They screw into standard outlets and are as bright as 40–60-Watt incandescent bulbs, appropriate for day-to-day use, but during an outage they will stay on for 3-5 hours, enough to get through a night or two without electricity.

Picture of the LED Light Bulb + Battery				
Model	GE - A21	YKDtronics	JackonLux	Neporal
Lighting Hours on Battery Power (hrs)	5	3-4	3-4	4-5
Wattage (W)	8	5	9	15
Lumens	760	500	850	800
Lumens/Watt	95	100	94.44	53.33
Price	$15	$8	$9	$11

Box Swapping a Gas Generator with an Electric Car

In the wake of the 2010 tsunami in Japan that shut down all nuclear power plants, 1/3rd of Japan's electricity supply, in 2011 Nissan began promoting their electric cars as a resiliency resource that can power a house or small commercial building. In our product guides you'll find products that perform this work in the U.S. The island of Maui, with its constrained grid, and the Los Angeles Air Force Base[47], with its need for resilience during emergencies, began using Nissans for Vehicle-to-Building and Vehicle-to-Grid chargers in 2014.[48] Honda, Mitsubishi, Toyota and other car manufacturers with standard CHAdeMO certified Level 2 charging plugs can now support bi-directional charging.

The Value of Resilience:

- $119 billion: The annual cost of power outages to the U.S.
- $20 – $55 billion: The annual cost to Americans of extreme weather and related power outages
- $243 billion – $1 trillion: Potential cost of a cyber-attack that shuts down New York and D.C. areas.

(source: Clean Coalition 2019)

September 2020, Typhoon Faxai ripped through Japan resulting in 934,000 homes losing power.[49] To help during the crisis, Nissan dealerships outside of the power outage zone invited Leaf owner to come and charge for free, and those with vehicle-to-home chargers were able to also power their homes. One vehicle owner, Mr. N, blogged about how his Nissan Leaf's was able to power the lights, refrigerator and heat pump water heater for two and a half days.[50] His first resource was a 4.5kW solar array, which was able to meet most of the loads, and Mr. N was able to drive to the closest Nissan dealer outside of the outage zone and bring back a full charge to meet the rest of his needs.

Figure 20: Nissan unveils the U.S. commercial offering of Vehicle-to-Home charging for the U.S., using battery-powered Leaf cars and Fermata Energy bi-directional charging. [51]

Figure 21: A Nissan Leaf charging the grid as part of the Hawaii's JUMPSmartMaui program.[52]

Figure 22: The LA Air Force Base increasing its resiliency with the largest EV fleet on a federal facility, 42 vehicles of Nissan Leafs, KIA plug-in hybrid vans, Ford C-MAXs, and Chevy Volts with all these cars using Vehicle-to-Grid technology.

Electric Retrofit Incentives and Rebates

Several different incentives and rebates are available for clean, electric heat pumps appliances and structural building efficiency upgrades. These are usually offered through utilities, local government, or states, and vary widely depending on your location. Taking the time to check with local utilities and agencies for discounts and incentives can save you thousands of dollars. PG&E, for example, has a marketplace with deep discounts and up to $500 in rebates on some heat pump models.[53] Other utilities offer even larger incentives summarized in the Table below. The Sacramento Municipal Utility District (SMUD) has one of the nation's most aggressive initiatives to encourage all-electric homes, offering incentives worth up to $13,500 toward the gas-to-electric conversion of existing homes.[54] The federal government also has various incentives, one good resource is the DSIRE Database of State Incentives for Renewables and Efficiency, which has state and federal incentive information. In addition, The Switch is On website has a incentive look up tool.

SMUD is also helping low-income customers by embedding electrification in its existing low-income energy efficiency program.[60] Roughly 80 percent of homes in the program receive electric heat pump heaters. Other energy providers are creating similar programs to assist low-income customers in the transition from gas to electric. Peninsula Clean Energy is launching a Low-Income Healthy Homes and Electrification Program in 2021, offering "turn-key" home upgrades that provide both energy efficiency and electrification at no cost to low-income residents in San Mateo County.

In California at least 16 different cities, community choice energy providers, and agencies offer additional rebates and incentives to replace gas appliances with electric. In the San Francisco Bay Area, the BayREN program gives $1,000 in incentives to the installing contractor for Heat Pump Water Heaters as well as rebates for other electric conversions in their Home Plus program.[62] Some area community choice energy providers layer additional rebates onto the BayREN discount, however these discount programs are not always "stackable" with other utility discounts.

Table 3: Just a few rebates and incentives for electric appliances.

SoCal Edison[55]	• Up to $1,000 for Electric Water Heaters • Up to $300 for Central HVAC Heat Pumps • Up to $600 for Mini Split HVAC Heat Pumps
SMUD[56] *which has the nation's largest "beneficial electrification" rebate program*	• Up to $750 for Induction cooktops • Up to $2500 for Heat pump HVAC • Up to $2500 for Heat Pump Water Heaters • Up to $2500 for Electrical Panel Upgrades
Great Northwest Installations, Oregon[57]	• Deep discounts on Heat Pump Water Heaters of roughly $1300 for a total installed cost of $800-$1550 (for 40 gallon to 80 gallon sizes)
Peninsula Clean Energy[58]	• $1,500 for HPWH on top of BayREN's $1,000 • Electrical Panel Upgrade to 100 amps $1,500 • Electrical Panel Upgrade to 200 amps $750
City of Palo Alto[59]	• $1,500 for heat pump water heater
Federal – Residential Energy Efficiency Tax Credit	• Up to $500 for water heaters, heat pumps, air conditioners, building insulation, windows, roofs

Figure 23: Summary of the incentives offered by BayREN.[61]

In addition, some local agencies, such as Silicon Valley Clean Energy, have developed online customer assistance programs to help customers replace gas appliances with electric; their eHUB helps customers find the best electric appliance including the discounts, as well as local installers.[63] Other agencies offer discounts on heat pump water heaters replacing gas water heaters as a means of reducing peak energy use (or "demand response"). Sonoma Clean Power offers incentives for smart thermostats and heat pump water heaters, in addition to free electric car chargers.[64] They have partnered with GridSavvy to offer a $5 per month bill credit on top of appliance discounts for customers that enroll in the demand response program.

Case Studies of Complete Electrification Retrofits

Below are all electric retrofits from across the United States - whether it be in the coldest climates of the mid-west or in the temperature forests of northern California, all-electric designs are the desired choice for comfortable, efficient and environmentally conscious homes.

1890 Ranch, Ravenna, OH

The region around Lake Erie has blizzards in the winter and humid heat in the summer, and older houses are rarely comfortable in all seasons. Habitat for Humanity volunteers in this small Ohio town near Cleveland retrofitted a very old home to help a disabled community member. The first step was reducing household moisture by sealing the basement's dirt floor with plastic sheeting. They then replaced the broken gas furnace and ductwork with a cold climate heat pump and new ductwork, paired with a dehumidifier on the fresh air supply. The heat pump water heater also does a small amount of dehumidification, along with reducing energy bills. With a final wrap of insulation and caulking all the cracks, the house is warm in winter, dry during the summer and supplied with clean, fresh air year-round. Retrofit design by Energy Smart Ohio.[65]

Figure 24: This 1890 home near Lake Erie was retrofitted by Habitat for Humanity volunteers to be all-electric and comfortable in all seasons.[66]

Ben and Sara Shalva's Home, Baltimore, MD

Ben and Sara moved into their Baltimore, 1950s home in the fall of 2019. Rather than refill the tank of fuel oil for their furnace, they joined their neighbors and electrified the old heating system by replacing the existing air conditioner with a heat pump of the same size. Because it snows in Baltimore, they selected a "cold climate" heat pump that still heats during extreme cold weather (e.g. -20F). Cold climate heat pumps use small computers to control the heat pump, so it works well at any temperature, while old-fashioned heat pumps lack a computer that allows sub-freezing functionality.

Figure 25: Ben and Sara Shalva replaced their fuel oil furnace with a heat pump for a more comfortable, fossil fuel free house. Multiple neighbors recommended a local installer who had already replaced their fuel oil furnaces with heat pumps, saving utility costs every winter and adding AC to an old house for comfortable summers.[67]

Steve and Lisa Schmidt's Home, Los Altos, CA: Electrifying Without Increasing the Power Supply

Lisa and Steve Schmidt, two "early adopters" in Silicon Valley's all-electric retrofit program and well-known energy consultants, run their large 4,000 square foot Los Altos family home on a standard 200 Amp panel, even as they have retrofitted chargers for two electric cars, an electric motorcycle, an induction range, a combined washer-condensing dryer, a heat pump water heater and a heat pump for space heating and cooling.

Figure 26: At the Schmidt's home, the Bosch electric induction stovetop[68] is shared on the same circuit as the Rheem heat pump water heater[69] using the NeoCharge (middle) (Images courtesy of Steve and Lisa Schmidt).

Figure 27: The NeoCharge allows two electric vehicles to be plugged in at the same time at the Schmidt's home, where one car is charged completely then it automatically switches over to the other car to charge (Images courtesy of Steve Schmidt).[70]

The trick to avoiding upsizing their power supply from 200 Amps to more (e.g. 400 Amps) was using NeoCharge plugs, which are similar to the SimpleSwitch, Dryer Buddy, Splitvolt and EV-PowerShare plugs. These plugs are designed to share power between two 240V devices using one plug. The NeoCharge controls power use, so one electric car waits for the other to charge, or the water heater waits while the induction stove cooks, then resumes heating the water in the storage tank when the stove is done. This power sharing strategy avoided the need for an expensive panel and service line wire upsize.

Their other strategy was efficiency--rather than using a 7000 Watt electric resistance laundry dryer and triggering a wiring upgrade, they bought 700 Watt condensing washer/dryer, so efficient with its power demand that it can plug into any existing 120V outlet. Lisa loves it-- *"The condensing Washer/Dryer is just outstanding. It washes quickly and does a better job than my old washer and dryer—the clothes come out cleaner and very dry. I'm thoroughly impressed."*

Wei-Tai Kwok's Home, Lafayette, CA

Wei-Tai Kwok, an engineer with construction skills, electrified his house to be part of the solution to global climate change.[72] *"I've seen and used ductless mini-split heat pumps countless times during my Asia travels, with each room having a remote control and the ability to adjust the fan levels. It didn't' really register in my head that the reason was because it's simply the* *<u>most cost-effective way</u>* *for them to get modern day comfort, and that someday my house would benefit from this same technology."*

Figure 28: Out with gas and in with electric mini-splits and induction cooking![71]

Peter and Margaret Darby's Home in Hamilton, NY

This all-electric home called Newbridge Farm was built in 1830 and has seen many transitions over 190 years, first burning wood, then coal, and next was fuel oil until Peter Darby completely electrified it, installing a water-source heat pump that uses heat from groundwater.[73] The chilled groundwater is then discharged into a lovely backyard stream. Peter is a City Councilmember in Hamilton and has helped lead political efforts to prevent new natural gas fracking within the town boundaries while educating his neighbors about how to completely electrify their homes.

Figure 29: Peter Darby's home that was built in 1830 was retrofitted to be zero emissions and all-electric, including a water source heat pump that uses well water as the heat source, and discharges the water into the adjacent creek.[74]

Campus Center for Appropriate Technology (CCAT) at Humboldt State University, Arcata, CA

This campus home to three student Co-Directors is the nation's last demonstration house from the 1970s, outliving hundreds of others founded by the Carter Administration because student funding made it immune to federal funding cut-backs. Tens of thousands students have toured, while hundreds have built and maintained a back yard wind turbine, pedal powered appliances, rooftop solar panels and even a French fry grease biodiesel refinery. Nightly meals are cooked on an induction range, and showers are heated with a heat pump water heater. The organization's unique student leadership model has led to students founding related groups, like Earth First! Humboldt that taught and organized tree sits to challenge local illegal logging of old growth redwood forests; Arcata's "Bayside Farm Park," which has started many professional organic farming careers; HSU's nearly first-in-the-nation Environmental Science degree program, and many more campus clubs that collect campus recyclables, compost cafeteria food waste, fix students' bicycles, and grow food for the homeless.

Figure 30: The Campus Center for Appropriate Technology: outside image of green house and garden, bike power generation, Julia Butterfly Hill an environmentalist activist, and the student staff.[75]

Perlita Passive House, Los Angeles, CA

The Gaucher Family retrofitted their home to be the first Passive House certified home in Southern California, removing the gas service and installing a 100% offset solar array. Significant amounts of insulation, both inside and wrapping the building, prevent thermal bridging, while high performance windows and a very tight envelope almost eliminate heating and cooling loads.[77] With these extra measures the all-electric home uses a modest 4kW array to power an entire 2,000 sf house, two thirds of what a similar house would require without deep efficiency measures.

Figure 31: The Perlita Passive House: the original house was stripped to the studs, re-insulated, tested and made into an LA modern masterpiece of efficiency.[76]

Jon and Kelly's Home, Cleveland Heights, OH

Jon and Kelly wanted to turn their 100-year-old house into a zero-emissions home to reduce their impact on the climate while also making the house more comfortable. Also, after living through several power outages, they wanted to make their home as off-grid as possible. A 3-ton Carrier Greenspeed heat pump was all that was needed to heat and cool their home and the resulting cost to heat their home is on par with other gas systems in the area.[78] The air sealing and insulated was extensive – special attention was paid to the attic, which was insulated with spray foam and finished with dry wall creating a workout room with AC. The end result of the envelope was R-13 walls and R-25 attic with an electric resistance water heater and electric stove. Kelly and Jon are happy they retrofitted – the value of their home increased, it is highly efficient and comfortable, their cost of living went down, and most importantly they are reducing their carbon footprint! Read the full detailed case study at [Energy Smart's website]!

Figure 32: Jon and Kelly's retrofit snap shots, new siding (left), adding insulation, and their Carrier Greenspeed heat pump.[79]

Colonial Solar House, Urbana, IL

Figure 33: All electric retrofit in Heartland (Building Performance Journal) [80]

Upon becoming increasingly concerned about the impacts of climate change and attending a presentation on net-positive energy housing, Scott Willenbrock made the decision to completely retrofit his colonial home to provide all its own energy. First, he installed solar photovoltaics on top of his garage and roof that have microinverters attached to the back. The microinverters allow for each of the modules to operate even if one of them is shaded. Next his natural gas furnace was replaced with a ground-source heat pump. Previously, the house was built with no insulation; however, after running an energy audit he was able to insulate with closed-cell foam. Paul and his family have been enjoying his all-electric retrofit for the past 3 years. [81]

The Bindley Carbon Neutral Renovation, Holderness, NH

After attending a seminar about the effects of climate change, Jane Bindley, owner of the original 70's ranch house, enlisted the help of Ben Southworth to curate a carbon neutral renovation. Ben and Marc Rosenbaum (the energy engineer) installed a 7.5-kilowatt solar array on top of the roof to produce all the power the house would consume over the course of a year. Next, a ground source heat pump was installed and replaced the old oil boiler system. High performance Thermotech windows and doors were installed for better insulation. CFL lights bulbs were switched out for LEDs for efficiency and durability. [82] Lastly, the envelope is tightly sealed with lots of insulation to keep its residents comfortable: wall R-52, roof R-72, basement wall R-40, basement Floor R-25. Combining thermal comfort and all-electric devices with solar meets Jane's goal of being carbon neutral.

Figure 34: The 1970's Ranch Home (left), during the renovation (top right) and Jane Bindley.[83]

Ross Residence, Amherst, MA

This old home built in 1884 was in need of a deep retrofit. The new homeowners, the Ross's, came to Coldham&Hartman Architects with a completely new design in mind. The first order of business was to completely redo the existing roof. The bay roofs were torn off and a new roof was installed, accompanied with 12.4 kW of photovoltaics. Moving towards a no combustion household, the Ross's decided to install a 15 Amp Steibel Eltron heat pump water heater and an induction cooktop. To heat and cool the house a Mitsubishi CityMulti Multi-port air source heat pump was installed. The Ross's are now enjoying their completely renovated home. Due to the well-insulated envelope, even during a snowstorm with no power for two and half days, and outside temperatures being 20 degrees, their home never went below 67 degrees. [84]
Read the full case study at the 1000 Home Challenge Website!

Figure 35: The Ross Residence newly renovated home.[85]

Erika Reinhardt's Family Residence, Bay Area, CA

To address the urgency of climate change, Erika Reinhardt and her family replaced their 2018 gas appliances— a gas stove, a gas dryer, and a gas boiler for radiant floor heating and domestic hot water. The replacements were a new induction range, an Energy Star efficient electric laundry dryer, and a Chiltrix CX34 air-to-water heat pump with tanks to provide hot water for both radiant heating and domestic hot water. A natural gas fireplace and outdoor grill were turned off—neither were used enough to justify replacement. Each of the appliances required a new 240V circuit, but the existing circuit breaker panel was right sized already for their new all-electric home.

The induction range and laundry dryer were easy to install because contractors are familiar with this process. The most challenging element of this renovation was finding a Bay Area contractor familiar with heat pumps that support radiant floor heating. Many interviews were necessary before finding an experienced crew, and Bay Area construction prices are double those of lower cost communities in the U.S.

Figure 36: Erika Reinhardt's electrified home in California (images and description courtesy of Erika Reinhardt).

Modest Manor, San Francisco, CA

A pair of shy do-it-yourself sorts electrified their 2,200 square foot two story home on a budget in little experimental stages. The original 1940's home had been remodeled in the late 1990's with a 150 Amp underground service line and has R-38 insulation in the roof and R-13 in walls. The first floor has about 900 square feet that is uninsulated over the "half dirt basement" where the old furnace and water heater used to sit. Watching a few plumbing and electrical videos, reading a how-to book on wiring and volunteering with **SunWork.org,** the homeowners built up skills and confidence to pair up with their buddies to take turns in electrifying each other's homes. They realized it's not rocket science and it can be a fun hobby that saves thousands of dollars.

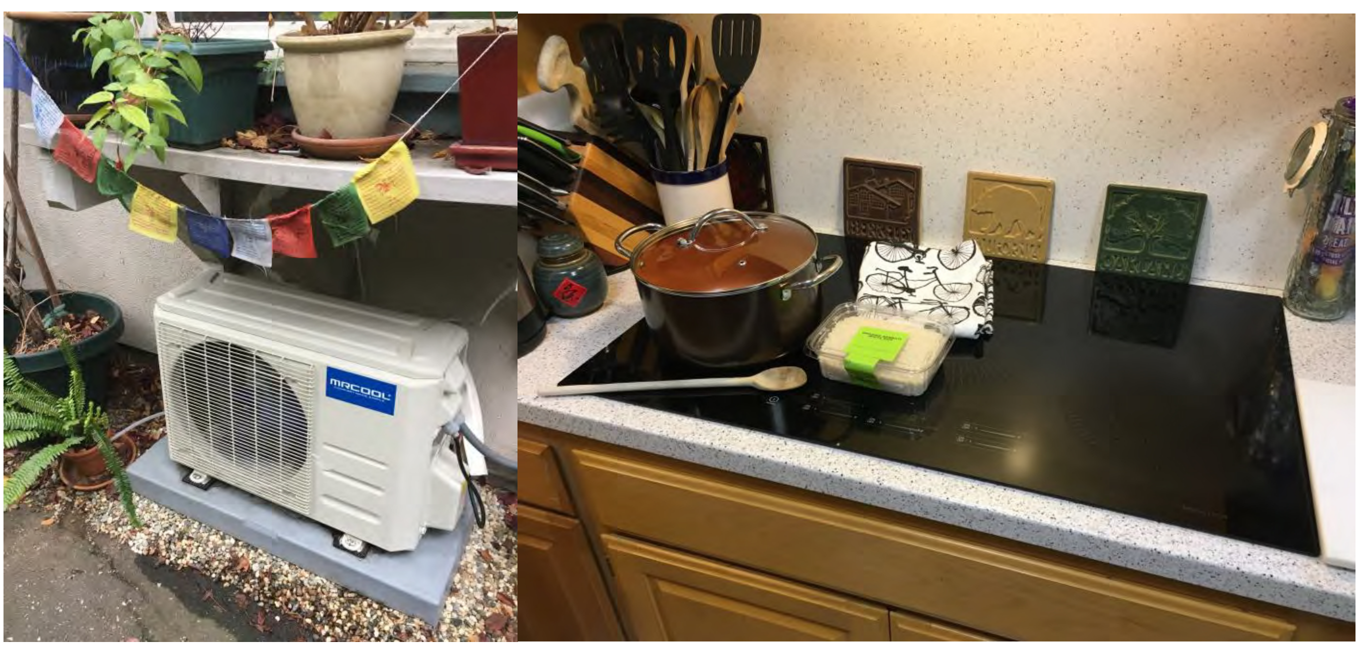


Figure 37: The Modest Manor's Mr. Cool Minisplits heat pump and induction cooktop.

We started with the heat pump water heater and included a couple of tee and ball valves to accommodate a future hydronic heating system. Next was the window heat pump – it was so easy that even renters can pop them in and take them out when they move. The third project was the pre-charged DIY version of "Mr. Cool" brand mini-split that can easily be installed on an exterior wall by passing the pre-charged sealed "line-set" through a 3 inch hole. The most recent project was a 36 inch five "burner" Frigidaire Gallery induction cooktop replacing our 20-year-old gas cooktop.

The homeowners love the new benefits of zoned heating and cooling as well as a gas-free kitchen. They may install another DIY mini split or a simpler $600 portable dual hose heat pump placed in and vented up the old brick fireplace and chimney. They plan to plug the old ductwork and abandon it in place and to remove the 35 year old gas furnace to free up some space.

The gross cost of purchasing and installation has been $6,400 all together and it avoided the cost of gas fired replacements. The gas cost alternatives would have cost at least $5,000 for the gas furnace, gas water heater, gas cooktop and gas dryer – so the net cost was only about $1,400. When any of the electric units burn out, the second replacement will be quick and easy because the new circuits are all in place now.

Table 4: Summary of costs for the Modest Manor DIY retrofit.

Appliance	Type of Cost	Cost	DIY Labor Hours	Specifications
Heat Pump Water Heater	Appliance	$1,200	4	50 Gal. Discontinued HPWH from Lowe's
	Materials Electrical	$150	5	New 240V 30A circuit in flexible armored conduit
	Pipes and fittings	$190 for materials & lunch for my buddy	10	Connectors and ball valves for future hydronic heating coil plus condensate pump and line
Window Heat Pump	Appliance	$390	1/2	Frigidaire 8,000 Btuh 120V plug-in window heat pump. # FFRH0822R1
Mini-Split Heat Pump	Appliance + shipping	$1,600	1	Mr. Cool DIY 12,000 Btuh variable speed 120V
	Electrical Materials	$120	5	New dedicated 120V 20 Amp outdoor outlet serving as "disconnecting means"
	Head Installation	Free with my buddy after we did hers	9	Watch video, mount bracket, drill hole, pass line-set through it
	Compressor Installation	$40	3	Bolt to plastic base on gravel bed
Induction Cooktop	Appliance	$900	1	Frigidaire Gallery "36
	Materials Electrical	$190	5	Crawling under house to run new 240V 40A circuit
Combined Washer/Condensing Dryer	Appliance	$1,600	1	It just plugs in where the prior washer was and replaces washer and dryer.
Total	Gross Cost	$6,400	45	Net Incremental Cost $1,400 if we subtract out the cost of new gas machines.

