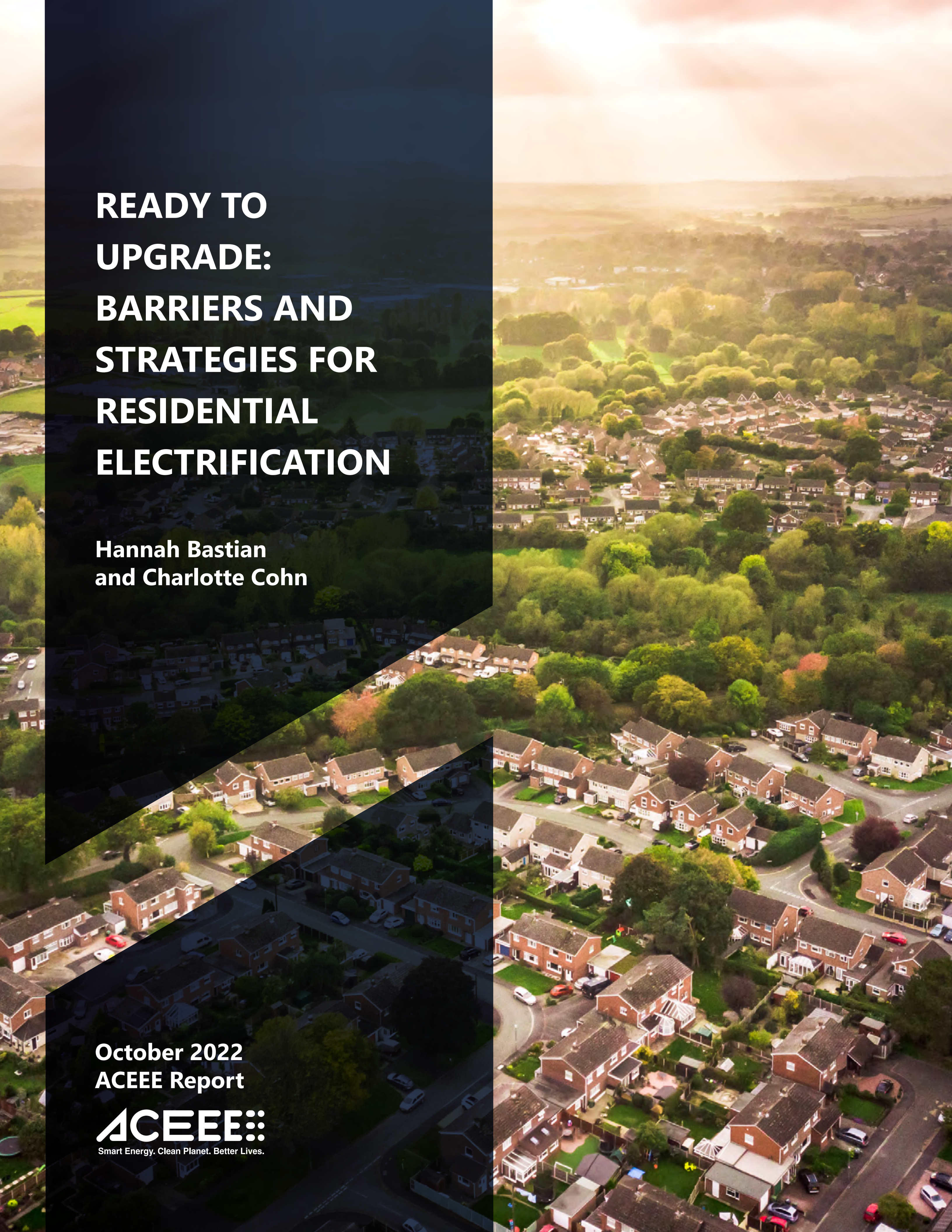

READY TO UPGRADE: BARRIERS AND STRATEGIES FOR RESIDENTIAL ELECTRIFICATION

Hannah Bastian
and Charlotte Cohn

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ACEEE Report

ACEEE
Smart Energy. Clean Planet. Better Lives.

Contents

About ACEEE

The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

About the Authors

Hannah Bastian conducted research for ACEEE's buildings team from 2017 until August 2022. Prior to joining ACEEE, Hannah interned at the UC Davis Energy Efficiency Center where she assisted research on the marketability of a direct-install HVAC program. She also worked as an assistant to the program manager and outreach director at the National Center for Sustainable Transportation. Hannah earned a bachelor of science in environmental and resource economics from the University of California, Davis.

Charlotte Cohn conducted research and analysis as a part of ACEEE's utilities team from January 2020 to September 2022. Prior to joining ACEEE, she worked with the Vermont Law School Institute for Energy and the Environment on building community solar projects for low-moderate income communities in New Hampshire. Additionally, she was a residential solar energy consultant in Massachusetts and worked with customers to control their home energy use by installing solar systems. She holds a master's in energy regulation and law from the Vermont Law School and a bachelor's degree from the University of Vermont.

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KEY FINDINGS

- Across the United States, cities, utilities, co-ops, community choice aggregations (CCAs), and third-party organizations are implementing electrification programs to help people complete home-electrification retrofits. These programs address key barriers to electrification, including whole-building barriers, technology barriers, and market barriers. Most successful programs offer one-stop-shop service for their customers to make participation straightforward.
- Whole-building and technology barriers to residential electrification retrofits include building upgrades (e.g., electrical panel and wiring) and environmental challenges (e.g., extremely cold temperatures). Emerging technology such as cold-climate heat pumps and smart electrical panels can help overcome these barriers.
- Market barriers include high costs, supply chain challenges (e.g., insufficient stock at distribution centers), contractor shortages, and lack of consumer awareness. Programs are addressing these barriers by offering incentives, providing engagement and training to contractors, and working with manufacturers and supply chains.
- High project costs and long payback times are another major barrier. Programs are incentivizing both electrification measures and complementary projects (e.g., weatherization and panel upgrades). Many programs work with other organizations and government agencies to combine incentives to improve project economics. Programs also train contractors to design cost-effective systems (e.g., how to avoid a panel upgrade through efficiency measures).
- Supply chain challenges also hinder electrification programs. Given that a high number of HVAC or water heating replacements happen in emergency situations (when old equipment fails), ensuring distributors have sufficient stock of heat pumps and heat pump water heaters is critical. Programs can work with distributors and manufacturers to ensure a sufficient stock of equipment in the program territory.
- Lack of available workforce is another major market barrier to electrification retrofits. Many areas in the United States do not have enough workers who are trained to design and install residential electric systems. In addition to training the local workforce, some programs maintain lists of recommended contractors to ensure customers are receiving quality service and to make finding a contractor easier for program participants.
- Consumer education and awareness is another key challenge for electrification programs. Consumers are generally unaware of or misinformed about efficient electric equipment and appliances and their benefits. Programs are addressing this barrier through awareness campaigns and web-based consumer education, leveraging trusted consumer resources such as ENERGY STAR®.

Executive Summary

Building electrification means converting a building's heating, hot-water, and other systems to efficient electric equivalents, which can be powered by 100% carbon-free electricity. Reducing carbon emission from buildings will be critical to meeting greenhouse gas reduction goals and avoiding the worst impacts of climate change. As the electric power sector transitions its generation to carbon-free energy sources, direct combustion of fossil fuels in buildings for heating and other uses remains a major source of carbon emissions. Over 60% of homes in the United States use fossil fuels to directly power at least one appliance or piece of equipment. Reaching a net-zero-carbon energy system will require switching homes away from fossil fuels to electricity powered by clean energy.

The end uses that present the greatest opportunity for electrification are space heating and water heating, which are served by fossil fuels in most homes in the United States. These end uses also account for the greatest share of energy consumption in homes. Household energy use in total accounts for roughly 20% of U.S. energy-related greenhouse gas (GHG) emissions.[1] Compared with GHG emissions globally, this is equivalent to the total GHG footprint of a nation the size of Brazil, the sixth-largest emitter of greenhouse gases in the world.

Fortunately, all-electric homes already exist, and are even common in certain parts of the United States (particularly the Northwest and South). For space heating, water heating, and cooking, efficient electric products have been on the market for decades and are continually improving in capability, efficiency, and quality. From a technical perspective, there is no building that cannot be retrofitted to be all electric. However, many challenges and barriers make electrification retrofits intimidating and expensive for homeowners. These can include significant building upgrades to support all-electric equipment, high upfront costs, long project time periods, and difficulty finding qualified contractors.

Many organizations across the country are working to accelerate electrification through market transformation efforts and electrification programs. These programs are designed to help owners navigate the process of electrifying their homes by alleviating common barriers. Programs might lower project costs by providing incentives and financing, provide lists of quality contractors to ensure projects are designed and installed properly, or distribute educational material about different technology options and their benefits.

This report explores the many barriers and challenges to residential electrification retrofits, including building-sited challenges, technology challenges, and broad market barriers like

[1] Goldstein, B., D. Gounaridis, and J. Newell. 2020. *The Carbon Footprint of Household Energy Use in the United States.* Pittsburgh, PA: Carnegie Mellon University. doi.org/10.1073/pnas.1922205117.

workforce development and consumer awareness and understanding. We then explore the ways electrification programs can address these challenges to create an environment where electrification retrofits are straightforward. The following summarizes our findings.

KEY BARRIERS TO RESIDENTIAL ELECTRIFICATION RETROFITS AND PROGRAM SOLUTIONS

Whole-Building Barriers

In the United States, each building presents a unique set of barriers. While some buildings may be ready for all electric equipment and can do a simple one-for-one replacement, many will have to make upgrades to become fully electric. Upgrading the electrical panel and wiring to support electric equipment will be a common requirement, particularly in older buildings that were designed to support limited electric equipment. Another barrier is space constraints: many homes, apartments, and condo buildings do not have sufficient space for heat pumps or heat pump water heaters and require creative solutions. An additional barrier concerns the local utility's distribution infrastructure, such as power lines and transformers, which may require capacity upgrades to service increased power demand from an all-electric home.

Solutions

Programs can help address these barriers by providing training and support to the workforce on best practices and solutions to common challenges. As contractors complete more electrification projects, they will learn solutions and be able to apply them to future projects. Programs can also assist homeowners who need to upgrade panels and wiring by walking them through the permitting process and scheduling an upgrade appointment, establishing contractor networks and offering midstream incentives for qualified electricians, providing technical assistance for larger-scale projects in multifamily buildings, and offering financial incentives to reduce the cost of necessary electrical upgrades for both the home and local grid infrastructure.

High Project Costs

Electrification projects can have significant upfront costs. Efficient electric equipment often costs more than fossil-fuel and inefficient electric alternatives, a challenge compounded if panel upgrades, wiring upgrades, and physical changes are required. In some areas, contractors may charge a premium for electrification projects because they will need to spend more time properly designing the system and may worry about callbacks if the customer is unhappy with their new system. Fuel switching may also result in higher utility costs despite the higher efficiency of equipment, as the cost of electricity significantly exceeds the cost of heating with natural gas in some regions.

SOLUTIONS

Programs can address project costs in several ways. First, they can provide incentives for electrification measures and complementary measures (like panel upgrades or weatherization). They can also use a home energy audit to identify other efficiency improvements like air sealing and insulation that can reduce the size of electric equipment needed for heating or cooling. In some cases, programs can help contractors identify opportunities to avoid panel upgrades by reducing electrical loads and using smart plugs and panels to avoid exceeding the panel's capacity. While electricity and natural gas prices are often a result of variable market conditions, electrification-friendly rate structures can create a more favorable environment for ongoing costs after fuel switching is complete. Lastly, programs can layer and streamline other available incentives and financing that are offered by other utilities, programs, and their local, state, or federal government.

LACK OF QUALIFIED WORKFORCE

Contractors are a key stakeholder in electrification retrofits because they are the main point of contact for home and building owners. In many parts of the United States, there are simply not enough contractors trained to properly install heat pumps and heat pump water heaters, particularly in retrofit situations. Contractors may be hesitant to learn new technologies because they have limited resources for training, and they may worry that entering a new market without existing demand is risky. At the same time, as many experienced contractors are retiring, not enough workers are entering the contractor workforce to replace them. This gap and labor shortage can severely limit the number of electrification retrofits in each region.

SOLUTIONS

Programs can support workforce development by assessing the local contractor market and identifying gaps in expertise. The best way programs can support local contractors is by cultivating consumer demand for electrification projects and calibrating workforce development efforts to ensure they do not train workers for jobs that do not exist. Once programs determine the number of contractors necessary to support their activity while still ensuring quality jobs and wages, they can begin offering free training (directly or through partnership) to interested contractors on installation best practices, sales and marketing to customers, and business development. Programs can also create mechanisms to ensure quality assurance, like requiring contractors to meet certain standards to qualify for the program and creating avenues for customers to report good or bad customer service from contractors.

CONSUMER AWARENESS AND UNDERSTANDING

Many consumers lack awareness and understanding of electrification and why it is important. They are also unfamiliar with efficient electric technologies and their benefits. Customers may also have concerns about electrification increasing their electricity bills. In addition, many consumers may have misconceptions about certain technologies like heat pumps not working in the cold or induction cooktops not providing even heat for cooking. It is critical to ensure consumers are aware of electric technologies and their benefits so that they seek them out when they pursue retrofits or equipment replacement. Customers must also understand how to use and maintain their new equipment for optimal performance, because properly running systems improve customer satisfaction. Both contractors and program implementers want customers to feel satisfied with their new equipment; a positive experience increases the likelihood that electrification technologies will gain traction through positive word of mouth.

SOLUTIONS

In order to engage and motivate action, it is critical to not only raise awareness of efficient electric technologies but also provide education that answers questions and addresses the lack of familiarity with a trusted voice of authority. Many utility programs, such as rebates or whole-home audit and retrofit programs, include consumer awareness and education as part of their marketing. These programs leverage multiple advertising streams, including social media, Google ads, mailers, and emails. They also feature a wide variety of educational resources to answer common questions, such as how to evaluate whether a heat pump is right for your home or energy savings from switching to a heat pump water heater. Familiar labels such as ENERGY STAR can also help support consumer awareness building, education, and adoption. Programs may also use data analytics to target specific customer segments, such as households with fossil-fueled equipment nearing the end of usable life, in order to install electrification upgrades when it is most cost effective for the homeowner.

SUPPLY CHAIN

Key stakeholders in the supply chain include manufacturers, distributors, retailers, and contractors. Insufficient supplies of efficient electric equipment can lead to "like for like" replacements of fossil-fueled equipment.

SOLUTIONS

Programs can engage with manufacturers and distributers to ensure sufficient equipment is always available. Manufacturers can also play a key role in engaging and training contractors. Distributors and manufacturers often provide free training on proper installation and marketing methods for their products. These training sessions can be used to connect installers to utility rebates and programs that directly serve end users.

PROGRAM OPPORTUNITY

While many barriers to electrification retrofits exist, organizations across the United States are demonstrating that programs can help customers make their homes both electric and more efficient. Addressing whole-building, technology and market barriers can help customers more easily navigate electrification retrofits and move us closer to local and federal environmental goals. Additionally, large-scale federal funding from bills such as the Inflation Reduction Act can potentially be leveraged to spur market development and accelerate building electrification across the United States.

Introduction

According to the Intergovernmental Panel on Climate Change, the United States will need to reduce greenhouse gas emissions by 80–100% by 2050 to avoid the most catastrophic impacts of climate change. Emissions from direct fuel use in commercial and residential buildings accounted for 13% of total GHG emissions in the United States in 2019 (EPA 2022b). This share of emissions is likely to grow as other major sectors, like transportation and electricity generation, decarbonize in years to come. Achieving reductions at the scale required to address global climate change will require significantly reducing these fossil-fueled end uses in buildings.

