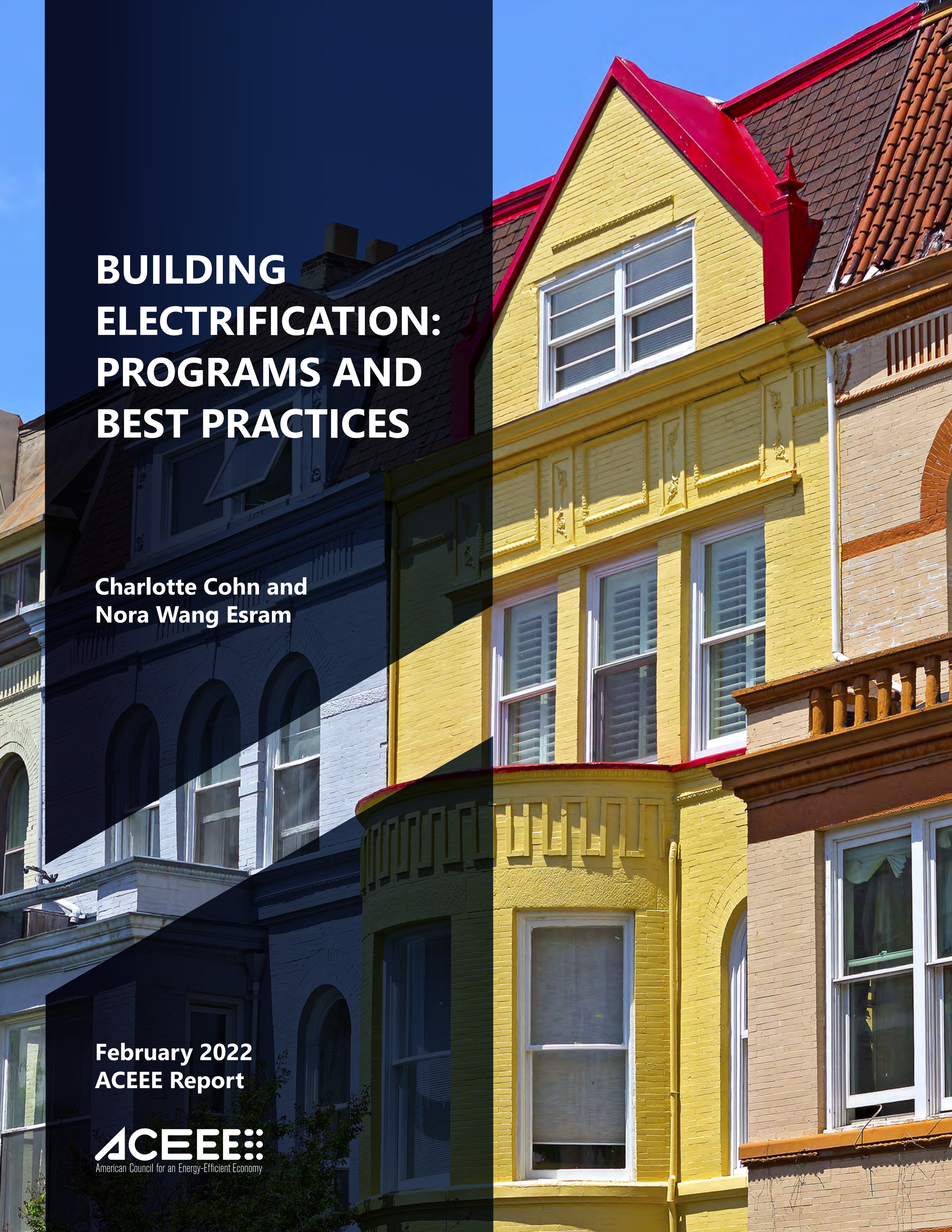

BUILDING ELECTRIFICATION: PROGRAMS AND BEST PRACTICES

Charlotte Cohn and
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ACEEE Report

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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.

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Executive Summary

KEY FINDINGS

Programs to promote the electrification of space heating, water heating, and other end uses of fossil fuels in buildings are expanding across the country. In a previous study, in 2020, ACEEE identified 22 programs with total annual spending of $108 million. This updated and expanded study—assessing the inventory of building electrification efforts to date—includes 42 programs. Of these, 32 programs reported budget data, with a collective annual budget of $166 million.

Air-source heat pumps for single-family residential space heating were the primary technology focus in 90% of the building electrification programs included in this study, primarily because space heating, as the largest fossil fuel energy use in the typical American home, presents a huge decarbonization opportunity.

When building efficiency upgrades (such as weatherization to improve building envelopes) are paired with electrification of space- and water-heating systems, those systems can be designed to serve a smaller thermal load, reducing upfront cost, improving comfort, and lowering peak electric demand.

Typical utility-run electrification programs usually involve technology-based rebates to residential customers. Nonutility program administrators are more likely to offer more comprehensive program models, including whole-home retrofit programs, financing for upgrades, workforce training programs, low- and moderate-income programs, market development, and other strategies.

Upstream incentives for heat pump manufacturers are not widely represented in this survey of programs but present an opportunity for even more cost-effective energy savings and greenhouse gas reductions because they are scalable and savings can be passed on to end-use customers.

Low- and moderate-income (LMI) customers and renters face significant obstacles to enjoying the benefits of building electrification. While some programs specifically target the needs of these customers, this segment of the market requires increased attention.

Where possible, electrification programs, measures, and incentives should be braided into existing energy efficiency programs to increase their reach and engagement with hard-to-reach customer groups such as low-income and multifamily households.

Contractors play a key role in building electrification. Expanding the workforce and educating and motivating contractors to install and service heat pumps is a critical strategy for scaling up capacity for electrification in buildings.

Electrification—the process of converting fossil fuel–based equipment used in heating, cooking, and transportation into efficient electric equivalents—is a critical step in addressing anthropogenic climate change. As the United States transitions away from burning fossil fuels for electricity generation, we must also carry out this same transition in our buildings and our daily lives to reduce emissions of greenhouse gases (GHGs). By creating incentives and programs to promote accelerated, widespread, and equitable electrification of fossil fuels, we can take steps to address the existential threat of global warming without compromising our safety, comfort, and quality of life.

This research examines the status and progress of electrification in buildings in the United States through the lens of local electrification programs and incentives. These programs, developed and administered by states, cities, utilities, and nongovernment organizations, aim to accelerate building electrification through incentives, education, job training and certification, and increased supply chain capacity. We collected a range of data from these electrification programs, including the end uses and measures that were incentivized, the sectors that were targeted, the level of spending and program budgets, and the anticipated or achieved impacts (measured by total participation and GHG reductions). In addition, we conducted interviews with program managers and technical experts to identify emerging trends, barriers, and best practices in program design and implementation. The objective of this report is to provide a high-level snapshot of electrification progress to date and to identify obstacles and opportunities to accelerate building electrification across the United States and beyond.

ACEEE published prior research on this subject in a 2020 paper surveying 22 local and regional programs to electrify space heating.[1] Our updated survey includes data from 42 programs providing strategies and incentives for increasing the amount of new electric heating, water heating, and cooking devices to replace fossil fuel systems in single-family residential, multifamily residential, and small to medium-size commercial building applications.[2] This report describes many of the largest and most comprehensive building electrification efforts as of 2021, including programs that are ongoing and those that have concluded. These programs, although not an exhaustive list, cover 17 states and 35 program administrators (24 utilities and 11 nonutility administrators) in the United States, as shown in figure ES1.

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[1] Nadel 2020. *Programs to Electrify Space Heating in Homes and Buildings.* aceee.org/topic-brief/2020/06/programs-electrify-space-heating-homes-and-buildings.

[2] To keep the scope of this report manageable, we do not include industrial programs. While industrial process end uses are a significant opportunity for electrification, these applications are often specific to the industry in question. ACEEE has published a body of research specific to electrification in the industrial sector, such as Rightor, Whitlock, and Elliott 2020. *Beneficial Electrification in Industry.* aceee.org/research-report/ie2002.