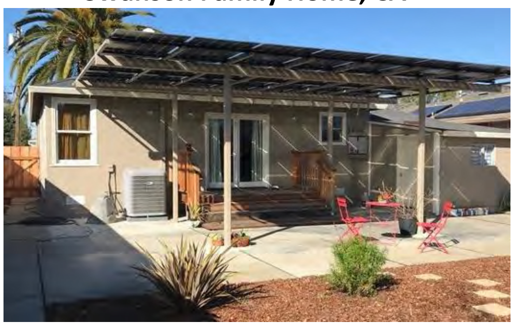
Additional All-Electric Case Studies

Mackey Deep Energy Retrofit, PA[1]

Dateo Family Home, CA[2]

Willowbrook House, TX[3]

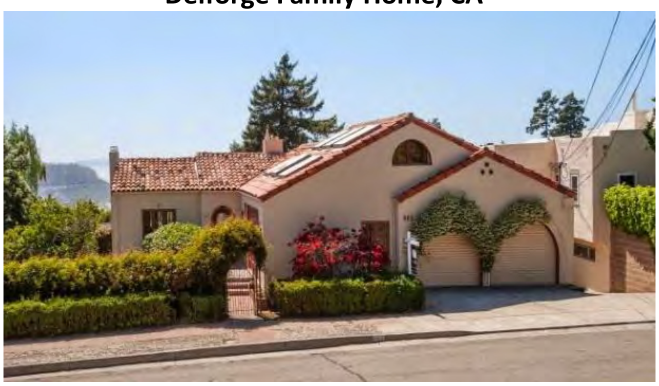
Swanson Family Home, CA[4]



Fink-Simo Family Home, MA[5]

Cinnamon Family Home, CA[6]

Delforge Family Home, CA[7]



Markiewicz and Ahrens Home, CA [8]

A Retrofit by emeraldECO, CA[9]

Ron and Lee's Family Home, ME[10]

Byron Family Home, CA[11]

Road to Energy Independence Retrofit, WI[12]

Ghosh Family Home, CA[13]

All-Electric Product Guides

The following product guides provide an overview of electric products on the market as guidance to electrify all the end uses in single-family homes. This guide includes the basics – space heating and cooling and domestic hot water – as well as cooking, laundry drying, and accessory end uses like electric fireplaces, electric cars, electric car chargers, landscaping, and pool heating. A snapshot of technical specifications as well as the retail price of each product is provided in the tables below. It is suggested to find the most up to date specifications online, exact numbers may change as newer product versions are available and costs may vary.

Heat pumps are the solution to meeting our largest energy demands in buildings. Heat pumps go by many names depending on their applications like "refrigerators," "air conditioners," "air source heat pumps," and "reverse chillers." The history of chemical refrigeration dates to the 1550's when saltpeter baths were first used to chill wine. Ice manufacturing was a booming business by the late 1700's, and the first true "refrigerator" was built to chill beer at the nation's largest brewery, S. Liebmann's Sons Brewery in Brooklyn, New York in 1870. Willis Carrier is credited with inventing the air conditioner compressor in 1902 also in Brooklyn, NY. Residential refrigerators were common by the 1920's, and reversible air conditioners (aka "heat pumps") came on the market in the 1950's.

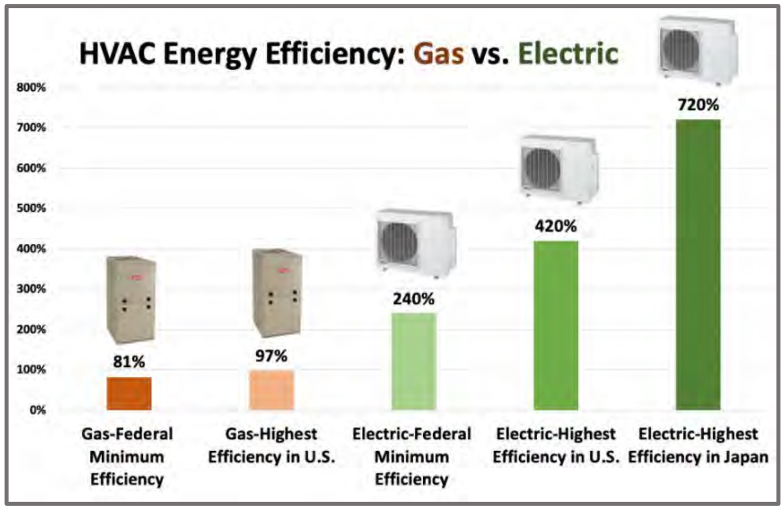


Figure 38: Air source heat pumps collect more energy from the air than they use to gather it. (Image by Redwood Energy).

Heat pumps can draw their energy from three main sources --the air, the ground and water - this energy is then moved into either air, water, or refrigerants which are cycled through the building to meet heating and cooling needs. The most common and flexible heat pumps are "air source", like that in your refrigerator or your air conditioner. Ground source and water source are a little less common and are usually used on larger scale and use the soil or bodies of water as heat sources. Sometimes, "Air to water heat pump" refers to a two-stage process, where there is a central air source heat pump that chills or heats water, then that water circulates through the building instead of air.

Heat pumps can move heat from one substance to another so well because of the compression and expansion of fluids called refrigerants. There are many types of refrigerants, but the most common for heating and cooling are the Hydrofluorocarbons r410 and r134a which are newer versions of refrigerants like R22 but do not contribute to ozone depletion. However, the industry has been moving toward "natural" refrigerants like CO2 (R744), Ammonia (R717) and Propane (R290) that do not deplete the ozone and contribute many orders of magnitude less to global warming.

Figure 39: Fujitsu heat pump in the snow.[86]

Cold Climate Heat Pumps can now collect heat from outside air down to Arctic temperatures (-20°F)[87], where early models were limited to warmer climates. With the use of inverters, heat pumps can now accelerate their compressor pump so they can operate in below freezing temperatures. In addition to inverter technology, cold climate heat pumps have a heating element to defrost the outside unit to keep ice from forming on it.

Cold climate products are indicated by a blue highlighted cell and bold text in the tables below.

Domestic Hot Water

The following section provides electric alternatives to gas water heaters for single family applications. The most common options are individual tank water heaters and on demand water heaters. Heat pump water heaters deliver hot water at high efficiencies and typically come with electric resistance back up for peak loads.

Individual Heat Pump Water Heaters (240V and 120V)

Typical electric water heaters that use electric resistance are not shown due to their inefficiency. The products shown collect 2.4 – 3.8 units of heat for every one unit of electricity powering the air source heat pump and provide 30-80 gallons of water storage. Some have a 4,000 BTU compressor integrated on top of the tank, others use a 12,000-36,000 BTU separate compressor outside that produces more BTUs at a higher efficiency. These models can be used as either serving one dwelling unit or can be combined in a distributed central plant to feed multiple units. Installing these units indoors especially in basements can provide dehumidification as well as avoid low ambient temperatures. Another way to think of it is they provide free hot water and dehumidification for half the year by offsetting a small amount of cooling load. New systems using CO_2 as a refrigerant (R744) can handle brutal winter climates

Figure 40: Jane Fisher decided to install an energy saving heat pump water heater at her investment property in Melbourne.[88]

Figure 41: A Sanden CO_2 heat pump water heater compressor working outside in 5°F (-15°C) weather.[89]

Heat Pump Water Heaters on US Market (240V)

Manufacturer and Product Image	**Eco2 Systems** 	**Steibel Eltron** Accelera 	**Rheem** Prestige Hybrid 	**AO Smith** Voltex Hybrid 	**Bradford White** AeroTherm 
Description	Large Volume Cold Climate CO_2 Refrigerant	Hybrid: Heat Pump and Resistance	Hybrid: Heat Pump and Resistance	Hybrid: Heat Pump and Resistance	Hybrid: Heat Pump and Resistance
Gallons	43, 83	58, 80	50, 65, 80	50, 66, 80	50, 80
Voltage (V)	208/230	220/240	208/240	208/240	208/240
Dimension (in)	27.5H x 35W x 11D	60H x 27Diam.	74H x 24Diam.	69H x 27Diam.	71H x 25Diam.
Ref. Type	R744 (CO_2)	R134a	R134a	R134a	R134a
Ambient Temp. Range (F)	**-30 – 110 (cold climate)**	42 – 108 / 6 – 42	37 – 145	45 - 109	35 – 120
Power (W)		650 - 1500		4,500	550 – 4,500
Max Amps (A)	13	15	15 – 30	30	30
Heating (BTU/h)	15,400	5,800	4,200	-	-
Heating (COP)	5.0	-	-	-	-
Energy Factor	3.09 – 3.84	3.05 – 3.39	3.55 – 3.70	3.06 – 3.61	2.40 – 3.39
Price ($)	$ 3,400	$ 2,300-2,600	$ 1,200-1,400-1,700	$ 1,400-1,500-1,900	$ 1,400-1,600

Retrofit Ready Heat Pump Water Heaters (120V)

There has been a market demand for heat pump water heaters that are "retrofit ready" meaning, they can plug into a 120V typical electrical socket, to rapidly electrify water heating. Both Rheem and GE have announced they will be releasing retrofit ready heat pump water heaters to the U.S. soon.

Manufacturer and Product Image	GE GeoSpring 	Rheem Prestige Hybrid 
Description	Heat Pump Only	Heat Pump Only
Gallons	40, 50	40
Voltage (V)	120V	120V
Dimension (in)	More Specifications Coming Soon	66H x 23 Diameter
Ref. Type		R134a
Ambient Temp. Range (F)		45 - 140
Power (W)		2,400
Breaker Size (A)		20A
Heating (BTU/h)		12,000
Energy Factor		3.0

Product Highlight – Eco2 Heat Pump Water Heater

The Eco2 uses CO_2 as a refrigerant (which does not contribute to global warming, like other typically used refrigerants) and allows the heat pump to have no "hard stop" of operation even at very low outdoor air temperatures.[90] At low outdoor air (-15°F) and low inlet water temperatures (Figure below) it can make hot water up to 145 degrees Fahrenheit, and it is still more efficient than the top-of-the-line natural gas hot water heater (COP of 1.9 vs. COP of 0.95). At warm outdoor air temperatures (above 70°F) the COP, or efficiency of the Eco2 heat pump water heater, increases to above a 5.0 COP, where a comparable natural gas water heater is still at a 0.95 COP.

Figure 42: The Eco2 heat pump water heater compressor working outside in 5°F (-15°C) weather.[91]

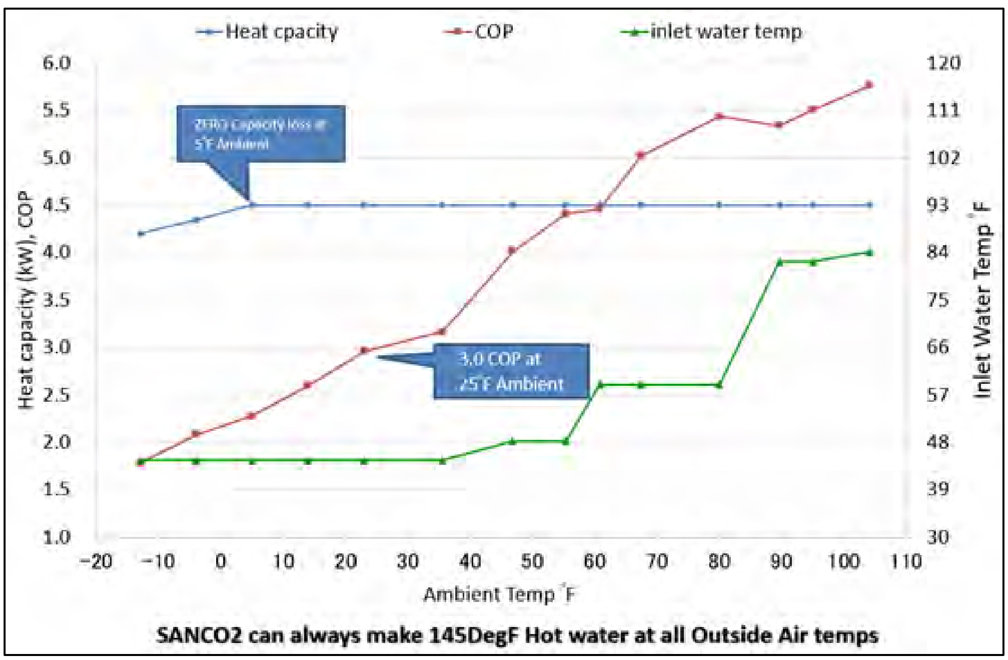


Figure 43: Eco2 heat pump water heater heating capacity, COP, and inlet water temperatures at various ambient air temperatures.[92]

On-Demand Water Heaters (120V and 240V)

Electric resistance water heaters are best used where hot water is needed in small amounts or when a project requires strict voltage limitations. Tankless water heaters can be used in a bathroom, or a 120sf tiny house that has no room for a 50-gallon tank or that is not sharing water system with other tiny homes. Electric resistance uses 2-4 times more energy than a heat pump but can be the right size for the right demand and they are helpful when there is no 220V electricity available. The 2 to 7-gallon tanks on the market use 120V, while anything larger uses 240V for more heating capability.

Small Demand and Low Power Applications (120V)

Manufacturer and Product Image	**Stiebel Eltron** SHC Series 	**Bosch Tronic** 3000 Series 	**Stiebel Eltron** Mini-E Series 
Description	Mini tank, Point of use	Mini tank, Point of use	Tankless, Point of use
Gallons	6, 4, 2.7	7, 4, 2.7	0.21 (gpm)
Voltage (V)	110/120	120	120/110
Dimension (in)	20H x 15W x 15D	17H x 17W x 14D	6H x 7W x 3D
Power (W)	1,300	1,440	1,800
Max Amps (A)	11.3	12	15
Heating (COP)	0.98	0.98	0.98
Price ($)	$ 230	$ 210	$ 160

Hybrid Heat Pump and Electric Resistance On-Demand Water Heaters

One specialty product is a hybrid heat pump and electric resistance back up water heater by Nulite. This product is meant to replace on-demand gas water heater systems and are more efficient that a typical electric resistance and gas on-demand water heaters. Created in China, they are now available in the United States.

Manufacturer and Product Image	**Nulite** NERS-FR1.5F 	**Nulite** NE-BZ2/W200 	**Rheem** EGSP2 – EGSP30 
Description	Hybrid Heat Pump with Resistance	DC Inverter Heat Pump Water Heater	Electric Resistance Tank
Gallons	18.5 (70L)	53 (200L)	2.5 – 30 Gal
Voltage (V)	220 @ 50 Hz	220V @ 50 Hz	120, 208, 240, 277, 480V
Ref. Type	R134A	R410A	Electric Resistance
Ambient Temp. Range (F)	**5 – 68 (cold climate)**	**-13 – 118 (cold climate)**	**Delivered Hot Water: 110-170F**
Power (W)	860 – 1500	5,000	1,500 – 6,000
Max Amps (A)	Pending	20	25A @ 240
Heating (BTU/h)	12,500	27,000	5,000 – 20,000
Heating (COP)	1.36 - 5.34	Pending, Approx. 5.4	>1
Energy Factor	Pending	Pending	-
Price ($)	UL Certification Pending	UL Certification Pending	$400 - $2,000

Three ways to get more hot water – which one is right for you?

The more people in the home, the more hot water you will use. If you have two people in your home you will probably want a 40 gallon water heater, for three people would use 50 gallons, 4 people would use 65 gallons, and 5+ people use 80 gallon tanks.[93] Current (no pun intended) Heat pump water heaters are generally either 30-amp or 15-amp machines based on the Amperage of the electric resistance backup elements they use to supplement the heat pump. The 15-amp products put less power into the water during the course of the first hour test so all else being equal, they would deliver slightly less hot water in the first hour test and thereby have a lower **first hour rating**.

Below is a figure that estimates the hypothetical first hour rating for the various power levels of heat pump water heaters (High Power, Half Power, and 120V Retrofit Ready) and for the size of the tank (40-80 gal). For example, in a three-person home, the first hour rating would be around 55 gallons, so a 120 V "retrofit ready" heat pump water heater or a 240V / 15-amp "half power" heat pump water heater that is 40 gallons would be adequate. Also, it's important to note that the more hot water storage you have, the more hot water you can deliver in the first hour.

Three ways to get more hot water:

1. Set the tank to a higher temperature (and use a mixing valve to avoid scalding if you are setting it above 130F)
2. Select a larger volume tank
3. Select a higher power heat pump water heater that is 30-amps

Interpreting the graph below, there are nine ways to get a 70 gallon first hour rating:

1. A full power 40 gal tank at 130F (no mixing valve needed).
2. A full power 50 gal tank at 120F
3. A half power 50 gal tank at 150F with mixing valve
4. A 120V 50 gal tank at 155F with mixing valve
5. A full power 60 Gal tank at 120F
6. A half power 60 gal tank at 135F
7. A 120V 60 gal tank at 145F with mixing valve
8. A half power 80 gal tank at 120F
9. A 120V 80 gal tank at 122 F

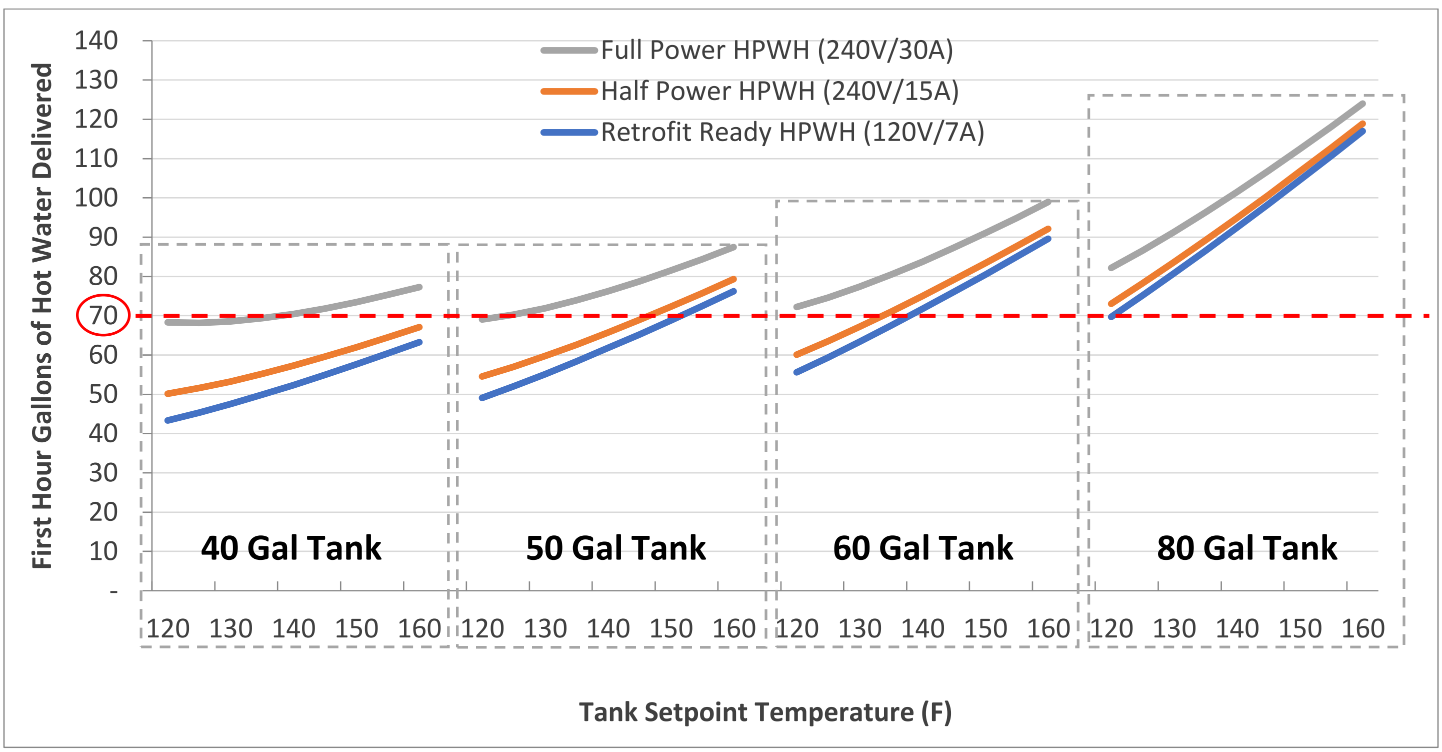


Figure 44: Approximate "first hour rating" (with a rate of 3 gpm until the hot water runs out) based on the power of heat pump water heater, tank size and temperature setting.

Heat Pumps for Swimming Pools and Hot Tubs

Utilizing a heat pump can be an efficient way to address the energy demands of heating a pool. To size a heat pump pool heater, assume the heat pump must produce 4 to 6 BTUs/Hour for each gallon of heated pool water, with higher productivity needed when the incoming water is colder in the winter. In addition, solar thermal can an efficient way to heat pools or supplement pool heating.

Figure 45: Pacific Companies Zero Net Energy apartment complexes built in 2014 with heat pumps for the hot tub and swimming pools. (left King Station Apartments, King City, CA and right Belle Vista Senior Apartments, Lakeport, CA.)

Listed briefly below are heat pump specifically designed for pools and cost $2400-$4200 for 90,000 BTUs/Hr to 140,000 BTUs/Hr of heating, about 1/10th the price of a similar-sized solar thermal pool heater. Heat pumps significantly reduce construction costs compared to solar thermal while providing the same ~80% offset of energy use by using ambient heat in the air, while working all 12 months of a year, compared to 5 to 8 months of renewable pool heating with solar thermal panels.

	Hayward HeatPro Low Ambient 	**Pentair** UltraTemp 110 Heat Pump 	**PHNIX** 	**Arctic** POOL-060ZA 	**AquaCal** Great Big Bopper 
Price	$3,000	$3,270	price unavailable	$4,300	Contact AquaCal
Heating Capacity (BTUh)	140,000	108,000	117,000	86,000	527,000
Heating COP	5.7	5.8	6.2	5.5	6.6
Temp. Range	40-104°F	45-104°F	50-110°F	**20°F**	40°F

Heating, Ventilation and Air Conditioning

The following guide gives an overview of heating and cooling electric systems that are used in single-family and multifamily buildings. The sample of heat pumps shown are in three major categories – air source, geothermal, and hydronic. They range in size from 9,000 BTUh to 600,000 BTUh and include central heat pumps, mini-split heat pumps, packaged terminal heat pump, vertical terminal heat pumps, "all-in-one" HRV heat pumps, geothermal heat pumps, and hydronic heat pumps.

Resources for Finding HVAC Products

Air-Conditioning, Heating and Refrigeration Institute (AHRI) Directory of Certified Product Performance
https://www.ahridirectory.org/Search/SearchHome

Northeast Energy Efficiency Partnerships (NEEA) - Cold Climate Air Source Heat Pump List
https://neep-ashp-prod.herokuapp.com/#!/product_list/

Energy Star Product Finder
https://www.energystar.gov/productfinder/

Overview of Single-Family HVAC

Ducted Split System (heat pump and air handler)	Ductless Mini-Split	Window Heat Pump	Portable Heat Pump	Through-wall Packaged Terminal Heat Pump	Hydronic Heat Pump	Geothermal Heat Pump
						
Bryant *– Evolution Extreme Variable-Speed*	***Mitsubishi*** *MUZ-HM18NA-U1*	***Frigidaire -*** *FFRH0822R1*	***Haier –*** *HPND14XCT*	***Ephoca / Innova*** *HPAC 2.0*	***Chiltrix*** *CX34*	***Water Furnace*** *7 Series 700A11*

What is considered "high efficiency" for space conditioning air-to-air heat pump?

SEER is used to rate air conditioner efficiency, while HSPF is used to rate heating efficiency. Typical efficiencies for a heat pump range from 14 SEER / 8.2 HSPF on the low end for ducted systems up to 33.1 SEER / 14 HSPF on the high end for ductless systems. If your home is striving for high performance goals, then seek a system above 20 SEER and above 10 HSPF. An important thing to note is that the most efficient furnace is only 97% percent efficient at converting fuel to heat, while the most efficient mini-split heat pump is 410% efficient at heating (HSPF ~ 14).[94]

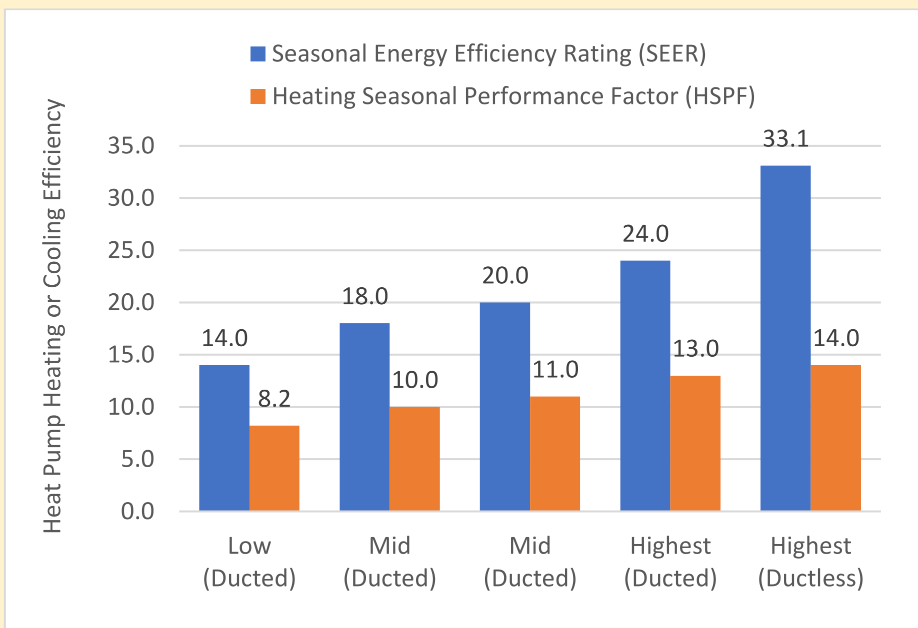


Figure 46: Typical heating and cooling efficiencies of heat pumps.