One key strategy for decarbonizing buildings is to switch space heating, water heating, clothes drying, and cooking from fossil fuels to electricity. Recent improvements in electric technologies for these end uses have made them more efficient, reliable, and viable for all homes in the United States. Advancements in heat pumps have made them up to four times more efficient than fossil-fuel and electric resistance heating systems, allowing this once marginal technology to become a foundational aspect of building decarbonization (McKenna, Shah, and Silberg 2020; DOE 2022b). Beyond energy savings and emissions reductions, efficient electric technologies can provide other benefits like making homes more healthy, comfortable, and resilient (Hayes, Kubes, and Gerbode 2020).

However, electrifying all end uses in existing single-family and multifamily buildings can pose significant challenges. Many older homes and multifamily buildings lack the electrical infrastructure to support increased electric loads and may need upgrades to the electrical panels, circuits, wiring, and transformer capacity. Some electric technologies may present other challenges, like lack of space for a heat pump water heater, requiring additional work and costs. Market barriers like lack of available workforce or limited consumer education can add to the potential difficulty of electrification retrofits.

The average consumer is likely to encounter more than one of these barriers when pursuing electrification retrofits. Many consumers are interested in building electrification, with more than 50% of consumers showing an interest in electric heating, water heating, cooking, and other efficient electric technologies (SECC 2020). However, these customers often do not know where to begin or are deterred by the obstacles they encounter, such as high prices and complexity of upgrades. There is an urgent need for clear guidance and support aimed at consumers who want to pursue these projects.

Efficiency programs run by cities, utilities, co-ops, CCAs, and third-party organizations can fill this need if they provide integrated and streamlined services like incentives, financing, and technical assistance in parallel with broader market support like workforce development and consumer education initiatives (Inclusive Economics 2021).

This research aims to (1) characterize the building, technology, and market barriers to electrifying existing homes and (2) identify ways to overcome these barriers to create an environment where electrification retrofits are considerably more straightforward than they are today. We focus on how residential efficiency and electrification programs can act as a one-stop-shop for consumers who want to electrify their homes. Specifically, our research will address the following questions:

- What are the building, technology, and market barriers to electrifying homes? What impact do these barriers have on the ability to electrify all residential buildings?
- How are current residential efficiency and electrification programs addressing these barriers and helping their customers electrify their homes?
- What services and offerings should programs include? Which are the highest priority to include in order to enable scaling up electrification efforts?

ALL-ELECTRIC HOMES AND TECHNOLOGIES

The number of all-electric homes in the United States is growing. As of 2015, 25% of all homes use only electricity, up from 20% in 2005 (EIA 2019). This growth is largely driven by new construction, of which 35% of homes built after 1979 are all electric. Looking at space heating tells an even more dramatic story. Researchers from UC Berkeley's Energy Institute at Haas analyzed historical census and American Survey Community data and found that the percentage of U.S. homes heated by electricity grew from 1% in 1950 to 39% in 2018 (Davis 2022). This growth is largely driven by electric resistance heaters, which consume at least twice the energy of heat pumps on the market today. However, recent Residential Energy Consumption Survey (RECS) data show that the percentage of electrically heated homes using heat pumps is growing. As of 2020, 36% of electrically heated homes use heat pumps, up from 29% in 2015 and 27% in 2005 (EIA 2021). Figure 1 below shows the growth of electrical heating in U.S. homes over the last 70 years.

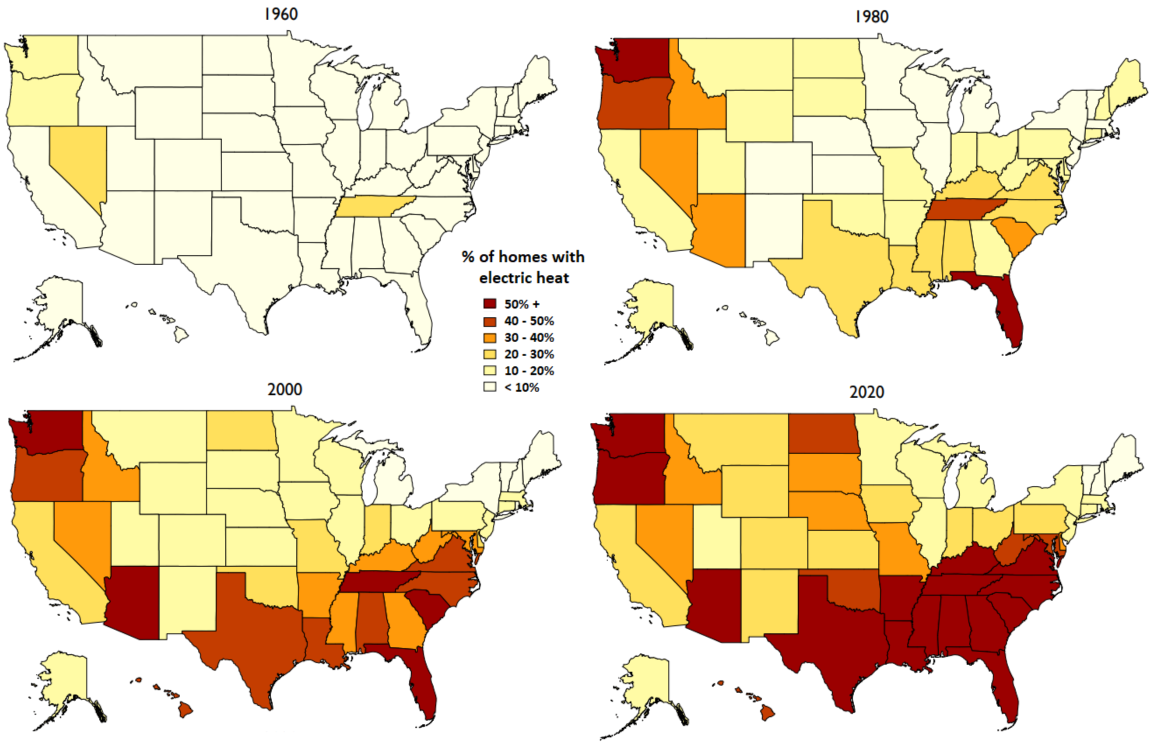

Figure 1. Growth in residential electric heating over the past 60 years (Davis 2022)

Figure 1 shows that the percentage of homes with electric heating varies greatly by geographical region. In the Northwest and South, the number of homes with electric heat has dramatically increased in the last 70 years.[2] The Energy Institute's research found that this change in heating choices is largely due to energy prices. Areas with cheaper electricity and higher fuel costs tend to have a greater percentage of homes heated with electricity. The research found that climate and geography also explain this growth, as areas with warmer climates tend to have more homes with electric heat while cold-climate areas tend to have more homes with fuel heating (i.e., natural gas, fuel oil, and propane) (Davis 2022).

While space heating is just one end use, it illustrates the general trend of electrification in U.S. homes. Other end uses in the home that can be served by either electricity or fuel

[2] Most homes in the United States with electricity as a primary fuel rely on electric resistance for space and water heating. This technology is comparatively less efficient and more costly to operate than a heat pump. Many heat pump incentive programs focus on replacement of resistance heat as an energy efficiency measure.

include clothes dryers, cooking appliances, and water heating. Figure 2 below shows how many of these end uses are served by electricity or fuel in the United States.[3]

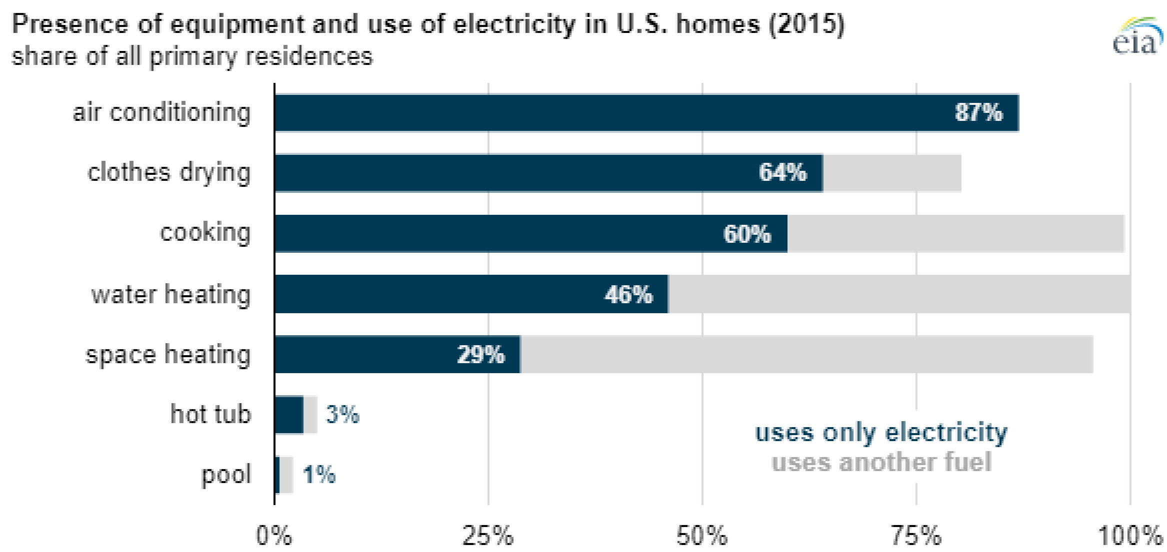

Figure 2. Percentage of residential end uses that use electricity versus another fuel. Source: EIA 2019.

The technologies to shift to all-electric homes already exist today. Over the last few decades, electric appliances and equipment have made significant strides in efficiency and quality, and continuing advances in heat pumps for space and water heating have upended the perception that electric heating is expensive or unsuitable for cold climates. There are more efficient electric options for homes than ever before, and they are becoming increasingly affordable as market adoption increases and economies of scale drive prices down. Unlike in decades past, an all-electric home is common and easy to imagine today. The infographic below shows the technologies that can help make an efficient all-electric home.

[3] These figures are from the Energy Information Administration (EIA) 2015 Residential Energy Consumption Survey (RECs). The EIA released preliminary data from the 2020 survey showing even higher percentages of electric space heating and clothes drying. We are unable to recreate figure 2 with the latest RECs data because the EIA has not released the microdata at the time of writing this report.

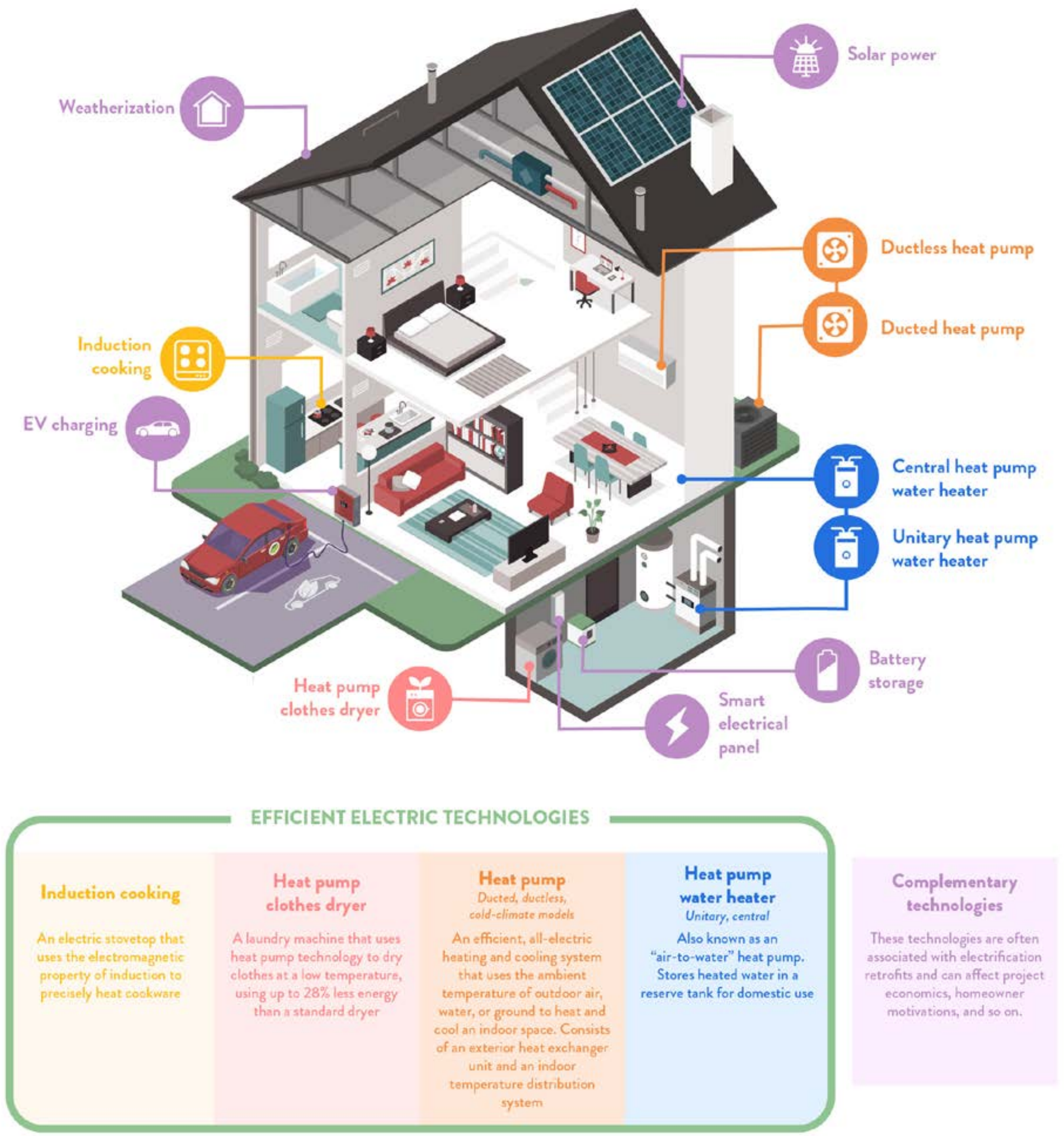

Figure 3. Efficient electric technologies in a single-family residential home

The first and most important step toward building decarbonization is prioritizing the low-hanging fruit of energy efficiency: weatherization, insulation, air sealing, and other measures that increase thermal comfort within the home. Efficiency enables space and water heating to do more with less energy, reducing upfront as well as ongoing costs, and should be paired with electrification wherever feasible.

The technologies in figure 3 above show the most efficient options for electrifying each common end use within the home. For space heating, air-source heat pumps use about 50% less electricity than electric resistance. They can also be more efficient than standard air conditioners, with advanced variable-speed units able to offer even greater efficiency, grid flexibility, and comfort benefits (Clean Cooling Collaborative 2022). Similarly, heat pump water heaters can be two to three times more efficient than electric resistance water heaters, with certain models nearly four times as efficient (DOE 2022c). While heat pump clothes dryers are not currently popular in the United States, European heat pump clothes dryers use up to 28% less energy to dry the same amount of clothes as a conventional electric dryer in the United States (SEDI 2012). Likewise, induction cooktops are 5–10% more efficient than electric resistance cooktops (EPA 2022a).

Throughout this report, we focus primarily on opportunities to retrofit homes to use efficient electric equipment described in figure 3 and the paragraph above. Switching equipment that uses expensive fossil-fueled or inefficient electric equipment to high efficiency electrical alternatives can help homeowners save on their energy bills and reduce greenhouse gas emissions. Furthermore, retrofitting homes with efficient electric equipment will be critical for meeting zero-carbon goals, because lowering the energy demand of residential buildings will reduce the amount of clean energy necessary to power all homes.

Increasing Adoption of Electrification Technology

Despite the availability of efficient electric technologies, their adoption remains low in existing buildings. The majority of heat pumps and heat pump water heaters (HPWHs) installed today are in new construction. Previous ACEEE research estimates that it will take over 500 years to retrofit the current U.S. building stock at the current rate of whole-building efficiency retrofits, at a rate of roughly 0.2% of buildings per year (Nadel and Hinge 2020). Considering electrification retrofits are only a fraction of these retrofits, it will take considerably longer to electrify all existing homes without aggressive market intervention and policy action.