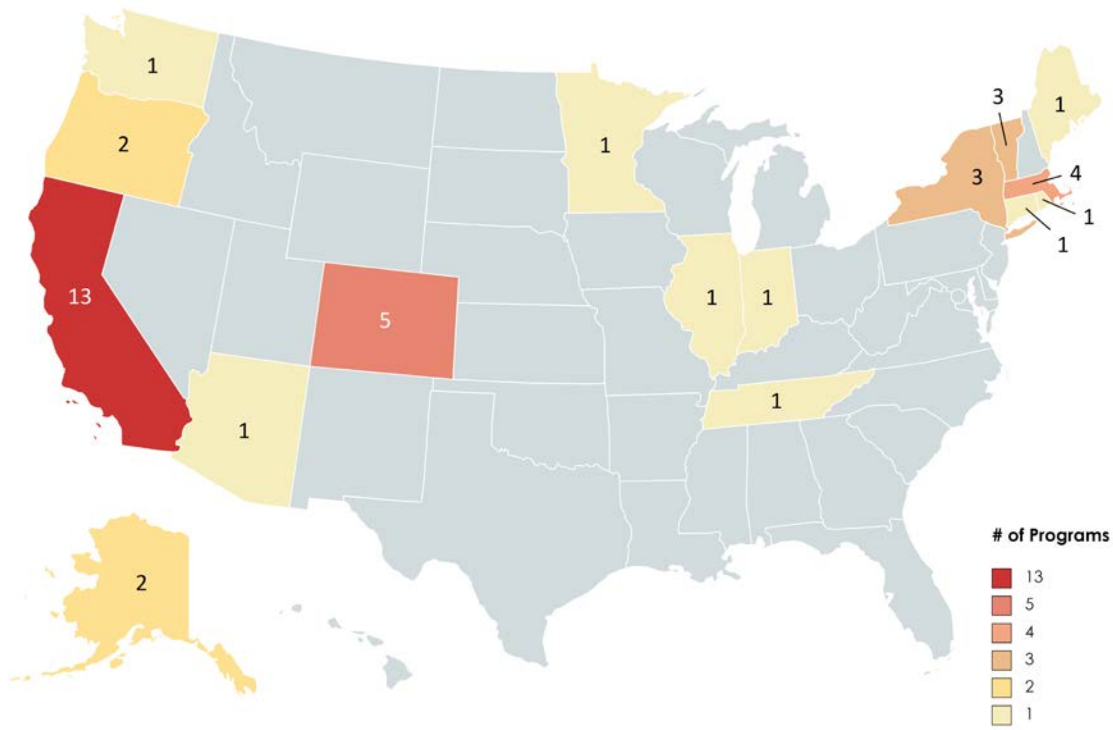

Figure ES1. Number of building electrification programs in this report, by state

Space heating is the most targeted end use, with 90% of programs in this study offering incentives for air-source and/or ground-source heat pumps. Certain programs, particularly those in cold-weather states such as New York and Minnesota, offer specific incentives for cold-climate air-source heat pumps, which are designed to provide ample space heating even at low ambient temperatures. Heat pump water heaters are another major end use for electrification, incentivized in 71% of programs. Electrification of cooking equipment (typically via induction stoves, which are more efficient than their conventional electric resistance cousins) is incentivized in 31% of programs. Other electric end uses, such as clothes dryers, lawn mowers, and industrial forklifts, also receive incentives in specific cases, but less frequently than the other applications mentioned above. Beyond direct incentives, certain programs include market development efforts to boost the capacity and technical skills of contractors and the knowledge base of both contractors and consumers.

The most common type of incentive is a direct rebate to utility customers for purchasing qualifying equipment. Some programs offer tiered rebates based on factors like the efficiency of equipment, its performance in cold climates, the type of fuel being displaced, customer income level, and other factors. A smaller percentage of programs deliver incentives in other ways. For example, six new-building programs offer incentives to help home builders lower the cost of all-electric new construction. Two programs provide incentives and specialized training to contractors who install equipment in customers' homes. Eight programs use multiple channels to provide incentives.

In this updated review, annual budgets total more than $166 million among the 32 programs reporting data, a 53% increase relative to the 2020 study. The average program spends approximately $5.2 million per year. Programs vary from small-scale pilots in fewer than 10 homes to statewide incentives and market transformation efforts with thousands of participants. Most utility-led programs are funded by ratepayers. Programs run by state-based organizations or other nonprofits rely on various funding methods, such as cap-and-trade funds, capacity market revenues, grants, and donations. The programs with the largest spending are most often found in states that prioritize electrification in policy and regulation, such as California, New York, and Colorado.

Equity is an objective in several programs. Seven programs have an explicit requirement that some or all participants in the programs be low-income customers. Several additional programs offer higher financial incentives to income-qualified customers. Our research shows, however, that multiple barriers remain for these customers, including an inability to afford high upfront costs of fuel switching (even with incentives), a lack of understanding or awareness of incentive opportunities and the multiple benefits of electrification, and a lack of control over their home energy systems in a rental unit.[3] The "Discussion" section in this report identifies additional barriers as well as strategies that some program administrators have adopted to address these issues.

Our interviews with program managers and experts revealed that contractors play a vital role in expanding building electrification efforts. Because heat pumps still represent a small (although growing) segment of the HVAC market, many contractors have limited experience with and understanding of heat pump technologies, particularly heat pump water heaters, which require both electrical and plumbing expertise. This unfamiliarity, along with lack of established methods to sell heat pumps to end customers, makes many contractors hesitant to incorporate heat pumps into their existing businesses. Contractor education and incentives targeting installers are key components of the largest market transformation efforts to date, such as in Maine and New York.

In addition, while new building electrification is a path to create long-term cost savings and emissions reduction, retrofits for existing homes and businesses present a variety of challenges. Efficiency, weatherization and building shell improvements, wiring and panel upgrades, and providing customer service all create additional complexity and can increase costs in building electrification efforts. By offering "comprehensive" incentives that combine electrification with building energy assessments, weatherization, panel upgrades, demand response and distributed energy generation, whole-building programs can offer solutions that are tailored to fit the unique needs of the building in question. Combining multiple

[3] More in-depth research on decarbonization for affordable housing will be published in a forthcoming ACEEE report (York et al. 2022).

energy solutions can enable program managers to lock in long-term energy savings and benefits that go beyond a simple technology replacement.

Our recommendations for expanding and scaling up electrification based on the findings of this study are detailed by actor in table ES1.

Table ES1. Recommendations by actor

Actor	Key recommendations
State legislatures	• Include explicit building electrification targets within larger climate plans, and prioritize access to resources and support for marginalized communities when setting goals • Provide consistent funding streams for building electrification programs, particularly whole-building retrofits for underserved communities • Capture electrification opportunities in new buildings through building codes and standards, such as requiring new buildings to be all-electric or "ready to electrify" • Enact a price on carbon via a tax or by joining a regional carbon cap-and-trade market. Utilize carbon market revenues to create sustainable funding streams for building decarbonization programs
Regulators	• Enable a rapid and smooth transition to a carbon-free power supply • Ensure that the grid has adequate transmission/distribution capacity to reliably accommodate additional electricity load from buildings • Allow program managers to offer fuel-switching measures and incentives • Set targets for utilities to provide building electrification incentives to their customers, including performance-based incentives where appropriate, and establish fuel-neutral impact tracking and reporting methods • Consider nonenergy benefits (e.g., environmental impacts) in cost-effectiveness testing and evaluations for building electrification programs • Encourage utilities to explore the integration of building electrification technologies with the grid in order to increase variable renewable energy resource utilization and reduce systemwide costs • Develop a transition plan for gas utilities, including gas distribution system downsizing and zero net carbon alternatives to natural gas • Consider impacts on electric rates, particularly for energy-burdened customers, and require utilities to offer programs specifically targeting hard-to-reach sectors