SEER: (Seasonal Energy Efficiency Rating) has units of Cooling BTUs provided per Watt-hour of electric use (SEER/3.412 = Seasonal cooling COP[95])
HSPF: (Heating Season Performance Factor) has units of Heating BTUs provided per Watt-hour of electric use (HSPF/3.412 = Seasonal heating COP[96])

Air Source Heat Pumps (Air-to-Air)

Using a reversible air conditioner – a “heat pump” – to heat people’s homes began in the 1930s, grew in popularity in the 1950s when they became smaller and more affordable, and has grown exponentially world-wide. Air source heat pumps that heat air do so with fan coils that may be mounted on the wall or ceiling or hidden in the ceiling or a closet and connected to ducts. Starting in 2001, computers began to be added to heat pumps—these small computers calculate in real-time the heat available outdoors vs. the heat requested indoors and speed up the internal parts to collect more heat as the outdoor temperature drops, even down to –31°F/-35°C. They have the side benefit of being much quieter than single-speed heat pumps. Heat pumps with these computerized controls are often advertised as having “inverter drives,” “variable speed” or “variable refrigerant flow,” phrases which all have the same meaning.

Central Ducted Heat Pumps (240V)

Ducted heat pump and air conditioning systems are usually driven by a central compressor that pumps air through ducts to vents in different areas throughout the building. These systems pair an outdoor air to air heat pump unit with an indoor evaporator coil and air handler unit.

Manufacturer and Product Image	**York** YZH02412C 	**Goodman** GSZC180481C 	**Daikin** DZ14SA0483 	**Carrier** Infinity 25VNA036A003 
Dimension (in) (WxDxH)	42 x 23 x 34	35 x 35 x 38	29 x 29 x 34	35 x 28 x 44
Crankcase Heater	No	Yes, with switch	Factory-installed	Internal, Factory Installed
Ref. Type	R410a	R410a	R410a	R410a
Ambient Temp. Range (H/C) (F)	**-10 – 115 (cold climate)**	**-5 – 115 (cold climate)**	**-10 – 65 (cold climate)**	**-4 – 68 (cold climate)**
Power (W)	2,500 – 3,412	4,830 – 4,840	3300	1,050 – 1,240
Heating Capacity (BTU/h)	18,000 - 59,000	22,000 – 59,500	44,500	25,000
Cooling Cap. (BTU/h)	19,000 – 58,000	23,000 – 56,500	45,000	36,000
Heating (COP)	2 -4	1.47 – 6.77	3.95	2.3 - 4
Cooling (COP)	4 – 4.4	3.66 – 4.10	4.1	4 – 4.4
Price ($)	$ 2,000	$ 2,500	$ 2,000	$ 3,200

Energy Consequences of Uncontrolled Crank Case Heaters

Traditional ducted Heat Pump and Air Conditioner Compressors are often heated with a crank case heater (or sump heater), which keeps the lubricant warm enough to not mix with refrigerant – preventing it from becoming “milky” and resulting in a noisy, inefficient heat pump. These can use a significant amount of electricity if uncontrolled (e.g., 100W on 24/7/365 becomes **876 kWh/year which can double the energy use of a smaller home**), but can be designed to use much less energy, and only when needed. Some HVAC heat pumps do not use them *at all* due to different lubricants or modified design. One should consider this non-rated, but real, energy use when choosing a heat pump.

Figure 5: “Belly Band” crankcase heater (heating wire wrapped around compressor).

Figure 6: Insertion crankcase heater (heating element inside compressor).

Many manufacturers have devised strategies to avoid or reduce the use of a crank case heater:

- Using lubricant that does not mix with refrigerant
- A recycling pump that stores refrigerant away from the compressor lubricant during shut down
- Temperature sensors that only turn on the crank case heater when the refrigerant gases are approaching liquid state and could mix with lubricant

While crank case heaters are not always clearly identified in product specification sheets, asking for information from the Contractor or their Distributor will clarify whether you may have a heat pump that performs as advertised or an unidentified, potentially large “phantom load.”

120V Air Handlers

Typical air handlers for furnaces are 120V, but typical air handlers for heat pumps are 240V. Supplying 240V electricity for a fan is overkill, and a relic of the era before 2009 inverter-controlled heat pumps allowed heat pumps to avoid resistance heat when the temperature dropped below freezing. This is no longer needed and some manufacturers, like Mitsubishi[1], Mr. Cool, and Fujitsu supply 240V power via wiring wire from the outdoor 240V compressor/condenser. However, below are 120V heat pump air handlers that can use the existing furnace fan wiring, avoiding the need to run a new wire.

Manufacturer and Product Image	**Advanced Distributor Products B Series Air Handler**[97] 	**Stelpro** SCV-P-1411[98] 	**King Electrical Mfg. Co.** AH1/5-120V[99] 
Price ($)	Not public	$925	$965
CFM	800	1400	1000
Size (in) LxWxH	22 x 15 x 44	24.75 x 22 x 22	20 x 16 x 30.5

[1] Page 44, shows the multi-position air handling unit that pairs with the Mitsubishi outdoor compressor heat pump <https://www.mitsubishipro.com/pdfs/m-series-catalog.pdf>

Mini-Split Heat Pumps (240V)

Figure 47: An example of a ductless mini-split heat pump outdoor compressor[100] mounted to stay above the snow and a wall-mounted indoor fan coil[101].

Mini-Split systems are comprised of a compressor outside the building and a fan inside the building. Mini split systems can also have many fans inside the building, commonly referred to as multi split systems, where one outside unit serves multiple fans or zones inside the building. Having multiple zones in the building allows for a more controlled, versatile arrangement of installations and temperature settings compared to a typical split HVAC system. Zones can be at different temperature settings while still being served by one outside unit. Multi/mini-split systems can be ductless (where refrigerant lines move heat around the building) or they can have mini ducts where air is moved around the building. Having no ducts prevents duct leakage energy losses but having many refrigerant lines running through the building can cause problems if they leak. In general, mini/multi split systems are more efficient than typical HVAC systems. No ducting also has an advantage because of reduced fan loads.

The Complete Cost of Mini-Split Systems

The following section gives an overview of the costs associated with hiring a contractor to install ductless heat pumps. The first table show the pricing for leading manufacturers for single-head and multi-head systems. Below is a 2019 interview with Jonathan Moscatello of the Heat Pump Store in Portland, Oregon, a description of the mark up on heat pump prices, and a description of costs for short ducted or mini-duct systems.

Single-Head					
	9k BTU	**12k BTU**	**15k BTU**	**18k BTU**	**24k BTU**
Daikin	$4,200	$4,450	$5,000	n/a	n/a
LG	$4,400	$4,500	$4,800	$5,000	$5,200
Panasonic	$4,400	$4,600	$5,800	n/a	n/a
Fujitsu	$4,600	$4,800	$5,100	$5,700	$5,900
Mitsubishi	$4,900	$5,400	$5,800	$6,100	$6,400

Multi-Head				
	2 Zone	**3 Zone**	**4 Zone**	**5 Zone**
Daikin	$6,800[a]	$8,500[a]	$10,500[a]	n/a
LG	$6,200[a]	$7,800[a]	$9,400[a]	n/a
Panasonic	$6,200	$7,100	$8,100	$10,200
Fujitsu	$7,400[a]	$9,000[a]	$11,200[a]	$12,500
Mitsubishi	$8,500[a]	$10,500[a]	$12,900[a]	$15,500[a]

- Multifamily installations, where the labor is onsite all day and able to accomplish 4-6 installations, cost ~30% less
- Indoor units involving simple installation method, the outdoor and indoor unit sharing an exterior wall with 15' of interconnecting line sets and electrical
- Indoor unit is of the high-wall mounted type
- $500 increase per indoor unit is typical when the refrigerant line set length increases to 25' or longer to cover the additional labor and materials to add refrigerant to the system
- Up to $1,000 increase per indoor unit when the indoor unit is located on an interior wall, necessitating that the refrigerant line set be installed through an attic or crawlspace
- [a] Indicates "cold climate" model

Interview on Heat Pump Pricing with Jonathan Moscatello of the Heat Pump Store in Portland, Oregon

The following section summarizes the correspondence between Sean Armstrong of Redwood Energy and Jonathan Moscatello of the Heat Pump Store in Portland, Oregon. Jonathan had just returned from China, where he has direct import relationships for ductless mini-split heat pumps, with decades in the business.

A lot of people are not clear about how heat pumps are sold in the market. Could you explain to us?

Sure, it's not that complicated, but it's true that most people aren't exactly sure how it works. The process starts with the Manufacturer--they sell to Distributors. I don't know what the Manufacturer pricing is, and generally it's not possible to buy directly from the Manufacturer. When you are a Contractor who wants to install a heat pump, you buy from the Distributor. Then you sell it the Client, and at each step there is a markup of 25 to 50%.

If the contractor is fair and the labor is well-trained and fairly paid, what is the total cost of installing a ductless mini split with one fan coil?

The lowest cost for a 1 ton, with one fan coil, that you'll see where someone can stay in business is $4,200 to do an individual house. For a 2-ton, $5,500 is the lowest price you would see. In multifamily, where a contractor could have a property owner or a general paying for electrical AND where the installers could be onsite for a week (operating in a highly productive installation - 4 to 6 systems per day) - we regularly see $3,000 per system installation—about 30% less than an individual home. I did this business for a number of years, and contractors take a lot of risks and work hard in difficult work environments.

How much does it cost to buy just the materials for a 1-ton mini split heat pump?

What the Contractor pays from the Distributor is $800 to $1,400 a ton, with the average around $1,200. Mitsubishi is an example of a $1,400 per ton product, while $1,200 a ton is found in products from Daikin, Panasonic, LG, and Aurora. What the contractor charges a client is 40% to 50% more than their price. So, $800-$1400 to the Contractor is $1100--$2100 to the Client, plus labor and additional materials.

Can you tell us about the cost for buying and installing a heat pump with multi-zone system, where there are 2-5 fan coils scattered in different rooms?

Well, if a 1-ton mini-split cost about $1,200, a 1.5 ton with two fan coils cost $1,600 to $1,800, and a 2-ton compressor with three fan coils cost about $3,200. Of course, this is marked up 40%-50% when sold to a client. The inside fan coils each cost about $450, while the compressor goes up in cost at about $800/ton.

What about the Labor costs for installing a ductless mini split?

Labor is a constrained resource. For a full-time job, labor is paid $25 an hour to $35 an hour, and sold to the client at $42 an hour to $60 an hour. To install a 1-ton heat pump by market leading contractors takes 2 to 4 hours, and for contractors who do not typically install ductless systems - that same work takes 4 to 8 hours because of contractor inefficiency, likely due to their relative inexperience.

Cost Breakdown of Overhead Minisplit Heat Pumps

Pricing of ductless heat pump installations vary widely due in large part to the margin goals of the installation company involved. Typically, installation companies fall into three margin categories based on attributes relating to their overhead and size. Below is an example of marked up costs and the breakdown of overhead pricing.

Table 1: Example of "Marked Up Costs" Pricing Model of Simple Installation of a Single Zone System.

Labor	$300 (5 hours x $60 per hour)
Equipment	40% of sale price or $1,200 (and up to $2,400 depending on equipment)
Materials	Approximately 5% of sale, roughly $300
Subcontractor (electrical)	$600-1000
Permits	$100-150
Subtotal	$2,500 /.6 (40% Margin)
Total	$4,166

Table 2: Cost breakdown of how overhead costs for mini split heat pumps.

Margin Categories	Attributes related to Overhead and Size	Gross Profit
Low	Staff size: less than 5 Business location: Work out of home Years in business: "New Entrants", less than 5. Type of work: Almost all installation sales. Annual revenue: under $1.5 million.	25-35%
Medium	Staff size: 5 to 15 Business location: Small shop with limited office space. Years in business: 5 to 15. Type of work: installation, with limited service and maintenance sales. Annual revenues: $1.5 to $3.5 million.	35-45%
High	Staff size: 15 to 50+ Business location: Professional office space, warehouse, loading dock. Years in business: over 15 years, often multi-generational. Type of work: Commercial and residential, installation, sales, and service. Annual revenue: over $3.5 million	>45%

What can you tell us about the installation costs of Short Ducted Heat Pumps?

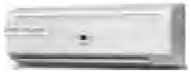
The pricing of so-called short run ducted mini-split systems varies widely, due in large part to the unique requirements of each installation. In general, the cost of equipment (only) used in short-run ducted split systems is comparable in cost to ductless split systems (when comparing the cost of equipment per unit of BTU output). The variability in installed cost comes from the labor and materials needed to install a ductwork system. In most installations, the ductwork system is newly installed instead of being reused from an older installation. In this way, the new ductwork system will satisfy the engineering requirements of the equipment and the space being conditioned.

The labor and materials involved in ductwork, insulation, air sealing and grills/registers should not be discounted. When ductwork is installed in attics and crawlspaces, the labor costs can increase when conditions make these spaces difficult to work in. When ductwork is installed within the conditioned space by attaching to the existing ceiling, there will be additional costs to install a "drop ceiling" to hide the ductwork. Many installers have found that when pricing short-run ducted systems, the ductwork materials can cost much more than the wholesale cost of the equipment.

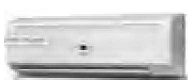
Given all the variability in labor and materials required to install a short-run ducted split system, most contractors price each installation as the opportunity arises. They do this by estimating the labor hours required in the prospective job, ask their distribution partner to provide a quote for all the materials and equipment needed, ask subcontractors for a quote, and finally enter all these costs into a spreadsheet whereby they apply a mark-up to satisfy their companies margin goals.

This method of marking up all the unique costs has many benefits to the installation company: it provides the installers with a materials and equipment list, and the company with a proforma model that they can manage by within should the company win the job. However, this pricing system doesn't provide government and utility programs with any simple pricing model to use.

Ductless Mini-Split Heat Pumps (120V)

Interior Wall-Mounted Fan Coil 	**GE** Caliber Series AS12CRA 	**Mitsubishi** MZ-JP12WA 	**Gree** LIV (09,12) HP115V1B 	**Carrier** 38MAR 	**Haier** 
Description	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil	1 Indoor Fan Coil
Dimension (in) (HxWxD)	21 x 31 x 10	22 x 32 x 11	33 x 21 x 13	32 x 21 x 13	28 x 35 x 14
Ref. Type	R410a	R410a	R410a	R410a	R410a
Ambient Temp. Range (H/C) (F)	**-4 - 115**	**-4 - 115**	**0 - 115**	**-13 - 122**	**-4 – 115**
Crankcase Heater	Not Indicated		Not Indicated	Not Indicated	Not Indicated
Power (W)		800 – 1,300	1,955	1,725	2,100
Max Amps (A)		11.8	17	15	18
Heating Cap. (BTU/h)	12,000	12,200	9,600; 12,500	12,000	16,000
Cooling Cap. (BTU/h)	12,000	12,000	9,000; 12,000	12,000	12,000
Heating (COP)	2.92	2.9	3.3	2.03 - 3.80	3.2
Cooling (COP)	2.92	2.9	4.67	3.8	3.75
Price ($)	$860	$1200	$790	$1800	

Ductless Mini-Split Heat Pumps (240V)

Interior Wall-Mounted Fan Coil 	**HAIER** Arctic Next Gen 	**Fujitsu** Halcyon Series 	**Mitsubishi** HyperCore FH50 	**MrCool** MDUO180(24-60) 	**LG**[102] Multi F MAX LGRED 
Description	1 Indoor Fan Coil	1 – 4 indoor Fan Coils	1 – 4 indoor Fan Coils	Pre-charged, 2 - 5 Fan Coils	2 - 5 Fan Coils
Dimension (in) (HxWxD)		39 x 38 x 14	36 x 9 x 12	56 x 38 x 13	54 x 24 x 15
Ref. Type	R410a	R410a	R410a	R410a	R410a
Ambient Temp. Range (H/C) (F)	**-31 / 95**	**-15 – 75 / 14 – 115**	**-13 / 115**	**-22 / 110**	**-13 – 64 / 14 – 118**
Crankcase Heater	Not Indicated	Not Indicated	Not Indicated	Not Indicated	Not Indicated
Power (W)	230 – 2,160	1,330 – 2,700	1,380 – 1,480	1090 – 3070	970 – 6,020
Max Amps (A)		16.4 - 26	13.6	14.8	23
Heating Cap. (BTU/h)	23,000	9,000 – 36,400	10,900 – 30,700	24,000 – 54,000	15,840 – 61,000
Cooling Cap. (BTU/h)	14,000	9,000 – 35,200	8,500 – 26,600	24,000 – 54,000	14,400 – 58,000
Heating (COP)	1.94 - 4.21	3.60 – 4.04	3.07 - 4.85	3.65	3.4
Cooling (COP)	2.74 - 4.46	3.52 – 3.60	3.31 – 4.11	4.12	4.1
Price ($)	$1,900	$ 2,000 - $5,000	$2,000 - $3,500	$3,000	$2,400 – 5,100

Ducted Mini-Split Heat Pumps

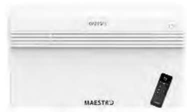
Attic Fan Coil and Ductwork 	**Senville** SENA/18HF/ID 	**Carrier** 38MGQC183 	**Gree** MULTI18HP230V1BO 	**Mitsubishi** MXZ3C24NAHZ2 
Indoor Unit Dimension (in)	34.7 x 28.5 x 8.27	36.2 x 8.3 x 25.0	35.4 x 7.9 x 24.2	37.4 x 16.4
Outdoor Unit Dimension (in)	33.3 x 14.3 x 27.64	33.3 x 27.6 x 12.6	38.0 x 27.6 x 15.6	41.3 x 37.4 x 13.0
Ref. Type	R410A	R410A	R410A	R410A
Ambient Temp. Range (F)	**-22 (cold climate)**	4 - 122	**-4 – 118 (cold climate)**	**-13 – 115 (cold climate)**
Crankcase Heater	Not Indicated	Not Indicated	Not Indicated	Not Indicated
Max Amps (A)	25	20	25	40
Heating Cap. (BTU/h)	18,000	18,500	19,000	25,000
Cooling Cap. (BTU/h)	17,000	17,500	18,000	22,000
Heating (COP)	3.0	2.8	2.6	2.6
Cooling (COP)	4.2	4.2	4.1	4.5
Per Indoor Unit Piping Length (ft)	98	98	65	82
Price for Outdoor Unit ($)	$ 1,400 (includes 50 ft refrigerant line)	$ 1,760 (no refrigerant lines)	$ 1,930 (no indoor units or refrigerant lines)	$ 3,110 (no ducting or refrigerant lines)

Attic Fan Coil and Ductwork 	**Pioneer** YN012GMFI22RPD 	**Mitsubishi** MXZ2C20NAHZ2 	**LG** LD127HV4 	**Fujitsu** 12RLFCD 
Indoor Unit Dim. (in)	27.5 x 17.8 x 7.9	16.4 x 37.4	7.5 x 27.6 x 38.3	7.8 x 27.6 x 24.4
Outdoor Unit Dim. (in) (HxWxD)	27.5 x 17.8 x 7.9	41.3 x 37.4 x 13.0	33.0 x 21.5 x 12.6	24.5 x 31.1 x 11.3
Ref. Type	R410A	R410A	R410A	R410A
Ambient Temp Range (F)	**-13 – 122 (cold climate)**	**-13 – 115 (cold climate)**	**-4 – 118 (cold climate)**	**-5 – 115 (cold climate)**
Crankcase Heater	Not Indicated	Not Indicated	Not Indicated	Not Indicated
Max Amps (A)	15	29.5	15	15
Heating Cap. (BTU/h)	12,000	13,700	16,000	16,000
Cooling Cap. (BTU/h)	12,000	18,000	11,600	12,000
Heating (COP)	3.37	2.79	3.1	3.4
Cooling (COP)	4.35	3.6	4.18	4.2
Per Indoor Unit Piping Length (ft)	82	82	66	66
Price for Outdoor Unit	$ 1,200 (includes 25ft refrigerant lines)	$ 2,780 (no refrigerant lines)	$ 2,050 (no refrigerant lines)	$ 1,660 (no refrigerant lines)

Packaged Terminal Heat Pumps (240V and 120V)

PTACs and PTHPs are all-in-one HVAC units that are used to heat and cool 1 to 3 rooms. These types of units are ductless and can be hung from a wall and ducted through (e.g., Innova, Sakura), mounted in a window or placed into a cutout in the wall. Packaged units deliver heating or cooling directly to the space, avoiding energy losses from ductwork but introducing potential leaks around the product if it is not sealed.

(120V) Packaged Terminal Heat Pumps

Manufacturer and Product Image	**Innova** HPAC 2.0 	**Olimpia** Maestro 	**Frigidaire** FFRH1122UE 	**Friedrich** YS10N10C 	**Gree** 26TTW09HP115V1A 
Description	Twin ducts through the wall, dehumidification, Resistance back-up	Twin ducts through the wall, dehumidification	Heat pump with Resistance (ER)	Heat pump model – no back up Resistance	Heat pump model with Resistance (ER)
Voltage (V)	120	120	120	120	120
Dimension (in)	1.8H x 3.3W x 0.5D	-	15H X 22W x 23D	15H x 25W x 29D	15H x 26W x 16D
Ref. Type	R410a	R410a	R410a	R410a	R410a
Min. Heat Pump Operating Temp (F)	**-14 (cold climate)**	**5 (cold climate)**	40	40	29
Power (W)	545 – 730	830-850	780 – 1,290	917 - 978	830 – 1,150
Heating Capacity (BTU/h)	3,100 - 10,000	10,600 (Heat Pump only)	9,900 (HP) 3,500 (ER)	8,000	6,600 (HP) 3,900 (ER)
Cooling Cap. (BTU/h)	2,600 - 10,000	11,600	11,000	10,000	9,000
Heating (COP)	2.84 – 3.22	3.8	2.63	2.6	3
Cooling (COP)	3.12 – 3.28	3.8	2.87	3.19	2.87
Price ($)	$1950	$1700-$2300	$ 700	$ 1000	$ 700

(240V) Packaged Terminal Heat Pumps

Manufacturer and Product Image	**Amana** AH (093,123,183) 	**Friedrich** Y (S12, M18, L2) 	**Gree** W (07,09,12) 	**LG** LP (073,093,123,153) 
Description	Heat pump model	Heat pump model – no back up ER	Heat pump model with ER + dehumidification	Heat Pump with ER, but HP functions in cold climates
Voltage (V)	208/230	230/208	230	208/230
Dimension (in)	16H x 26W x 27D	20H x 28W x 35D	15H x 26W x 16D	16H x 42W x 21D in
Ref. Type	R410a	R410a	R410a	R410a
Ambient Temp. Range (H/C) (F)	61 - 86	60 - 115	29 - 125	**-4 - 75 / 54 – 115 (cold climate)**
Power (W)	920 – 3,680	1,100 – 2,400	680 – 3,500	2,300 - 4,700
Amps (A)	4.2 – 16.0	4.9 – 19.5	3.0 – 15.2	15,20, 30-amp cord
Heating Capacity (BTU/h)	10,700 – 9,000 (ER) 8,100 – 16,00 (HP)	11,300 – 22,000	3,900 – 11,000 (ER) 6,600 – 11,400 (HP)	6200- 13,400
Cooling Cap. (BTU/h)	9,200 – 17,300	12,000 – 24,00	7,200 – 11,700	7,100 – 14,900
Heating (COP)	2.6 - 2.9	2.6 -2.7	2.9 – 3.1	3.1 – 3.5
Cooling (COP)	2.63 – 2.93	3.02 – 3.19	2.81 – 3.11	3.28 – 3.90
Price ($)	$ 700 - 1,250	$ 1,000 - 1,500	$ 930	$ 1,000 – 2,000

Portable Air Source Heat Pumps (120V)

Heat pumps can come on wheels for those who want to electrify their space heating but may not have the budget or permission from the landlord to install a permanent, whole house solution.