However, some areas with dedicated market transformation efforts and programs have seen dramatic increases in adoption rates for efficient electric equipment and appliances in existing buildings. For example, Efficiency Maine's Home Energy Savings Program installed over 23,000 heat pumps in residential buildings in 2021 (Efficiency Maine 2021). The program has also helped create demand for HPWHs—ENERGY STAR data show that 9% of HPWHs shipped in 2018 were sent to Maine, which is remarkable considering the state accounts for only 0.4% of the U.S. population (Stoddard 2020). Robust programs and policies have similarly encouraged adoption of efficient electric equipment in other areas of the United States including, but not limited to, parts of the Northeast, Northwest, and California.

Program and market evaluation reports suggest that electric end-use or whole-building retrofits are still in the "early adopter" phase of technology adoption life cycle as shown in figure 4. Research on technology adoption shows that when a technology is first introduced to a market, a small group of innovators (approximately 2.5% of population) and early adopters (about 13.5% of population) are critical for building market demand. For example, when cell phones were first introduced to the market, the only people who bought them were tech enthusiasts or people who had a strong need for them (Khan 2021). These innovators and early adopters provided enough business to keep cellphone companies afloat so that they could continue developing the technology and eventually create a product that grew to nearly 100% market share.

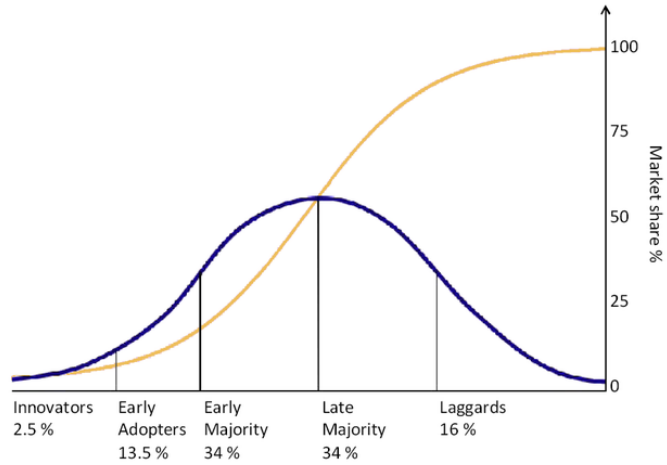

Figure 4. Tech adoption life cycles. Source: Moore 1991.

In the case of efficient electric technology retrofits, the United States is still very much in the innovator and early adopter phase. Most electrification programs and market evaluation reports suggest that the customers who are adopting efficient electric technologies either have a significant need (like needing air conditioning due to rising temperatures), are avoiding the high cost associated with unregulated fuels like oil and propane, or are seeking to mitigate their carbon footprints and are willing to tolerate higher costs in exchange. In the following sections, we highlight barriers to electrification retrofits that can discourage the early majority from electrifying their homes. Later in the report, we will explore the ways in which programs can alleviate these barriers and create a market where these technologies are mainstream in residential retrofits.

BARRIERS TO ELECTRIFICATION RETROFITS

Retrofitting existing buildings to all-electric end uses will be necessary for achieving our climate goals. However, a wide variety of barriers exist to electrifying single-family homes and multifamily buildings. In the following sections, we outline the main barriers for each building type and efficient electric technology, as well as the general market barriers that make electrification retrofits challenging.

WHOLE-BUILDING BARRIERS

The following section describes barriers to electrification retrofits for single-family and multifamily housing.[4] While each building has its own unique considerations for retrofits, certain barriers are common across housing types, such as cost considerations, space constraints, and owner/resident conflicts of interest.

Single-Family Housing

Single-family homes are the largest sector of housing in the United States, representing 69% of the total available housing stock, with 138 million homes nationwide (ACS 2020). Single-family homes tend to be in suburban or rural areas, whereas multifamily housing tends to be in urban areas. In addition to the above, 6% of the U.S. housing stock is manufactured housing. These prefabricated buildings have unique considerations that often require specialized solutions and program design.[5]

Approximately two-thirds (61%) of all single-family homes used fossil fuels for space heating in 2020, with the majority (52%) relying on natural gas, as shown in figure 5. Though this represents a proportionate decrease from 65% in 2015, it still accounts for the largest proportion of fuels in space heating. To meaningfully decarbonize our housing stock, we must scale up the availability of heat pumps for the single-family housing market.

[4] Larger multifamily buildings often have unique needs that are more like commercial buildings than other housing sectors. These building types often require custom solutions specific to that sector, which were out of scope for this project. Therefore, this section primarily addresses the needs of low-rise building electrification projects.

[5] One program that aims to provide building decarbonization for manufactured homes is Efficiency Vermont's Zero Energy Modular Homes program. This program offers incentives and subsidies for manufactured homeowners to replace their existing manufactured homes with new, all-electric models, with higher incentives and flexible financing options for income-qualified households. www.efficiencyvermont.com/services/income-based-assistance/mobile-home-replacement.

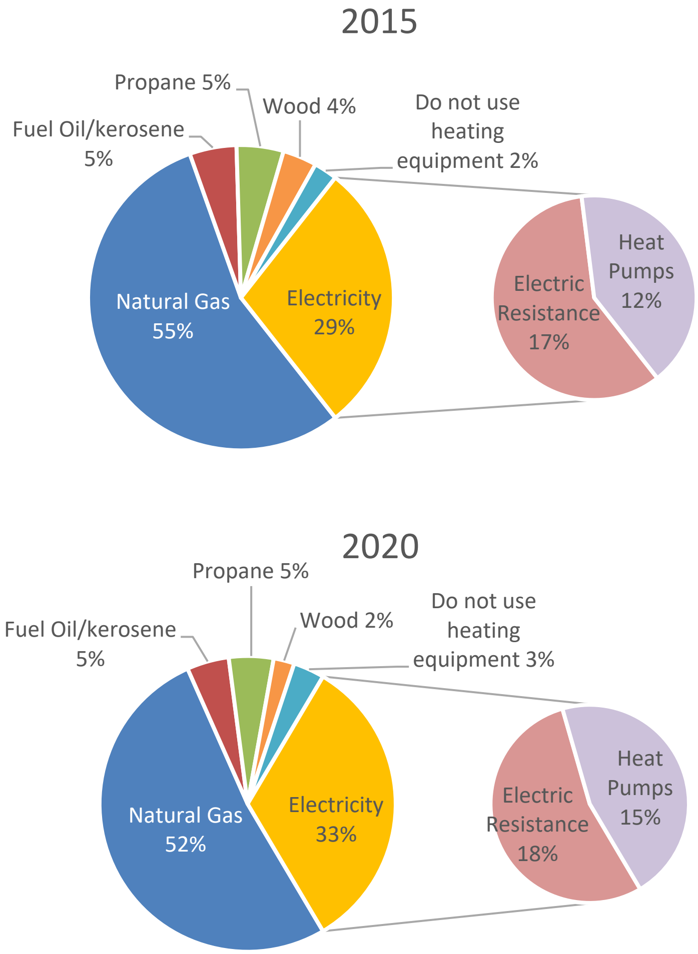

Figure 5. Major fuels used for space heating in single-family homes. Source: EIA Residential Energy Consumption Survey 2015 and 2020.

While single-family housing represents the largest market sector for building electrification, certain barriers commonly arise for retrofit projects in this sector. In addition to the technology-specific barriers described in the next section, single-family home retrofit barriers include the following:

Panel Upgrades. When replacing a fossil-fueled device, such as a furnace, boiler, or gas cookstove, the electric equivalent requires power supply of a sufficient amperage (likely at 240 V). Depending on the age and design of the home's electrical system, there may not be sufficient electrical capacity to accommodate these new appliance loads. Most all-electric homes require a minimum of 200-amp service (Pecan Street 2021). In addition to the age of the home, the recent completion of a renovation will determine whether a house has a 200-A panel. The cost to upgrade an electrical panel to 200 A can run between $750 to $2,000, depending on local equipment and labor costs (HomeAdvisor 2022). Depending on the type of upgrades, homes of 4,000 sq. ft. or more may require an electrical panel with up to 400-A in capacity. These types of upgrades are not generally incentivized by utilities, requiring the homeowners to finance this aspect of project cost themselves. Panel upgrades may also require hiring a certified electrician, obtaining a building permit, and/or obtaining approval from the local utility, all of which can increase costs, extend project timelines, and discourage homeowners who would be otherwise willing to make the investment. “Smart panels” and “smart circuits” are a type of technology that can sometimes circumvent the need to upgrade a home’s electrical service, though they often come at a higher cost than standard electrical panels and wiring. We discuss these in greater detail in the “Strategies to Avoid Electrical Upgrades” section below.

Wiring. In addition to requiring capacity on a home’s electrical panel, all-electric appliances require access to an outlet. In the case of central heat pumps, electric dryers, and other critical home appliances, this is often a specialized 240-V outlet rather than the 120-V standard.[6] Installing the wiring for a new outlet may involve opening walls and/or floors, which can delay the project timelines and add to overall cost. It may again trigger the need for a permit from the local building department, which can discourage some projects. New wiring is most often required in cases where the electric appliance is being installed where no power outlet was there previously, such as an electric stove or ductless heat pump system.

Space Constraints. Certain all-electric appliances are larger than their fossil-fueled counterparts. Heat pump water heaters, in particular, require space for the heat pump as well as adequate ventilation and air flow. In a retrofit scenario, the existing space (in a basement room, closet, etc.) may not be sufficient to accommodate a new system, particularly if the existing fossil heating system is left in place as a backup, a common approach in cold-weather regions.

Multifamily Housing

Multifamily housing is a large portion of the U.S. housing stock, with 26% of total housing units located in multifamily buildings (ACS 2020). Like single-family buildings, multifamily buildings have similar but also unique structural and logistical barriers to electrification. Building size is also a factor: Large multifamily buildings with 10 or more units tend to have unique requirements and constraints. Programs and incentives will need to deliver specialized solutions for these types of buildings, whose aggregate load profiles may more closely resemble commercial than residential. This section will address barriers unique to multifamily homes as well as logistical and financial barriers associated with administering projects to renters and underserved residents in the multifamily sector.

[6] 120-V models of appliances, such as heat pump water heaters, are viable options in some cases and may become more widely available soon based on manufacturer and market interest.

Electrical Service Upgrades. Multifamily buildings may require electrical panel and wiring upgrades in both common areas and individual units. Additionally, because of the potential increase in overall building energy load, electrification retrofits for large multifamily buildings may also require utility service upgrades to power lines and transformers in areas where distribution infrastructure is inadequate to serve the building's increased demand. This can be extremely expensive if the property owners are required to cover the costs of service upgrades themselves, increasing costs by tens or even hundreds of thousands of dollars, depending on location. To address this risk, local distribution utilities may want to proactively engage in distribution system planning and identify constrained areas that will require upgrades to enable electrification (where such upgrades are cost effective and will not incur significant costs to ratepayers). Program administrators and utilities may also offer incentives to "future-proof" buildings by building excess electrical capacity in anticipation of electrification in the future to avoid added cost.

Space Constraints. Much like in single-family homes, finding the proper space and location for some electric appliances and equipment in multifamily buildings can be challenging in retrofit situations. The locations where electric equipment (e.g., outdoor units for heat pumps, ductless heat pumps, hot-water storage tanks, etc.) are sited may affect residents, particularly if located in common spaces, balconies, or other locations that could disrupt tenants. This is especially the case for very tall buildings, which may require dedicated usable floor space for mechanical rooms every few floors. These siting decisions should be carefully considered and clearly communicated to tenants before the upgrade takes place.

Split Incentives. Multifamily buildings can also face market barriers with respect to renter occupied units, which comprise the majority (86%) of multifamily units in contrast to only 18% of single-family units, as shown in figure 6 (ACS 2020).

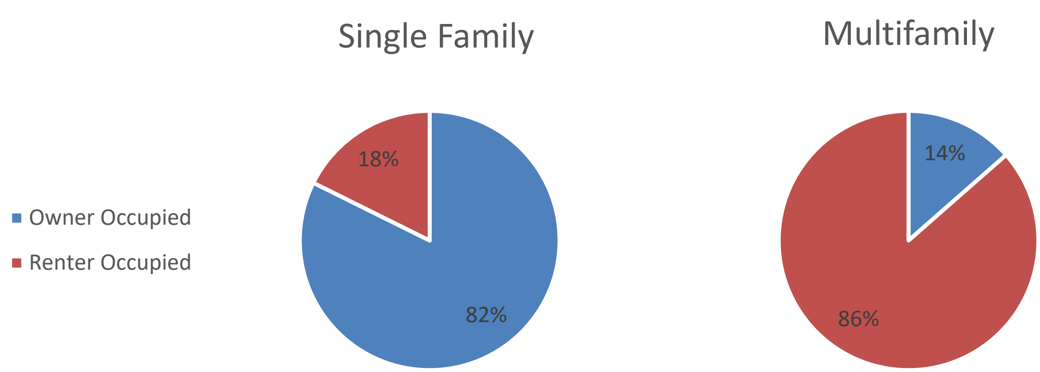

Figure 6. Owner- and renter-occupied housing units in the United States. Source: American Community Survey 2020.

The large number of renters in multifamily buildings leads to the issue of *split incentives*. This refers to building owners being unwilling to invest energy upgrades for tenants who pay for their own utility costs. Because the value of energy efficiency upgrades accrues to the tenant in the form of reduced cost and/or quality of life improvement, property owners see little to no return. This creates a financial and motivational barrier that demand-side programs for renters must address.

Energy and Cost Burdens.[7] Electrification upgrades are often very costly in terms of upfront expenses and may additionally increase ongoing energy costs for customers in the case of some gas to electric conversions. In a single-family setting, one party is generally responsible for handling all the risk of cost increases, but in a multifamily setting this may lead to disproportionate impacts on renters, many of whom are already dealing with high costs of living. For high-cost upgrades, landlords may seek to recover some or all of these costs from tenants in the form of increased rent payments. Except in places where rent control policies exist (such as subsidized affordable housing or areas with a strong tenants' union), increasing rents may end up pricing vulnerable residents out of their homes and contribute to a growing nationwide shortage of affordable housing.

Secondly, at the time of writing, the price of electricity often compares unfavorably with that of natural gas in many regions of the United States.[8] This makes the long-term economics of electrifying natural gas systems especially challenging. For individually metered rental units in particular, a switch from natural gas fuels to electric equivalents can sometimes lead to an increase in monthly energy costs. Even if the rent does not increase, these added monthly costs may place added burdens on residents that make existing housing unaffordable. Furthermore, in multifamily apartments, electricity is often individually metered per unit whereas fossil fuels are metered per building. This can result in a situation where electrification creates a cost transfer onto tenants, resulting in an increased cost of living. To address these potential cost concerns, electrification upgrades should prioritize efficient equipment like heat pumps and should be paired with traditional energy efficiency and weatherization whenever possible to decrease energy costs for residents (York et al. 2022).

Disruption of Residents. The construction required to replace a central home energy system such as heating or hot water can be a time-consuming and, in some cases, noisy and highly disruptive process for residents in a building. Landlords and/or property managers need to coordinate with building residents to clearly communicate and schedule times for contractors to enter building units to perform the necessary upgrades. While this barrier will come up for any retrofit, it will likely disincentivize owners from pursuing an electric retrofit outside of an equipment failure.

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[7] ACEEE defines *energy burden* as the portion of household income that goes toward energy costs (electricity, heating fuel, transportation, etc.). www.aceee.org/energy-burden.

[8] While natural gas is relatively inexpensive in 2022, changes in the power system due to energy transition and demand constraints may lead to more volatile prices in future years.

TECHNOLOGY BARRIERS TO ELECTRIFICATION

The following section describes various efficient electric technologies and the common challenges that arise when installing them in existing homes.

Heat Pumps

Heat pumps are a highly efficient method to provide both heating and cooling.[9] They operate on an evaporation/condensation cycle, concentrating heat to a higher temperature at the condenser and a lower temperature at the evaporator, and shifting it (via a "pump") to moderate the temperature of an interior space (Pears and Andrews 2016). A heat pump system generally has two main components: an outdoor heat exchanger and an indoor distribution system, shown in figure 7.