<table>
<tr><td>Utilities</td><td>Incorporate building electrification into the integrated resource planning process
Develop pilots and expand existing building electrification program offerings
Incorporate demand response, distributed generation, energy storage, and other demand-side resources to mitigate grid impacts of electrification
Combine electrification incentives with existing in-home energy efficiency programs to streamline the delivery progress
Offer incentives for electric panel and service upgrades to support electrification
Phase out incentive programs for fossil fuel equipment</td></tr>
<tr><td>Manufacturers/ distributors</td><td>Expand production and distribution of building electrification technologies, particularly for whole-home systems designed for use in cold climates and for homes with hot-water distribution systems.
Provide contractor education programs and work with installers to broaden understanding and expertise in heat pump technologies for buildings
Ensure that heat pump equipment is widely available and stocked in distribution centers to allow replacement of fossil fuel equipment on an emergency basis</td></tr>
<tr><td>Contractors, home builders, architects, and engineers</td><td>Participate in education, job training, and certification programs to incorporate building electrification technologies in building design and installations
Develop specialized product and service offerings to integrate heat pump technologies into existing business models and sales processes
Join local/regional business groups to share knowledge and receive support for building electrification
Combine electrification with energy efficiency to reduce total system cost and ongoing energy costs for customers
Educate customers on heat pump technologies, incentives, and benefits</td></tr>
<tr><td>Homeowners and property managers</td><td>Learn about building electrification technologies and share this information with neighbors and peers
Understand the local utility incentives for building electrification measures
Plan to replace existing fossil fuel equipment as it nears the end of its useful life span to avoid an emergency replacement when existing equipment fails
Implement energy efficiency measures, such as improving building envelopes, along with building electrification to reduce lifetime energy cost and improve comfort</td></tr>
</table>

Introduction

In the past year, many states and utilities have ramped up their commitments to reducing greenhouse gas (GHG) emissions. To address global climate change, we must reduce these emissions from every part of our energy system. The energy used in residential and commercial buildings accounts for 40% of total energy use in this country (EPA 2021). The burning of fossil fuels in buildings alone accounts for 13% of total U.S. emissions. Reducing these numbers through efficiency and electrification is a critical step toward reaching total decarbonization.

Electrification in the context of building decarbonization refers to the replacement of fossil-fueled equipment (such as for space heating, water heating, and cooking) with electric equivalents. When building electrification reduces overall emissions and energy costs, it is often termed *beneficial* or *strategic electrification* (Farnsworth et al. 2018). Today, replacing a natural gas furnace with an electric heat pump will reduce carbon emissions in 46 out of the 48 contiguous United States—that is, in 99% of all U.S. households—while switching from a propane or fuel oil furnace to a heat pump will reduce carbon emissions essentially anywhere in the Lower 48 (McKenna, Shah, and Silberg 2020). As the power sector generates more and more electricity from carbon-free sources, electrifying fossil-fueled end uses will increasingly reduce carbon emissions.

Several studies have found that building electrification is more cost effective than fossil fuels for most new home construction, especially when considering the avoided cost of gas mains, services, and meters in all-electric homes and neighborhoods (McKenna, Shah, and Louis-Prescott 2020). For existing home retrofits, electrification is most cost effective at the time when existing equipment reaches the end of its useful life and needs to be replaced. Space-heating electrification also tends to be more economically favorable when replacing equipment that runs on delivered fuels (i.e., oil and propane) with heat pumps, since electricity rates are regulated and are therefore more stable than unregulated fuel prices (Nadel 2018). Heat pumps are also significantly more efficient than fossil-fueled and electric resistance heating systems; moreover, they provide air-conditioning as well as space heating, making them attractive from a cost savings as well as a comfort perspective (Nadel 2016). The economics of electrification may be more challenging when replacing existing gas heating systems, due in particular to the historically low price of natural gas.[1]

However, heat pumps can still be favorable relative to natural gas in mild climates where heating needs are moderate and where electricity cost is often lower than the national average (Nadel 2020; Kaufman et al. 2019). In a previous study, ACEEE concluded that 27%

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[1] These economics may change, as the price of natural gas is expected to fluctuate and increase beginning in the winter of 2022.

of existing commercial floor space heated with fossil fuel systems can be electrified today with a simple payback of less than 10 years on average and without any rebates or carbon pricing; with additional incentives, the share increases to 60% (Nadel and Perry 2020).

Some end uses in buildings may be partially electrified or electrified in stages due to the limitations of today's technology or cost constraints in some regions. For example, while cold-climate air-source heat pumps work for space heating to temperatures well below 10 °F, efficiency may be reduced. Therefore, in some cases, heat pump space heating in cold climates may need a source of backup heating depending on the condition of the building envelope and selection of heating equipment. Another example is electrifying water heating in multifamily buildings. A central heat pump water heating system can be designed to displace a portion of the hot-water load in a multiunit dwelling and still remain cost effective (Ceci 2021). In any event, heat pump technologies continue advancing; this will be discussed in the "Improved Heat Pump Performance" section of this report.

Policies and incentives often play a critical role in catalyzing new technology uptake. Electrifying buildings is an essential part of many local, state, and national climate strategies, and utilities and program administrators across the nation are working to accelerate adoption of electric replacements for fossil fuel equipment. Their efforts often come in the form of financial incentives and other programs that aim to address the cost and knowledge barriers and other obstacles to conversion to efficient electric end uses, generally in tandem with efforts to "green the grid" by replacing fossil fuel generation with zero-carbon renewables. The benefits of electrification will only increase as the carbon intensity of the grid is reduced.

This study is intended to identify emerging trends and best practices in building electrification programs. It updates and expands on past ACEEE research on building electrification. In June 2020, ACEEE published a topic brief on programs to electrify space heating in homes and buildings (Nadel 2020). The 2020 study reviewed 22 utility programs and identified a trend of rapid growth in electrification programs, which primarily use high-efficiency heat pumps to displace fossil fuels and electric-resistance space heating. The total program budget in 2020 was nearly $109 million, up 70% from the prior year.[2] The continuing rising interest and rapid growth in electrification programs and policies since then warrant a new report on electrification programs nationwide. For example, the Minnesota Energy Conservation and Optimization (ECO) Act, passed in May 2021, provides

[2] For comparison, U.S. customer-funded energy efficiency expenditures in 2018 totaled $7.2 billion (Cooper, Shuster, and Watkins 2020).

an incentive pathway for fuel switching[3] (Minnesota Legislature 2021). Colorado SB21-246, signed into law in June 2021, requires investor-owned electric utilities to incentivize building electrification (Colorado General Assembly 2021b). Colorado SB21-264, passed in the same session, requires investor-owned gas utilities to reduce greenhouse gas emissions through a variety of "clean heat" strategies, of which electrification is one (Colorado General Assembly, 2021a). Illinois's Climate and Equitable Jobs Act (CEJA) allows utilities to meet some of their annual energy efficiency goals through efficient electrification measures.

This report provides an overview of the building electrification programs offered nationwide to date, including program budgets, types, and savings. We requested updated information from all of the programs included in the 2020 ACEEE study, reached out to administrators of new electrification programs, and collected more detailed program information (such as participation and savings) from program administrators. We added 20 programs from a total of 36 utilities and administrators to our research. We also conducted interviews to compile success stories and gain insight into lessons learned. Our study includes both commercial programs and residential programs (for both single-family and multifamily buildings, but not including manufactured homes). Similar to ACEEE's previous findings reported by Nadel (2020), the existing electrification programs are by and large aimed at residential and small commercial buildings. Figure 1 shows which sectors have been targeted by programs in this study. We elaborate on program details, including end uses, measures, budgets, and more, in the "Electrification Programs Landscape" section below.