These retrofit-ready heat pumps can plug into any outlet in a home and come with ducts that fit into an open window. The ducts allow outside air to be pulled in as a heat source or sink and then exhausted while the heat pump heats or cools the inside air. They can do additional work as powerful dehumidifiers, with a storage tank and/or condensate drain line.

Figure 48: A "two-pipe" portable heat pump.

Manufacturer and Product Image	**Edge Star** 	**Black + Decker** BPACT12HWT 	**Whynter** ARC-14SH 	**Haier** HPND14XHT 
Voltage	120V	120V	120V	120V
Power (W)	1250W (cool)/ 1200W (heat)	-	1250W	1260W (cooling)
Max Amps (A)	-	9A	10.8A	11.4A
Dehumidifying Capacity	85 pints/day	-	101 pints/day	88.8 pints/day
Heating Capacity (BTU/h)	14,000	10,000 and 11,000	13,000	10,000
Cooling Capacity (BTU/h)	14,000	14,000	14,000	14,000
Temperature Range F (Output)	61 - 89	55 - 81F	61 - 89	61 – 100 *(can go below freezing at lower capacities)*
Refrigerant	R410a	R410a	R32	R410a
Dimensions (in) (HxWxD)	35 x 19 x 16	28 x 17 x 14	36 x 19 x 16	29 x 15 x 17
Price	TBA	$697	$575	$670

Hydronic Heat Pumps (Air-to-Water) (240V)

The air to water (aka hydronic) heat pumps are used in radiant floor heating, domestic hot water and swimming pools and hot tubs in cold climates—note in blue the ambient temperatures in which they can operate.

Manufacturer and Product Image	**Stiebel Eltron** WPL (15,20,25) (AS, ACS) 	**Arctic** 020A 	**Spacepak** Split System Inverter 	**Aermec** **ANK** (030,045,050) 	**Chiltrix** CX34 	**Nordic** ATW Series 
Description	Air-to-water heat pump outdoor unit, combined DHW and HVAC	Hydronic Heating, Domestic Hot Water, Pools and hot tubs	Air to water, heating and cooling, inverter compressor	HVAC and DHW combination	Air to Water Heat Pump	Hydronic heating, fan coils air-conditioning
Voltage (V)	230	220-240V	240	208/230	220	208/230
Dimension (in) (HxWxD)	-	33 x 18.5 x 45	55H x 35W x 15D	50H x 58W x 18D	38.15 x 43.9 x 16.74	34 x 34 x 35
Ref. Type	R410a	R410a	R410a	R134a	R410a	R410a
Ambient Temp. Range (H/C) (F)	**-4 (Air) – 140 (Water)**	**-15 (cold climate)**	**-22 – 105 (cold climate)**	**-4 – 107 (cold climate)**	**-4 – 122 (cold climate)**	**-7 - 120**
Power (W)	1,090 -7,530	2,710 - 3,000	5,200 – 9,500	2,810 – 4,520	360 - 2,360	1,190 – 2,500
Max Amps (A)	7.9 - 30	15	32	45	15	15 - 30
Heating Cap. (BTU/h)	8,525 – 46,500	35,826	21,000 – 68,000	37,670 – 57,598	4,000 - 33,800	4,280 – 22,700
Cooling Cap. (BTU/h)	7,330 – 58,000	25,600	20,400 – 51,600	30,120 – 48,240	4,000 – 30,000	17,400
Heating (COP)	1.85-5.09	3.14	4.23	3. 1 – 4.4	3.92	1.38 - 4.94
Cooling (COP)	2.39-3.76	2.5	4.09	-	6.75	1.57 - 5.84
Price		$3750	$7500	$5500-$7500	$4300	$5000

Manufacturer and Product Image	**Stiebel Eltron** WPL (15,20,25) (AS, ACS) 	**Stiebel Eltron** WPL (19A, 23A) 	**Chiltrix** CX34 	**Nyle** C25A – C250A 
Description	Air-to-water heat pump outdoor unit, combined DHW and HVAC	Air-to-water heat pump outdoor unit, combined DHW and HVAC	Air to Water Heat Pump	Air to Water Heat Pump
Voltage (V)	230	230	220	208/230/440-480/575
Dimension (in) (HxWxD)	41 x 59 x 23	55 x 49 x 50	38.15 x 43.9 x 16.74	-
Ref. Type	R410a	R410a	R410a	R134a
Ambient Temp. Range (H/C) (F)	**-4 (Air) – 140 (Water) (cold climate)**	**-4 (Air) – 149 (Water) (cold climate)**	**-4 – 122 (cold climate)**	**35 - 120**
Power (W)	1,090 -7,530	2,900	360 - 2,360	5,500 - 24,000
Max Amps (A)	7.9 - 30	15	15	(@ 240V) 28 - 150
Heating Cap. (BTU/h)	8,525 – 46,500	25,000; 31,000	4,000 - 33,800	27,500 – 272,500
Cooling Cap. (BTU/h)	7,330 – 58,000	-	4,000 – 30,000	21,200 – 218,000
Heating (COP)	1.85-5.09	3.0 - 4.12	3.92	(max) 4.58 – 5.33
Cooling (COP)	2.39-3.76	-	6.75	(max) 3.88 – 4.33
Price	-	-	$4300	-

Geothermal Heat Pumps (Ground/Water-to-Air/Water) (240V)

Geothermal Heat Pumps rely on the constant temperature in the ground or a large body of water to deliver conditioned air to a home year-round, typically their coils are buried in the ground and can have various configurations (vertical, horizontal, etc.). In the winter when the temperature above ground is lower than the temperature below the ground, the heat from the ground is transferred into the building for space heating, and vice versa in the summer for cooling. Geothermal heat pumps can provide space heating, space cooling, domestic hot water heating and/or pool heating. For domestic hot water, a desuperheater (which is a small heat exchanger) uses the heat generated form the compressor to heat water for the home. For pool heating, either the heat from the ground can be transferred directly to the pool, or the heat from the ground can be transferred to a compressor (with refrigerant lines) to then heat the water further. Each unit pictured works with ground loops, water loops or ground water loops with optional hot water.

Manufacturer and Product Image	**Nordic** R Series Residential 	**Water Furnace** 7 Series - 700A11 	**York** York Affinity YAF 	**Geostar** Aston Series 	**Bosch** Green Source ES Model 
Voltage (V)	208/230	208/230	208/230	208-230	208-230
Dimension (in) (HxWxD)	66 x 36 x 44	58 x 32 x 26	25x31x58	25x31x58	21x26x54
Ref. Type	R410a	R-410a	R-410A	R_410A	R-410a
Ambient Temp. Range (H/C) (F)	23 - 110	45 – 85 / 45 – 100 (air) 20 – 90 / 30 – 120 (water)	45-100/45-85(air) 30-120/20-90(water)	(45-100) air (30-120) water	50-100
Power (W)	1203- 1,764	-	-	-	-
Max - Amps (A)	7.8	32 - 46	-	-	-
Heating Cap. (BTU/h)	15,200 – 23,000	13,000 – 78,000	14,000-85,000	16400-19500	20,500-80,000
Cooling Cap. (BTU/h)	20,100 – 26,800	11,000 – 60,000	11,000-66,000	21000-26000	18,000-72000
Heating (COP)	3.7 - 4.9	3.5 - 7.6	4.6-5.9	3.4-5.88	3.6-4.1
Cooling (COP)	5.7 - 9.6	4.7 – 15.6	3.8-5.2	4.8-7.032	41-7.6

Heat and Energy Recovery Ventilation (HRV and ERVs)

Heat Recovery Ventilators (HRV) and Energy Recovery Ventilators (ERV) are the same systems but with a different heat exchanger core. The ERVs heat exchanger allows water droplets to be transferred with the heat. The key difference is that an ERV will make your home more humid in winter, and less humid in summer, compared with an HRV.[103] The goal with an HRV is rid the house of its stale, moist air while transferring the maximum amount of heat into the clean incoming air. This keeps your heat and money inside while filtering contaminated air out. The location of the project will generally determine need for an HRV or ERV.

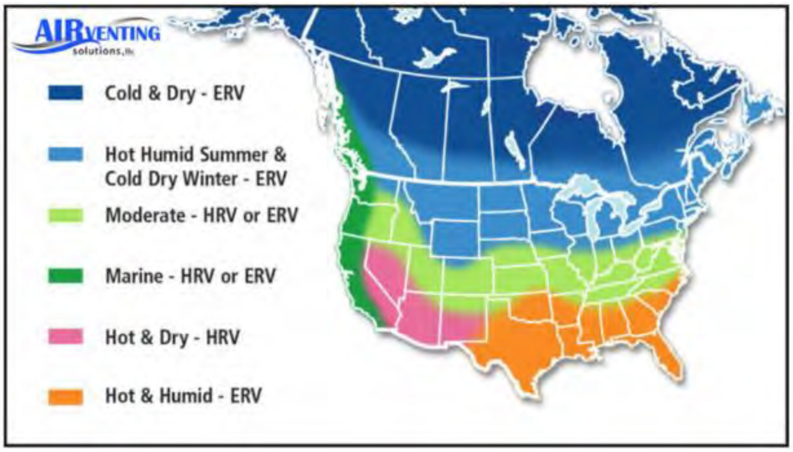


Figure 49: Choosing an HRV or ERV system based on location map.[104]

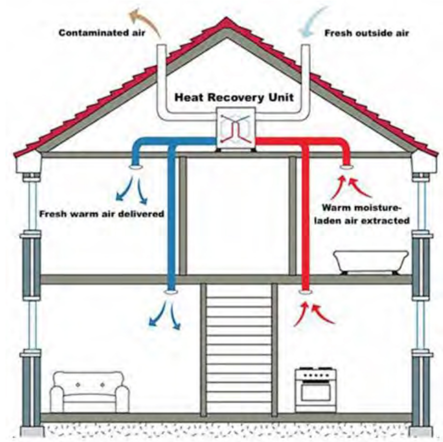


Figure 50: Heat Recovery ventilation system example.[105]

The unit operates continuously, sucking air through ducts that are positioned in prime generation locations of moisture and odor ex. bathrooms and kitchen. As the air flows out to an exterior vent, it passes through a metal box containing a matrix of crimped aluminum plates, full of air channels. At the same time, fresh outdoor air is being sucked into the building, passing through the same box on its way to outlets located in two central locations. The two airstreams never mix, but as they pass each other, heat migrates from the warm outbound stream to the cool inbound, preheating it and reducing load on the heating plant. There is no running cost to this process as all of its operations are done by the laws of physics. In the summer, the system works in reverse, using the house's cooler conditioned air to strip off some of the incoming fresh air's heat, precooling it and reducing load on the air-conditioning system.

Manufacturer and Product Image	**Fantech** VHR70 Fresh Air Appliance 	**Fantech** FLEX 100H ES Fr. Air Appliance 	**BLAUGER** ERV EC D(R) 150 	**Zehnder** ComfoAir Q350 	**BLAUGEG** KOMFORT EC D5B180(-E) 	**BLAUBERG** KOMFORT EC SB5506 
Max air flow	57 CFM	104 CFM	181 CFM	206 CFM	220 CFM	441 CFM
Home size	1-to-3-bedroom homes	3 to 4 bedrooms homes	Apartments to small homes	Medium to large homes	Large apartments and homes	Large homes
Ambient / Transported air temp [°F]	-13 to 32 heating	-12 to 32 heating	-13 to 32 heating	-4 to 104	-13 to 140	-13 to 140
Voltage	120	120	120	240	120	120
Max Amps (A)	0.4	1.6	2.5	1.42	0.71	2.3
Sensible Recovery Efficiency (%)	61-72% from -13°F to 32°F	62% - 65% from -12°F to 32°F	77% - 82% from -13°F to 32°F	86.5%	88-98%	88-98%

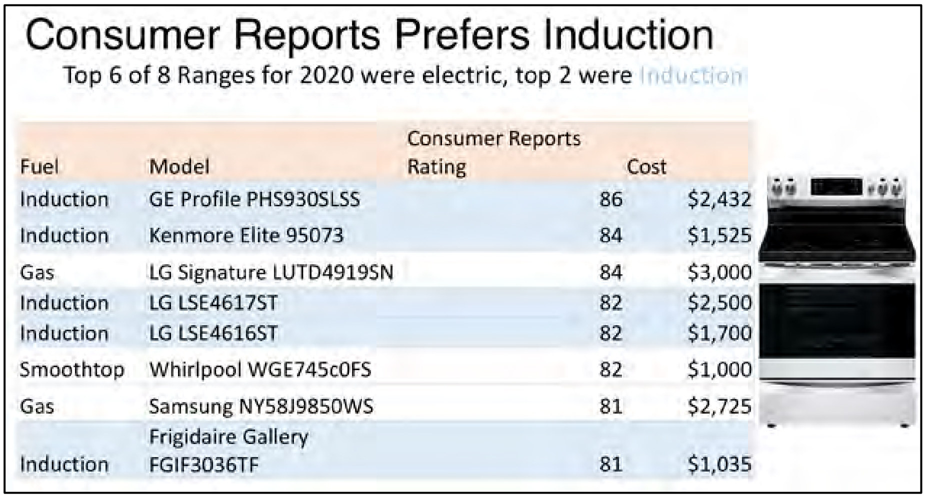
ERV, HRV, and Heat Pump Combined Products

The products shown below are all-in-one systems that provide filtered ventilation as well as heat pump heating. They are most applicable to small apartments but could also be used for tiny homes and smaller zones within a larger home. The CERV-2 for example, is used by VEIC for their zero net energy highly efficient modular homes.

Manufacturer and Product Image	**CERV-2** 	**Minotair** Pentacare V12 	**Ephoca** xK92NSGx 
Description	Ducted Ventilation and Heat Pump – HRV Combo	Ducted Heat Pump, HRV, and Ventilation (MERV-15) Combo with 5kW resistance heat	Ducted Ventilation, Heat Pump, ERV, MERV-13 filtration
Unit Dim. (in) (HxWxD)	38 x 25.5 x 40	16 x 18 x 40	39 x 38 x 10
Refrigerant	R410a	R410a	R410a
Ambient Temp Range (F)	**No low temperature cutoff**	**No Low Temperature cutoff, resistance heater is controlled for efficiency**	**-5F**
Voltage	120V	120V / 240V	240V (120V available)
Max Amps (A)	12A	6.6A (HP-only), 27A Max	15
Heating Cap. (BTU/h)	9,720 (17F) – 11,262 (47F)	5,600 (17F) – 8,700 (47F)	10,300 – 16,600 (47F)
Cooling Cap. (BTU/h)	7,544 (95F)	11,200 (95F)	3,100 – 10,500
Heating (COP)	2.8 – 3.6	2.4 (17F) – 3.0 (47F)	4.0
Cooling (COP)	3.2	3.3 (95F)	3.6
Price for Unit	$6000	$6000	$4000 Wholesale, $6000 Retail

Electric Cooking

The LED “flame” of a Samsung induction stove (at left) is an example of how intuitive it can be to transition to cleaner, faster, and safer all-electric cooking. Gas stoves cause unhealthy levels of Nitrous Oxides that would be illegal if it were from a gas power plant. After just twenty minutes of cooking and a sunny window, a kitchen can have actual smog and trigger asthma and lung ailments. Gas cooking appliances are 25-40% efficient, while electric cooking appliances are 70-95% efficient, meaning electric kitchens use $1/3^{rd}$ as much energy and require only $1/3^{rd}$ as much cooling. Using electric appliances avoids the construction costs and costs to run extra gas venting equipment. In addition to being more efficient, induction cooking appliances are faster, provide more temperature control and cause less kitchen fires than gasstoves. [106] Below are products that facilitate both retrofits and new construction with high performance cooking equipment. Countertop products do not require any installation retrofits and plug into a standard wall outlet. Drop-in cooktops, on the other hand, are installed into a cut-out of the countertop and hard-wired to a 120V or 240V outlet. Electric cooking comes in a variety of technologies, standard electric, glass top radiant electric, and induction.



Consumer Reports Prefers Induction

Top 6 of 8 Ranges for 2020 were electric, top 2 were Induction

Fuel	Model	Consumer Reports Rating	Cost
Induction	GE Profile PHS930SLSS	86	$2,432
Induction	Kenmore Elite 95073	84	$1,525
Gas	LG Signature LUTD4919SN	84	$3,000
Induction	LG LSE4617ST	82	$2,500
Induction	LG LSE4616ST	82	$1,700
Smoothtop	Whirlpool WGE745c0FS	82	$1,000
Gas	Samsung NY58J9850WS	81	$2,725
Induction	Frigidaire Gallery FGIF3036TF	81	$1,035

Figure 51: Consumer Reports prefer induction, the top 6 of 8 ranges for 2020 were induction.

Glass Top Radiant Range ($550 or less)

Manufacturer and Product Image	**Amana** AER6303MFS 	**Whirlpool** WFE320M0ES 	**Frigidaire** FFEF3052TS 	**GE Appliances** JBS60DKBB 
Max Power (Watts)	1,800	3,000	100-3,000	3,100
Price	$450	$550	$550	$550
Oven space (cu. ft)	4.8	4.8	4.9	5.3

Glass Top Radiant Range (Greater than $500) (240V using a 40amp circuit)

Manufacturer and Product Image	**Samsung** NE59M4310SS/AA 	**GE** JB480DMBB 	**LG** LSSE3026ST 	**Bosch** 800 Series 
Max Power (Watts)	9,600	10,500	13,500	14,800
Price	$700	$950	$1,800	$2,200
Oven Space (cu. ft)	5.9	5.0	6.3	4.6

Slide-In Induction Ranges (240V, 40 amp)

Manufacturer and Product Image	**Frigidaire** FFIF3054TS 	**LG** LSE4616ST 	**Frigidaire** Gallery FGIH3047VF 	**Samsung** Virtual Flame NE58K9560WS 	**GE** Profile PHS930SLSS 
Price	$1,000	$1,900	$2,000	$2,400	$2,440

Slide-In Induction Range (240V, 40 amp)

Manufacturer and Product Image	**KitchenAid** KSIB900ESS 	**Bosch** HII8056U 	**Café** CHS900P2MS1 	**Bertazzoni** Professional PROF304INSROT 	**Fisher & Paykel** Series 9 OR36SCI6R1 
Price	$2,970	$3,400	$3,420	$4,990	$7499 (50 amp)

Retro Induction Ranges

Manufacturer and Product Image	**Smeg Range Cooker Victoria** TR4110IPG 	**Retro Collection** BCRI30 	**Elmira Northstar** 1954P 	**Ilve Majestic II Collection** UMDI10NS3MBP 	**AGA Classic** ATC3 
Price	$3,500	$5,100	$5,800	$9,100	$22,000
Max Power (W)	8,400	2,500	2,500	12,000	9,600
Oven space (cu. ft)	-	4.0	4.3	3.82	1.4 per oven

Single Burner Countertop Induction (1800W, 120V and using a 15amp circuit)

Manufacturer and Product Image	**Aicok** 	**Avantco** ICBTM-20 Light Duty 	**Avantco** IC1800 Heavy Duty 	**NuWave** PIC Platinum 	**Vollrath** Mirage Cadet 59300 
Price	$40	$50	$120	$200	$270
Temp. Range	140°F - 460°F	140°F - 460°F	140°F - 460°F	100°F-575°F	100°F - 400°F

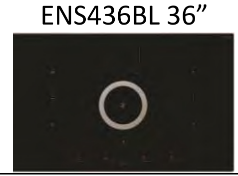
Single Burner Drop-In Induction (1800W, 120V and using a 15amp circuit)

Manufacturer and Product Image	**True Induction** TI-1B 	**Avantco** DC1800 	**Adcraft** IND-DR120V 	**Spring** SM-651R 	**Bon Chef** 12083 
Price	$140	$170	$190	$440	$500
Temp. Range	150°F-450°F	140°F-464°F	Up to 464°F	145°F-185°F	150°F-450°F

Double and Triple Burner Countertop Induction (1800W, 120V and using a 15amp circuit)

Manufacturer and Product Image	**Eurodib** S2F1 	**True Induction** TI-3B 	**NuWave** PIC Double 	**Inducto** 	**Duxtop** 9620LS 
Price	$200	$525	$200	$150	$190
Temp. Range	150°F -450°F	140°F -460°F *(Three Burners!)*	100°F – 575°F	176°F -460°F	140°F -460°F

Four+ Burner Induction Stovetops (9600W, 240V using a 40amp circuit)

Manufacturer and Product Image	**Empava** IDC-36 36" 	**Bosch** NETP068SUC 30" 	**Samsung** NZ36K7880UG 36" 	**Frigidaire** FPIC3677RF 36" 	**Elica** ENS436BL 36" 
Price	$900	$1,300	$2,300	$2,500	$4,410

Cooking Energy Use with High Efficiency Cookware

Five types of cookware were compared to find the lowest possible use of cooking energy. Three are insulated; a Crock-Pot slow cooker, a COSORI pressure cooker and an Air Core insulated pot and two non-insulated; a SUNAVO electric hotplate and a Avantco countertop induction range. The standard cooking material used for each type of cookware was chickpeas. One cup of dried chickpeas was soaked for 8 hours, and drained. It was then added to the cookware with 4 cups of room temperature water. The chickpeas were declared fully cooked when the color change was consistent all the way through but not so far as the chickpea would become saturated and lose it structure. For both stovetop methods the pot of water was brought to a boil then left to simmer until the chickpeas cooked to the required texture. Time and energy use in kWh were taken from a P3 P4400 Kill A Watt Electricity Usage Monitor.

Insulating your cookware saves energy by dramatically reducing heat loss during cooking. This study concluded that the ideal cookware to reduce energy consumption are the pressure cooker or slow cooker. Time is always a factor when it comes to the convenience of cooking, so pressure cooker is a great way to limit cooking time while getting similar low energy use as a slow cooker. For a traditional cooking experience, the induction stove top is a great alternative to the electric resistance cooktop. This method saves about 40 minutes in cooking time and uses about 22% less energy.

Manufacturer and Product Image	**Crock-Pot** SCR200-R slow cooker 	**COSORI** C3120-PC pressure cooker 	**Avantco** IC1800 countertop induction range 	**SUNAVO** 1500W electric resistance cooktop 	**Air Core** insulated pot w/ SUNAVO electric resistance 
Price	$10	$70	$110	$50	$50
Cooking time (hours)	2.76	0.34	1.21	1.87	0.34
Energy use (kWh)	0.19	0.19	0.64	0.82	0.31
Cost (cents)	3.2¢	3.2¢	10.7¢	13.7¢	5.2¢

**Cost is calculated from the Californian 2019 average of 16.7 cents per kWh.*

Countertop Ovens (120V)

Are you looking to cook a full rotisserie chicken, but live in a tiny home or small electrified apartment? Well look no further, you can live large on a small circuit - countertop kitchen ovens are widely popular and can satisfy your oven cooking needs. The collection below represents the largest countertop ovens on the market that have various functions like convection and air fry technology.

Manufacturer and Product Image	**Luby Large** Toaster Oven 	**Aobosi** Convection Toaster Oven 	**Galanz Airfry** Toaster Oven 	**Oster** Countertop Oven 
Oven Size (ft^3)	1.9	1.6	1.5	1.3
Dimensions (DxWxH) (in)	16.1 x 22.0 x 14.4	26.2 x 19 x 18.5	19.3 x 21.8 x 13.0	22.0 x 19.5 x 13.0
Power (W)	1800	1500	1800	1525
Price	$133	$169	$199	$220
Remarks	Mfr. Claims to be able to roast a 20 lb. turkey	Has rotisserie as well as upper and lower heating element settings	"Toast function" French doors	French door design allows for single door to be opened when checking on food. Dials or digital touch interface.