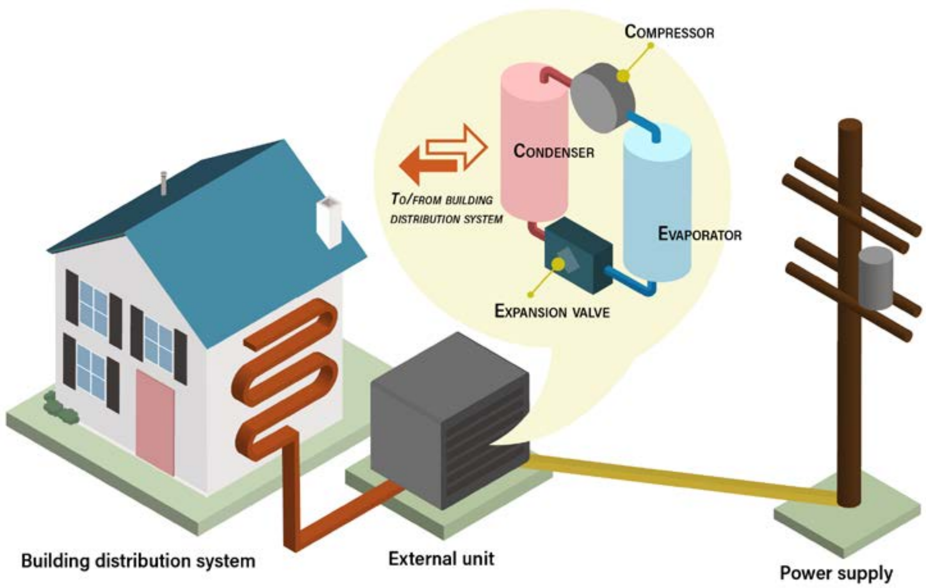

Figure 7. Simple model of a heat pump system in a single-family home

Though most heat pump systems in the United States are air-source systems that utilize ambient air temperature as a source of heat, there are also ground-source and water-source heat pumps for space heating and cooling. These models may provide more consistent

[9] In this report, "heat pump" refers specifically to indoor heating, ventilation, and air-conditioning (HVAC) systems, while "heat pump water heater" (HPWH) refers to water heating systems that utilize heat pump technology to heat water instead of air.

thermal control but have location-specific requirements that can limit their widespread application.

For residential heat pumps, we divide these into two distinct categories: a *ducted* system, which uses HVAC ducts for heat distribution, and a *ductless* system, which contains a separate mini split for each heating/cooling zone inside a home or building.[10] Which type of heat pump system is appropriate for a specific home or building will depend on the floor layout and the presence of any preexisting ductwork. The following describes technical barriers when incorporating a heat pump into existing buildings in a retrofit context.

Thermal Envelope. The building's heat loss—the amount of heat exchanged with the outdoors through air leaks and heat radiation from walls, windows, and other surfaces—has substantial implications for the size and design of a new HVAC system. By improving the building's envelope through insulation, air sealing, and improved doors and windows, a smaller heating system may serve the new, smaller thermal load effectively. Similarly, heat gain is also reduced by an improved envelope, allowing a smaller cooling system. A smaller HVAC system reduces costs, both in terms of upfront equipment cost, operating energy costs, and grid system demand. Envelope measures also improve comfort, safety, and resiliency in both extreme heat and cold or during a power outage. However, thermal upgrades, weatherization, and window and door replacements can increase overall project cost and retrofit timelines (Medakkar 2020).

Climate. Because heat pumps draw in temperature from the external environment to heat an indoor space, the efficiency of these systems and the amount of heat they can deliver generally declines in cooler temperatures. Though recent advancements have led to substantial improvements in cold-climate models, their efficiency decreases in below-freezing temperatures, which may have consequences for increasing system peak demand in the winter as more buildings electrify their heating load. Depending on the system model, when outdoor temperature drops below a certain set point, it may automatically trigger a switch to a backup heating system. Recent ACEEE research on the potential for electric heat pumps has found that all-electric heat pump systems have the lowest life-cycle costs for residential homes in areas with fewer than 6,000 heating degree days (across an 18-year life cycle), and hybrid systems with alternate fuel as backups have the lowest life-cycle costs in regions with over 6,000 heating degree days (Nadel and Fadali 2022). However, other factors can impact this life-cycle cost estimate, including equipment efficiency, weatherization, electricity rates, program incentives, and other market factors.

[10] A secondary important distinction between heat pump types is inverter-driven versus standard heat pump models. Mini-split systems (ducted and ductless) are always inverter driven, which are much more efficient but may be incompatible with certain preexisting commercial thermostat models.

Refrigerants. Heat pump systems use a refrigerant to perform the evaporation-condensation cycle described in figure 7. Depending on refrigerant type, these gases can have significant global warming potential if the system is damaged or improperly disposed of. Proper installation practices are vital to mitigate the risk of leakage, and end-of-life refrigerant management and recovery plans are necessary to avoid adverse impacts.

Controls. Many heat pump systems come with specific control configurations that are different from the existing thermostat in the building. In cases where an existing furnace is left in place for backup heat, these control systems may not seamlessly integrate. Difficulties may also be encountered when third-party thermostats are integrated with inverter-driven heat pump models. Homeowners and tenants should be educated on how to control their new heating system, what temperature set point the system requires to switch to backup heat, and how to troubleshoot issues in the event of a malfunction.

Dual-Fuel Systems. Some heat pump systems include a fossil fuel–powered furnace as a backup heating source. Dual-fuel systems are popular in cold climates and in situations where grid reliability is a major concern for building owners. In some cases, the preexisting fossil system is left as a backup when a new heat pump is installed. However, depending on which temperature set point initiates the transition to backup heat, building residents may end up accidentally or deliberately relying on fossil-fueled heat and not receiving the benefits of installing a heat pump. Because temperature set points are often determined by the installer, guidance and quality control is vital for contractors installing dual-fuel systems.

Location of Outdoor Unit(s). Outdoor heat exchangers should be free-standing or wall-mounted, sheltered from ice and sunlight, with a clear space around to prevent debris from interfering with the fan or interior components. The unit may be situated in a garage or large boiler room, which can mitigate freezing issues because temperatures are more stable indoors. However, the farther away the unit, the longer the refrigerant line that connects it to the home, which can potentially increase installation costs. In the case of multifamily buildings and other shared property (such as condominiums), siting the outdoor unit(s) in an area with less foot traffic may lead to disputes between residents and property owners and managers, especially when units are located in areas such as resident balconies, yards, and other spaces with a shared function.

Ducted Heat Pumps

Replacing a ducted gas, oil, or electric furnace with a heat pump is the most straightforward retrofit scenario when electrifying a building's heat system, particularly when an air-conditioning system (i.e., a cooling-only heat pump) is already integrated into the furnace. The most cost-effective time to do this is when the previous system is at or near its end of usable life. Some retrofits repair and leave in the existing furnace as a backup heating system while replacing 80% or more of the home's heating load with a heat pump. "Hybrid" systems of this type have been on the market for decades. While dual-fuel systems allow for greater efficiency and reduced air emissions, they do not eliminate the dependence on fossil fuels. This type of approach is more frequently seen in cold-climate regions where leaving a fossil fuel–based system to kick on during extremely cold days is significantly cheaper than installing a larger heat pump system or a cold climate–rated system that is only necessary a few days a year.[11] However, certain programs and funding sources may not offer the same level of incentives for hybrid systems as they do for all-electric heating systems.

Condition of the ductwork. The existing ductwork must be able to support the heating and cooling volume of a new heat pump system. Heat pumps will typically need a larger air volume to deliver the same heat as a furnace. Preexisting ductwork may not be able to handle this volume of air. The condition and size of the ducts and other elements should be considered before replacing. Additionally, the presence of mold, rust, or other issues with existing ductwork needs to be addressed and may delay a retrofit project.

Ductless Heat Pumps

For building retrofits without existing ductwork or ductwork that is inadequate to serve a full heating load, ductless heat pump systems can provide an energy-efficient option for enhanced thermal control and comfort. When replacing a heat distribution system such as hydronic radiant heat, electric baseboard heaters, or steam heat, ductless systems generally offer more precise zonal temperature control for each room or building zone that is served by a discrete heat pump unit. These systems may also provide air-conditioning, which is a major motivator for many households to install heat pumps. Regions such as the Pacific Northwest and Mountain West are seeing significant growth in the heat pump market in response to rising temperatures in the summer. Many homes in this region do not have ductwork, making ductless units attractive. The provision of air-conditioning is also a motivator for disadvantaged communities where air-conditioning access is low and vulnerability in heat waves is high.

Wiring and electrical capacity. Each floor-, wall- or ceiling-mounted heat pump unit must be connected to power in order to operate. In some ductless systems, this power comes from the external heat exchanger unit, which is connected to the home electrical panel on a dedicated 240-V circuit. Other system configurations have each indoor unit provide its own low-voltage power from an outlet located in the room. Rooms with no available outlet may require additional wiring in order to accommodate a ductless heat pump. Additionally, homes where no AC was present before retrofits may require expanding or upgrading the electrical panel to provide a dedicated circuit for the external unit.

[11] Nadel and Fadali (2022) find that hybrid cold-climate systems with alternative fuel backups offer the lowest life-cycle costs in places with 6,000 heating degree days or more, whereas all-electric systems offer the lowest costs in areas with fewer than 6,000 heating degree days.

Complex systems. In ductless heat pump systems, one or two ductless system "heads" (indoor units) must be connected via refrigerant lines to the outdoor heat exchanger unit. For larger houses with multiple rooms and floors, a separate head is required for each room or area that needs heating and cooling. Each indoor unit in a ductless heat pump system controls the air temperature within a given "zone" of the home or building. This can create multiple temperature zones within a single home, which has advantages in terms of elevated comfort and cost savings for residents. However, increasingly complex systems will incur additional cost as they require more refrigerant lines, outdoor heat exchangers, additional wiring, and other associated upgrades.

Heat Pump Water Heaters

Water heating is the second-largest energy end use in residential buildings in the United States and can be the largest energy use in multifamily buildings (EIA 2021). In addition to providing hot water for domestic use, hot water may also be used for space heating in a hydronic or radiant heating system. A heat pump water heater (HPWH) is a highly efficient form of water heating that can displace a fossil-fueled water heater and/or boiler. It operates on the same principle as an HVAC heat pump, using an external medium (air, water, or ground) to draw in heat and store the heated water for later use. In this analysis we divide HPWHs into two main categories: unitary HPWHs, which are smaller in size and typically serve the water heating needs of a single household, and central HPWHs, which contain large (generally external) storage tanks and can serve multiple units in an apartment or housing complex.

Figure 8 displays basic differences between three common water heating system types: heat pump water heaters, electric resistance water heaters, and gas- and other fossil-fueled water heaters.

Figure 8. Types of water heaters. Source: Perry, Khanolkar, and Bastian 2021.

Because HPWHs with external storage tanks can store energy (in the form of heated water) for many hours, they are prime targets for load flexibility and utility demand response programs. Preheating HPWH water tanks during periods of low demand on the grid can reduce peak system loads and can even save residents money when paired with a time-of-use electricity rate.

HPWHs are not without their limitations, as their size, lack of familiarity with their installation and maintenance, and operational differences from conventional water heaters and boilers such as a lower output temperature and longer recovery time can create barriers around their deployment. This section discusses technical barriers for implementing heat pump water heaters in general, followed by specific barriers for unitary and central HPWH systems.

Electrical Capacity. Central heat pump water heating systems can trigger panel and electrical service upgrades that add significant costs and time to projects, particularly if a distribution upgrade is triggered on larger-scale projects.

Unitary Heat Pump Water Heater

Unitary heat pump water heaters are the most common type of HPWH available in the United States. A unitary system typically includes the tank and all internal components together in a single package. It is generally suitable to provide water heating for a single household, and may be located inside a closet, basement, garage, laundry room, or another location within the home. Figure 9 shows the four unitary water heater models currently available in the United States.

Figure 9. Unitary water heater models. From left to right: A.O. Smith Voltex Hybrid, Bradford White AeroTherm, Rheem Prestige Hybrid, and Stiebel Eltron Accelera. Source: Manufacturer product literature.

In addition, split model HPWHs may provide an option in certain instances. Split system water heaters separate the compressor from the tank. There are multiple models available internationally, but at the time of writing only one split system model (the SanCO_2) is available in the U.S. market, shown in figure 10.

Figure 10. ECO_2 Systems $SanCO_2$ Split HPSH system model. Source: Manufacturer product literature.

The current industry standard for unitary HPWH requires a 240-V connection, akin to other large appliances such as electric dryers, ovens, and so on. The first 120-V model was introduced to the U.S. market in Q3 of 2022, with others expected to become available later in the year. Since the majority of replacements are on system failure, a low-voltage compatible model will support more straightforward replacement in situations where a high-voltage outlet is not accessible in the current water heater location. Otherwise, the plumber will often have no choice but to replace like for like and install a new fossil-fueled system. This flexibility is offset by a longer heat recovery time for a lower-voltage model, because it lacks an electric resistance component. As a result, it may not be appropriate for bigger households that need large volumes of water quickly.

There are a few constraints specific to unitary system retrofits, listed below.

Size constraints. The addition of a compressor means that HPWHs are usually larger than their fossil fuel counterparts. Additionally, the longer recovery time may necessitate a larger water tank to store enough water to meet the minimum first-hour rating under plumbing codes to provide a sufficient capacity of hot water for occupants. Tankless gas-fired water heaters also represent a significant portion of the market. This can create issues in a retrofit scenario where a larger water tank cannot fit in the preexisting water heater location.

Ventilation. Heat pump water heaters require sufficient fresh air to function. In an enclosed space such as a closet that lacks enough ventilation, cold air will gather around the heat pump and eventually reduce system efficiency. While newer models require less air space than before, many still require ~500 cubic feet of air to perform optimally.

Location. Unlike an HVAC heat pump, heat pump water heaters need to be located indoors. In multifamily buildings, the location can cause some challenges for retrofits. If the preexisting water heater is stored in a closet, the closet may not be large enough to hold an HPWH or may not offer sufficient ventilation. Placing an HPWH in a closet may have negative impacts on residents, including making too much noise and potentially exhausting cold air into the apartment. This can also cause issues in single-family housing where the heat pump is in a basement or co-located along with a ductless HVAC system. The cold temperatures in an unconditioned basement can result in poor performance by the HPWH and even cause it to revert to electric resistance backup. In certain cases, a *desuperheater* may be used to integrate a heat pump HVAC and water heating system, using the waste heat from an HVAC heat pump's cooling cycle to heat water more efficiently.

Central Heat Pump Water Heater

A centralized HPWH system can deliver heated water to a large multifamily or commercial building. These systems heat water in one or multiple locations and then pump it throughout the building. Due to variations in size and building layouts, these types of systems are more customizable than a unitary HPWH. Figure 11 describes the primary components of these central HPWH systems.