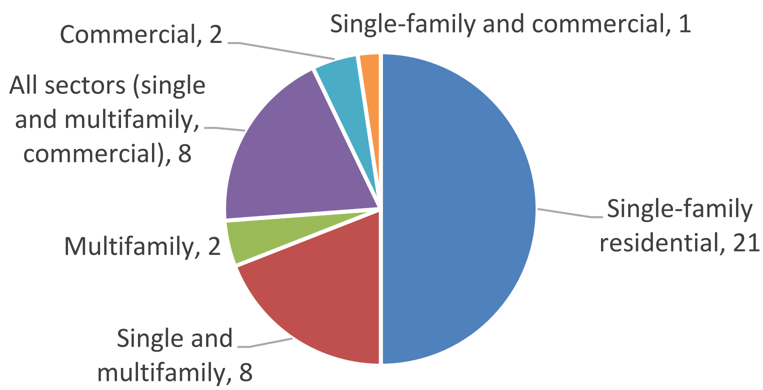

Figure 1. Number of electrification programs in target sectors

[3] Fuel switching is the practice of replacing an end-use customer-facing technology (such as space heating or water heating) with one that uses a different fuel. In the context of decarbonization, fuel switching encourages moving away from fossil fuel technologies, such as those using oil, propane, or natural gas, through the installation of an electric air-source heat pump.

Since our focus is on electrification, heat pump programs that do not include fuel switching, such as programs to replace electric resistance heating with heat pumps, are excluded from this study. These other heat pump programs offer multiple benefits such as cost savings and carbon reductions; however, we exclude them in order to concentrate specifically on the unique needs and attributes of electrification programs.

Whole-building energy efficiency provides a strong foundation for electrification because it reduces a building's thermal load and peak demand. A smaller overall heating load makes electrification more cost effective by reducing HVAC size, and a building's demand flexibility and resilience improve when a constant indoor temperature can be maintained for a longer period of time. As electrification increases electric load during peak times, it may raise carbon emissions for some periods when carbon-intensive units, such as coal, are used for marginal generation. A lower peak demand reduces these marginal emissions. With an emphasis on efficiency, our study also looked into the integration of electrification program and weatherization measures, which reduce building energy loads and costs, especially for low-income families. More in-depth research on how to align energy efficiency with climate goals and how electrification will affect low-income families in residing in affordable housing is available in two other ACEEE reports (Specian and Gold 2021; York et al., forthcoming).

OVERVIEW OF THIS REPORT

This report begins by providing its readers with necessary background information, key terms, and context in terms of electrification policies, technologies, and drivers of change. We also summarize findings from the existing literature to illustrate the sphere of knowledge and information on this topic to date.

Following this introductory section, we describe our methods and key findings in the "Electrification Programs Landscape" section. We present our analysis of the 42 electrification programs in terms of general program information; targeted end uses; target customer sectors; measures and incentives; delivery pathways; integration with weatherization, demand response, and other clean energy technologies; program budgets including administrative and incentive costs; and program impacts including participation, energy savings, and greenhouse gas reductions.

After the analysis of electrification programs across the nation, we present four case studies in California, New York, and Washington, DC, based on our in-depth interviews with program managers. We then discuss our research findings and the emerging barriers and opportunities for electrification across four levels of decision making: homeowners, contractors, manufacturers, and policymakers. We conclude with our recommendations for strategies that various actors can employ to accelerate electrification of buildings in the United States.

The full set of data for each program can be found in Appendix A. Appendix B presents the survey we used to collect data for this study.

DRIVERS OF CHANGE

Uptake of electrification programs needs multiple drivers, including a supporting policy environment to enable program development and implementation; a cleaner utility grid to achieve the intended carbon reduction goals; and reliable, efficient technologies to meet customer needs and deliver consumer benefits. Consumer interest and motivation certainly play a critical role. For example, one big driver of heat pump installation in some regions (such as Northern California and the Pacific Northwest) is encouraging homeowners to consider heat pumps when they are thinking of installing central air-conditioning, since heat pumps can provide cooling as well as space heating.

State Policies

A growing number of states are updating their policies to enable electrification through customer-funded efficiency and other demand-side management programs. ACEEE presented a landscape of the state policies and rules for beneficial electrification in a policy brief published in May 2020 (Berg, Cooper, and Cortez 2020) and updated in January 2022. The 2020 policy brief showed that six states (California, Hawaii, New York, Vermont, Tennessee, and Massachusetts) were encouraging fuel switching through guidelines or fuel-neutral goals. Three states (Minnesota, Colorado, and Illinois) have since passed similar legislation. For example, Minnesota recently lifted its prohibition on fuel switching in its ECO legislation, creating opportunities for utilities such as Xcel Energy and Otter Tail Power to expand their existing heat pump offerings and begin providing additional incentives for conversion (Minnesota Legislature 2021). Three more states (New Jersey, Maine, and Rhode Island) have supportive policy in place with pending guidelines or rules. The rest of the states have no policy or specifically prohibit fuel switching.

Some policy changes in the last year have paved the way for more aggressive electrification in certain regions. As of July 2021, 49 municipalities in California had passed measures to require all-electric new construction (commercial and/or residential) or pre-wiring for future electric appliance installation (CEC 2021b; Gough 2021). The California Energy Commission released the new Title 24 Building Energy Efficiency Standards in August 2021 with rules that will give builders strong incentives to choose electric over natural gas–fired heating for residential and small commercial buildings starting in 2023 (CEC 2021a). At the national level, the U.S. Environmental Protection Agency (EPA) announced in September 2021 that gas appliances would not be included in its "most efficient" designation list starting in 2022 (EPA 2021).[4]

Energy efficiency resource standards (EERS)—policies requiring utilities to meet long-term (three or more years) energy savings targets—have also been revised in some states (such as

[4] The EPA notice did leave the door open for potentially including gas heat pumps in the future.

Massachusetts, Vermont, Minnesota, New York, and California), with more states following suit (such as Maryland and Connecticut), to better align with state climate goals (Berg et al. 2020; Specian and Gold 2021). The two primary approaches, which are often used in combination, are *multiple goals*, directing energy efficiency programs to meet a number of policy objectives, and *fuel-neutral goals*, enabling program administrators to prioritize the highest-potential GHG mitigation measures across fuels and sectors) (Gold, Gilleo, and Berg 2019). In Colorado, SB21-246, signed into law in June 2021, establishes electrification goals for investor-owned utilities, requiring them to develop plans for building electrification and submit them to the Colorado Public Utilities Commission for approval (Colorado General Assembly 2021b). This policy, the first of its kind in the United States, will promote the use of energy-efficient electric equipment in place of less efficient fossil fuel–based systems.

Changing Grid Mix

Reducing the carbon intensity of the power grid (in terms of carbon emissions per megawatt-hour of electricity) is crucial to maximizing the environmental benefits of end-use electrification. While electric appliances are generally more efficient than fossil-fueled versions, the overall environmental and GHG benefits of electrification depend on the grid mix that provides power to these systems. Over the last 20 years, the percentage of total electricity generated from renewable sources (including wind, solar, hydroelectric, biomass, and geothermal) has increased from 9% of the grid in 2000 to 20% in 2020, as shown in figure 2.