Manufacturer and Product Image	**Black and Decker** Toaster Oven 	**KitchenAid** Dual Convection Countertop Oven 	**Breville** BOV900BSS Smart Oven Air 	**Hamilton Beach** Convection Oven 
Oven Size (ft^3)	1.1	1	1	-
Dimensions (DxWxH) (in)	21.5 x 14.5 x 11.2	16.4 x 18.5 x 13.0	17.5 x 21.5 x 12.7	20.6 x 16.5 x 13.1
Power (W)	1500	1800	1800	1500
Price	$105	$280	$400	$130
Remarks	Airfry setting Can fit a 9"x 13" pan	Built in temperature probe "Can bake 2 whole chickens (based on 3.6 lb. weight)"	14 lb. turkey, LCD display, 6 independent heating elements, 13 cooking functions	Rotisserie, convection

Kitchen Hoods (Low Sound, High Air Flow)

To evacuate pollution from cooking properly, a quiet yet high air flow kitchen hood is essential. The effectiveness of kitchen hoods is so important that California is instituting a new policy in their building energy code - kitchen hoods for electric stoves must have a flow rate of 110 to 160 cfm and gas stoves must have a flow rate of 180 to 280 cfm, depending on the size of the unit. Venting pollution from gas cooking requires a higher flow rate because gas creates more pollutants when burned (like NO2, which is regulated by the EPA to maintain high outdoor air quality). The kitchen hood must also be at a sound level of 3 sones or less, so residents can use them comfortably. The following kitchen hoods meet this requirement in California, and are considered products for best practices for efficient, comfortable, and all-electric buildings.

Proposed minimum range hood capture efficiency (CE) requirements, and proposed alternative airflow compliance requirements for demand-controlled range hoods

Dwelling Unit Floor Area (ft^2)	Hood Over Electric Range	Hood Over Natural Gas Range
>1500	50% CE or 110 cfm	70% CE or 180 cfm
1000 - 1500	50% CE or 110 cfm	80% CE or 250 cfm
750 - 1000	55% CE or 130 cfm	85% CE or 280 cfm
<750	65% CE or 160 cfm	85% CE or 280 cfm

Or
Downdraft exhaust with minimum of 300 cfm (no change from 2019 requirements)
Or
Continuous exhaust at 5 kitchen ACH50 (applies to enclosed kitchens only – no change from 2019 requirements)

Quiet Kitchen Hoods

Manufacturer and Product Image	**ProLine** PLJW 125 series 	**Zephyr Power** Typhoon Series AK2100BS 	**KOBE** Brillia CHX91 SQB-1 	**KOBE** Premium RA38 SQB-1 	**FOTILE** JQG7501 
Noise (sones)	1.5 @ 385 CFM 7.5 @ 900 CFM	2.5 @ 300 CFM	3 @ 300 CFM	3 @ 300 CFM	2.64 @ 510 CFM
Air Flow (CFM)	900	850	680	680	850
Width (inches)	30, 36	30, 36, 42, 48	30, 36	30, 36	30
Cost ($)	$719 (30 in) $740 (36 in)	$679 (30 in) $629 - $709 (36 in)	$593 (30 in) $600 (36 in)	$539 (30 in) $575 (36 in)	$1,099.00

Quiet Low-Cost Hoods Compliant with 2022 Code

Manufacturer and Product Image	**Broan** QS136AA 	**Broan** RP136WW 	**Broan** 	**Whirlpool** WVU57UC0FS 	**KitchenAid** KVUB400GSS 30" 	**BV** Range Hood 
Noise (sones)	5.0 @ 210 CFM 5.0 @ 220 CFM 5.0 @ 230 CFM	0.5 @ 120 CFM* 7.0 @ 440 CFM	1.2 @150 CFM 3.0 @ 200 CFM 5.5 @ 280 CFM	0.5 @ low speed 5.2 @ 350 CFM	0.1 @ low speed 5.2 @ 400 CFM	1.5 @ 200 CFM 7.5 @ 750 CFM
Air Flow (CFM)	210/230 vertical, 220 horizontal	440	300	350	400	750
Width (inches)	36"	36"	30”	30"	30"	30"
Exhaust Method	Ducted & Ductless	Ducted	Ducted & Ductless	Ducted & Ductless	Ducted & Ductless	Ducted
Cost	$85	$170	$200	$220	$365	$340

*compliant airflow for a dwelling unit of 1500 ft^2 or less floor area

Electric Laundry Dryers

As our building systems become more efficient, the energy use of appliances becomes more apparent. Laundry loads can sometimes be the largest load, so ensuring that the most efficient equipment is used is important. More surprising may be that the first cause of high consumption is convenience—households with in-unit laundry run twice as many loads as households with only access to a central laundromat.[107] While washing machines and clothes dryers use about the same amount of motor energy per load, boiling the water out of wet laundry uses 81% of all the energy in an average laundry load in 2010,[108] assuming one is using a standard ~30% efficient gas dryer, rather than a ~250% efficient electric heat pump dryer.

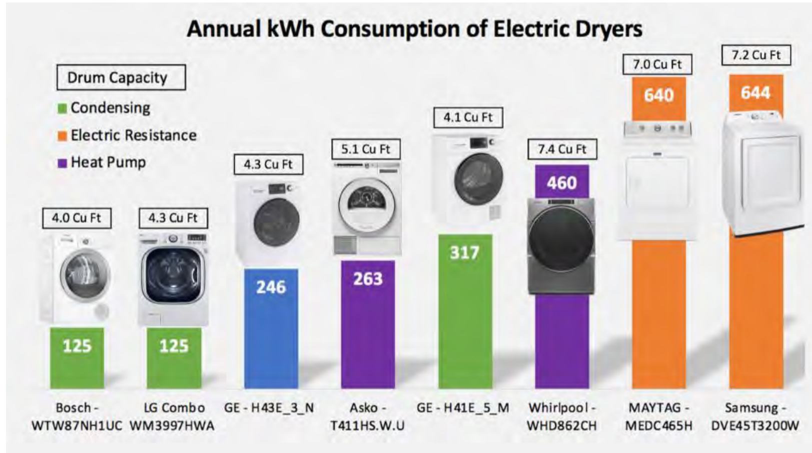


Figure 52: Relative dryer energy use, condensing dryers and heat pump dryers use roughly half the energy of a standard electric resistance dryer.

Energy Star, a program led by the US Environmental Protection Agency (EPA), aims to inform consumers and businesses on how to cut down on operating costs by listing and ranking energy efficient products[109]. Until recently, both residential and commercial/coin-operated clothes drying machines were excluded from the list of Energy Star rated appliances because of their consistently high-power demand between all products available on the market. Innovative technologies like moisture sensors, heat pump drying and condensation drying have led to a rise in the availability of residential-grade Energy Star rated dryers.[110]

Condensing Washer & Dryer—**A combined appliance**

Condensing Washer/Dryers combine both space and energy efficiency, and are ventless—laundry water instead goes down the drain. They are most common in retrofitted apartments in Europe, and run on 120V outlets, using as much energy as a hair dryer on medium and stresses fabrics less. After washing the clothes, the same machine dries the laundry using a condenser. A laundry cycle, from loading to unloading, takes 2-4 hours, depending on the fabric and load size.

"Oh my God, it's a dream come true. **Set it and forget it is best thing since sliced bread…** we throw our laundry in when we go to bed and wake up to a fresh ready batch. I'll never go back to the disappointment of opening up to wet laundry." – ***Sierra Martinez, a satisfied condensing combined washer/dryer user***

Combination Condensing Washer & Dryer (120V)

Manufacturer and Product Image	**Magic Chef** MCSCWD20W3 	**Haier** HLC1700AXW 	**Summit** SPWD2201SS 	**Deco** DC4400CV 	**Whirlpool** WFC8090GX 	**LG** WM3998HBA 
Price	$720	$1,000	$1,000	$1,200	$1,500	$2,000
Energy Use (kWh/year)	85	65	65	96	180	120
Drum Capacity (cu. ft.)	2.0	2.0	2.0	3.5	2.8	4.5
Volts/Amps	120V/12A	120V/10A	115V/12A	110V/15A	240V/30A	120V/10A

Heat Pump Dryers

Heat pump dryers are also ventless but maintain a higher temperature than a condensing dryer and lower than that of electric resistance, and therefore dry clothing at a rate between the two. Note that smaller drum sizes hold less clothes, and consequently take less time to dry. Hybrid heat pump dryers combine resistance elements and heat pump technology to improve overall energy efficiency.

Heat Pump Dryers (240V)

Manufacturer and Product Image	**Samsung** DV22N685H 	**Blomberg** DHP24400W 	**Kenmore** Elite 81783 	**Beko** HPD24412W 	**Whirlpool** Hybrid WHD560CHW 	**Miele** TWI180WP 
Price	$1,000	$1,100	$1,100	$1,300	$1,250	$1,900
kWh/year	145kWh/year	149kWh/year	-	149kWh/year	460kWh/year	133kWh/year
Drum Capacity (cu. ft.)	4.0	4.1	7.4	4.1	7.4	4.1
Cycle Time (min)	60	46	-	46	70	35

Standard Electric Dryers

Energy Star ranked Laundry Dryers use a variety of strategies to better eliminate water from clothes, such as fans, humidity sensors and heating technologies. Electric resistance dryers require a vent, while condensing dryers do not. The following products use electric resistance to dry clothes.

Standard Electric Dryers (240V)

Manufacturer and Product Image	Samsung DV45K76E 	LG DLE1501 	GE GTD65EB 	Maytag MED3500W 	Whirlpool WED75HEFW 	Electrolux EFME417 
Price	$400	$450	$500	$650	$650	$700
Drum Capacity (cu. ft)	7.4	7.4	7.4	7.4	7.4	8.0
kWh/year	607	607	608	608	608	608

Energy Management Systems

This section focuses on products that can monitor energy in the home as well as control it. The smart panels and smart circuit splitters shown below can avoid power upgrades by prioritizing different electric loads, like pausing EV charging, allowing the dryer to run, then restarting EV charging. Other products allow scheduling loads, connecting with solar PV, and home battery charging optimization, among many other features. See above for the Ossiaco product.

Whole House Panels

	Span[111] 	**Eaton**[112] Pow-R-Command 	**Koben**[113] GENIUS Smart Panel 
Cost	$2,500 including installation costs	TBA	TBA
Description	• Can monitor and control electrical usage at the circuit level • Puts control into the hands of the homeowner with intuitive smartphone app • Plug-in-play solution for rooftop solar, battery storage and EV charging	• Control lighting and plug loads with time and space occupancy schedules to maximize energy savings • 15 A, 20 A and 30 A configurations in single- and two-pole models suitable for voltage systems up to 480V • Can add expansion panels up to 168 controllable circuit breakers	• Allows home to become "Smart Grid" ready • Can integrate EV Charging, Solar, Battery Storage, Generator, and your utility whether you are planning for the new energy era or have already installed your new energy technology.

Subpanels

Eaton[114] Energy Management Circuit Breaker (EMCB)  **Available for purchase**	• Programmable breakers to prioritize loads in power outage scenarios, control shedding of lighting and plug loads • Remote cycling of HVAC, WH, to offset energy demands and save money • Can connect with solar monitoring, home networks and demand response • In the future could simplify EV charging	**Lumin**[115] Smart Panel  **$2,500 – 4,000 Single Family home Install**	• Real time balancing of battery use and EV charging • Manages renewable generation, energy use and storage • Dynamic switching of loads based on time of use rates • Off-grid mode sheds non-critical loads and islands • Can pair with batteries to create an integrated energy management system, removes requirement of a subpanel or protected loads panel • Programmable schedules to automatically control loads • Max size: (x6) 60A, (x6) 30A

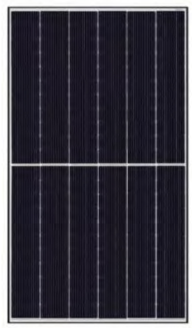
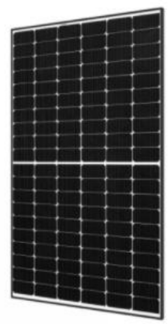
Smart Circuit Splitters (EV Charging and Appliances)

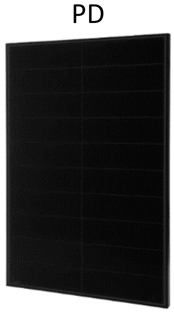
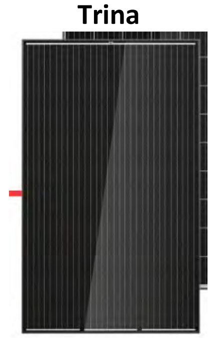
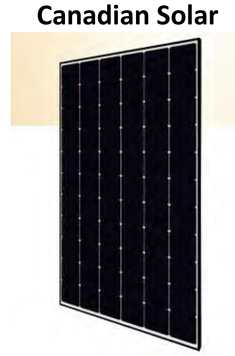
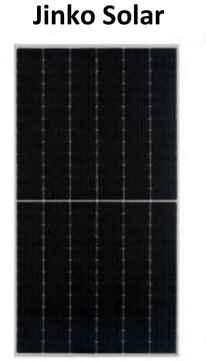
There are a few types of smart circuit splitters shown in the table below. Smart circuit breakers allow two devices (typically high power) to share a circuit, which can avoid an electrical panel upgrade (For example, like an EV charger and a Dryer). A more sophisticated version of this (DCC and EVduty) will actually monitor the whole home's power consumption then adjust EV charging accordingly. The Neo Charge and the Dryer Buddy both come with built in plugs for attaching to the wall and two appliances, so they are easy to install. Both products also have two options for power sharing – the first, power is supplied to one device or another, and the second, power is supplied to two devices simultaneously. The SimpleSwitch is typically hardwired and just has the first option of powering one device at a time. The Thermolec DCC products and the Evduty will both monitor a whole homes power consumption – however the DCC products will turn EV charging off when the load on the home panel exceeds 80% of its rated capacity, versus the Evduty that will determine the left-over power space on the panel, then supply this to the EV for continuous charging.

	Neo Charge[116] Smart Splitter 	**BSA Electronics**[117] Dryer Buddy 	**SimpleSwitch**[118] 240V Circuit Switch 	**Splitvolt**[119] Splitter Switch 	**Thermolec**[120] DCC 	**Evduty**[121] Smart Current Sensor 
Cost ($)	$500 (Appliance) $550 (Dual Car)	$200 – 365 (several outlet versions)	$550 (240V) $650 (EV) $550 (120V)	$319	$1,050 (DCC-9), $945 (DCC-10)	$500
Switch On/Off Between Two Devices	Yes	Yes	Yes	Yes	NA	NA
Continuous Power to Two Devices	Yes	Yes	No	No	NA	Yes, *shares power between appliance circuit and EV circuit*
Monitors Whole House Loads	No	No	No	No	Yes, *if total panel exceeds 80% rated load, turns off EV charging. Reconnects automatically*	Yes, *monitors a unit/home's current draw, left over current will be used to charge EV*
NEMA Outlet *(NEMA-Amps)*	*10-30, 14-30, 14-50, (10-50 for portable))*	*10-30 to 10-30, 10-30 to 14-50, 14-30 to 14-30)*	Hardwired, Optional Plugin	*10-30, 14-30, 14-50*	Hardwired	Hardwired, or NEMA 6-50, 14-50 outlet
Additional Notes		digital display that shows the draw of each load.	120V version as well	Full color display screen	Multifamily and Single Family, DCC-10 uses one double pole breaker slot	Multifamily and Single Family.

Solar Photovoltaic Panels

The cost of installing solar on a home depends on the amount of electricity a homeowner wants to generate. In addition, the state you are in, how much energy you use, your roof's sunlight exposure and complexity, panel manufacturer, and size of the system all contribute to the costs of a solar array. Over the last 10 years residential photovoltaic systems have dropped more than 60% for a commonly used 6 kW system from $50,000 to about $20,000 or less before incentives. There is a 22% tax credit from the Federal Government on installing solar in homes in the year 2021 and by the year 2022 there will only be available tax credit of 10% to commercial buildings. About 47% of the cost of solar systems is solar equipment, 35% of cost on installation and permits, and 18% of cost is operation and maintenance. Below are some of the leading manufacturers of solar panels with their associated cost from August 2020. Unshaded good exposure solar arrays produce power that ends up costing only 6-8 cents per kWh over the life of the system. It pays to own the system and to maximize the power output by going **large** and **efficient** to decrease the amount of grid power you need to buy. Think of solar panels as the way to make electrification extremely cost effective and saving hundreds of dollars over the course of the solar array's lifetime.

	SunPower Maxeon® Gen5 	**Q Cells** Q. Peak DUO ML-G9 	**REC** Alpha 	**LG** Neon 2 	**Winaico** WSP-340MX 
Type	Monocrystalline	Monocrystalline	Monocrystalline	Monocrystalline	Monocrystalline
Power Output (W)	400	390	370	345	340
Efficiency	22.3%	20.8%	21.2%	20.1%	19.4%
Size (in) (LxWxD)	Contact SunPower	72.4 x 40.6 x 1.3	67.8 x 40 x 1.2	66.9 x 40 x 1.6	67.2 x 40.5 x 1.4
Price ($)		$240	$360	$310	Contact Winaico

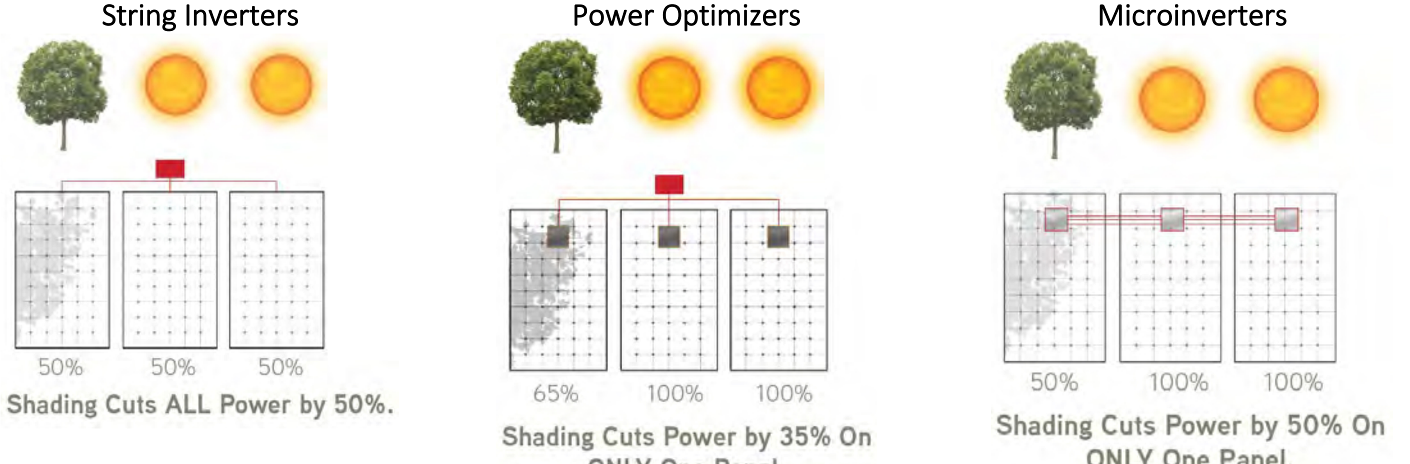
	Solaria PowerXT-370R-PD 	**Panasonic** HIT 	**Trina** 	**Canadian Solar** 	**Jinko Solar** 
Type	Monocrystalline	Monocrystalline	Monocrystalline	monocrystalline	monocrystalline
Power Output (W)	370	340	275-315	237-255	455
Efficiency	19.4%	20.3%	19.2%	19.9%	20.6%
Size (in) (LxWxD)	63.8 x 43.9 x 1.6	62.6 x 41.5 x 1.6	65.0x 39.1x 1.38	81.8x39.1x1.38	85.91x40.51x1.59
Price ($)	$360	$340	contact	contact	Contact

Solar Inverters and Solar Array Sizing

Figure 53: A typical 1,200 sq. ft. and 2,000 sq. ft. home. Illustration by Isabella Barrios Silva.

Solar inverters are one of the most important parts of a solar panel system - they take energy from solar panels and convert it from DC power to AC power to use within a building. To offset the average energy use of a typical 1,200 square foot house, the solar array will be about 200 square feet and 4 kW of DC power. For an average 2,000 square foot house, the solar array will be about 400 square feet and about 8 kW of DC power. Each panel is about 20 square feet and about 400 Watts per panel. To power an average electric car for a year (12,000 miles), it requires an additional 2 kW solar array using 100 square feet of roof space.

String Inverters | Power Optimizers | Microinverters



Illustrations by Isabella Barrios Silvia

String Inverters

Solar string inverters use **one central inverter** connected to all solar panels in a **single circuit,** such that one panel's shading affects the power produced by all panels. The circuit may have multiple wired ("strings") connecting the panels.

Advantages: lower installation and maintenance costs
Disadvantages: warranty will be shorter (10-12 years) compared to micro-inverters (25-year warranty).

Power Optimizers

A solar array with power optimizers has **one central circuit / inverter making** wiring easier to install, and **multiple system optimizers** on each solar panel allows **each panel to provide maximum power** without being affected by other panels negatively.

Advantages: similar advantages as micro-inverters but at a lower cost and have a 20–25-year warranty.
Disadvantages: higher maintenance costs since they are exposed to the environment on the roof. Central inverters only have a 10-12-year warranty.

Microinverters

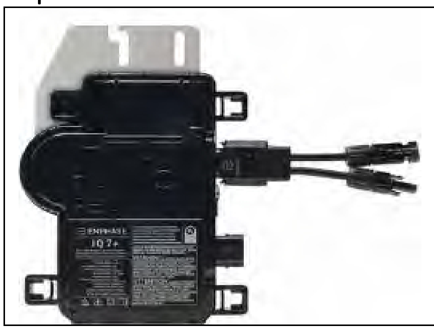
Microinverters are an **individual inverter and circuit on each solar panel,** allowing them to operate independently to provide maximum power and to **not be negatively affected by other panels.**

Advantages: can track production of each panel individually, making it easier to detect if panels need maintenance.
Disadvantages: more hardware the on roof requires more maintenance compared to a string inverter.

Solar Array Size and the Watt Diet

The size of your electrical panel will cap the size of your solar array – because the code limits the maximum solar circuit to 20% of the size of the panel, a 100 Amp electric panel is limited to 20-amp solar circuits. Because long duration loaded circuits cannot be loaded to their maximum for safety reasons, this means only 16-amps are available (the “80%” rule). A typical solar array for a home is 240 volts, so this multiplied by 16-amps gives you a 3.8 kW max of AC power. However, most inverters allow for “clipping” which means you can install a solar array that is larger than 3.8 kW DC. Each inverter company allows a different “inverter load ratio” or how much an inverter can be overloaded. For the state-of-the-art Solar Edge and Enphase inverters, this ratio is 1.55, meaning you can have a max solar array DC size of 5.9 kWdc. When the solar array is producing more than the 3.8 kW AC the inverter can process, the excess energy is “clipped”. However, this allows for the max amount of energy allowed by the inverter for more hours of the day, instead of just at around noon. Using DC coupled battery storage can also mitigate clipping by moving excess energy into storage instead of clipping it. With today’s low solar panel prices and comparatively higher grid power prices it often makes good sense to install solar panels up to the inverter’s load ratio, which can result in a cost less than 8 cents per kWh.

Enphase - Microinverters



Model	IQ7	IQ7X	IQ7	IQ7A
Price ($)	147	175	155	179
Max Output AC Power (VA)	295	320	250	366
DC Input Power (W)	235 - 440	320 - 460	235 - 350	350 - 460
Max DC input Voltage (V)	60	79.5	48	58

Solar Edge – Single Phase Inverters

	SE3800H-US	SE5000A-US	SE6000H-US	SE11400H-US	SE10000A-US
					
Maximum Ac Power Output (VA)	3,800 @ 240V	5,450 @ 240 V	6,000 @ 240V	11,400 @ 240 V	10,950 @ 240 V
AC Output Voltage Range (Vac)	240	240	240	240	240
AC Frequency (Hz)	59.3-60-60.5	59.3-60-60.5	59.3-60-60.5	59.3-60-60.5	59.3-60-60.5
Max. Input Current @ 240V (dc)	10.5 A / 2520 W	15.5 / 3720 W	16.5 A / 3960 W	30.5 A / 7320 W	30.5 A / 7320 W

Solar Edge – Combined EV Charger and Solar Inverter

Model	SE3800H-US	SE7600H-US
Maximum Ac Power Output (VA)	3,800 @ 240V	7,600 @ 240V
AC Output Voltage Range (Vac)	240	240
AC Frequency (Hz)	59.3-60-60.5	59.3-60-60.5
Max DC Charger Power (W)	9,600	
EV Charger Connector Type	SAE-J1772-2009, aka CCS	
Maximum DC Power (W)	5,900	11,800

Electric Battery Storage

Battery storage provides resiliency during disasters and shorter power outages, can be sold to utilities as a resource for their grid management, or allow you to go off-grid in more rural regions. Solar electric panels, with rare examples of residential wind turbines and micro hydro turbines, are paired with batteries and often an energy management system to make it easy for occupants to live within their energy budget. An innovation discussed above, vehicle to home charging, gives the possibility of delivering more power to a home with an electric car, a needed alternative to the too-common practice of using gas generators to meet loads during the least sunny parts of a winter. Owners and builders can include the full solar plus energy storage when they build or remodel, or pre-wire for the capability to add these systems later. The Clean Coalition has developed the "Electrification and Community Microgrid Ready" (ECMR) document to guide the easy and inexpensive installation of prewiring for grid interactive solar plus energy storage systems.[122]

Battery system prices have dropped 87% in price over the last decade, from $1100/kWh in 2010 to $156/kWh in 2019, helping drive the rapid international growth in affordable electric vehicles and home batteries.[123] Home batteries can be modest and scaled to a reduced set of power needs during outages, or large and able to take your home "off--grid" altogether. Home batteries are now so common that you can pick up a Yeti battery power pack as an alternative to a home generator at Home Depot.[124] Sunshine is roughly 1/5th as strong on Winter Solstice as Summer Solstice, which makes powering a home off grid with just solar panels a challenge without significant efficiency efforts, resorting to fossil fuel generators, or getting power from a grid-charged electric car (see below Vehicle to Home section). Home batteries are made with a variety of chemicals and minerals, but leading products currently all incorporate Lithium, which is highly reactive, lightweight, and relatively common, found on every continent in rocks of volcanic origin and mined heavily in Chile, Australia, and China. Some manufacturers such as Sonnen include inverter Wi-Fi integration and off products that are standalone units.