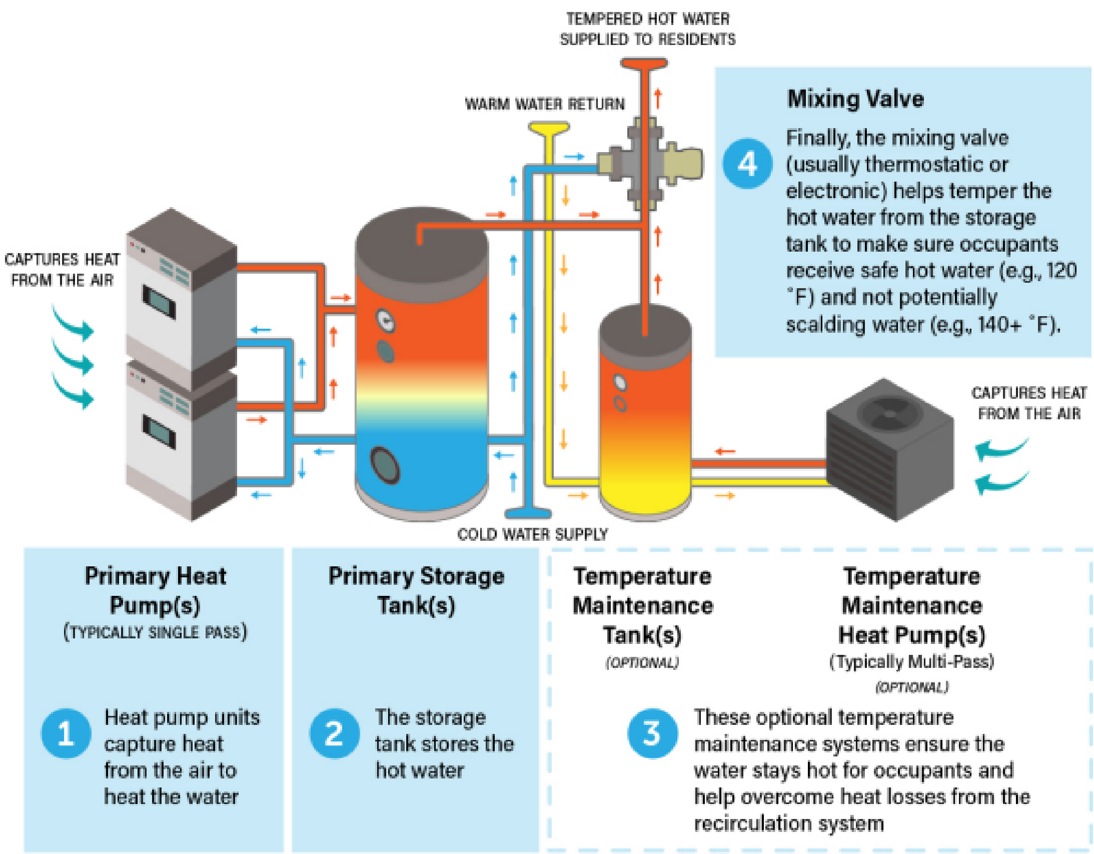

Figure 11. Primary components of central heat pump water heater system, showing a typical "parallel loop tank" configuration. Source: Perry, Khanolkar, and Bastian 2021; Kintner et al. 2020.

In addition to a primary heat pump and water storage tank, central systems will often have a secondary "swing tank" that stores water at a higher temperature than the primary tank. A mixing valve combines water from the two tanks to deliver hot water at usable temperatures to residents. Because HPWHs function optimally with incoming water at lower temperatures, a two-tank system configuration allows for greater efficiency with the trade-off of increased complexity and cost.

Custom builds. Because each central HPWH system has components that are sized and configured to meet the unique layout and hot-water needs of a building's residents, these custom systems tend to have a higher upfront cost for design and installation (Perry, Khanolkar, and Bastian 2021). Manufacturers are in the process of bringing new types of systems to the U.S. market, including prepackaged options that may reduce the upfront design and installation cost.

Specialized skill sets. Large, central systems require several different trades, including plumbing and electrical expertise to engineer and design the systems. These trade skills require extensive training and education and do not necessarily overlap. A shortage of qualified contractors can delay project timelines and increase labor costs. We further discuss workforce related challenges in the "Market Barriers" section below.

Ventilation. Central HPWH systems require sufficient air flow that may not be available in existing buildings.

Electric Stoves and Cookware

Although cooking represents a smaller share of total energy use compared with space and water heating, the kitchen is the part of the home where many residents have the closest visual and physical connection to the type of fuels used in daily life. Gas-fired stoves, with an adjustable blue flame, are often seen as a luxury item, and many consumers show a moderate to strong preference for cooking with gas (NAHB 2021). However, electric cooking appliances (stovetops and ovens) present several advantages over their gas equivalents. From a GHG standpoint, a recent study indicated that leaks from gas stoves are more widespread than previously believed, with an annual climate impact equivalent to emissions from about 500,000 gasoline-powered cars (Jordan 2022). Switching to electric cooking can eliminate these gas leaks. Eliminating a gas stove from the home results in improved indoor air quality and reduced exposure to particulate matter and other contaminants that are correlated with asthma and other health conditions (Lebel et al. 2022).

Electric resistance stoves are widely available on the market at a lower upfront cost than many gas stoves. Additionally, the increasing availability and decreasing cost of induction stoves presents even more advantages when compared to both gas and electric resistance options. While ACEEE recommends induction stoves based on their increased efficiency and ease of use, the increased affordability of electric resistance stoves continues to make them a viable option for customers who are more sensitive to the difference in price.

Figure 12 demonstrates some basic differences between these types of stovetops.

Figure 12. Types of stove tops: gas-fired, electric resistance, and induction

Induction stoves represent a more efficient alternative to a conventional electric resistance cooktop. Rather than heating the cooking surface itself, induction stoves utilize the electromagnetic property of induction to heat up cast iron and most stainless-steel pots and pans. This allows for precise control of cooking temperature, while also being comparatively safer than electric resistance cooktops because the cooking surface itself does not get very hot and cools quickly, reducing the risk of accidental burns. Induction also performs better than gas, with significantly faster times to boil water (ENERGY STAR 2022c).

While there are multiple advantages of electric cooking appliances compared with gas, some barriers still exist, which we outline below.

Cost. The higher upfront cost of induction stoves has historically been a deterrent for many consumers, with many models at a price range of $1,000–2,500, compared to electric resistance models, which cost around $500, and gas models at $300–1,500. Though induction stoves are more efficient than electric resistance, the relatively small share of household energy use attributable to cooking means that the efficiency benefits may not make up for the upfront cost differential. Point-of-sale incentives can be highly effective in reducing “sticker shock” when comparing prices between induction stoves and other units, and are therefore especially critical for driving adoption.

Specialized Cookware. Induction stovetops heat cast-iron or stainless-steel pans using electromagnetism. If the household’s existing pots and pans are not compatible with induction, they may require replacement. Although induction-ready cookware is not especially rare or prohibitively expensive, non-magnetic pots, such as those made of aluminum, are not compatible with induction burners. Replacing existing cookware may place an additional cost burden on residents, especially low-income households. Additionally, some ethnic cuisine requires special-shaped cookware (e.g., woks), which may not work with a typical induction stove.

Consumer Preference. Stoves, more than most other appliances, have a strong behavioral component that is heavily influenced by customer attitudes. There is a widespread perception in the United States that gas stoves offer superior control over temperature and level of flame in comparison to conventional electric coil–based cooking surfaces. Because of the relative novelty of induction cooktops, many households are unfamiliar with how they operate and the benefits they provide; however, hands-on demonstrations have been shown to change consumer perceptions. In terms of ovens, gas-fired models tend to heat up more quickly, retain moisture more effectively, and may be compatible with convection and other features. In general, customers tend to prefer the familiarity of whichever cooking fuel they have in their home and may be hesitant to switch.

Wiring. In retrofits where an induction cooktop replaces a natural gas stove, the home might not have wiring in place behind the stove location or with sufficient amperage to support a new large appliance load. As with other electric appliances, needing to run electrical wires (and locate space on the breaker box) can significantly increase project cost and complexity.

Electric Clothes Dryer

Clothes drying represents the third-largest energy end use after space and water heating in many residential homes, so clothes dryers that utilize natural gas can also be a target for electrification. Currently, electric resistance clothes dryers dominate the residential market, with 80% of homes with dryers having electric models (RECS 2020). However, due to the high energy demand of these dryers and the comparatively low price of natural gas, some customers may opt for gas-heated dryers.

Heat pump dryers are an alternative to electric resistance dryers and can operate at a higher efficiency, reducing energy use by up to 28% compared to standard electric dryers (ENERGY STAR 2022a). This type of clothes drying is popular in Europe but has a comparatively small share of the U.S. market. Another advantage of heat pump dryers is that they do not require ventilation because of the way they use air-conditioning technology to extract water, as they tumble-dry at lower temperatures than electric resistance. This lower operating temperature leads to less wear and tear on clothing. Low drying temperatures also mean that heat pump dryers may take longer to finish drying a load of laundry, although this varies greatly, with some heat pump dryers performing at comparable speeds to conventional gas and electric resistance dryer models.

Product Availability. For multifamily buildings that require commercial dryers, there are fewer options to choose from and there may not be sufficient heat pump dryers available. In many cases, multifamily property owners may contract with a third-party vendor to lease laundry equipment, making the situation even more complex (Schaaf and Shah 2017).

MARKET BARRIERS

Costs

The costs of electrification retrofit projects can be a major barrier to widespread adoption. The cost will be unique to each building and depend on the complexity of the project. Some homes can simply do a drop-in replacement with new electric technologies, while other homes may need electrical upgrades, envelope upgrades, and health and safety upgrades (i.e., asbestos or lead remediation) to support new electric equipment. These additional upgrades can add significant costs and time to a retrofit project and make it less attractive than a simple like-for-like replacement with a new fossil fuel–based system.

Despite potentially higher upfront costs, many electric retrofit projects may still be cost effective over the lifetime of the equipment if they cost less to operate. Heat pump systems are significantly more efficient than electric resistance equipment and often yield large enough energy cost savings to overcome upfront price premiums. Similarly, oil and propane systems can often cost significantly more to run than heat pump systems, making electric retrofit projects potentially cost effective.

Natural gas is the one incumbent fuel that remains cheaper than electricity in many parts of the United States. In areas with abundant supplies of cheap natural gas, electric heat pump systems may come at a higher operating cost or simply not yield enough cost savings to overcome the high upfront cost of an electric system, despite performing at a much higher efficiency than a gas-fired furnace.

In these regions, while cost effectiveness can be a major barrier for electrification retrofits, other financial considerations may justify electrification. First, gas price volatility can be a driver for building owners to switch to electric systems. This may be particularly important for low-income households that may pursue risky financing like payday loans to afford natural gas price spikes. In comparison, the relative consistency of electricity prices in most energy markets can be attractive for households to enjoy long-term stability in fuel prices. Installing a heat pump and keeping the existing furnace in place can also be a cost-effective option. It also allows building owners to future-proof their homes and use the equipment with the cheaper fuel cost—especially considering these systems can stay in the home for 20 years.

Workforce

Contractors and installers are at the core of residential efficiency programs because they are the main touchpoint for customers. When customers are looking to replace their HVAC system or water heater, they typically call local contractors to solicit bids for a new system. A study by the Northwest Energy Efficiency Alliance (NEEA) found that most consumer education comes from sales and design technicians from the HVAC contracting business when they do an onsite visit (Kirszner, Hogan, and Pitt 2022). Contractors will often recommend a few options for replacement that the customer will eventually choose from. To achieve customer uptake of electric systems, it is critical that contractors present them as an attractive option to their customers. Electrification program implementers will need to engage contractors to educate them on electric technologies, ensure they feel comfortable installing these systems, and prepare them to communicate their benefits to their customers.

Many areas of the United States lack a large enough workforce to install heat pumps. In these areas, program implementers will need to support workforce development efforts that both engage the existing workforce (contractors, electricians, plumbers, etc.) and bring new talent into the industry.

Existing HVAC contractors may feel hesitant to begin installing heat pump technology and including HPWHs in their offerings. They have already spent years installing other technologies and may be wary of changing their business model. Furthermore, they may have outdated perceptions about the effectiveness of heat pump technology, particularly in cold climates (older heat pumps could not operate well at low temperatures; new "cold-climate" heat pumps can generally operate well down to about –15°F). Workforce development programs will need to provide sufficient training and support to contractors to teach them the new skills for design, installation, and marketing of heat pump technologies in retrofit projects. Electrification programs should ensure that a large enough market exists for these technologies so that contractors will feel comfortable spending the time and resources to adapt their business.

Workforce development efforts will also need to bring new talent into the workforce. Many existing older contractors will retire soon, and not enough contractors are entering the workforce. This presents a great opportunity to ensure the availability of new workers and generate interest in electrification among individuals from diverse backgrounds[12]. Having a diverse workforce can build trust with historically underrepresented customers—like women and people of color—and make them feel more comfortable with electrification retrofits.

Program implementers will also need to ensure that the workforce has adequate skills for installing electric technologies. Replacing fossil-fuel systems with heat pumps is often more complex than a like-for-like fossil-fuel replacement and contractors will likely need training on how to properly decommission fossil-fuel systems. Many program implementers collaborate with local organizations to provide training and guidance on best practices for installation. This is particularly important for heat pump installations because poor installation practices can lead to customer discomfort and dissatisfaction. These bad experiences can have an impact on future customer recruiting and add costs for contractors if they have callbacks that require more labor and resources. Programs can also support

[12] ACEEE's Report *Expanding Opportunity through Energy Efficiency Jobs: Strategies to Ensure a More Resilient, Diverse Workforce* provides recommendations for how utilities can diversify the energy efficiency workforce through inclusive workforce development programs (Shoemaker, Ayala, and York 2020).

contractors by connecting workers in various trades like HVAC contractors, electricians, and weatherization contractors to help provide comprehensive retrofit services.

Lastly, workforce development efforts should have a focus on equity and ensuring underserved groups receive proper access and support for participating in electrification programs and related workforce development programs. Small and disadvantaged businesses often face additional constraints to participating in trainings. For many small businesses, it may not be cost effective to participate in trainings because it requires taking workers out of the field to attend classes. Also, if there is high turnover in workers, small businesses may not want to front the cost or may be concerned about profit loss if a worker decides to move to a new company. Disadvantaged businesses are those that are based in under-resourced communities or take on projects that generate lower revenue.

Consumer Awareness and Understanding

Consumer awareness and understanding is one of the most important barriers to electrification retrofits. Many of the decisions around home retrofits happen when equipment fails or nears the end of its life; consumers must be aware of electric technologies and their many benefits so that they consider these technologies when making replacement or upgrade decisions.

Recent research conducted by the Environmental Protection Agency (EPA) on attitudes and behaviors related to beneficial electrification found broad support for electrification among consumers, as well as strong interest in learning more about how it will impact homeowners and energy infrastructure, how the transition will occur and how quickly. Consumers highlighted the importance of a trusted resource to answer questions and build confidence and buy-in. They wanted to be able to adopt these new technologies in a way that makes sense for them and at their own pace. Given its trusted brand position and consumer awareness, ENERGY STAR was cited as a strong potential voice of authority on electrification and an expert resource on energy and environmental protection. EPA has since developed a comprehensive resource for interested homeowners called ENERGY STAR Home Upgrade, which can be leveraged by heat pump and other programs to engage customers in improvements that meet them where they are while also providing decarbonization benefits.

Currently, many consumers are simply unaware of efficient electric technologies. A 2020 statewide poll found that 62% of Californians were unfamiliar with heat pump appliances and only 53% were somewhat familiar with induction cook stoves (Metz and Everitt 2020; Gerdes 2020). Consumers may also have misconceptions about electric technologies. For example, consumers may not know the difference between electric resistance and induction cooktops or may fear that a heat pump will not work as well as a furnace. Consumer education will be critical for raising the awareness of electric technologies and correcting misconceptions.

Consumers also need to learn how to operate and maintain their new electric systems to ensure they are satisfied with their investments. For example, customers that have lived in homes with furnaces their whole lives will need to learn a completely new system. Many consumers will not know that heat pumps work more efficiently when they are set to constant temperature and may have to change their habit of setting the thermostat back when they leave their house (Efficiency Maine 2022). Similarly, customers with dual-fuel systems will need to learn to set the thermostat for the heat pump higher than the thermostat for the backup fuel system to ensure that the backup system only kicks on when the heat pump is unable reach the desired temperature. If the dual-fuel system uses a thermostat that integrates both electric and gas units, customers will likely need training on how to use their new thermostat for optimal performance. Programs will need to ensure that customers are properly educated about their new electric equipment and provide consistent reminders about the best operation and maintenance practices so that customers feel empowered and satisfied with the performance of their new system.

Technology Availability

Most of the technologies needed to fully electrify our homes and multifamily buildings exist today. In fact, heat pumps and induction stoves are common and popular in Asia and parts of Europe. Working with upstream supply chain stakeholders is necessary to ensure that electric technologies are widely available in the United States. This includes engaging with manufacturers to introduce and develop technologies for the U.S. market and engaging distributors to ensure they keep sufficient stock of electric technologies available for contractors and retailers.