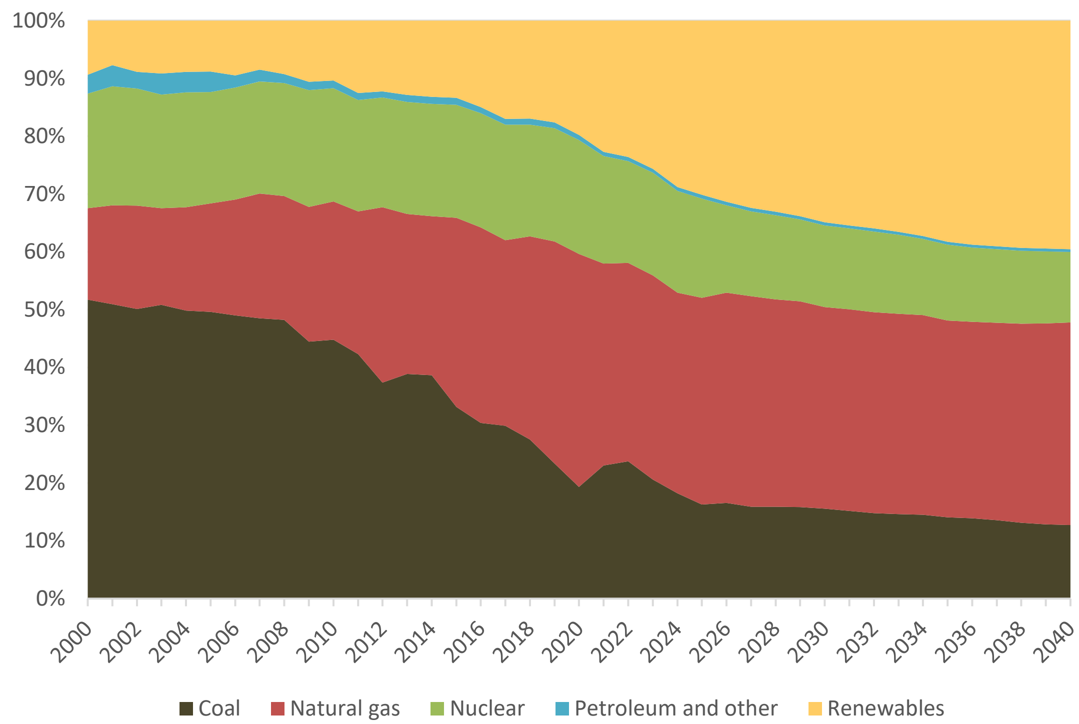

Figure 2. U.S. electricity generation by major energy source, 2000–2040. Values past 2020 are based on forecast data (EIA 2021a).

Electricity generated from renewable energy sources exceeded that generated from coal-fired power plants in 2020, for the first time since the U.S. Energy Information Administration (EIA) started tracking nationwide energy generation data, in 1950 (EIA 2021c). The fuel mix nationwide for electricity generation in 2020 was 40% natural gas, 21% renewables, 20% nuclear, and 19% coal. According to EIA, the growth of renewables came primarily from gains in wind (up 14%) and solar (up 26%). EIA predicts renewable generation to continue to steadily grow in 2022 (10% increase relative to 2021) and in future years (EIA 2021d). Over the long term, to 2050, EIA projects a robust competition between renewable energy and natural gas, with renewables supported by incentives and falling technology costs and potentially benefiting from rising costs of natural gas. The agency also predicts that coal and nuclear power will continue decreasing in the electricity mix (EIA 2021a). A Lazard analysis shows that selected renewable generation technologies are cost competitive with conventional generation technologies under certain circumstances (Lazard 2020).

Electrification can lead to lower emissions today—in all but the most coal-heavy systems—and will achieve greater reductions as the electric grid becomes cleaner (McKenna, Shah, and Silberg 2020). A study of co-op electrification programs estimates that electrification can reduce co-op members' fossil fuel consumption by more than 30% (Yañez-Barnuevo et al. 2019). Nationally, the fuel mix of co-ops is 68% fossil fuel (a slightly higher percentage than the national average), 15% nuclear, and 17% renewable (Yañez-Barnuevo et al. 2019).

As electrification increases electric load, it may also increase peak demand on the power grid. This may lead to greater carbon emissions during specific times and in certain regions where carbon-intensive power generation units, such as coal peaker plants, are used to maintain reliability during peak demand times. Also, increasing peak demand can spur utilities to invest in supply-side generation and electric transmission and distribution upgrades, leading to increased costs throughout the power system. Therefore, demand reduction and flexibility are critical to realize the projected emission reductions of electrification and to keep costs manageable.

Demand flexibility can come in the form of grid-connected device controls, "smart" thermostats, preheating and precooling, battery storage, and more. With demand flexibility, electrification can become a valuable grid resource as opposed to a potential liability. Connected heat pump equipment with smart controls and variable-speed motors can respond to grid signals and reduce its energy use during these peak times. Flexible demand can also support renewable energy growth by better utilizing intermittent resources like solar and wind. It can help balance the grid by shifting load away from peak demand hours, thereby reducing the need for peaker plants and helping to maximize GHG reductions. As of 2020, the ENERGY STAR® version 3.3 standard includes "connectedness" criteria for residential water heaters that will allow them to participate in utility demand response programs (ASAP 2021).

In addition to "active" demand flexibility measures, "passive" measures such as home envelope upgrades can also contribute to demand-side management and provide meaningful benefits in tandem with electrification. Comprehensive energy efficiency measures, particularly weatherization that includes air sealing and insulation, can reduce the overall energy required to heat and cool a building. This allows installers to downsize HVAC equipment, leading to reduced equipment costs and more energy savings and mitigating the impact on peak electric demand. This is particularly important in cold-climate regions where rising winter peaks are a concern, such as the Northeast (Specian, York, and Cohn 2021).

Improved Heat Pump Performance

Heat pumps are among the foundational technologies to enable building electrification. Figure 3 illustrates the basic structure of a heat pump system, which relies on a closed loop of evaporation and condensation using a refrigerant liquid that has a very low boiling point. By exchanging heat with an outdoor source (air, ground, or water), a heat pump can provide both heating and cooling, based on the needs of the indoor space at the time.

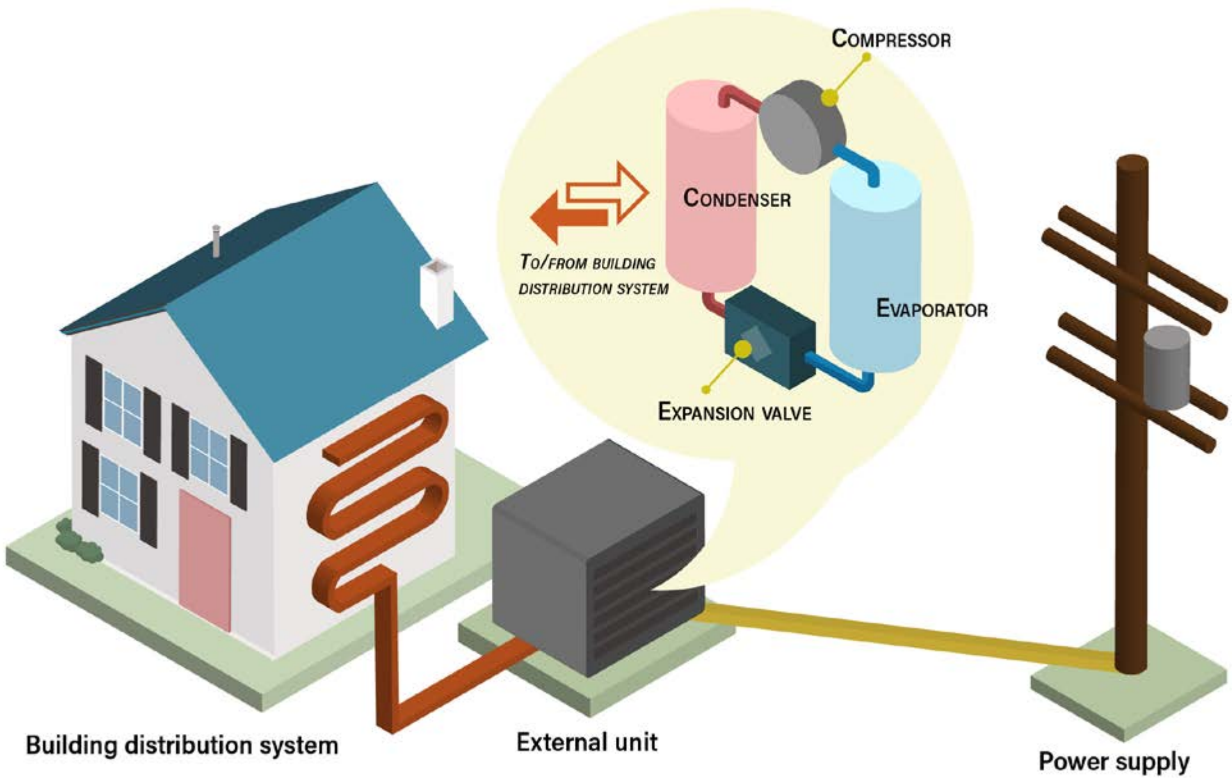

Figure 3. Basic characteristics of a heat pump system with a vapor condensation-evaporation cycle

The applications of heat pumps have been expanding with technology advancement. The following section details various heat pump technologies and uses.