	DC Batteries			AC Batteries			
DC Battery	**Blue Planet** Energy	**LG** RESU 10H	**SimpliPhi** Power 2.4	**Tesla** Powerwall	**Panasonic** EVDC-105	**Sonnen** Eco	**Sonnen** EcoLinx
							
Capacity (kWh)	8, 12, 16	9.3	2.4	13.5 (combinations up to 135)	5.7, 11.4, 17.1	5 – 20 (2.5 kWh steps)	10, 12, 14, 16, 18, 20
Round Trip Eff.	98%	94.5%	98.0%	98%	89%	90%	86%
Chemistry	Lithium Iron Phosphate	Lithium-ion	Lithium Iron Phosphate	Lithium Nickel Manganese Cobalt Oxide	Lithium-ion	Lithium Iron Phosphate	Lithium Iron Phosphate
Price		$5,520		$7,600 (+ $2,500 install)	$12,700, $15,300 $18,500	$9,000 (5kwh)	

Low-Cost Resilience

A full home sized solar array and battery system can be costly, so this section aims to provide a few products that can help improve your home's resilience, but for an affordable cost. When the power grid goes down, having a back up power for lighting and phone charging at a minimum is essential. This section also provides a solution to propane fueled camp stoves.

Electric Generators

Electric generators are high-capacity batteries that can provide power to a range of devices (devices with 12V car ports that use DC power or devices with 120V plugs typical in a home). To recharge the internal battery, power may be input from various sources such as solar, car batteries, or directly from the grid. Electric generators that have solar charging available directly connect to solar panels and draw power from them to recharge. The batteries go up in cost as their capacity increases which is measured in Watt-hours. For example, the Goal Zero Yeti 500X could power a 10-Watt lightbulb for 50 hours or could charge a 12W smart phone 42 times. The largest two batteries shown below, have a higher rate of power supply which enables them to power more energy consuming devices. As another example, the Goal Zero Yeti 6000X could run an average full-sized fridge (100W) for 60 hours.

Picture	**Pecron** S200 	**Rockpals** 	**RIVER** 600 	**Goal Zero** Yeti 500X 	**Goal Zero** Yeti 1500X 	**Goal Zero** Yeti 6000X 
Price	$170	$220	$350	$700	$2000	$5000
Solar charging	Yes	Yes	Yes	Yes	Yes	Yes
Battery Capacity (Wh)	193	288	288	500	1500	6000
Output Voltage (V)	5, 12 (VDC) 120 (VAC)	5, 12 (VDC) 120 (VAC)	5, 12 (VDC) 120 (VAC)	5, 9, 12, 20 (VDC) 120 (VAC) / 2.5A	5, 12, 20 (VDC) 120 (VAC) / 16.5A	5, 12, 20 (VDC) 120 (VAC) / 16.5A
Full charge time with 120VAC input (hrs)	6-7	6-7	1.6	4.5 (120V/1A)	7 (120V/2A)	12 (120V/5A)

Electric Cooking on Small Batteries

Electric cooking devices such as induction stovetops are viable alternatives to natural gas cooking options because they eliminate the risks of burning natural gas. However, typical induction stoves require a lot of power and can use up battery storage quickly. The alternative cooking devices shown below can be powered by electric generators more efficiently and use a typical car outlet (which are in all electric vehicles as well). For example, the RoadPro car frying pan can run for 8.3 hours using the Goal Zero Yeti 1500X. Keep in mind only the larger electric generators will pair with these cooking devices because of their amperage draw.

Picture	**RoadPro** Car Frying Pan 	**RoadPro** Car Oven 	**RoadPro** Crock Pot 
Price	$30	$35	$50
Watts	180	144	150
Voltage	12V DC	12V DC	12V DC
Amps	15	12	12
Run time with Goal Zero Yeti 1500X (hr)	8.3	10.4	10

Back-up Battery Light Bulbs

These light bulbs are equipped with backup batteries that stay charged while power is being supplied as normal and get discharged when power goes out. This is a viable option for areas that require constant lighting and cannot be disturbed even during power outages.

Picture of the LED Light Bulb + Battery				
Model	GE - A21	YKDtronics	JackonLux	Neporal
Lighting Hours on Battery Power (hrs)	5	3-4	3-4	4-5
Wattage (W)	8	5	9	15
Lumens	760	500	850	800
Lumens/Watt	95	100	94.44	53.33
Price	$15	$8	$9	$11

Electric Camp Stoves and Grills

Biolite CampStove 2 is a camp stove that burns twigs found at any campsite with a battery-powered fan that creates a vortex of hot, smokeless fire. Biolite cooks food quickly while simultaneously recharging the battery from the heat, which is transformed into electricity and can additionally charge a headlamp or cellphone. This Biolite is perfect for backpacking because it is lighter than the average butane canister. An additional grill attachment also available, shown in the image on the right above, for cooking small meals. This model also provides the option of USB charging for small electronics. The specs for the stove are below:

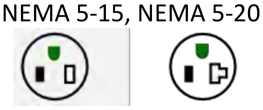
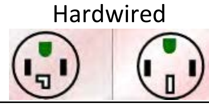
- Charge phones, lights, and more with 3W generated power
- Burn twigs, sticks, wood scraps, or pellets
- Boil Time: 1L in 4.5 min
- Battery Capacity: 2600 mAh
- Packs down to size of a 32oz wide mouth water bottle
- Weight: 2.06 lbs

BioLite FirePit: Enjoy the warmth, smell, crackle, and feel of a wood campfire, but fan-assisted to reduce smoke. With capacity for up to 4 standard firewood logs, the BioLite FirePit creates hyper-efficient flames with patented airflow technology and gives you a front-row seat to the magic thanks to the X-Ray mesh body, enabling 360 views. Lift the fuel rack and toss in charcoal to transform it from a fire pit to a portable hibachi style grill, complete with an included grill grate. Control the size of your flames manually or remotely with the free Bluetooth app.

- Fuel: Burns firewood or charcoal
- Burn time: 24hr on low, 10hr on medium, 5hr on High
- Dimensions: 27" x 13" x 15.8"
- Weight: 19.8 lbs

Electric Vehicle Supply Equipment (EVSE) Charging Levels

EV Charging standards have been developed under the EVSE protocol. There are three levels, Level 1, Level 2, and Level 3 (aka DC Fast Charging). These levels are associated with how much power can be delivered to your car. The EV charger can be connected to the grid via a hardwired connection to an electrical panel, done by an electrician, or a NEMA (National Electrical Manufacturer's Association) standardized outlet. For Level 1 this will be the standard 120-volt and 15 to 20-amp socket found on your kitchen counter, bathroom, or bedroom outlet. For Level 2 chargers, depending on the power requirement you may see a typical 30-amp electric clothes dryer outlet, also called NEMA 14-30, or a typical 50-amp electric oven outlet, called NEMA 14-50; or else the charger may be hardwired by an electrician. DC Fast Chargers use DC power, as opposed to AC power coming from the grid, to charge the battery of your car. Level 3 chargers are almost never found in single-family homes, due to the amount of power needed.

	Level 1[125]	**Level 2**[126]	**Level 3**
			
Electrical Specifications	120 Volts, 15 to 20 Amps maximum	240 Volts, 20 to 40 Amps, 30 Amps is common	DC Fast Charging, 12kW or greater
Grid Connection, NEMA Receptacle	NEMA 5-15, NEMA 5-20 	NEMA 14-30, NEMA 14-50, Hardwired 	Always Hardwired, very rare outside of Multifamily and Commercial applications
Connector Types	SAE J1772	SAE J1772	CHAdeMO, SAE J1772 aka CCS + 2 pins, Tesla proprietary

Electric Vehicle Supply Equipment (EVSE) Level 2 EV Chargers

	SolarEdge LJ40P-KIT-SA-EV-S	**Juicebox**[127] JuiceBox 40	**Chargepoint**[128] ChargePoint Home Flex	**Siemens** VersiCharge
				
Connector	SAE J1772	SAE J1772	SAE J1772	SAE J1772
NEMA Types[129]	NEMA 6-50	Hardwired or Plug (NEMA14-50)	Hardwired or Plug (NEMA 6-50 or 14-50)	Hardwired or Plug (NEMA 6-50)
Output Amps	40	40	50	30
Output Power (kW)	Up to 9.6	Up to 9.6	3.8 - 12	1.8 - 7.2
Mounting Method	Wall-mounted	Wall, Column, or Pedestal	Wall, Column, or Pedestal	Wall-mounted
Input Amps (240V)	40A	40A	50A, 40A continuous	32
Breaker Size (Amps)	50, 2-phase	50, 2-pole	50, 2-pole	40, 2-pole
Input Voltage	240 AC	208-240 VAC, 1-phase	208-240 VAC, 1-phase	208-240 VAC
Input Power	-	10,000W	10,000W	7,700W
Price	$550	$599 (base)	$699	$730

Vehicle to Home and Vehicle to Grid Charging

Vehicle-to-Home Charging was developed in Japan after the 2011 tsunami closed the nation's nuclear power plants. Nissan pioneered the concept of **"Vehicle-to-Home" (V2H)** which uses a charger to isolate a home from the grid and draws on the vehicle's battery power for its electrical needs when utility grid power is not available. Nissan estimates that its all-electric Leaf can power an average home in Japan for two to four days without solar,[130] and with rooftop solar the system is sufficient for off grid living most of the year. The term **"Vehicle-to-Grid" (V2G)** describes the situation where the car's excess electricity is provided to the utility grid. The International Energy Agency estimated that in 2030 there will be 130 million electric vehicles on the road, which will contain almost ten times the amount of energy storage needed for a renewably powered grid.[131]

Available Soon in the United States

	Wallbox[132] Quasar 	**Ossiaco**[133] dcbel 	**Nuvve**[134] PowerPort 	**Fermata Energy**[135]
Vehicle-to-Home	X	X		X
Vehicle-to-Grid			X	X
Other Capabilities	• It charges and discharges through a CHAdeMO vehicle connector • Max power of 7.4 kW	• Also operates as a solar inverter and home energy management system	• Max 3-phase power of 99kW • Max single-phase power of 19kW for commercial use	• Commercial and residential capabilities • Coming to the US market in 2021

Not Available in the United States

A plethora of companies outside the United States have V2H and V2G chargers, demonstrating that the market is ready for this technology. Using a car's battery to power your home or to give back to the grid will be an essential service in our all-electric future.

Vehicle to Building (V2B) Chargers			**Vehicle to Grid (V2G) Chargers**			
Honda	**Mitsubishi**	**Nissan**	**Nissan**	**Endesa**	**OVO**	**Princeton Power Systems**
						

Electric Vehicles

In California, the greatest percentage of smog and greenhouse gas emissions in the state come from fuel burning vehicles. Electric vehicles create no direct air pollution, rely on a grid in California that is 50% renewables, use just 1/3rd the energy of gas engines. Electric vehicles are the key to reducing the carbon impact of driving, and their battery systems can provide resilience to your home by running critical electric loads when the power goes out—see below discussion of Vehicle to Home charging. The below section provides a list of 2019 model electric vehicles with their specifications, provided by Menlo Spark.[2] For inspiration is also an example of a 1946 pickup truck electrification.

MENLO SPARK

ELECTRIC VEHICLE BUYER'S GUIDE* AUGUST 2020

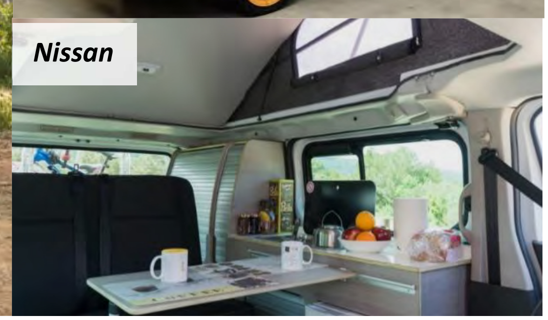
Manufacturer	BMW	BMW	Chevrolet	Fiat	Hyundai	Hyundai	Jaguar	Kia	Mercedes Benz
Model	2019 i3	2019 i3s	Bolt EV	2019 500e	Ioniq EV	Kona Electric	I-Pace S	e-Niro 4	EQC 400 4Matic
Passengers	4	4	5	4	5	5	5	5	5
Doors	4	4	4	2	4	4	5	4	4
MSRP (from)	$44,450	$47,650	$37,495	$33,460	$34,020	$38,330	$69,500	$38,500	$67,900
Car Body	Hatchback	Hatchback	Hatchback	Hatchback	Hatchback	SUV	SUV	Crossover	SUV
Range (miles)	153	153	259	84	170	258	234	239	220
MPGe City / Highway	124/102	124/102	127/108	121/103	145/121	132/108	80/72	123/102	
MPGe Combined	113 miles	113 miles	118	112 miles	133	120	76	112	
Battery Capacity	42.2 kWh	42.2 kWh	66 kWh	24 kWh	38.3	64 kWh	90 kWh	64 kWh	80 kWh
Horsepower	170	181	200	111	118	201	394	201	
0-60 Speed	7.2 seconds	6.9 seconds	6.9 seconds	8.4 seconds	10.2 seconds	7.6	4.5 seconds	7.5 seconds	4.9 seconds
Top Speed	93 mph	99.4 mph	90.1 mph	85 mph	102.5 mph	103.8 mph	124 mph	103.8 mph	111.8 mph
Charge Time (120 volt)	24-48 hours	24-48 hours	4 miles/hour	24 hours	24 hours	60 hours	2+ days	28 hours	
Charge Time (240 volt)	11-15 hours	9-12 hours	25 miles/hour	4 hours	4 hours 25 min	9 hours 35 min	13 hours	9 hours	10 hours
Quick Charge Option	80% in 41 min	80% in 32 min	ɔ to 1000 miles in 30 m	not available	80% in 23 min	80% in 54 min	80% in 45 - 85 minutes	80% in 1 hour	80% in 44 minutes
Max Cargo	39 cu ft	40 cu ft	56.6 cu ft	7 cu ft	23 cu ft	45.8 cu ft	25.3 cu ft	15.93 cu ft	17.66 cu ft
Comments		2020 model available in Europe only		only available in California and Oregon					
Leasing**									
Monthly Rate	$299	$339	$239		$239	$309	$899	$319	
Term (months)	36	36	36		36	36	36	36	
Down Payment	$3,999	$3,999	$1,629		$2,500	$3,999	$5,995	$3,499	

Manufacturer	Mercedes Benz	Mini	Nissan	Nissan	Polestar	Porsche	Rivian	Tesla	Tesla
Model	EQC 400 4Matic	Cooper SE	Leaf S	Leaf S Plus	Posestar 2	Taycan 4S	R1S/R1T	Model S	Model X
Passengers	5	4	5	5	5	4	4	5	5 to 7
Doors	4	2	4	4	5	4	5 or 7	4	4
MSRP (from)	$67,900	$30,750	$29,900	$36,550	$63,000	$106,410		$74,990	$79,990
Car Body	SUV	Hatchback	Hatchback	Hatchback		Sedan	Pick-up	Sedan	SUV
Range (miles)	220	110	149	226	275		300?	402	305
MPGe City / Highway			123/99	118/97				121/112	89/90
MPGe Combined			111	108				117	90
Battery Capacity	80 kWh	32.6 kWh	40 kWh	62 kWh	78 kWh	79.2 kWh	135 kWh	100 kWh	100kWh
Horsepower		181	147	215		214.6 hp		518	502.9+258.8
0-60 Speed	4.9 seconds	6.9 seconds	7.4 seconds			3.8 seconds	3 seconds	3.6 seconds	2.7 seconds
Top Speed	111.8 mph	93.2 mph	89.5 mph	98.8 mph		155.3 mph	124.9 mph	155.3 mph	155.3 mph
Charge Time (120 volt)				27 hours					
Charge Time (240 volt)	10 hours	4.25 hours	8 hours	10 hours	7 hours	7 hours		8.75 hours	5.75 - 8.75 hours
Quick Charge Option	80% in 44 minutes	80% in 39 min	80% in 40 min	80% in 43 min	80% in 31 min	80% in 1.6 hrs	80% in 41 min	80% in 40 min at Supercharger	80% in 50 min at Supercharger
Max Cargo	17.66 cu ft	7.45 cu ft	30 cu ft	30 cu ft	14.27 cu ft	14.37 cu ft	11.65 cu ft	58.1 cu ft	81.21 cu ft
Comments						other models with higher ranges		other models with higher ranges	other models with higher ranges
Leasing**									
Monthly Rate			$163					$921	$1,019
Term (months)			36					36	36
Down Payment			$2,999					$7,500	$7,500

[2] Go to www.menlospark.org to learn more.

Manufacturer	Tesla	Tesla	Volkswagon		Tesla	Byton	Ford	Kia	Volkswagon	Volvo
Model	Model 3	Model Y	e-Golf	Models coming in 2021 >>	Cybertruck	M Byte	Mustang Mach-E	Soul EV	ID3	XC40 Electric
Passengers	5	5 to 7	5		6	5	5	5	5	5
Doors	4	4	4		4	4	4	4	4	4
MSRP (from)	$37,990	$49,990			$39,900	$46,595	$59,900	$37,500	29,990 euros	
Car Body	Sedan	SUV	Hatchback		Pick-up	SUV	SUV	Crossover	Hatchback	SUV
Range (miles)	250	230	123		300	270	270	243	205	
MPGe City / Highway	148/132		122/104					127/101		
MPGe Combined	141		113					114		
Battery Capacity	54 kWh		35.8 kWh			95 kwh	75.7 kWh	63 kWh	45 kWh	78 kWh
Horsepower	283		134.1 hp			469.4		201	125	
0-60 Speed	5.3 seconds	5.9 seconds	9.6 seco		6.4 seconds	5.5 seconds	5.5 seconds	7 seconds		4.9 seconds
Top Speed	140 mph	119.9 mph	93.2 mph		110 mph	118.1		105 mph	99.4 mph	111.8 mph
Charge Time (120 volt)								44 hours		
Charge Time (240 volt)	5.75 hours		5 hours					9 hours	6.25 hours	
Quick Charge Option	80% in 30 min at Supercharger		80% in 34-43 min			80% in 38 minutes	80% in 45 minues	80% in 1 hour	80% in 54 min	
Max Cargo	12 cu ft	66 cu ft	12.04 cu ft		100 cu ft	19.42 cu ft	29 cu ft	47.3 cu ft	13.6 cu ft	
Comments	other models with higher ranges	other models with higher ranges					8 models available		offered in Europe in 2020	My only be available in Europe
Leasing**										
Monthly Rate	$371	$499								
Term (months)	36	36								
Down Payment	$4,500	$4,500								

EVs and Outdoor Recreation Inspiration



Electric Fireplaces

Swirling, fire-like mist lit with LEDs and a campfire's worth of heat: these are electric fireplaces. They are less expensive than gas stoves, safer, cleaner, and plug into a normal 120V wall outlet. They provide heat in a more efficient and smokeless way – a 3,000-Watt electric fireplace can warm spaces up to 800 feet and look great doing it. From convincing to dramatic, electric fireplaces are ready to match the tastes of any owner. Outdoor electric space heaters are similarly versatile and ready to replace headache-inducing propane burners.

Figure 54: A Dimplex Opti-Myst cassette within a commercial space.[136]

What is a water vapor fireplace?

Ultra-fine water vapor, LED lights, and different air pressures allow realism within the mist flames to replace actual fire to reduce emissions in a building. A transducer helps convert pressure into an electrical signal that forms ultrasounds that vibrates water and turns it into ultra-fine water vapor and LED lights illuminate a life-like flame effect. The depth of the frame can be customized as well by adjusting the opening where the water vapor comes out. Opti-Myst has many different styles of LED water vapor fireplaces to provide a more comfortable aesthetic environment in residential, commercial, and high-rise buildings. AFireWater has also released a set of fireplaces that consist of water vapor flames with multicolored options to provide occupant comfort within public and private spaces.

Why buy an LED fireplace?

These fireplaces do not only feel like a real fireplace, but they are the safest and cleanest electric technologies to put within a home or office. Unlike real fireplaces, they are not emitting CO2 into a space and can be controlled for optimal comfort and aesthetics.

Manufacturer and Product Image	**Dimplex Opti-Myst** (CDFI 500-PRO) 	**Dimplex Opti-Myst** (CDFI 1000-PRO) 	**AFireWater** 	**Dimplex Opti-Myst** (GBF 1000-PRO) 	**Dimplex Opti-Myst** (GBF 1500-PRO) 
Price ($)	$1,430	$2,640	$3,460	$3,630	$5,640
Power (Watt)	230	460	60-180	1400	1460
Amps	1.91	3.8	Not Available	11.67	12.17
Voltage (V)	120	120	120	120	120
Heating (BTU)	785	Not Available	Not Available	4981	4981

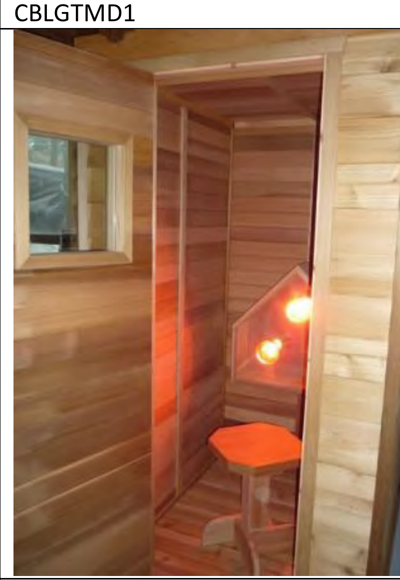
Electric Sauna Heaters

The following section offers alternatives to gas powered saunas: electric resistance and infrared. Electric resistance saunas offer an experience just like traditional saunas – electric resistance coils warm up rocks so that water can be poured over them to create steam. Infrared saunas have made improvements to traditional steam saunas. This style of products uses low intensity infrared lights to increase body and air temperature, which is better for the lifetime of the wood rooms and creates an enjoyable experience comparable to steam.

(240V) Electric Resistance, heater unit only

Model	**Finlandia** FLB30-ESH	**Finlandia** FLB80-ESH	**Polar** HNVR 45SC	**Harvia** HPC-HTR61	**Harvia** HNC-HTR105
Picture					
Capacity (kW)	3.0	8.0	4.5	6.8	10.5
Price	$630	$780	$910	$1,070	$2,040

(120V) Infrared, Full Room

Model	**JNH Lifestyles** MG217HB	**Radiant Saunas** BSA2409	**Cedarbrook** CBLGTMD1
Picture			
Price	$1,100	$1,400	$2,040

Electric Outdoor Heaters

Keeping warm outside does not need to come from odorous and polluting propane outdoor heaters, there are many electric equivalents that range from wall mounted high power 240V to free standing 120V options for your outdoor heating needs.