Additionally, there is still a need to improve existing technologies and potentially develop new technologies to reach widescale electric retrofits. Fortunately, manufacturers are working toward filling these gaps in the market. Advancements in cold-climate heat pumps can improve the economics of electric retrofits in colder parts of the United States. In 2021 the Department of Energy (DOE) announced the Cold Climate Heat Pump Technology Challenge to advance the development of next-generation cold-climate heat pumps. Nine major HVAC manufacturers are participating in the challenge (DOE 2022a). Similarly, there can be significant improvements and development of solutions for multifamily buildings. For example, many central HPWH manufacturers are designing "skid" systems that can go into a variety of buildings with similar structures so that installers do not have to design a system for each building from scratch (Hydro-Thermal 2022). Scenarios exist where heat pumps can combine function for water heating and HVAC, solving space problems with electric capacity limitations.

Changing Regulations

Finally, the likely prospect of changing standards and regulations may make building owners and contractors hesitant to install certain systems. For example, the California government is pursuing regulations that restrict the use of certain refrigerants with high global warming potential. Heat pump systems rely on refrigerants, and many on the market today use refrigerants that may be regulated in the future. Owners and contractors may be hesitant to install these systems if they worry that they will not be able to service them in the future due to regulations banning certain refrigerants. Clear signals from policymakers will allow for various market actors to anticipate changes that may affect their businesses long before enforcement begins on new building codes and policies.

Electrification Programs

While many barriers to building electrification exist, these challenges also present an opportunity for market transformation. We found that electrification programs can help participants navigate electric retrofit projects by simplifying the process and addressing market barriers to create an environment where electric retrofits are more straightforward.

We identified many leading cities, utilities, co-ops, CCAs, and third-party organizations implementing programs that are starting to move the needle and prove the value of electrification programs. In our review, it became clear that comprehensive programs that offer a range of services will be necessary to overcome the multitude of barriers. These services can include incentives, financing, consumer education, workforce development, and supply chain engagement. Table 1 below summarizes a sample of comprehensive building electrification (BE) programs.[13] We selected these programs as examples due to their robust delivery, innovation in implementation, and early results.

Table 1. Sample of comprehensive residential BE electrification programs

State	Utility/Organization	Building type	Program
CA	Association for Energy Affordability and California Department of Community Services and Development	Multifamily	Low Income Weatherization Program for Multifamily
CA	Bay Area Regional Energy Network	Single-Family	BayREN Home+
CA	Tri-County Regional Energy Network	Multifamily	Multifamily Home Energy Savings Program
CA	Los Angeles Department of Water and Power	Multifamily	Comprehensive Multifamily Retrofits Program

[13] This is not a complete list of all residential electrification retrofit programs.

State	Utility/Organization	Building type	Program
CA	Sacramento Municipal Utility District	Multifamily	SMUD Multifamily
CO	City of Boulder	Single-Family	Comfort365
CO	Mountain Parks Electric	Single-Family	Electrify Everything!
DC	DC Sustainable Energy Utility	Single-Family	Low Income Decarbonization Pilot Low Income HVAC Replacement Program
DC	DC Sustainable Energy Utility	Multifamily	Affordable Housing Retrofit Accelerator
MA	Energy Futures Group	Single-Family	Massachusetts Solar Access Program
MA	Massachusetts Clean Energy Center	Single-Family	Whole-Home Air-Source Heat Pump Pilot
MA	Massachusetts Dept. of Environmental Resources	Single-Family	Home MVP
NY	New York State Joint Utilities	Single-Family and Multifamily	NYS Clean Heat Program
VT	Efficiency Vermont	Single-Family and Commercial	Deep Retrofit
WA	Orcas Power and Light Co-operative	Single-Family and Multifamily	Switch It Up!

In our review of current programs, we found that most programs have a one-stop-shop program design that coordinates a comprehensive set of services and offerings to provide a simplified and straightforward process for participants. For example, New York State Joint Utilities' New York State Clean Heat website shows customers four easy steps to participate in the program and install a heat pump, as seen in figure 13 below.

Step 1: Explore Different Heat Pump Systems

Depending on your home type, you have different heat pump options. Use our simple tool to learn more about which heat pump is right for you. Our tool can also help you compare costs between the different systems.

LEARN MORE (/COMPARE-YOUR-OPTIONS/)

Step 2: Find a Participating Contractor

Enter your address to find a NYS Clean Heat participating contractor in your area. You can also search for specific contractors you have worked with in the past.

LEARN MORE (/FIND-A-CONTRACTOR/)

Step 3: Choose the Right System

Your contractor will conduct an assessment of your home to determine what heat pump system will work best. They will also guide you through what to expect from each system, such as estimated monthly and annual savings and changes to your fuel and electric bills.

LEARN MORE (/WHAT-TO-EXPECT/)

Step 4: Explore Financing & Rebates

Once you determine the system, your contractor will fill out the program application and submit all qualifying documents for your rebate. They can also guide you through the different financing options (/financing-options/) New York State offers to make the purchase even more affordable.

LEARN MORE (/FIND-AVAILABLE-REBATES/)

Figure 13. New York State Energy Research and Development Authority's (NYSERDA's) Clean Heat program website

The New York State Clean Heat program coordinates a comprehensive set of offerings and services including consumer education (Step 1), workforce engagement (Step 2), optional free home assessment and cost estimate (Step 3), and incentives and financing (Step 4). All other programs that we included in table 1 above follow a similar structure that essentially coordinate all the complicated steps of an electrification retrofit on the back end and provide a simple participation process of customers on the front end.

In reviewing the types of offerings and services provided by comprehensive programs, we find that most of these offerings address the major barriers described earlier in this report. In the following sections, we describe how program design can address the major barriers to building electrification retrofits, including technology and building specific barriers, project costs, workforce development, consumer education, and supply chain engagement. We recommend that programs provide a comprehensive set of offerings that address each of these barriers and present the program in an easy-to-follow structure like a one-stop shop.

ADDRESS TECHNOLOGY AND BUILDING SPECIFIC BARRIERS

Programs need to be designed broadly and nimbly enough to accommodate the technology and building barriers that will be unique for each home and project. In our interviews with program implementers, many suggested that technology- and building-specific barriers can be addressed primarily through workforce education and engagement. Providing training and technical assistance to contractors will help them solve technology- and building-specific challenges that arise during a project. As contractors install more efficient electric equipment, they will learn solutions to common challenges like space constraints or avoiding panel upgrades and be able to apply these solutions to future projects.

Similarly, addressing other market barriers like high project costs and supply chain challenges can also help address technology and building barriers. Providing sufficient incentives for electric equipment and complementary measures like duct sealing or panel upgrades can help customers afford more complicated projects. Likewise, engaging manufacturers to understand the best applications and installation practices of their devices can help ensure contractors and consumers pick the right products for their home and install them properly. Program implementers can also work with manufacturers to create products to meet certain needs like 120-V HPWHs for buildings that are unable to pursue electrical upgrades to support 240-V products, or specialized controls for dual-fuel systems.

Beyond addressing market barriers, we identified several specific strategies that programs use to address the building- and technology-specific barriers that are common in their territories, including the following:

Perform a Building Stock Characterization. Every program administrator we interviewed had a good understanding of the typical characteristics of buildings in their territory, including age, size, design, and existing systems. Characterizing typical buildings in each territory can help implementers identify the best solutions for buildings in their territory and provide tailored technical assistance, incentives, and education.

Provide Free or Low-Cost Building Energy Audits. Many programs require owners to get an energy audit as the first step to participating in the program. Audits can identify the unique challenges and needs in the home to support efficient electric equipment and provide guidance on how to overcome these challenges. Audits can empower owners by providing guidance on which technologies to pursue and provide useful information to contractors to inform their product recommendations and system designs. Programs that offer audits should require auditors to collect information on the existing electrical panel and wiring and identify any necessary upgrades to support electrification of end uses in the future. Finally, programs should consider not making audits if this process is cost prohibitive or creates a bottleneck that deters customers from participating. In some territories, requiring an audit may increase the project timeline and prevent projects from moving forward.

Provide a Project Manager. Several programs provide one-on-one project managers or advisors to participating customers. These experts can help customers identify key technology and building barriers and provide solutions for overcoming those barriers. This can be particularly helpful because project managers can apply lessons learned from previous projects to any future projects. Program implementers can consider working with third-party contractors to provide project management if it is a more cost-effective and scalable solution than hiring them in-house.

Provide Technical Assistance. Most programs provide some level of technical assistance to both consumers and contractors on systems designs and guidance on overcoming technology- or building-specific challenges.

Facilitate Information Sharing. Information sharing among project managers, contractors, and manufacturers is a helpful way for them to learn new strategies for overcoming typical building- or technology-specific challenges. Program implementers can create an avenue for open conversation where contractors or project managers can ask for advice on specific challenges by providing online tools (like Slack), hosting webinars, hosting lunch-and-learn sessions, or a help hotline (phone or email).

REDUCE PROJECT COST

Project costs are a major barrier for electrification retrofits. The cost of equipment, labor, wiring and panel upgrades, energy audits, weatherization, distribution system upgrades, and other necessary measures can be prohibitive for a project's success unless programs specifically address them by leveraging every available tool to reduce costs for their customers. A "one-stop-shop" program model (described above) can be an effective tool to leverage and streamline various incentives and financing methods to lower the total costs for the project. The following are potential sources and avenues for program administrators to reduce electrification retrofit costs.

Incentives for Electrification Measures

Utility rebates are the most common form of incentive for electrification measures (Cohn and Esram 2022). Many jurisdictions will offer rebates for efficient electric equipment like ductless or ducted heat pumps, heat pump water heaters, induction stoves, and other devices. These are generally offered to customers in the form of a mail-in or point-of-sale rebate (the latter being less common). By claiming these preexisting utility rebates, program administrators can reduce project costs and lower friction in the retrofit process by processing the necessary paperwork for end users.

Additionally, since the passing of the federal Inflation Reduction Act in August of 2022, billions of dollars will become available for building decarbonization technologies in the form of tax credits, whole-home rebates, low-income housing, new building incentives, commercial electrification incentives, and more. The bill also includes more than $30 billion in flexible incentives for states and cities to direct into decarbonization efforts, though implementation of these funds in specific programs may not occur until 2023 or later

(Smedick, Golden, and Petersen 2022). This bill represents an historic investment in building electrification and decarbonization technologies that may drive additional development in this sector for years to come.

Incentivize Complementary Measures and Prioritize Efficiency

There are certain home energy improvements that can also impact the economics of electrification upgrades and reduce project costs. Primary among these is weatherization, including air sealing and insulation that improves a building's thermal envelope. By reducing heat loss to the outdoor environment, the home's total heating and cooling load is decreased, allowing installers to put in a smaller-capacity HVAC system that will still serve the home's full heating load. This reduces both upfront equipment costs and ongoing costs related to operating the new electric heating and cooling system. However, weatherization upgrades can themselves be costly and time consuming to install. Multiple avenues for weatherization funds exist, particularly for low-income housing, which customers may not be aware of.

Strategies to Avoid Electrical Upgrades

Panel upgrades can add substantial costs and time to projects. As described in the single-family barriers section, upgrading an electrical panel from 100 to 200 A can cost between $750 and $2,000, while upgrading to 400 A for especially large projects can sometimes cost up to $4,000 (HomeGuide 2022). Additionally, if the increase in the home's electrical load is significant enough, it may require upgraded electrical service on the distribution utility side, such as a new transformer. In many cases, homeowners are required to finance these service upgrades themselves, which can increase costs potentially by thousands of dollars.

To address this barrier, utilities and program implementers can offer customers incentives for upgrading their home's electrical panel. However, there are several workarounds to avoid panel upgrades that can make projects more attractive and straightforward.

Watt Diet. A watt diet involves carefully choosing efficient equipment and using circuit sharing to avoid electrical panel upgrades. Most single-family homes typically have a power demand of between 5–15 kW of power that can be served by a basic 100-A panel that typically delivers 24 kW of power (Kabat and Gaillard 2021). By reducing, consolidating, and managing appliance loads with tools like energy efficiency, managing power loads using smart circuits,[14] and selective charging of devices like electric vehicles, even all-electric

[14] "Smart circuits" are plug-in devices that sit between the appliance and the electrical panel. Two appliances (e.g., an electric vehicle (EV) charger and a heat pump) connect to the same 240-V smart circuit. The smart circuit prevents both loads from simultaneously drawing power, reducing the risk of system overload while helping to stretch the capacity of the circuit board by combining two loads on the same circuit.

homes can reduce their maximum power draw in order to avoid going over the maximum allowable wattage. Redwood Energy published a guide to watt diets, including the following examples that show how the strategy can be used to avoid panel upgrades (Armstrong et al. 2021):

1. Select energy-efficient versions of appliances
2. Select appliances that combine two functions into one machine
3. Reducing heat loss and cooling loss by insulating and air sealing
4. Use prioritized circuit sharing devices that prevent overloading
5. Use EV charger pausing circuits that automatically curtail charging when other appliances are drawing too much power
6. Charge EVs at a lower power level setting

Redwood Energy designed the graphic below (figure 14) to show how an all-electric home can undergo a watt diet to remain on a 100-A panel.

Figure 14. Example of an electrical panel that has undergone a "watt diet" to incorporate multiple circuits on a 100-amp panel. Source: Armstrong et al. 2021.

Smart Panels. A *smart panel* is an upgraded version of a home electric panel that can efficiently manage multiple electric loads, including a solar energy system and battery storage device simultaneously. A smart electrical panel monitors and controls every circuit in the home, with an Internet-connected gateway that provides real-time information to users regarding the home's power load. When smart panels are installed, they frequently are put in place alongside upgrades such as a solar energy, home battery, and/or electric vehicle (St. John 2022). While the smart panel itself may come at a higher cost than a conventional electrical panel, it may be a solution for homeowners seeking to avoid an even more costly distribution utility service upgrade.

Meter Adapters. For electric devices on the exterior of the home such as solar panels and EV chargers, a new technology solution that can avoid thousands of dollars in panel upgrade costs is a "meter collar" that is installed between the home's utility meter socket and the meter itself (Lewis 2022). This device (shown in figure 15) can add new electrical service capacity for external devices such as solar panels and EV chargers. Bypassing the electrical panel in this way reduces EV charger installation cost by avoiding panel upgrades. Currently, this technology is offered on a limited basis by ConnectDER, a Philadelphia-based company that partners with utilities offering distributed energy resource (DER) programs.

Figure 15. Meter collar that attaches to a home's electrical meter. Source: ConnectDER web page (https://connectder.com/).

Energy Monitoring and Efficiency Upgrades. Energy monitoring uses smart devices and home energy data to provide customers with insight into how much power their home uses, when peak usage occurs, and potentially which solutions they might utilize to improve energy efficiency while reducing costs and peak demand. An energy monitor is a device that connects to the home's energy panel (or, if the home has a smart panel, it may provide this service automatically). The device's sensors can deliver valuable information in terms of load shape and consumption that goes beyond the typical kWh-per-month recorded by a home's electric meter.

Energy monitoring can sometimes reveal opportunities for energy savings that bring down peak loads. For example, an Association for Energy Affordability (AEA) multifamily project found that the building had a very high water-heating load. By focusing on efficiency upgrades to the water heating distribution system, program implementers were able to capture enough energy and peak demand savings that an electrical service upgrade was no longer necessary. Like the watt diet approach, choosing high efficiency equipment and measures to improve the performance of the entire building can mitigate the need for costly electrical upgrades in some cases.

Many electricians and utility engineers will call for a panel or service upgrade out of an abundance of caution, even when the risk is negligible, leading to unnecessarily high costs for the homeowner. Energy monitoring data can sometimes be used as evidence that the actual load and peak demand impact from electrification is below the threshold required to trigger a service upgrade, avoiding those higher fees.