Air-source heat pumps are the most common type of heat pump for residential applications. There are two types of air-source heat pumps, **ducted** and **ductless** systems. Ducted systems fill the role of a central furnace and air conditioner simultaneously, delivering heating and cooling for a building with centralized HVAC ducts. A ductless system, also called a mini-split system, is a version of an air-source heat pump for homes without HVAC ducts. Mini-splits can provide heating or cooling within a zone such as a room, floor, or attached unit. Air-source heat pumps can also heat or cool water rather than air (these are called air-to-water heat pumps) and may be used with radiant floor heating systems for more efficient space heating.

Cold-climate air-source heat pumps (ccASHPs) are a specialized model of air-source heat pump that can operate in colder temperatures. Both ducted and ductless systems offer cold-climate models. Modern ccASHPs are capable of delivering 100% rated heating capacity at 5°F and up to 76% capacity at –13°F (Mitsubishi 2020). Below those temperatures, the heat pump may switch to an electric resistance or fossil fuel backup heating system. Heat pump efficacy in cold climates has improved in recent years due to advancements in inverter-driven compressors and refrigerants (Shoenbauer et al. 2017).

Geothermal heat pumps, also called **ground-source heat pumps (GSHPs)**, rely on relatively stable temperatures underground or underwater to provide heating and cooling. Because geothermal systems do not depend on the temperature of the outside air, these heat pumps have more efficient and stable energy performance than air-source systems. However, the installation cost is generally several times higher than air-source heat pumps due to the cost of drilling underground wells. Some pilot studies have examined the possibility of retrofitting stranded natural gas distribution infrastructure to distribute geothermal heat on a neighborhood level (HEET 2019). However, this application is not currently included in any of the programs featured in this study.

Water-source heat pumps (WSHPs) operate by rejecting heat to a water-pipe system during the summer or by absorbing heat from the same water loop during the winter. WHSPs are more efficient than air-source heat pumps because water has a higher capacity to carry heat than air does. They are also more applicable to large commercial buildings. Other advantages include quiet operation, a small system footprint, and the ability to meet simultaneous heating and cooling demand in multiuse buildings (Halbhavi 2016). Due to the highly specific siting and infrastructure required, this type of heat pump system is not widely represented in our study.

Hybrid (dual-fuel) heat pump systems combine a heat pump with a backup gas or propane furnace that operates when the heat pump cannot provide adequate heat. These systems may be used in new construction or building retrofits as full load replacements for the existing heating system. An alternative dual-fuel approach involves installation of a new heat pump system while the previous legacy fossil fuel system is left behind as a backup until it reaches the end of its useful life. Some programs are pursuing this option where customers are uncertain about a heat pump's ability to provide reliable full-load heating, while others, like New York, are developing strategies to mitigate the need for backup heat even in the coldest climates to fully achieve their decarbonization goals. Some market actors have suggested dual-fuel systems are a good solution to have a backup system in the event of a power outage, but the fossil fuel furnace still requires electricity to operate some form of onsite generation would be needed to fulfill that need.

Improved performance of heat pumps for water heating and space heating, especially cold-climate air-source heat pumps, is an essential driver for heat pump adoption.[5] Regulations and technology advancements have been key forces driving heat pump efficiency improvement. The average seasonal performance factor of heat pumps sold in the United States rose by 13% in 2006 and 8% in 2015 following two increases in minimum energy performance standards (IEA 2020). The technological upgrades in recent years include advances in refrigerant composition and volume, improved compressors (two-speed compressors, scroll compressors), dual-speed/variable-speed motors, and waste heat recovery for integrated space-heating/water-heating systems using a desuperheater[6] to further increase efficiency (DOE 2021).

Most heat pumps use electric resistance heaters as a backup in very cold weather. Some heat pumps are equipped with backup burners that use fossil fuels to provide supplementary heat and reduce the use of electricity during the winter peak season. These dual-fuel heat pumps may be cheaper to operate in some regions while still reducing fossil fuel consumption (relative to a 100% fossil fuel heater). In climates where temperatures fall below 0 °F, a dual-fuel heat pump system can still significantly cut onsite fossil fuel use by 50% or more (Yañez-Barnuevo et al. 2019). However, with advancements in refrigerant technology, heat pumps with minimal electric backup heating can meet users' needs in most applications. A study in Minnesota found that current ccASHP technology performs well and can deliver 55% savings (compared with electric resistance heating) in Minnesota's climate (McPherson, Smith, and Nelson 2020).[7] Elsewhere, a study in Vermont that examined a total of 77 ccASHPs (all electric) installed at 65 residential locations showed an average seasonal efficiency of 314% and annual fuel savings of approximately $200 after upgrading to heat pumps (Walczyk 2017). These savings could have been even higher if paired with consumer education about efficient operation of ccASHPs. None of the surveyed homeowners expressed dissatisfaction with their system.

[5] We use heat pump here to refer to general heat pump technologies. When we discuss heat pump applications and case studies, it refers primarily to air-source heat pumps, which are the most popular application, unless we specify ground-source heat pumps (GSHP).

[6] A desuperheater is a secondary heat exchange device that uses excess heat generated from the refrigeration cycle on a heat pump to heat water in a connected water-heating system.

[7] In this Minnesota study, air-source heat pumps were installed in six occupied homes where natural gas was unavailable. Propane furnaces were used for backup at four sites, and the existing electric resistance baseboards were used for backup in two homes.

FINDINGS FROM EXISTING STUDIES

This study builds on existing research and analysis of the potential impacts of electrification in buildings. Findings from prior studies—summarized below—can also provide useful insights for policymakers and program administrators striving to design and operate electrification programs more effectively. The following list describes key findings from prior studies of electrification programs and practices.

Program maturity: Many electrification programs are still in their infancy. Program administrators continue refining their approaches and adjusting incentives (Nadel 2020). Heavily rebated heat pump water heater programs (not specific to electrification) are prevalent across the nation. (Yañez-Barnuevo et al. 2019).

Benefits: Additional load from added electrical end-use equipment increased revenue for utilities, especially co-ops, which have been experiencing flat sales or low sales growth for the past decade. Beneficial electrification is seen as a new investment opportunity for some utilities (Yañez-Barnuevo et al. 2019).

Locations: Electrification programs are most extensive on the West Coast and in the Northeast (Nadel 2020).

Full versus partial electrification: The bulk of program participants (i.e., utility customers) use heat pumps alongside existing fossil fuel systems (Nadel 2020).

Weatherization: Most programs encourage—but do not require—weatherization to reduce loads in conjunction with the purchase of a new heat pump (Nadel 2020).

Target customers: Many programs emphasize the residential sector and target customers who use fuel oil and propane because the economics of electrification in these situations are often better than when displacing natural gas at current retail energy prices (Nadel 2020).

Participation: Midstream incentives to contractors, distributors, and/or retailers have been found to increase participation, but come with additional challenges, including difficulty tracking sales and ensuring high-quality installations.[8] Higher incentives have also led to higher participation. A study on Northeast electrification with a focus on ductless mini-splits showed that among 10 programs, Efficiency Vermont's offering using a midstream incentive model had the highest installation rate (1.26% of homes).