Wall Mounted

Manufacturer and Product Image	**Bronic** 	**Sunheat** 	**Heatstrip** 
Power (W)	2300	4500	6000
Voltage (V)	240	240	240
Price	$985	$450	$800
	Infratrech 	**RADtec** 	**Heatstrip** 
Power (W)	6000	1500	1500
Voltage (V)	240	120	120
Price	$800	$150	$200

Free Standing

Manufacturer and Product Image	**Ener-G+** 	**Fire sense** 	**Aura** 
Power (W)	1400	1500	1500
Voltage (V)	120	120	120
Price	$300	$300	$400

Electric Barbeques

Electric BBQ grills heat up much more quickly than charcoal or gas grills and distribute heat more evenly over the entire grill area. With no charcoal fumes and no propane gas burning, they are safer and can be used indoors in inclement weather. Electric grills are cheaper to operate, clean up easier, need little maintenance and can also be used in high rise buildings where typical combustion grills are not allowed due to fire code restrictions.

Manufacturer and Product Image	**Electri Chef** The Safire 115V 	**Electri Chef** Emerald 24” 	**Electri Chef** Ruby 32” Built-in 	**Kenyon** B70590 	**Kenyon** B70060 
Cooking Surface (sq. in.)	224	336	448	115	115
Price	$700	$3,600	$3,500	$1200	$650
Voltage	115V	220V	220V	120V	120V

Manufacturer and Product Image	**Weber** 55020001 	**Char-Broil** 804142 	**Kuma** Profile 150 	**Americana** 9359U8.181 	**Maverick** E-50S 
Cooking Surface (sq. in.)	280	240	145	200	173
Price	$320	$200	$220	$245	$180
Voltage	120V	120V	110	120V	120V

Manufacturer and Product Image	**Fire Magic** E250S-1Z1E-P6 	**Char-Broil** Patio Bistro 240 	**Weber** Q 2400 	**Meco** Easy Street 	**Kenyon** Floridian 
Cooking Surface (sq. in.)	240	240	280	200	240
Price	$1400	$190	$246	$248	$710
Type	Patio Post	Mobile	Mobile	Mobile	Built-in
Voltage/ Amp	120V / 20A	120V / 15A	120V / 13A	120V / 12.5A	240V / 5.5A
Heat Output	1800W	1750W	1560W	1500W	1300W

Electric Landscaping

Powerful electric landscaping equipment uses lightweight batteries and efficient motors that are half as loud as gas equivalents, produce no local air pollution, and are easier to maintain. Modern batteries now offer comparable length of operating time to gas tanks, and batteries are safer to store than gasoline, oil and rags.

Residential Grade

These products are designed for weekly use at a residence, and are somewhat less expensive (but also less durable) than the commercial grade equipment shown further below. You'll love how quiet they are.

	Blower	**Chain Saw**	**Pole Pruner**	**Trimmer**	**Hedge Trimmer**	
STIHL[137]	BGA 45 ($130) 	MSA 120C ($350) 	HTA 65 ($660) 	FSA 56 ($150) 	HAS 56 ($280) 	RMA 460 ($420) 
Husqvarna[138]	320iB ($230) 	120i ($260) 	536LiP4 ($400) 	336LiLC ($250) 	115iHD55 ($230) 	LE121P ($450) 
RYOBI[139]	RY40411 ($170) 	RY40530 ($200) 	P4361 ($140) 	P2080 ($130) 	P2660 ($130) 	RY48110 ($2700) 

*Prices will vary – visit retailers for the most current cost information.

Commercial Grade

These products are designed for durability so they can sustain constant use by landscaping crews. If you're tired of the noise from a "mow and blow" landscaper, encourage them to switch to these dramatically quieter electric equivalents to their equipment.

	Blower	Chain Saw	Pole Pruner	Trimmer	Hedge Trimmer	
STIHL[140]	BGA 100 ($350) 	MSA 160 C-BQ ($350) 	HTA 85 ($490) 	FSA 130 R ($400) 	HAS 94 R ($500) 	RMA 510 ($520) 
Husqvarna[141]	550iBTX ($500) 	T536Li XP ($400) 	536LiPT5 ($500) 	536LiLX **($300)** 	536LiHD60X ($430) 	LE221R ($430) 
RYOBI[142]	RY40440 ($270) 	P549 ($200) 	RY40561 ($200) 	RY40250 ($160) 	RY40610A ($150) 	RY48ZTR100 ($4100) 

*Prices will vary – visit retailers for the most current cost information.

Electric Snowblowers

There is a wide range of electric snowblowers on the market ranging from a few hundred up to about 800 USD. Their lack of a need for maintenance makes them extremely convenient. This equipment does not require oil changes, filter changes, new spark plugs, or any gasoline. This also makes storage and usage safer for the operator.

Electric snowblowers, on average, are significantly quieter than their gasoline counterparts making blowing before work in the morning much more bearable for you and your neighbors. This clean, quiet, and efficient alternative to gas now also is readily available as battery powered rather than corded, giving you all the freedom of a gas-powered engine without the hassle.

Manufacturer and Product Image	**EGO** SNT2102 	**Snow Joe** iON18SB 	**PowerSmart** DB2401 	**Earthwise** SN74018 	**Toro** 38381 	**Snow Joe** Ultra SJ620 
Lbs. of snow/ minute	1500	500	700	500	700	650
Terrain conditions	Paved & Gravel	Flat/Paved	Flat/Paved	Flat/Paved	Flat/paved	Flat/paved
Snow handling	Heavy wet to fluffy light	Heavy wet to fluffy light	Moderate dry to fluffy light	Heavy wet to fluffy light	Fluffy light	Fluffy light
Battery requirements	(2) 56-Volt 5.0Ah Lithium- Ion	40-Volt 4.0-Ah Lithium-Ion	40-Volt 4.0 Ah Lithium- Ion	40-Volt 4.0 Ah Lithium- Ion		
Run time	15 minutes	65 minutes	25 minuets	30 minuets		
Motor Type					15 Amp Series Wound Electric	13.5 Amp
Throwing distance	35ft	20ft	30ft	30ft	30ft	20ft
Clearance	21" wide & 10" deep	18" wide & 8" deep	18'' wide & 11'' deep	18'' wide & 12'' deep	18" wide & 8" deep	18" wide & 10" deep
Weight	70 lbs.	32 lbs.	18.5 lbs.	35 lbs.	25 lbs.	31.5 lbs.
Price	$604*	$300*	$270*	$250*	$280	$150

*batteries and charger included

Electric Snowmobiles

Cold weather transportation is a sector that has not regularly been in the spotlight of renewable energy, but it is in desperate needs of clean solutions. This rapidly improving technology has many benefits over its gas counterparts. Gas-powered snowmobiles have little to no emissions standards and many have two stroke engines causing them to be sometimes as much as 50 times more polluting than the average car.[1] Less emissions and pollution is an obvious plus, but financially these machines also have the huge advantage of needing practically no maintenance, which reduces cost of ownership. There is no fuel, no oil, no transmission, and no drive belts, so the cost of operation is much lower and that means more time can be spent out riding rather than doing costly fixes back at home. These snowmobiles are compatible with and can charge anywhere with automotive standard equipment. The average charging time with the AC 240V Level 2 charger is about 2 hours, but now there exists a DC fast charger which can bring the battery up to 80% in just 20 minutes.[143]

Manufacturer and Product Image	**Taiga Motors** Ekko TS3 	**Taiga Motors** Atlas 	**Taiga Motors** Nomad 
Range	131km	140km	134km
0-100km/h	3.3s	2.9s	NA
Towing (1,124lbs)	NA	NA	510kg
Engine Package	180hp	180hp	120hp
Battery	27 kWh	27 kWh	27 kWh
Weight (ride ready)	265kg / 586lbs	271kg / 597lbs	275kg / 607lbs
Track	154”x 15”x 2.5” 165”x 15”x 2.5”	137”x15”x1.6”	Studded 154”x16”x1.6”
Front Suspension	Double wishbone Travel: 220mm / 8.66”	Double wishbone Travel: 220mm / 9.05”	Double wishbone Travel: 224mm / 8.82”
Rear Suspension	Rad-M multilink Travel: 270mm / 10.6”	Rad-X multilink Travel: 300mm / 11.8”	Rad-u multilink Travel: 300mm / 11.8”
Stance	950mm / 37.4in	1074mm / 42.3in	1074mm / 42.3in
Dimensions	Height: 1482mm / 58.2in Length: 3360mm / 132.3in	Height: 1278mm / 50.3in Length: 3158mm / 124.3in	Height: 1550mm / 61.0in Length: 3275mm / 128.9in
Features	HD display with GPS mapping Custom terrain profiles Powder flow package	HD display with GPS mapping Custom terrain profiles Click adjustable shocks	HD display with GPS mapping 2-up seating Active stability management

References

Cover Page Citations

Top left: Ross Residence, Amherst, MA: 1000 Home Challenge. (2012). Deep Energy Retrofit Goes for Zero. https://1000homechallenge.com/case-studies/
Middle left: Darby Residence, Hamilton, NY: Jay Egg (2019) 1830 Home in Hamilton, New York is an all-electric Geothermal Masterpiece. Green Builder. https://www.greenbuildermedia.com/energy-solutions/1830-home-in-hamilton-ny-is-an-all-electric-geothermal-masterpiece
Top right: 1918 House of the Future, Cleveland Heights, OH: https://energysmartohio.com/case_studies/1917-net-zero-ready/
Bottom left: Big Chill Retro Induction Stove: https://bigchill.com/
Middle right: Neo Charge Smart Circuit Splitter: https://www.getneocharge.com/
Bottom right: Water Vapor Fireplace, Nero Fire Design: https://www.nerofiredesign.com/gallery

Additional All-Electric Case Studies

1: 1000 Home Challenge. (2012). Mackey Deep Energy Reduction Case Study. Accessed: https://jhn.e94.myftpupload.com/wp-content/uploads/2020/10/Mackey_THC_Case_Study.pdf
2: Image Courtesy of Mary Dateo.
3: International Living Future Institute. (2021). Willowbrook House. Accessed: https://living-future.org/lbc/case-studies/willowbrook-house/ (Image by Sunshine Mathon)
4: Image Courtesy of Dick Swanson.
5: Northeast Sustainable Energy Association. (2021). Fink-Simko Zero Net Energy Deep Energy Retrofit. Accessed: https://nesea.org/project-case-study/fink-simko-zero-net-energy-deep-energy-retrofit/general
6: Image Courtesy of Barry Cinnamon.
7: Image Courtesy of Pierre Delforge.
8: Image Courtesy of Eva Markiewicz and Spencer Ahrens.
9: Image Courtesy of Diane Sweet of EmeraldECO.
10: Earth Mother News. (2015). A Renewable Home Energy Retrofit: How We Did It. Accessed: https://www.motherearthnews.com/renewable-energy/other-renewables/home-energy-retrofit-zm0z15jjzhir
11: Image Courtesy of Jeff and Debbie Byron.
12: 1000 Home Challenge. (2010). Road to Energy Independence. Accessed: https://jhn.e94.myftpupload.com/wp-content/uploads/2020/10/Joann-Olson-Wisconsin-Case-Study.pdf
13: Image Courtesy of Indra Ghosh.

---

1 Federal Energy Information Administration. (2019). "One in four U.S. homes is all-electric." https://www.eia.gov/todayinenergy/detail.php?id=39293
2 Statista (2020). "Unit shipments of electric/gas cooking appliances in the U.S. from 2007 to 2017." https://www.statista.com/statistics/295477/unit-shipments-of-electric-gas-cooking-appliances/
3 Statista (2020) "Gas dryer unit shipments in the United States from 2005 to 2017." https://www.statista.com/statistics/322357/gas-dryers-shipments-united-states/
4 Engelberg, Jeremy and Brassell, Evan. (2019). "Differences in Fuel Usage in the United States Housing Stock: American Housing Survey Report." U.S. Census Bureau. https://www.census.gov/content/dam/Census/library/publications/2019/demo/h150-19.pdf
5 UN Environment Global Status Report 2017; EIA International Energy Outlook 2017
6 Environmental Defense Fund. (2020). Methane, The Other Important Greenhouse Gas. EDF calculation based on IPCC AR5 WGI Chapter 8." <www.edf.org/climate/methane-other-important-greenhouse-gas> Note that other sources like livestock (e.g. cows) contribute to methane emissions also.
7 Griffith, Saul. (2020). Rewiring America: A Field Manual for the Climate Fight. Accessed: static1.squarespace.com/static/5e540e7fb9d1816038da0314/t/5f21edad94f7832d9b1a31bf/1596059082636/Rewiring_America_Field_Manual.pdf
Roberts, David, Vox Explainer, https://www.vox.com/2016/9/19/12938086/electrify-everything
8 Marketplace Tech. (2020). Podcast: Making old building resilient to climate change requires new financial tools. https://www.marketplace.org/shows/marketplace-tech/making-old-buildings-resilient-to-climate-change-requires-new-financial-tools/
99 Lacey, S. (2021). Watt It Takes: BlocPower CEO Donnel Baird Wants to Electrify Buildings for Everyone. https://www.greentechmedia.com/articles/read/watt-it-takes-blocpower-ceo-donnel-baird-wants-to-electrify-buildings-for-everyone
10 Clean Energy Connection. (2021). Find a Contactor. Accessed: https://www.cleanenergyconnection.org/find-contractor
11 TRC. (2021). Building Electrification Technical Assistance. Accessed: https://allelectricdesign.org/
12 Weiwei Lin, Bert Brunekreef, and Ulrike Gehring, "Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children," International Journal of Epidemiology, Volume 42, Issue 6, (December 2013): 1724–1737, https://doi.org/10.1093/ije/dyt150.
13 Asthma and Allergy Foundation of America. "Asthma Facts and Figures." Accessed July 23, 2020. www.aafa.org/asthma-facts/.
14 Tursynbek Nurmagambetov, Robin Kuwahara, and Paul Garbe. "The Economic Burden of Asthma in the United States 2008-2013." Annals of the American Thoracic Society.
15 Jarvis et al. (1996) "Evaluation of asthma prescription measures and health system performance based on emergency department utilization." <https://www.ncbi.nlm.nih.gov/pubmed/8618483>
16 Singer, B. (2018). Healthy Efficient Homes: Research Findings. ACEEE 2018 Conference on Health, Environment and Energy. <https://aceee.org/sites/default/files/pdf/conferences/chee/2018/1b.singer.pdf>
17 Environmental Protection Agency. (2009). Preventing Carbon Monoxide Poisoning.<https://www.epa.gov/sites/production/files/2015-08/documents/pcmp_english_100-f-09-001.pdf>
18 San Francisco Department of the Environment. (2017). Methane Math: How Cities Can Rethink Emissions from Natural Gas. <https://sfenvironment.org/sites/default/files/fliers/files/methane-math_natural-gas-report_final.pdf>
19 Joseph, G. (2016). "30 Years of Oil and Gas Pipeline Accidents, Mapped." Citylab.
20 Jarosz, Brooks. "Construction worker called in gas line rupture before explosion." Dec 22, 2016. ABC 6 News, Columbus, Ohio. <https://abc6onyourside.com/investigators/construction-worker-called-in-gas-line-rupture-before-explosion>
21 Synapse Energy. (2018). Economics, Decarbonization of Heating Energy Use in California Buildings at 2, 39. <http://www.synapse-energy.com/sites/default/files/Decarbonization-Heating-CA-Buildings-17-092-1.pdf>
22 Billimoria et al. "The Economic of Electrifying Buildings." Rocky Mountain Institute. 2018. rmi.org/insight/the-economics-of-electrifying-buildings/
23 Levy, R. and Sledge, J. (2012) A Complex Portrait: An Examination of Small-Dollar Credit Consumers. Center for Financial Services Innovation.
24 Energy Sage. "How to calculate solar panel payback period (ROI)." Accessed Dec. 28, 2020. https://news.energysage.com/understanding-your-solar-panel-payback-period/#:~:text=The%20typical%20solar%20payback%20period,20%2C000%2F%242%2C500%20%3D%208).
25 Sierra Club. (2020). New Analysis: Heat Pumps Slow Climate Change in Every Corner of the County. Accessed: https://www.sierraclub.org/articles/2020/04/new-analysis-heat-pumps-slow-climate-change-every-corner-country
26 Architecture 2030. (2020). Why the Building Sector? <https://architecture2030.org/buildings_problem_why/>
27 Environmental Defense Fund. (2020). Methane, The Other Important Greenhouse Gas. *EDF calculation based on IPCC AR5 WGI Chapter 8." <www.edf.org/climate/methane-other-important-greenhouse-gas> Note that other sources like livestock (e.g. cows) contribute to methane emissions also.
28 Energy Sage. "How to calculate solar panel payback period (ROI)." Accessed Dec. 28, 2020. https://news.energysage.com/understanding-your-solar-panel-payback-period/#:~:text=The%20typical%20solar%20payback%20period,20%2C000%2F%242%2C500%20%3D%208).
29 U.S. Energy Information Administration. "U.S. Shipments of Solar Photovoltaic Modules Increase as Prices Continue to Fall." August 19, 2020. https://www.eia.gov/todayinenergy/detail.php?id=44816#:~:text=The%20average%20value%20of%20solar,per%20peak%20watt%20in%202019.
30 Thiele, Timothy. "Average Costs for 12 Common Electrical Projects." Dec 21, 2020. The Spruce. https://www.thespruce.com/electrical-project-costs-1152463

31 Silicon Valley Clean Energy. “Award Winning All-Electric Living.” https://www.svcleanenergy.org/all-electric-award/
32 Thiele, Timothy. “Average Costs for 12 Common Electrical Projects.” Dec 21, 2020. The Spruce. https://www.thespruce.com/electrical-project-costs-1152463
33 Environmental Protection Agency. ”Energy Star Product Finder.” Searched Nov 29, 2020. https://www.energystar.gov/productfinder/product/certified-clothes-dryers/results
34 Sacramento Municipal Utility District. “SMUD Residential Electrification Project Costs.” CEC TN # 234862, Docket Number 19-DECARB-01. 9/22/2020.
35 Sacramento Municipal Utility District. “SMUD Residential Electrification Project Costs.” September 22, 2020. Docketed to California Energy Commission #19-DECARB-01, TN 2348620.
36 Mini-split costs courtesy of Jonathan and Sarah Moscatello, owners of the Heat Pump Store in Portland, Oregon.
37 Electrification cost data courtesy of Nate Adams of Energy Smart Ohio.
38 Personal communication from Li Ling Young, VEIC, on September 15, 2020.
39 Diversified Energy Specialists for MEMA. “Case Study: Massachusetts Air-Source Heat Pump Installations 2014-2019.” November 25, 2019. https://massenergymarketers.org/files/3115/7858/1868/DES_-_Heat_Pump_Study.pdf
40 Thiele, Timothy. “Average Costs for 12 Common Electrical Projects.” Dec 21, 2020. The Spruce. https://www.thespruce.com/electrical-project-costs-1152463
41 Homeguide.com. “How Much Does It Cost to Upgrade Or Replace An Electrical Panel?” Accessed Jan 2, 2021. https://homeguide.com/costs/cost-to-replace-electrical-panel#:~:text=Cost%20To%20Replace%20Circuit%20Breaker,of%20circuits%2C%20and%20the%20amperage.
42 Sioux Center (n.d.) General Electrical Requirements for Single Family Dwellings. Accessed: https://www.siouxcenter.org/DocumentCenter/View/246/GENERAL-ELECTRICAL-REQUIREMENTS-?bidId=
43 Sioux Center (n.d.) General Electrical Requirements for Single Family Dwellings. Accessed: https://www.siouxcenter.org/DocumentCenter/View/246/GENERAL-ELECTRICAL-REQUIREMENTS-?bidId=
44 Fujitsu (2021). Downloads. Accessed: https://www.fujitsu-general.com/us/resources/pdf/support/downloads/specification-sheets/pdf-fo-14r-pfj-806-04.pdf
45 Water Heater Timer. (n.d.) What size indirect water heater do you need? Accessed: http://waterheatertimer.org/What-size-indirect-heater.html
46 Resnik, Max. (2019). “Nevada County crews battle generator fires during planned outages.” KCRA 3, Nevada County, California.< https://www.kcra.com/article/nevada-county-generator-fires-pg-e-outages-california/29256051>
47 Pappalardo, J. (2014). The World’s Biggest Vehicle-to-Grid Experiment Is Happening at a California Air Force Base. Popular Mechanics. <https://www.popularmechanics.com/cars/hybrid-electric/a13460/electric-vehicles-to-grid-experiment-us-air-force/>
48 Hawaiian Electric (2018). Electrification of Transportation: Strategic Roadmap. Retrieved from Energy and Environmental Economics: < https://www.ethree.com/wp-content/uploads/2018/04/201803_EOT_roadmap.pdf>
49 Asahi Shimbun Digital. (2019). The power transmission tower is tilted in Chiba. <https://www.asahi.com/articles/ASM991F7RM98UTIL01M.html>
50 EVsmartBlog. 2019. Experiences of victims who survived the Chiba power outage of 2019 with electric cars and V2H. <https://blog.evsmart.net/electric-vehicles/report-from-2019-chiba-power-outage/?>
51 Lambert, F. (2018). “Nissan launches ‘Nissan Energy’ to commercialize vehicle-to-home/building with the Leaf. Electrek. <https://electrek.co/2018/11/28/nissan-energy-leaf-vehicle-to-home-building/>
52 Maui Now (2017). JUMPSmartMaui Announces Successful Completion of Project. Maui Now. <https://mauinow.com/2017/05/05/jumpsmartmaui-announces-successful-completion-of-project/>
53 PG&E (2021). Marketplace. Accessed: marketplace.pge.com/
54 Sacramento Municipal Utility District (2021). A whole house approach to energy efficiency. Accessed: https://www.smud.org/en/Rebates-and-Savings-Tips/Improve-Home-Efficiency
55 SoCal Edison (2021). Marketplace. Accessed: https://www.sce.com/sites/default/files/2019-07/Marketplace%20Fact%20Sheet%200719%20r5_WCAG.pdf
56 Sacramento Municipal Utility District. (2021). SMUD Go electric With rebates up to $2,500. Accessed: https://www.smud.org/en/Rebates-and-Savings-Tips/Go-electric
57 Great Northwest Installations (2020). Portland Area Water Heater Promos. Accessed: www.greatnorthwestinstallations.com/waterheaterpromo
58 Peninsula Clean Energy. (2020). Residential Programs and Rebates <https://www.peninsulacleanenergy.com/heat-pump-water-heater/>
59 City of Palo Alto (2020). Heat Pump Water Heater Program Details. Accessed: https://www.cityofpaloalto.org/gov/depts/utl/residents/save_energy_n_water/rebates/heat_pump_water_heater/program_details.asp
60 Note that these services are free for customers who qualify for energy assistance.
61 BayREN. (2021). Electrification: Programs to Electrify Homes. Accessed: https://www.bayren.org/electrification
62 BAYREN Home (2021). “Bring Out the Best in Your Home.” BayREN Residential. Accessed: https://bayrenresidential.org
63 Silicon Valley Clean Energy. (2021). Electric Appliances at Home. Accessed: https://www.svcleanenergy.org/electric-home/
64 Sonoma Clean Power (2021). Accessed: https://sonomacleanpower.org/news/incentives-for-smart-thermostats-and-heat-pump-water-heaters-now-available
65 Energy Smart Home Performance (2016) 1890 Ranch – Habitat for Humanity Deep Energy Retrofit. Energy Smart Home Performance <http://energysmartohio.com/case_studies/1890-ranch-habitat-humanity-deep-energy-retrofit/>
66 Energy Smart Home Performance (2016) 1890 Ranch – Habitat for Humanity Deep Energy Retrofit. Energy Smart Home Performance <http://energysmartohio.com/case_studies/1890-ranch-habitat-humanity-deep-energy-retrofit/>
67 Photos courtesy of Ben and Sara Shalva
68 Best Buy. (2020). Bosch-Benchmark Series 30” Electric Induction Cooktop. Accessed: https://www.bestbuy.com/site/bosch-benchmark-series-30-electric-induction-cooktop/6335504.p>
69 Photos courtesy of Steve Schmidt
70 Photos courtesy of Steve Schmidt
71 Sustainable Lafayette. (2021). Home Electrification Part 1: Why We are Removing Gas from our Home and Going All Electric. Accessed: https://www.sustainablelafayette.org/post/why-we-are-removing-gas-from-our-home-and-going-all-electric
72 Sustainable Lafayette. (2021). Home Electrification Part 1: Why We are Removing Gas from our Home and Going All Electric. Accessed: https://www.sustainablelafayette.org/post/why-we-are-removing-gas-from-our-home-and-going-all-electric
73 Jay Egg (2019) 1830 Home in Hamilton, New York is an all-electric Geothermal Masterpiece. Green Builder. <https://www.greenbuildermedia.com/energy-solutions/1830-home-in-hamilton-ny-is-an-all-electric-geothermal-masterpiece>
74 Jay Egg (2019) 1830 Home in Hamilton, New York is an all-electric Geothermal Masterpiece. Green Builder. <https://www.greenbuildermedia.com/energy-solutions/1830-home-in-hamilton-ny-is-an-all-electric-geothermal-masterpiece>
75 Campus Center for Appropriate Technology. (2021). Accessed: https://ccat.humboldt.edu/
76 Photographs courtesy of Xavier Gaucher. Personal Communication.
77 Gaucher, X. (n.d.) The Perlita Passive House Journey. Builder and Developer. <https://bdmag.com/perlita-passive-house-journey/>
78 Energy Smart Ohio. (2016). 1918 House of the Future in Cleveland Heights. Accessed: https://energysmartohio.com/case_studies/1917-net-zero-ready/
79 Energy Smart Ohio. (2016). 1918 House of the Future in Cleveland Heights. Accessed: https://energysmartohio.com/case_studies/1917-net-zero-ready/
80 Willenbrook, Scott. (2020). Colonial Solar House. https://ws.engr.illinois.edu/blogs/getfile/37/40688
81 Willenbrook, Scott. (2020). Colonial Solar House. https://ws.engr.illinois.edu/blogs/getfile/37/40688
82 1000 Home Challenge. (2010). The Bindley Carbon Neutral Renovation. Accessed: https://jhn.e94.myftpupload.com/wp-content/uploads/2020/10/Bindley-Carbon-Neutral-Rennovation-Case-Study.pdf
83 1000 Home Challenge. (2010). The Bindley Carbon Neutral Renovation. Accessed: https://jhn.e94.myftpupload.com/wp-content/uploads/2020/10/Bindley-Carbon-Neutral-Rennovation-Case-Study.pdf
84 1000 Home Challenge. (2012). Deep Energy Retrofit Goes for Zero. Accessed: https://jhn.e94.myftpupload.com/wp-content/uploads/2020/10/Ross-Residence-Case-Study.pdf
85 Northeast Sustainable Energy Association. (2021). Ross Residence. Accessed: https://nesea.org/project-case-study/ross-residence/general
86 Refrigeration Kings. (2019). “Protect Your Heat Pump From the Harsh Atlantic Weather” <https://www.kingsrefrigeration.com/residential/heat-pump-accessories>
87 Sanden. (n.d.) Heat Pump Water Heater. <https://www.sandenwaterheater.com/sanden/assets/File/SANDEN_CO2WaterHeaterG3_3_17.pdf>
88 Renew. Heat pump hot water systems. <https://renew.org.au/resources/how-we-can-help/efficient-electric-homes/how-we-can-help-heat-pump-hot-water-systems/>