Financing

Providing low-cost, accessible financing for beneficial electrification is another avenue program administrators can take to address the barrier of high upfront costs. Even middle-income customers may not be able to fund a large-scale home energy upgrade; distributing these costs over time may empower more homeowners to engage in electrification retrofits. Affordability, transparency, and ease of use are vital for a good financing program. Customers should be able to access financing at a low interest rate, with clear terms, and a trusted lender, and the application process should be as straightforward and transparent as possible. When offering financing options, program administrators (and their contractors) should refrain from using high-pressure sales tactics to encourage customers to take out a loan for home energy upgrades, especially for vulnerable groups such as low-income, non-English speaking, or elderly customers.

The following are several financing pathways for electrification retrofits:

Inclusive Utility Investment. There are variety of financing methods for utilities to cover the upfront cost of home energy upgrades and allow customers to pay back the cost over time (ENERGY STAR 2022b). Also known as a tariffed on-bill program, this strategy allows the costs of energy-related home upgrades to be recovered via a site-specific rider attached to the customer’s monthly energy bill. There are numerous advantages to this approach, from eliminating high first-cost barriers, to broadening access for underserved customer groups such as renters and low-income, to transferability to future owners or tenants in the event of a lease or home sale.

Homes with high energy usage and intensity per square foot are the most cost-effective targets for this model and typically see the largest reduction in upfront and overall cost. If the upgrades decrease a home’s monthly energy cost (i.e., through energy efficiency) by more than the recurring cost of payments, customers can realize energy savings immediately with no upfront cost and no additional costs beyond the electricity bill they were already paying. By using a customer’s bill payment history instead of credit rating to qualify for the loan, on-bill tariffed programs are accessible to more customers who would be excluded from traditional financing methods due to a poor credit history, particularly low-income customers. Finally, because the loan is attached to a utility account rather than an individual, it can be transferred to a new resident or homeowner on sale of the home or end of a lease.

Customer protections are central to the success of an inclusive utility financing program. The U.S. EPA defines 10 key consumer protections that should be part of any inclusive financing model, including the following: protections against service disconnections for non-payment, site-specific energy assessments, allowing customers to optionally co-pay for upgrades, offering extended equipment warranties, and providing notice to subsequent owners and occupants of the unit (ENERGY STAR 2022b). Historically, inclusive utility investment programs are generally small in scope and have been implemented by rural electric cooperatives and municipal utilities. Investor-owned utilities may be hesitant to offer on-bill programs due to the perceived risk from taking on tariff obligations toward unpaid customer payments. Some states also restrict which entities (aside from banks) can provide loans. Tariffed on-bill programs typically require enabling legislation or regulation, which may limit the kinds of utilities that are able to offer them. However, initial results from existing programs, such as Orcas Power and Light Cooperative (OPALCO)'s Switch It Up! program, are promising in terms of customers experiencing real net energy savings (Yanez-Barnuevo 2020). The potential for inclusive financing programs to reach marginalized customers has led over 30 states to enable on-bill financing via legislation and/or utility programs approved in the state public utility commission (PUC) (Center for the New Energy Economy 2016).

Green Banks. A green bank is a financial entity that makes low-cost investments in clean energy projects. These banks are generally established through government actions, which provide seed funding to attract private investment in the fund. By lending money at an affordable rate to support clean energy projects and upgrades, green banks can rapidly accelerate growth of a robust, sustainable, clean energy industry in the area. While no federal green bank exists at the time of writing, these financing entities have existed for years internationally in the United Kingdom and Australia, and domestically in states like Connecticut, New York, and Washington, DC (Nilsen 2021). Though a conventional green bank provides funding for large-scale clean energy generation projects (e.g., community solar arrays), these funds could also be leveraged for other decarbonization efforts, particularly when done in bulk by a third-party program administrator.

As an example, the NY Green Bank, operated under the New York State Energy Research and Development Authority (NYSERDA), provides financing for affordable multifamily housing electrification projects (NYSERDA 2021). This financing comes in various forms, including project finance loans to support the purchase/lease of specific equipment; pre-development loans to cover the cost of auditing, repairing, and designing a building energy retrofit plan; construction loans to offer competitively priced gap financing during a project's construction or retrofit/installation phase; and permanent loans that underwrite housing mortgages.

A national green bank could potentially go even further and be a more effective tool to mobilize funds for decarbonization projects, especially for states that have yet to adopt robust building decarbonization policies. An independent entity, established by federal seed funds, could operate more nimbly than an agency within the executive branch, and leverage public-private partnerships to rapidly accelerate low-carbon technologies and buildings (Coalition for Green Capital 2021). This type of federal leadership may be required to ensure that the United States is able to compete on equal footing with international low-carbon industries in countries that provide national backing for such projects, such as China, India, Germany, and Great Britain.

Federal Grants. Beyond a green bank, other federal agencies and programs offer funding that may be leveraged for specific projects that align with policy goals. The U.S. Department of Energy administers numerous programs, most notably the Weatherization Assistance Program (WAP), which provides low-income residents with technical and financial assistance to improve their homes' energy efficiency. While these measures are most often conventional energy efficiency (insulation, duct sealing, appliances), these funds could potentially be used to support electrification retrofits, including heating and hot-water system replacements, if they are more cost effective, such as when displacing delivered fuels or electric resistance.

The U.S. Department of Agriculture oversees rural energy and broadband development and offers grants for low-income housing projects in rural areas (USDA 2022). The Rural Energy Savings Program (RESP), administered by the U.S. Department of Agriculture, is a no-interest loan program for rural utilities and green banks to apply for and reloan to customers for energy efficiency and fuel-switching purposes. Since its inception in 2016, RESP has awarded more than $275 million in zero-interest loans for rural electric cooperatives and municipal utilities to reloan them to families and businesses in rural areas to invest in renewable energy and energy efficiency projects. OPALCO secured $46 million in RESP funds to capitalize its Switch It Up! program.

The Department of Housing and Urban Development also awards grant funds to a set number of projects per year across a variety of areas and policy objectives (HUD 2022). Additionally, for retrofits of buildings where weatherization and electrification improve indoor air quality and other health outcomes, federal healthcare funds like Medicare could potentially offer an additional source of funding (Hayes and Gerbode 2020). Program administrators should be mindful of opportunities to leverage federal grant funds to reduce overall project capital costs, including potential grants made available to the public through the congressional budget reconciliation process.

Lastly, the federal Inflation Reduction Act of 2022 allocates large sums of funding for a multitude of decarbonization technologies and energy retrofits for low-income housing.

Layer and Streamline Incentives and Financing

The optimal approach for dealing with high project costs is for program implementers to combine and stack multiple incentives, financing, and so on to streamline the retrofit from start to finish. Program implementers can stack incentives from multiple sources including utility rebates, city rebates, county rebates, state rebates, federal rebates, and manufacturer rebates. They can also pair these incentives with financing from traditional banks with green-lending programs (e.g., Fannie Mae), property assessed clean energy (PACE) financing, green banks, and state-offered loan programs. Figure 16 demonstrates how a variety of incentives and financing can be layered to bring down overall project cost.

Figure 16. An example of stacking different funding sources to improve the economics of a project. Based on findings from Kresowik and Reeg 2022.

When stacking incentives, it is important that this process is invisible (or nearly so) to the customer and straightforward for the installer. To the extent that programs can work with other key organizations to streamline incentives, they should establish consistent requirements for each incentive and coordinate any messaging material (Menten 2020). For example, East Bay Community Energy (EBCE) offers one application for the midstream and Home+ program and is working to integrate Pacific Gas & Electric's (PG&E) WatterSaver application as well.

Incentive stacking provides other advantages as well. For one, it can allow customers to gain access to additional resources that would not otherwise be offered through one program. For example, the BayREN program streamlined incentives with PG&E's WatterSaver program to incentivize thermostatic mixing valves. Another advantage of incentive stacking is that it allows implementers to be flexible. For example, as more state or federal incentives become available, implementers can lower their incentives and shift program funds to other needed areas. Another example of successful incentive layering can be seen in the TECH Clean California program, a statewide initiative that began in 2020 and offered midstream incentives to installers. These incentives can combine with local utility incentives to deliver up to $6,600 for a single-family heat pump or HPWH system retrofit (Velez and Borgeson 2022).

Example of Incentive and Financing Stacking

Table 2 below shows the incentive stack for Boulder's Comfort365 Program.

Table 2. Incentive and financing stack for Boulder's Comfort365 Program

Source	Description
Manufacturer Rebate	$300 from Mitsubishi for "Hyper-Heating" cold-climate air-source heat pump (ASHP)
Boulder County Rebate	Up to $350 for cold climate ENERGY STAR ASHP Up to $200 for non–cold-climate ASHP
City of Boulder Rebates	Up to $400 for cold-climate ASHP Up to $250 for non–cold-climate ASHP
Utility Rebates	$300 for ductless mini-split heat pumps from Xcel $500 for residential heat pumps from Longmont Power
Total Rebates	$1,050–1,550

Source: Terry and Stori 2019

SUPPORT WORKFORCE DEVELOPMENT

Local contractors are at the center of electrification programs because they are often the ones to educate and sell customers on efficient electric technologies. Our discussions with program implementers revealed that building a strong contractor network is essential for the success of a program. For most program implementers, this will require engaging both existing contractors and recruiting new workers to the market.

There is no silver-bullet approach for engaging local contractor networks to promote and sell efficient electric technologies. However, program implementers should focus on building consumer demand to create a market where the local contractors have enough business to support jobs with family-sustaining wages and benefits. High consumer demand will create the business case for contractors to learn about efficient electric technologies and include them in the service offerings. Lieberman Research created the graphic below detailing the "perfect storm" of supportive conditions for contractors to offer variable speed heat pumps (VSHPs) in the Northwest, as seen in figure 17.

Figure 17. Market actors supporting heat pump adoption. Source: Kirszner, Hogan, and Pitt 2022.

The following sections detail best practices for thoughtfully engaging local contractor networks to support electrification programs. Other sections in this report explore how to build demand for efficient electric technologies.

Assess the Local Contractor Market

Program implementers need to assess the local contractor network in their territories to identify gaps in available workers (quantity) and their skills (quality) (Jones et al. 2019). Many programs likely have an existing base of contractors that have delivered previous home performance, energy efficiency, and HVAC programs and could be trained to deliver electrification programs. Most electrification programs will also require recruiting new contracting companies and workers to join the program.

How program implementers can assess their local contractor market:

- Identify existing home performance and HVAC contractors in your network.
- Find other contractors that could expand their services to include energy upgrades and/or electrification.
- Assess the need for new skills and certifications for contractors.
- Evaluate existing training and education providers who could become workforce development partners, such as community colleges, trade association chapters, and community-based organizations.
- Identify options for creating new training programs if none exist.
- Identify organizations that can help find workers and match them to jobs.

Source: Adapted from DOE 2018

Assessing the market also includes connecting with local contractors to understand their motivations, challenges, and what they need to succeed. It is important for program implementers to engage the workforce throughout the program design, implementation, and evaluation processes to ensure the program is supporting their needs. For example, across several contractor market research reports, contractors report being customer centric as high priority because it affects their business's reputation (Kirszner, Hogan, and Pitt 2022). They care most about attributes that yield high customer satisfaction like product reliability, lower fuel cost for customers, and products that are easy to service (Kirszner, Hogan, and Pitt 2022). Aligning program offerings, marketing materials, and contractor trainings with these priorities can help bring contractors into a program.

Program implementers should also learn and understand the nuances of different contractor business models. For example, many contractors may subcontract their work to multiple trades like electricians or plumbers. Implementers should take this in consideration when deciding how to deliver incentives and rebates. Similarly, programs can teach contractors how to offer additional services either through subcontracting or in-house staff. Having a solid understanding of contactor business models will help program implementers offer benefits to local business including access to rebates, financing, marketing funds, free training, technical assistance, and customer leads. Programs can also provide coaching to business owners on how to expand their business offerings, support their workers, and prudently increase their staff.

Provide Training

Program implementers should partner with organizations that provide workforce training and certification programs. Research on workforce training best practices suggests that training programs should include both broad occupational training and specialized training (Jones et al. 2019). For example, stackable credential programs allow students to earn a series of shorter credentials that "stack up" to a professional degree. An example stackable credential program may include three certificates: fundamentals certificate with a broad curriculum that prepares workers for entry-level positions, technical certificate that provides deeper education on specific job skills, and an associate's degree for long-term careers (Foshay and Steigauf 2019). Programs with stackable credentials allow students to join the workforce while earning their degrees, identify different career paths and opportunities to up-skill, and provide avenues to continually grow throughout their careers (Smith 2021).

Program implementers should also look for training programs that provide both in-classroom and on-the-job training. Building electrification retrofits are complex projects and require formal classroom training to teach workers to evaluate the building as a whole rather than a set of individual equipment replacements. However, education should not stop at the classroom. The Vermont Energy Action Network workforce report found that many contractors in Vermont thought on-the-job training was important for setting expectations as to what retrofitting work entails (Smith 2021). Retrofits require intensive labor that can sometimes be physically demanding, and on-the-job training helps trainees understand the type of work they will be doing should they choose to pursue a career in the field.

In addition to occupational skills, many program implementers recommended including sales and marketing skills as part of training programs. Many contractors are interested in learning new sales techniques and often report appreciating sales and marketing training offered as part of efficiency programs (Suzi Asmus, program manager, Integrated Systems, Northwest Energy Efficiency Alliance, pers. comms., February 25, 2022.) This can be especially important for building electrification retrofits as contractors may have less experience selling the technologies and may need to provide extra education to sell to customers who have limited awareness of electric technologies.

Potential Partnerships

Program implementers will need to partner with local organizations offering workforce training. Implementers can collaborate with partners to support marketing, develop curriculum, provide scholarships, and recruit new students. The following are common partners for workforce training:

- Manufacturers
- Distributers
- Community colleges
- Trade schools
- Trade associations

Further, program implementers should evaluate how the local contractor market is selling certain products and offer ways to improve their sale pitches. For example, Lieberman Research's market research on contractors selling variable speed heat pumps in the Northwest found that contractors often provide three choices that are good, better, and best. Often, contractors say variable speed heat pumps (VSHP) are the "best" or premium option. Lieberman Research recommended that NEEA should teach contractors how to sell customers on the "best" approach and ease any concerns about picking the premium option. They also recommend that NEEA advocate contractors to pitch VSHP as the "better" or mid-tier option, as customers often view it as the more fiscally prudent choice than the high-end option (Kirszner, Hogan, and Pitt 2022). Similarly, program implementers can train contractors to explain and sell important complementary measures like weatherization to enhance the comfort of their home and increase energy bill savings.

Create Mechanisms for Quality Assurance

Ensuring contractors are properly designing, installing, and commissioning equipment is also essential for program success. The following are strategies existing programs use to provide quality assurance.

Hire Third-Party Experts on Retainer to Review Plans

Several programs hire experts on retainer to provide technical assistance and feedback to contractors participating in the program. Third-party experts could include electricians, system design experts, manufacturer representatives, and any other qualified professional that can fill expertise gaps. MassCEC hired a third-party expert to review designs, give feedback to installers and homeowners, and provide technical assistance to installers on system design (MassCEC 2022). AEA also mentioned hiring an electrician on retainer to evaluate and review electrical plans, as well as working with manufacturer representatives to review system designs. Working with third-party experts to provide technical assistance acts as both a quality control mechanism and a training opportunity.

Create a Qualified Professionals List

Programs can also create a contractor certification process that requires contractors to meet certain skills and labor requirements to participate in the program and receive rebates. Specific requirements vary based on the equipment category, but generally the programs require documentation of training certificates, licenses, and insurance certificates (New York State 2022).

Many programs include qualified contractor lists. Mass Save's Heat Pump Installer Network and NYSERDA's NYS Clean Heat Participating Contractor Network are two such examples. Both networks consist of licensed, insured, and actively engaged installers. NYSERDA's network includes professionals in cold-climate air-source heat pumps, ground-source heat pumps, and heat pump water heaters. Participating contractors are considered provisional until they achieve a passing score in three successive field assessments. Qualified professional certification programs are best organized at the state level but can also be implemented by local program implementers in the absence of a statewide effort (Jones et al. 2019).