[8] Throughout this report, "midstream" incentives are incentives that are delivered in the middle of the supply chain to vendors or contractors. Upstream refers to program incentives delivered early in the supply chain, such as incentives to manufacturers and distributors. Downstream incentives mostly target end-use customers.

Efficiency Maine, which had the second-highest rate (0.82%), offered substantial incentives of at least $500 per unit (Levin 2018).

Cost and financing: The economics of electrification are challenging in many cases, especially in cold climates and regions with relatively low gas prices, such as the upper Midwest. However, the economics may change if the price of natural gas rises. The EIA estimates that midwestern natural gas customers could pay on average 49% more for natural gas in the winter of 2021–22 (EIA 2021d). ACEEE conducted a study to evaluate the feasibility of electrifying water heaters in multifamily buildings (Perry, Khanolkar, and Bastian 2021). The results of this study showed that, while water-heating system retrofits for multifamily are an effective way to reduce greenhouse gas emissions, the average payback period for water heater electrification in a multifamily building was 20 years for an in-unit water heater or 30 years for a central water heater. These findings were specific to a retrofit context; the economics for all-electric new buildings are much more favorable in many areas.

In general, while many electric heat pump programs are offered across the nation, they are not often specifically designed to align with the goals of beneficial electrification. First, fuel-switching requirements are not clearly stated in most heat pump incentive programs. For example, in a 2021 study, the Pacific Northwest National Laboratory compiled information from 244 utility programs that provide incentives for heat pump water heaters. Nearly 88% (214 in total) do not specify the fuel used by the water heater being replaced. Only seven programs (less than 3%) target fuel switching from natural gas to electricity. The remaining 9% prohibit fuel switching, in effect offering rebates only for replacing electric water heaters. Second, heat pump programs generally do not provide additional incentives for fuel switching. An analysis by the Environmental and Energy Study Institute (EESI) of the programs offered by Midwest co-ops found that no existing programs can be characterized as full beneficial electrification programs per EESI's definition (Yañez-Barnuevo et al. 2019).[9] The co-op members do not receive a rebate for fuel switching (from propane to electric), nor do the co-ops track whether fuel switching has occurred. EESI has since helped co-ops launch full beneficial electrification programs nationwide. For example, the Orcas Power and Light Cooperative (OPALCO) and Mountain Park Electric are successfully operating on-bill

[9] The EESI report defines beneficial electrification as "switching fossil-fuel end-use equipment to electric equipment in a way that reduces overall carbon emissions, while providing benefits to the environment and to members." It defines a fully beneficial electrification program as one that includes the following elements: 1) incentives and/or financing to cost effectively convert fossil fuel–powered equipment to electric equipment, 2) a central program goal of reducing net carbon emissions, 3) a verification process to check that the replacement has indeed occurred, and 4) energy audits to calculate estimated energy and monetary savings resulting from the switch-out.

tariff programs for beneficial electrification to help their members switch to electric equipment for residential and commercial space and water heating.

In summary, electrification program design and implementation is still in its infancy, particularly when compared with traditional efficiency programs that focus primarily on energy use reductions and cost savings. Learning the achievements and pain points of existing electrification programs will help states and utilities design more effective incentive programs.

Building Electrification Programs Landscape

Our data collection covered both electrification program characteristics and performance. We gathered data on which end uses (space heating, water heating, cooking, etc.) are being targeted in these programs, whether the programs are designed to replace a specific source fuel (natural gas, oil, propane, etc.), what measures are included in the programs, and what incentives are being provided. We also investigated whether these electrification programs were integrated with other demand-side programs, such as those for conventional energy efficiency upgrades, weatherization, demand response, or solar and battery storage.

To evaluate program performance, we used metrics including participation, budget, and energy and greenhouse gas savings. We also sought to determine the extent to which programs are reaching customers in low-income areas.

In addition to aggregating data on program characteristics and performance, this report identifies the strategies program administrators are using to overcome market barriers to electrification. On the basis of interviews we conducted with a select group of program administrators, we developed a set of emerging best practices.

METHODOLOGY

The data collection process for this research began with updating and expanding the data gathered for a previous ACEEE review of 22 electrification programs (Nadel 2020). We reached out to program managers for updated data as of 2021 and expanded the data set to include measures beyond space heating, such as hot-water heating, induction cooking, and other electrification end uses. Furthermore, we contacted research institutes, advocacy organizations, and state and utility program implementers to identify additional electrification programs and efforts in their respective regions. We also examined program offerings in states where electrification policies have been enacted.

Beyond adding more programs to our study and collecting quantitative data on cost effectiveness, energy savings, and GHG savings, we also collected qualitative data around barriers to accelerating electric technology adoption, the strategies program administrators use to address these barriers, and practices to integrate electrification with weatherization, demand response, distributed solar, and EV charging. Our data collection and qualitative survey form can be found in Appendix B.

These data requests were supplemented by interviews with program managers and other experts in the field. We sought to interview program managers from a diverse range of implementers—including large investor-owned utilities, smaller co-op utilities, and nonutility administrators—representing a range of geography, climate, and market conditions. The purpose of these interviews was to learn more about program goals and to gain a deeper understanding of barriers and lessons learned in the process of administering the programs. Our findings from these interviews are discussed in the “Program Examples and Experience” and “Discussion” sections below.

UPDATED REVIEW OF PROGRAMS IN THE UNITED STATES

Electrification efforts across the United States vary in their targets, scales, strategies, and outcomes. The common aspects across many programs include an emphasis on air-source heat pumps and a focus on rebates to end users as a delivery strategy. Beyond these aspects, program enrollment, budgets, delivery strategies, target sectors, source fuels, energy savings, and GHG impacts vary substantially.

We limited our survey to programs that specifically offer incentives for converting fossil-fueled end uses to electric equivalents. Although hundreds of utility incentives for heat pumps exist, and some customers may have used them for fuel switching, we considered these to be conventional energy efficiency measures, as opposed to electrification measures, because these programs are not specifically designed to replace fossil fuel end uses. We focused specifically on electrification programs with a fuel-switching component, or incentives for all-electric new buildings. Some electrification programs in our study also include components that incentivize electric-to-electric conversions (e.g., replacing electric resistance equipment with heat pumps). Those components are included in our data collection and analysis.

Figure 4 shows the geographical distribution of the programs in our study. The state with the most programs represented in this report is California, with 13 programs offered by 6 different administrators. Other states with robust electrification program offerings include Colorado, New York, Massachusetts, and Vermont.