89 SANCO2 Water Heater. (2020). Twitter, <https://twitter.com/sandenco2hpwh?lang=en>
90 John Miles. SANCO2 performance curves at cold temperatures [email correspondence]. Message to: Sean Armstrong. 2020 Oct 29.
91 SANCO2 Water Heater. (2020). Twitter, <https://twitter.com/sandenco2hpwh?lang=en>
92 SANCO2 Water Heater. (2020). Twitter, <https://twitter.com/sandenco2hpwh?lang=en>
93 Water Heater Timer. (n.d.) What size indirect water heater do you need? Accessed: http://waterheatertimer.org/What-size-indirect-heater.html
94 The Carrier Infinity 24 Heat Pump with Greenspeed Intelligence (25VNA4) is being marketed with a cooling efficiency up to 24 SEER and a heating efficiency up to 13 HSPF. This heating efficiency corresponds to 3.8 COP. Although gas and electric efficiency differ on a more technical level, this simplified version of comparison is considered effective at communicating the difference in efficiencies of the two heating technologies.
95 <https://en.wikipedia.org/wiki/Seasonal_energy_efficiency_ratio>
96 <https://en.wikipedia.org/wiki/Heating_seasonal_performance_factor>
97 Advanced Distributer Products Air Hander <https://www.carrierenterprise.com/b-series-air-handler-2-ton-cu-multi-position-cased-painted-r-410a-ac-txv-hot-water-heat-with-pump-120v-bcrma3624s3p3>
98 Stelpro Air Handler <https://www.homelectrical.com/120v-air-handler-psc-built-control-1400-cfm-62-amp.stp-scvp1411.1.html>
99 King Electrical Mfg. Co. <https://www.gordonelectricsupply.com/p/King-Ah1-2-120V-Air-Handler-1-2-Hp-120V-Job-Htr/6499432?ID=/King-Electrical-Mfg-Co/mfr-1IFU>
100 Quadomated. (2012). Fujitsu 15RLS2 Heat Pump Installed – My Initial Thoughts. <http://www.quadomated.com/house/fujitsu-15rls2-heat-pump-installed-my-initial-thoughts/>
101 Beuerlein, K. Is Ductless Heating and Cooling Right for You? HGTV. <https://www.hgtv.com/remodel/mechanical-systems/is-ductless-heating-and-cooling-right-for-you>
102 LG (2019). Residential/Light Commercial Systems Counter Quick Reference Guide. < https://www.victordist.com/content/PI_Home_Comfort_Solutions_Reference.pdf>
103 https://www.thisoldhouse.com/milton-house/21015136/the-case-for-installing-a-heat-recovery-ventilator
104 The difference between an HRV and an ERV - AVS - the Best Choice. (2020). < http://www.airventingsolutions.com/how-to-choose-between-hrv-erv-home-ventilation-systems-usa-canada>
105 How Do Heat Recovery Systems Work?. (2017). < https://www.bpcventilation.com/blog/do-heat-recovery-systems-work>
106 See the Induction Cooking Fact Sheet by Tom Lent: <https://docs.google.com/document/d/1qiGX6-tFdawfA6Nqp8SYifRbtucX9RzqAdjZ_5NdwBE/edit>
107 Baylon et. al. (2013). “Residential Building Stock Assessment: Multifamily Characteristics and Energy Use.” Ecotope, Inc. for NEEA.
108 Korn & Dimetrosky. (2010). “Do the Savings Come Out in the Wash? A Large-Scale Study of In-Situ Residential Laundry Systems.” The Cadmus Group. ACEEE Summer Study on Energy Efficiency in Buildings
109 U.S. Department of Energy. (2017). “Saving Energy and Money with Appliance and Equipment Standards in the United States” <https://www.energy.gov/sites/prod/files/2017/01/f34/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-011917_0.pdf>
110 Janeway, K. (2014). “Finally, the lowly dryer can reach for Energy Star” <https://www.consumerreports.org/cro/news/2014/05/finally-the-humble-dryer-can-reach-for-energy-star/index.htm>
111 Span. (2019). Flexible energy for the modern home <https://www.span.io/>
112 Eaton. (2017). Eaton Pow-R-Command intelligent panelboard. <https://www.eaton.com/ecm/groups/public/@pub/@electrical/documents/content/pa144001en.pdf>
113 Koben. (2020). Energy Management. The GENIUS Smart Panel. <https://kobensystems.com/energy-management/>
114 Eaton. (2019). Energy management circuit breaker <https://www.eaton.com/us/en-us/markets/innovation-stories/energy-management-circuit-breaker.html>
115 Lumin. (2019). Lumin energy management platform <https://www.luminsmart.com/platform>
116 NeoCharge. (2019). NeoCharge Smart Splitter <https://www.getneocharge.com/>
117 BSA Electronics. (2019). Dryer Buddy <https://www.bsaelectronics.com/collections/dryer-buddys>
118 SimpleSwitch. (2020). https://simpleswitch.io/products/simple-switch
119 SpitVolt (2020). https://www.splitvolt.com/splitter-switches/
120 DCC. (2018). DCC-9 <https://dcc.technology/dcc-9/>
121 EVduty. (2019) EVduty Smart Current Sensor. <https://evdutystore.elmec.ca/blogs/news/b-new-evduty-product-smart-current-sensor-b>
122 Contact Clean Coalition for more information. <https://clean-coalition.org/>
123 Bandyk, Matthew. “Battery prices fall nearly 50% in 3 years, spurring more electrification: BNEF.” Utility Dive. Dec. 3, 2019. <https://www.utilitydive.com/news/battery-prices-fall-nearly-50-in-3-years-spurring-more-electrification-b/568363/>
124 Goal Zero. Discover Power Station. <https://www.goalzero.com/product-features/portable-power-stations/>
125 Lectron Level 1 EV Charger (n.d.) < https://ev-lectron.com/products/lectron-portable-electric-car-charger-16a?variant=31869379477550&currency=USD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&gclid=Cj0KCQjw8rT8BRCbARIsALWiOvTPOzVj9F1DMDM8zMMz6K8Sfk3-kREz2Cr7Y62B_OpG2ewdtcmFhhUaAkjMEALw_wcB >
126 <https://ev-lectron.com/products/lectron-portable-electric-car-charger-40a?variant=31879961313326&currency=USD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&gclid=CjwKCAiAi_D_BRApEiwASslbJ9axEuKodVZMhOuDFAEXcGTcxjY1jFlZhxISmfrd9u1wuIj5zTRkeRoCOAQQAvD_BwE>
127 Inside EVs. (2021). “Enelx Juicebox Smart EV Charger Review” <https://insideevs.com/news/402950/enelx-juicebox-smart-ev-charger-review/>
128 Chargepoint Home Flex. (2021). “Chargepoint Home Flex” <https://www.chargepoint.com/drivers/home/chargepoint-home-flex/?gclid=Cj0KCQiA5vb-BRCRARIsAJBKc6KZWI3-tz92cM3FqHwL9J70Tj4G3k6UvqOcmmCRmQzN59JrCARydFsaAmaoEALw_wcB>
129 NEMA Sockets For EV Charging (n.d) < https://www.splitvolt.com/nema-sockets-for-ev-charging-at-home/ >
130 Gerdes, J. (2019). Will Your EV Keep the Lights On When the Grid Goes Down? Green Tech Media. <https://www.greentechmedia.com/articles/read/will-your-ev-keep-the-lights-on-when-the-grid-goes-down>
131 McMahon, J. (2019). All The Energy Storage The Grid Needs Will Soon Be Under Our Noses. Forbes. <https://www.forbes.com/sites/jeffmcmahon/2019/11/12/all-the-grid-batteries-we-need-and-more-will-soon-be-under-our-noses/#696c61f136e3>
132 Wallbox. (2020). https://wallbox.com/en_us/
133 Ossiaco. (2020) Dcbel. Your Energy Without Compromise. <https://dcbel.ossiaco.com/>
134 Nuvve. (2020). https://nuvve.com/2019/05/01/nuvve-powerport/
135 Fermenta Energy. (2020). https://www.fermataenergy.com/homeowners
136 Modern Blaze (2020). Commercial electric fireplace. <https://www.google.com/maps/uv?pb=!1s0x88137ddbda180241%3A0xd2a0ba797ab5122b!3m1!7e115!>
137 STIHL. (2019) “AP Series” <https://www.stihlusa.com/products/battery-products/ap-series/>
138 Husqvarna. (2019). “Battery Series” <https://www.husqvarna.com/us/products/battery/>
139 RYOBI. (2019). “Lawn and Garden” <https://www.ryobitools.com/outdoor>
140 STIHL. (2019) “AP Series” <https://www.stihlusa.com/products/battery-products/ap-series/>
141 Husqvarna. (2019). “Battery Series” https://www.husqvarna.com/us/products/battery/
142 RYOBI. (2019). “Lawn and Garden” https://www.ryobitools.com/outdoor
143 Taiga Electric /snowmobile - 100% electric high torque sleds. (2020). Retrieved 29 October 2020, from https://taigamotors.ca/snowmobiles/

Attachment to Question 9b (1 out of 3): 2011 Anaheim-Santa Ana Housing Survey

2011 Anaheim-Santa Ana - General Housing Data - All Occupied Units
Anaheim-Santa Ana-Garden Grove, CA SMSA (1971 OMB definition)

[Estimates in thousands of housing units, except as indicated. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards]

Subject Definitions

Characteristics	Estimate	
Total	974.3	
Units in Structure		
1, detached	499.3	
1, attached	142.9	
2 to 4	94.8	
5 to 9	62.7	
10 to 19	62.5	
20 to 49	40.5	
50 or more	42.6	
Manufactured/mobile home or trailer	28.9	
Cooperatives and Condominiums		
Cooperatives	9	
Condominiums	187.2	
Year Structure Built[1,2]		
2010 to 2011	3.6	0.4%
2005 to 2009	34.3	3.5%
2000 to 2004	42	4.3%
1995 to 1999	47.7	4.9%
1990 to 1994	53	5.4%
1985 to 1989	82.3	8.4%
1980 to 1984	57.9	5.9%
1975 to 1979	114.4	11.7%

2011 Anaheim-Santa Ana - General Housing Data - All Occupied Units
Anaheim-Santa Ana-Garden Grove, CA SMSA (1971 OMB definition)

[Estimates in thousands of housing units, except as indicated. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards]

Subject Definitions

Characteristics	Estimate	
1970 to 1974	162.7	16.7%
1960 to 1969	238.9	24.5%
1950 to 1959	98	10.1%
1940 to 1949	21.8	2.2%
1930 to 1939	11.5	1.2%
1920 to 1929	2.9	0.3%
1919 or earlier	3.3	0.3%
Median (year)	1973	
Stories in Structure[3]		
1	368.7	
2	490.5	
3	59.9	
4 to 6	24.3	
7 or more	2.1	
Access to Structure		
Entering building from outside[4]	303.1	
Use of steps not required	137.7	
Use of steps required	165.4	
Use of steps not reported	.	
Entering home from outside[5]	671.1	
Use of steps not required	386.1	
Use of steps required	285	
Use of steps not reported	.	

2011 Anaheim-Santa Ana - General Housing Data - All Occupied Units
Anaheim-Santa Ana-Garden Grove, CA SMSA (1971 OMB definition)

[Estimates in thousands of housing units, except as indicated. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards]

Subject Definitions

Characteristics	Estimate
Stories Between Main and Apartment Entrances[3]	
Multiunits, 2 or more floors	244.9
None (on same floor)	90.1
1 (up or down)	71.7
2 or more (up or down)	83.1
Elevator on Floor[3]	
Multiunits, 2 or more floors	244.9
With at least 1 working elevator	31.1
With at least 1 elevator, none in working condition	.
No elevator	213.8
3 or more floors from main entrance	6.2
Foundation[3]	
1-unit buildings	642.2
With basement under all of building	1.9
With basement under part of building	3.6
With crawl space	78.4
On concrete slab	548.8
Other	9.5
Manufactured/Mobile Home Setup	
Manufactured/mobile homes	28.9
Set on permanent masonry foundation	3.4

2011 Anaheim-Santa Ana - General Housing Data - All Occupied Units
Anaheim-Santa Ana-Garden Grove, CA SMSA (1971 OMB definition)

[Estimates in thousands of housing units, except as indicated. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards]

Subject Definitions

Characteristics	Estimate
Resting on concrete pad	5.7
Up on blocks, but not on concrete pad	10.2
Setup in some other way	8.4
Setup not reported	1.3
Manufactured/Mobile Home Anchoring	
Manufactured/mobile homes	28.9
Anchored by tiedowns, bolts, or other means	21.9
Not anchored	5.1
Anchoring not reported	2
Manufactured/Mobile Home Size	
Manufactured/mobile homes	28.9
Single-wide	4.6
Double-wide	23.3
Triple-wide or larger	1
Size not reported	.
Manufactured/Mobile Home Site Placement	
Manufactured/mobile homes	28.9
First site	17.2
Moved from another site	2.1
Don't know	3.3
Site placement not reported	6.4

2011 Anaheim-Santa Ana - General Housing Data - All Occupied Units
Anaheim-Santa Ana-Garden Grove, CA SMSA (1971 OMB definition)

[Estimates in thousands of housing units, except as indicated. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards]

Subject Definitions

Characteristics	Estimate
Manufactured/Mobile Homes in Group	
Manufactured/mobile homes	28.9
1 to 6	5.8
7 to 20	2.9
21 or more	20.2

[1] For manufactured/mobile homes, oldest category is 1939 or earlier.
[2] Median is estimated from the printed distribution; see Subject Definitions.
[3] Figures exclude manufactured/mobile homes.

Source: U.S. Census Bureau, American Housing Survey.
Generated on: 04OCT22:17:07:36

Attachment to Question 9b (2 out of 3): 2019 California Housing Survey

2019 California - General Housing Data - All Occupied Units

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

[Subject Definitions]

Characteristics	Estimate
Total	13306.8
Units in Structure	
1, detached	7921.2
1, attached	723.6
2 to 4	1195.6
5 to 9	783.7
10 to 19	617.3
20 to 49	699.7
50 or more	921.9
Manufactured/mobile home or trailer	419.4
Other (Boat, RV, van, etc.)	S
Cooperatives and Condominiums	
Cooperatives	111.1
Condominiums	1182.7
Member of Any Type of Cooperative or Association	
Member of condominium association only	245.1
Member of cooperative only	61
Member of homeowners association only	1722.4
Member of condominium association and homeowners association	896.5
Member of cooperative and homeowners association	45.4
No membership	9926.6
Membership not reported	409.7

2019 California - General Housing Data - All Occupied Units

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

[Subject Definitions]

Characteristics	Estimate	
Year Structure Built[1,2]		
2018 to 2019	98.2	0.7%
2016 to 2017	167.7	1.3%
2010 to 2015	343.1	2.6%
2005 to 2009	615.3	4.6%
2000 to 2004	852.6	6.4%
1995 to 1999	670.9	5.0%
1990 to 1994	639.4	4.8%
1985 to 1989	1213.3	9.1%
1980 to 1984	832.6	6.3%
1970 to 1979	2225.5	16.7%
1960 to 1969	1849.7	13.9%
1950 to 1959	1810.7	13.6%
1940 to 1949	745.7	5.6%
1930 to 1939	359.5	2.7%
1920 to 1929	473.2	3.6%
1919 or earlier	409.3	3.1%
Median (year)	1974	100.0%
Stories in Structure[3]		
1	6016	
2	5087.3	
3	1189.3	
4 to 6	440.9	
7 or more	129.4	
Access to Structure		

2019 California - General Housing Data - All Occupied Units

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

Subject Definitions

Characteristics	Estimate
Entering building from outside[4]	4218.1
Use of steps not required	2205.7
Use of steps required	2004.7
Use of steps not reported	S
Entering home from outside[5]	9088.7
Use of steps not required	6204.1
Use of steps required	2881.9
Use of steps not reported	S
Foundation Type	
Single-family, attached and detached	8669.3
Basement under all of house	138.4
Basement under part of house	201.8
Crawl space	2575.3
Concrete slab	5555
Setup in some other way	198.9
Manufactured/mobile homes	419.4
Mobile home set on masonry foundation	S
Mobile home resting on concrete pad	S
Mobile home up on blocks, but not on concrete pad	S
Mobile home setup in some other way	S
Mobile home foundation not reported	S
Manufactured/Mobile Home Anchoring	
Manufactured/mobile homes	419.4

2019 California - General Housing Data - All Occupied Units

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

Subject Definitions

Characteristics	Estimate
Anchored by tiedowns, bolts, or other means	353
Not anchored	40.5
Anchoring not reported	S
Manufactured/Mobile Home Size	
Manufactured/mobile homes	419.4
Single-wide	S
Double-wide	S
Triple-wide or larger	S
Size not reported	S
Manufactured/Mobile Homes in Group	
Manufactured/mobile homes	419.4
1 to 6	202
7 to 20	S
21 or more	202.4

[1] For manufactured/mobile homes, oldest category is 1939 or earlier.

[2] Median is estimated from the printed distribution; see Subject Definitions.

[3] Figures exclude manufactured/mobile homes and boats, RVs, vans, etc.

[4] Restricted to multiunits.

[5] Restricted to single units.

Source: U.S. Census Bureau, American Housing Survey.

Generated on: 04OCT22:17:05:58

Attachment to Question 9b (3 out of 3): 2019 LA-LB Glendale Housing Survey

2019 Los Angeles-Long Beach - General Housing Data - All Occupied Units
Los Angeles-Long Beach-Anaheim, CA MSA (2013 OMB definition)

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

Subject Definitions

Characteristics	Estimate
Total	4408
Units in Structure	
1, detached	2258.8
1, attached	235.4
2 to 4	431.9
5 to 9	327.4
10 to 19	308
20 to 49	391.4
50 or more	381.6
Manufactured/mobile home or trailer	71.9
Other (Boat, RV, van, etc.)	S
Cooperatives and Condominiums	
Cooperatives	46.8
Condominiums	430
Member of Any Type of Cooperative or Association	
Member of condominium association only	70.8
Member of cooperative only	S
Member of homeowners association only	463.3
Member of condominium association and homeowners association	340.1
Member of cooperative and homeowners association	23.1
No membership	3325.1

2019 Los Angeles-Long Beach - General Housing Data - All Occupied Units
Los Angeles-Long Beach-Anaheim, CA MSA (2013 OMB definition)

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

Subject Definitions

Characteristics	Estimate
Membership not reported	166.5
Year Structure Built[1,2]	
2018 to 2019	S
2016 to 2017	51.4
2010 to 2015	108.9
2005 to 2009	106
2000 to 2004	177.9
1995 to 1999	141.6
1990 to 1994	142
1985 to 1989	283.7
1980 to 1984	241.8
1970 to 1979	647.7
1960 to 1969	735.5
1950 to 1959	856.8
1940 to 1949	328.7
1930 to 1939	180.3
1920 to 1929	251.6
1919 or earlier	140.9
Median (year)	1966
Stories in Structure[3]	
1	1828.5
2	1792
3	461.4

2019 Los Angeles-Long Beach - General Housing Data - All Occupied Units
Los Angeles-Long Beach-Anaheim, CA MSA (2013 OMB definition)

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

Subject Definitions

Characteristics	Estimate
4 to 6	192.6
7 or more	60.1
Access to Structure	
Entering building from outside[4]	1840.3
Use of steps not required	897.3
Use of steps required	939.4
Use of steps not reported	S
Entering home from outside[5]	2567.7
Use of steps not required	1649.2
Use of steps required	916.8
Use of steps not reported	S
Foundation Type	
Single-family, attached and detached	2495.7
Basement under all of house	28.3
Basement under part of house	52.3
Crawl space	831.2
Concrete slab	1506.5
Setup in some other way	77.4
Manufactured/mobile homes	71.9
Mobile home set on masonry foundation	S
Mobile home resting on concrete pad	S
Mobile home up on blocks, but not on concrete pad	43.7

2019 Los Angeles-Long Beach - General Housing Data - All Occupied Units
Los Angeles-Long Beach-Anaheim, CA MSA (2013 OMB definition)

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

Subject Definitions

Characteristics	Estimate
Mobile home setup in some other way	S
Mobile home foundation not reported	.
Manufactured/Mobile Home Anchoring	
Manufactured/mobile homes	71.9
Anchored by tiedowns, bolts, or other means	61.8
Not anchored	S
Anchoring not reported	S
Manufactured/Mobile Home Size	
Manufactured/mobile homes	71.9
Single-wide	S
Double-wide	S
Triple-wide or larger	S
Size not reported	S
Manufactured/Mobile Homes in Group	
Manufactured/mobile homes	71.9
1 to 6	S
7 to 20	S
21 or more	S

[1] ***For manufactured/mobile homes, oldest category is 1939 or earlier.***

[2] ***Median is estimated from the printed distribution; see Subject Definitions.***

2019 Los Angeles-Long Beach - General Housing Data - All Occupied Units
Los Angeles-Long Beach-Anaheim, CA MSA (2013 OMB definition)

[Estimates and Margins of Error in thousands of housing units, except as indicated. Medians are rounded to four significant digits as part of disclosure avoidance protocol. Margin of Error is calculated at the 90% confidence interval. Weighting consistent with Census 2010. Blank cells represent zero; Z rounds to zero; '.' Represents not applicable or no cases in sample; S represents estimates that did not meet publication standards or withheld to avoid disclosure]

[Subject Definitions]

Characteristics	Estimate

[3] Figures exclude manufactured/mobile homes and boats, RVs, vans, etc.

[4] Restricted to multiunits.

[5] Restricted to single units.

Source: U.S. Census Bureau, American Housing Survey.

Generated on: 04OCT22:17:06:41