Create an Avenue for Customers to Provide Feedback on Service

Programs should also make it easy for customers to provide feedback on the service they received. This will allow program implementers to praise high performing contractors and provide additional training and support to poorly performing contractors. Programs can solicit feedback from customers through post-installation surveys, targeted calls, and by offering contact information to submit feedback on service.

PROVIDE CUSTOMER EDUCATION

Every program implementer that we spoke to said raising consumer awareness and providing education throughout the customer journey[15] was a key component of their program design. The goal of customer education is to increase customer satisfaction—customers who know how to use their new equipment properly are more likely to be happy with it—and ultimately the uptake of efficient technologies. Figure 18 below shows the consumer education opportunities along the customer's journey. We provide more information about these opportunities in the sections below.

[15] The customer journey refers to "the complete story of a typical customer's end-to-end experience with your company—from first contact to adoption of your product or service to (ideally) complete loyalty to your brand" (Franklin Energy 2018).

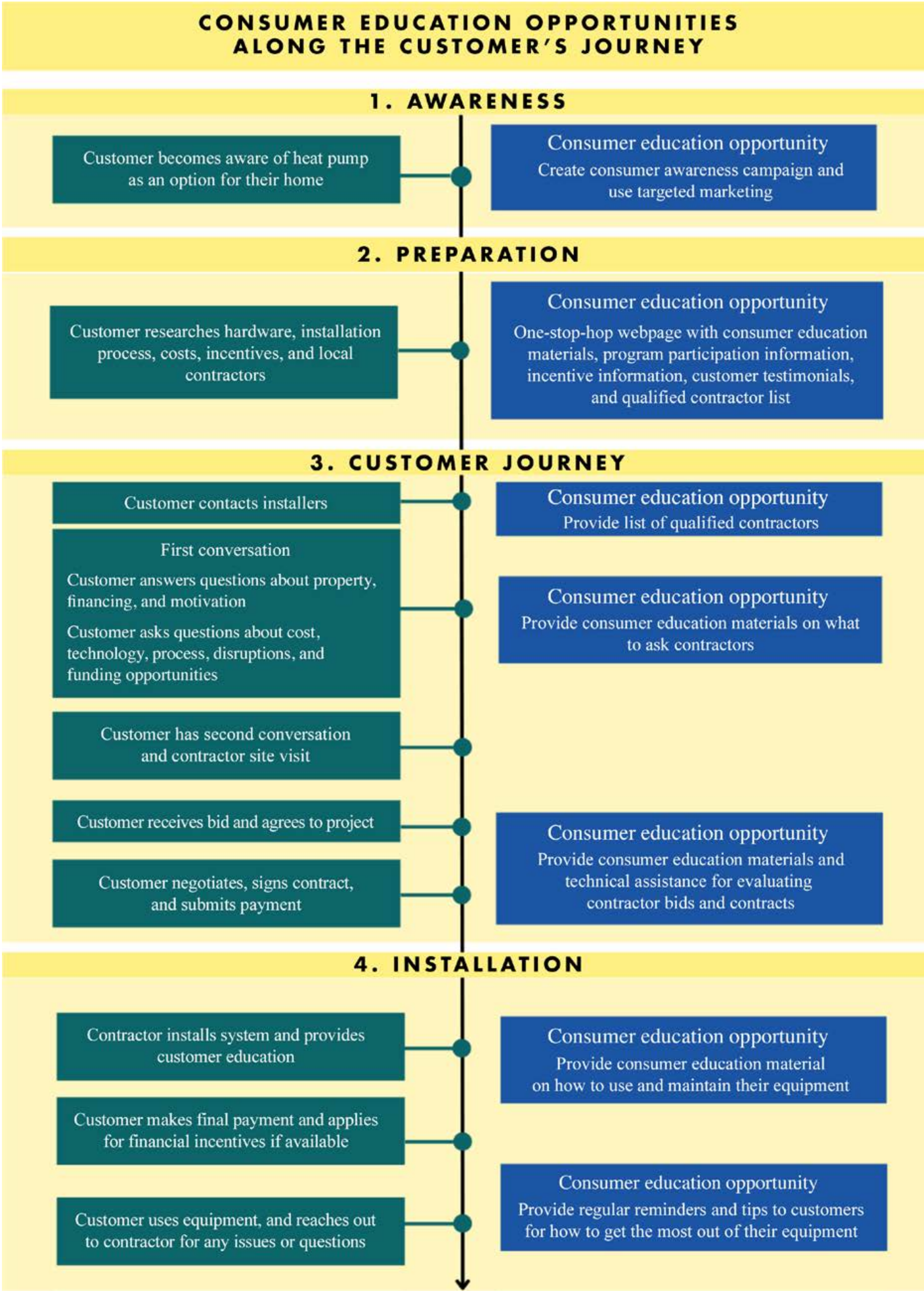

Figure 18. Heat pump customer journey. Based on research from Cretu and Zanetti 2021.

Consumer Awareness Campaigns

Consumer awareness campaigns are an essential part of beneficial electrification programs. Raising customer awareness of efficient electric technologies is the first step in setting customers on their journey to adoption. Customers need to be aware of technologies so that they ask contractors about them as a potential option for their home. Consumer awareness can also motivate customers to advocate to their contractors that they prefer efficient electric options and push back on contractors who might try to sway them toward a less efficient like-for-like replacement.

Consumer awareness campaigns can use a variety of outreach channels. These can include TV and digital video, radio, digital marketing (social ads and paid search), email marketing, and direct mail. NYS Clean Heat program uses a variety of these strategies and has seen high levels of lead generation through their website (New York State 2021). Many of the program implementers that we spoke to talked about the need for greater coordination among the various consumer awareness campaigns locally, statewide, and even nationally. Having a consistent single trusted source of information is easier for consumers to navigate and builds consumer confidence because there is less conflicting information. Many programs leverage ENERGY STAR certification as this source by utilizing free educational content and media materials that have been expanded to support the ENERGY STAR Home Upgrade platform. Programs that are limited in their ability to promote fuel switching can benefit from platforms like ENERGY STAR Home Upgrade that feature efficient electric technologies but focus on broader benefits to motivate adoption.

There are many consumer awareness campaigns for efficient electric equipment across the country. Most of these campaigns emphasize non-energy benefits equally or more than the energy savings from the technologies. This includes appealing to environmentally conscious consumers, emphasizing the improved comfort of their homes, and highlighting guaranteed product quality with long lifetimes and warranties.

All campaigns also strive to make understanding the technologies and their benefits as simple as possible. For example, the Northwest Energy Efficiency Alliance's Boring but Efficient campaign released a consumer education video that explains the benefits of hybrid heat pump water heaters. The video illustrates how a hybrid HPWH will deliver three times the amount of hot water for the same amount of electricity as a standard tank water heater using the visual in figure 19 below. Table 3 summarizes customer awareness campaigns for efficient electric equipment and appliances.

Figure 19. Visual comparison of an efficient heat pump water heater versus a standard tank model. Source: Hot Water Solutions 2021.

Current Consumer Awareness Campaigns for Efficient Electric Technologies

Table 3. Consumer awareness campaigns

Campaign	Description
Boring but Efficient *Implementer: Northwest Energy Efficiency Alliance*	National campaign for HPWHs Link: www.boringbutefficient.com
The Switch Is On *Implementer: California TECH Program*	Statewide campaign for comprehensive clean energy residential retrofits Link: www.switchison.org
Clean Heat Lives Here *Implementer: MassCEC*	Statewide campaign for comprehensive clean energy residential retrofits Link: goclean.masscec.com

Create Customer Segments and Use Targeted Marketing

Many programs use customer segmentation to identify potential participants. Implementers use billing data, city permit data, county assessor data, and census data to identify potential buildings that could be a good fit for the program. They may also use customer management software to track information about their customers and create customer segment profiles. For example, Boulder's Comfort365 program worked with Radiant Labs to use local data and energy modeling to identify homes with heating equipment nearing the end of life. Boulder's program staff combined that information with its salesforce database to identify customers that were likely to adopt energy-efficient equipment and create groups of potential adopters. The program staff directly reached out to customers in these groups to teach them about the heat pump technologies and program offerings prior to their equipment failing. Using this approach of focusing on buildings with older equipment and customers that were likely to switch to efficient equipment, the program staff got 40% of participants enrolled in the program to adopt at least one clean heating technology (Terry and Stori 2019).

Customer segmentation also offers an opportunity for programs to create more equitable programs by identifying and targeting historically underserved customer segments. Program implementers can use data and indicators to identify underserved communities in their territories and develop pilots and programs for these communities. Following Greenlining Institute's Framework (Mohnot, Bishop, and Sanchez 2019), program implementers should partner with community leaders and organizations to engage with community members and learn their specific concerns and needs. If program implementers cannot offer specific programs for these communities, they should still engage with them early on to factor their needs into the design of broader electrification programs.

Example: San Joaquin Valley (SJV) Affordable Energy Pilot

The SJV Affordable Energy Pilot, approved by the California Public Utilities Commission, provides free energy efficiency retrofits to 11 historically underserved communities with the goal of improving energy affordability for residents (Halbrook 2021; Cunningham, Ralston, and Wu 2019). The state organized a Data Working Group with key stakeholders to collect the data necessary to determine disadvantaged communities (as defined by Section 783.5 of the California Public Utilities Code) (Opinion Dynamics 2021). The working group identified 170 communities that qualified as disadvantaged, and the CPUC approved pilots targeting 11 of these communities.

The pilots launched in 2020 and have shared only preliminary results and lessons learned so far. One of the early findings is the importance of community-based organizations and community energy navigators (CENs) for engaging local communities (Halbrook 2021). They have also uncovered specific concerns for community members, including reluctance to replace appliances and equipment they have already invested in, fear of electrical service outages and reliability, and space constraints leading to storing appliances outdoors. These early findings highlight the importance of using a leading-with-equity approach to both target specific communities and design programs that meet their needs.

Customer Education

All electrification programs provide consumer education on their program websites. As seen in the customer journey graphic (figure 18), consumers need a reliable and easy-to-understand resource to learn about efficient electric options for their homes. Programs are in a unique position to be the reliable resource for customers and make learning everything they need to know about electric retrofits as straightforward as possible. The following programs in table 4 are typical consumer education materials found on program websites:

Table 4. Typical consumer education materials on program websites

Education material	Description
Clean energy home guidebooks *Formats: Webpages, PDFs, Videos*	Guidebooks that explain the different technologies, how they work, whether they might work in your home, their benefits, estimated costs, available incentives and guidance on what to ask your installer *Example: goclean.masscec.com/clean-energy-solutions/*
Available incentives *Formats: Webpages, PDFs*	Typically charts or tables that show all the available incentives and financing for each technology; some programs may also provide average project costs after incentives, and may also include a tool to search by zip code. *Example: goclean.masscec.com/benefits-savings/*
Local installer search *Formats: Webpages*	Webpages that allow customers to find local installers; some programs list any available installers while others list only qualified installers (if they have a certified installer qualification program); some programs may include a tool to search by zip code. *Example: goclean.masscec.com/installers/*
Customer testimonials and case studies *Format: Webpages, PDFs, Videos*	Positive customer testimonials and case studies describing their experience adopting efficient electric technologies and satisfaction post-installation *Example: goclean.masscec.com/masscec-pilot-showcases-success-of-whole-home-heat-pumps/*
Proper usage and maintenance tips *Format: Webpages, PDFs, Videos*	Guidance for customers on how to get the most out of their new equipment *Example: www.youtube.com/watch?v=JFvT77a8KhQ*
Additional resources *Format: Webpage with external links and PDFs*	Webpages that share additional resources on efficient electric technologies with links to external webpages, blogs, downloads, videos, and podcasts *Example: goclean.masscec.com/resources/. And* www.energystar.gov/products/energy_star_home_upgrade

ENGAGE THE SUPPLY CHAIN

Providing incentives and technical assistance at various stages throughout the supply chain can be a vital and cost-effective method for accelerating electrification technology deployment, lowering costs, and broadening access for downstream consumers. Engaging market participants at the upstream and midstream level can also provide vital information for downstream market participants, including sales associates and contractors, to aid in selling products and services to end users. The following section describes various methods for programs to engage different levels of the supply chain and expand access to technologies such as heat pumps and water heaters.

Manufacturers

Manufacturers of electrification technologies are essential participants in the market, and manufacturer-level incentives to scale up production of heat pumps may be one of the most cost-effective methods to drive down technology costs for all participants. According to research by the Collaborative Labeling and Appliance Standards Program (CLASP), an incentive of $400–500 per unit for manufacturers of central air conditioners to convert all new central ACs to heat pumps would lead to $80 billion or more in societal benefits through maximizing the spread of more efficient, emissions-free technologies (Pantano et al. 2021). Industrial manufacturers are uniquely well-suited to take advantage of this incentive, the report’s authors argue, since the production of a one-way AC requires only slight modification to the manufacturing process, with most AC models already having a heat pump model. Consolidating product lines in this way may lead to additional efficiency and other benefits in terms of production, distribution, and marketing.

Additionally, manufacturers can provide further resources, education, and training for contractors and installers working with heat pump technologies. By following guidance from the product manufacturers for proper installation and maintenance, using premade marketing materials from manufacturers, and educating end users on how to properly operate the equipment, manufacturer-installer partnerships can lower costs, reduce friction in the sales process, and improve customer experience to reduce callbacks.

Distributors

Distributors are midstream entities (wholesalers, suppliers, market networks) that manage the transportation, stocking, and in some cases direct sales of appliances to retailers and end users. These businesses play a vital role in the supply chain, especially in bringing electrification to rural areas or underserved regions. Stocking of heat pump equipment in supply depots is essential, particularly in the case of emergency replacements, which comprise a majority of HVAC contracting projects in existing residential buildings. Distributors may also be valuable partners with program administrators, for example, when building out demand for heat pumps in a new region.

Conclusions and Recommendations

In reviewing existing electrification programs, it was clear that no single program design approach will work for all service territories and customers. All programs should strive to make electrification retrofits as straightforward as possible for their customers by addressing the main barriers to electrification. Table 5 below summarizes the program offerings and services that can address each barrier.

Table 5. Recommended program offerings and services to address key barriers

Barrier	Offerings and services
Building or technology	• Perform building stock characterization to understand the common building types, challenges, and best efficient electric technology solutions • Provide energy audit that identifies specific building needs and recommends best solutions for each home • Provide technical assistance and/or project manager to offer guidance and support on building or technology specific challenges • Facilitate information sharing among contractors, project managers, and manufacturers to share solutions to common project challenges
Project costs	• Help identify incentives and financing for electric and complementary measures • Provide information about sources of incentives and financing • Streamline and layer incentive and financing offerings with other programs to make customer or contractor application process simple
Workforce	• Partner with workforce training organizations and initiatives • Create a participating contractor program • Implement quality assurance mechanisms
Consumer awareness and education	• Run consumer awareness campaigns • Create targeted marketing and communications to different customer segments (elderly, environmentally conscious, young families, etc.) • Supply educational materials about efficient electric products that explain how they work, their benefits, how to evaluate if they are a good fit for the customer's home, and estimated project cost information

Barrier	Offerings and services
	• Offer information about program offerings and how to participate
Supply chain	• Provide incentives to manufacturers for the development of high efficiency electric products • Partner with manufacturers to provide workforce education • Work with manufacturers to design products suited for the U.S. market • Partner with distributers to ensure they have sufficient stock of efficient electric products

While electrification retrofits face many challenges and barriers, programs across the country are proving that they can play a key role in helping customers move toward efficient, all-electric homes. Electrification programs can serve as trusted advisors to home and building owners by helping them navigate retrofit projects and providing solutions to common challenges. In order to reach our climate goals, more states and localities need to pursue these programs to create an environment where electrification retrofits are easier and eventually become the default for customers.

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