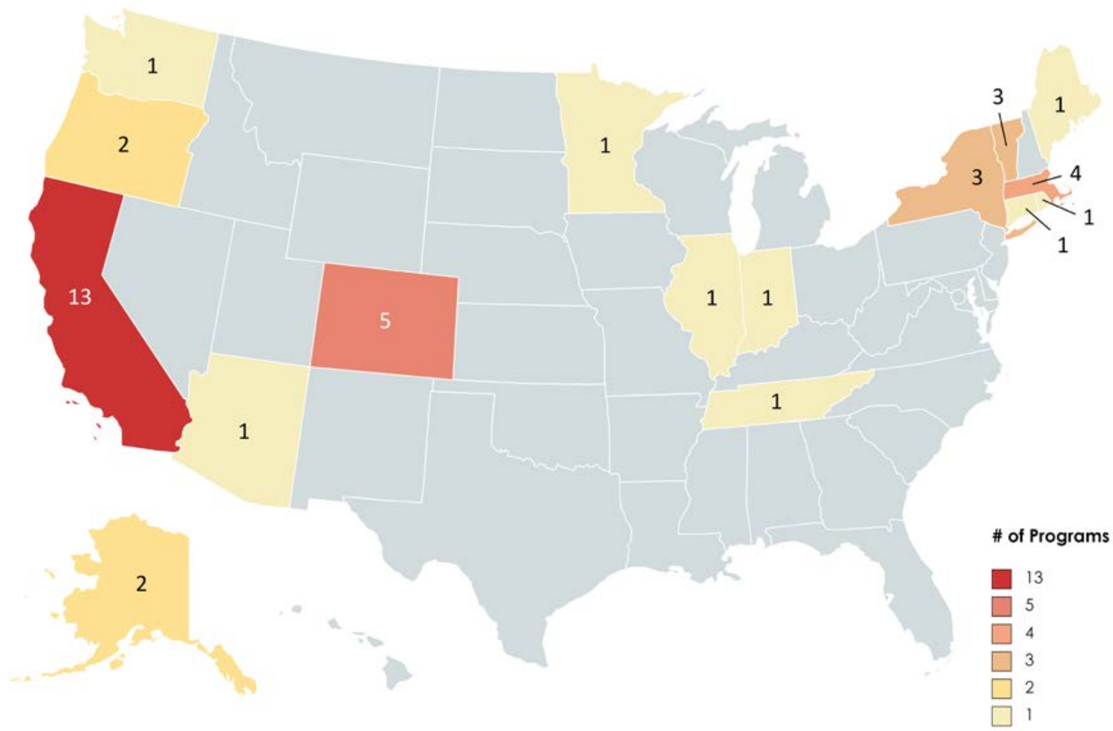

Figure 4. Map of electrification programs included in this study

We identified 42 different building electrification programs. Twenty-three of them are still ongoing, while 19 concluded prior to this study. These were generally pilots and demonstration projects with an intentionally limited run, or programs that transitioned to a new administrator (such as the New York State Energy Research and Development Authority's heat pump rebate program, which transferred to the New York State Investor-Owned Utilities in 2020). Table 1 lists the basic characteristics of each program, including its name, the name of the utility or administrative organization, the primary state in which the program operates, and years of operation. Each program is assigned an abbreviated name that is used throughout this report. All programs are or were in operation; planned and forthcoming initiatives, such as California's BUILD program, were excluded from our study. Throughout this report, "n/d" indicates where no data could be found.

Table 1. List of electrification programs – basic characteristics

#	Short program name	Full program name	Program administrator/implementer	State	Years
1	AEA LIWP	Low Income Weatherization Program Multifamily	Association for Energy Affordability	CA	2016–2021
2	AK Heat $mart	Alaska Heat Smart and Thermalize Juneau	Alaska Heat Smart	AK	2020–2021
3	APS Reserve Rewards	Reserve Rewards	Arizona Public Service	AZ	n/d

#	Short program name	Full program name	Program administrator/implementer	State	Years
4	Avangrid Energize CT	Energize CT	Eversource CT	CT	n/d
5	BayREN Home+	Home+	Bay Area Regional Energy Network	CA	2020–2021
6	BED Net Zero City	Net Zero Energy City	Burlington Electric Department	VT	n/d
7	City of Ashland	Conservation Division Incentive Programs	City of Ashland, Oregon	OR	n/d
8	ComEd Electric New Homes	Electric Homes New Construction	Commonwealth Edison	IL	n/d
9	Comfort365	Comfort365	City of Boulder, CO	CO	2018–2021
10	DCSEU LIDP	Low Income Decarbonization Pilot	DC Sustainable Energy Utility	DC	2020–2020
11	Efficiency VT	Efficiency Vermont Electrification Incentives	Efficiency Vermont	VT	n/d
12	EFG Hudson Valley HP*	Hudson Valley Heat Pump Program	Energy Futures Group	NY	2017–2019
13	EFG MA Solar Access	Massachusetts Solar Access Program	Energy Futures Group	MA	2017–2019
14	EFG Zero Energy Now	Zero Energy Now	Energy Futures Group	VT	2016–2018
15	EMT HP Rebate	Efficiency Maine Trust Heat Pump Rebates	Efficiency Maine Trust	ME	n/d
16	EWEB Smart Electrification	Smart Electrification	Eugene Water and Energy Board	OR	n/d
17	Holy Cross BE Rebates	Beneficial Electrification	Holy Cross Energy	CO	n/d
18	MA CEC ASHP Pilot	Whole-Home Air-Source Heat Pump Pilot	Massachusetts Clean Energy Center	MA	n/d
19	MA DOER Home MVP	Home MVP	Massachusetts Department of Energy Resources	MA	n/d
20	Mass Save Fuel Optimization	Mass Save Fuel Optimization for Residential, Small Business, and Income Eligible	Mass Save (National Grid, Cape Light Compact, Unitil, Eversource)	MA	2019–2021
21	MN ASHP	Minnesota ASHP Collaborative	Minnesota ASHP Collaborative	MN	2020–2021

#	Short program name	Full program name	Program administrator/implementer	State	Years
22	MPE Electrify Everything*	Electrify Everything	Mountain Parks Electric, Inc.	CO	2018–2021
23	NG RI HVAC	HVAC Program	National Grid Rhode Island	RI	n/d
24	NYS Clean Heat	NYS Clean Heat: Statewide Heat Pump Program	NYS Electric Utilities	NY	2020–2021
25	NYSERDA HP Rebate	NYSERDA Heat Pump Rebates and Clean Heat Challenge	New York State Energy Research and Development Authority	NY	2017–2019
26	OPALCO Switch It Up!	Switch It Up! On-Bill Program	Orcas Power & Light Co-op	WA	n/d
27	Palo Alto HPWH	Heat Pump Water Heater Rebate	City of Palo Alto Utilities	CA	2019–2021
28	PG&E/SCP AER	Advanced Energy Rebuild	Pacific Gas & Electric, Sonoma Clean Power, Bay Area Air Quality Management District	CA	2017–2019
29	Renewable Juneau	Juneau Carbon Offset Fund	Renewable Juneau	AK	2019–2021
30	SCAQMD CLEANair	CLEANair Furnace Rebate Program	South Coast Air Quality Management District	CA	2020–2021
31	SCE CLEAR	Clean Energy and Resiliency (CLEAR)	Southern California Edison	CA	n/d
32	SCE Residential Upstream	Plug Load and Appliance (Residential Upstream Incentives for Space and Water Heat Pumps)	Southern California Edison	CA	n/d
33	SMUD Advanced Homes	Advanced Homes Electrification	Sacramento Municipal Utility Department	CA	2018–2021
34	SMUD Commercial	Commercial	Sacramento Municipal Utility Department	CA	2019–2021
35	SMUD Home Appliance	Home Appliance	Sacramento Municipal Utility Department	CA	2018–2021
36	SMUD Low Income	Low Income Electrification	Sacramento Municipal Utility Department	CA	2019–2021
37	SMUD Multifamily	Existing Multifamily	Sacramento Municipal Utility Department	CA	2018–2021
38	SMUD New Homes	New Homes Electrification Single and Multifamily	Sacramento Municipal Utility Department	CA	2018–2021

#	Short program name	Full program name	Program administrator/implementer	State	Years
39	Tri-State Heat Pump	Heat Pumps	Tri-State Generation and Transmission	CO	2014–2021
40	Tri-State HPWH	Heat Pump Water Heaters	Tri-State Generation and Transmission	CO	2018–2021
41	TVA C&I	Electrification Rebates for Commercial and Industrial	Tennessee Valley Authority	TN	2017–2020
42	WVPA Power Moves	Power Moves	Wabash Valley Power Alliance (WVPA)	IN	2010–2021

*** Two programs were funded all or in part by other programs on this list, namely, EFG Hudson Valley is funded through competitive grants from NYSERDA and MPE Electrify Everything is partially funded through rebates provided by Tri-State Generation and Transmission.**

Summary of Programs and Findings

The programs identified in table 1 provide a range of incentives among several distinct end uses, including space heating, water heating, cooking, and others. Below we include several figures that summarize these programs in terms of commonly targeted end uses (figure 5), source fuels for conversion (figure 6), target sectors (figure 7), and method of incentive delivery (figure 8). A detailed breakdown of these characteristics for each individual program can be found in Appendix A.

Targeted End Uses

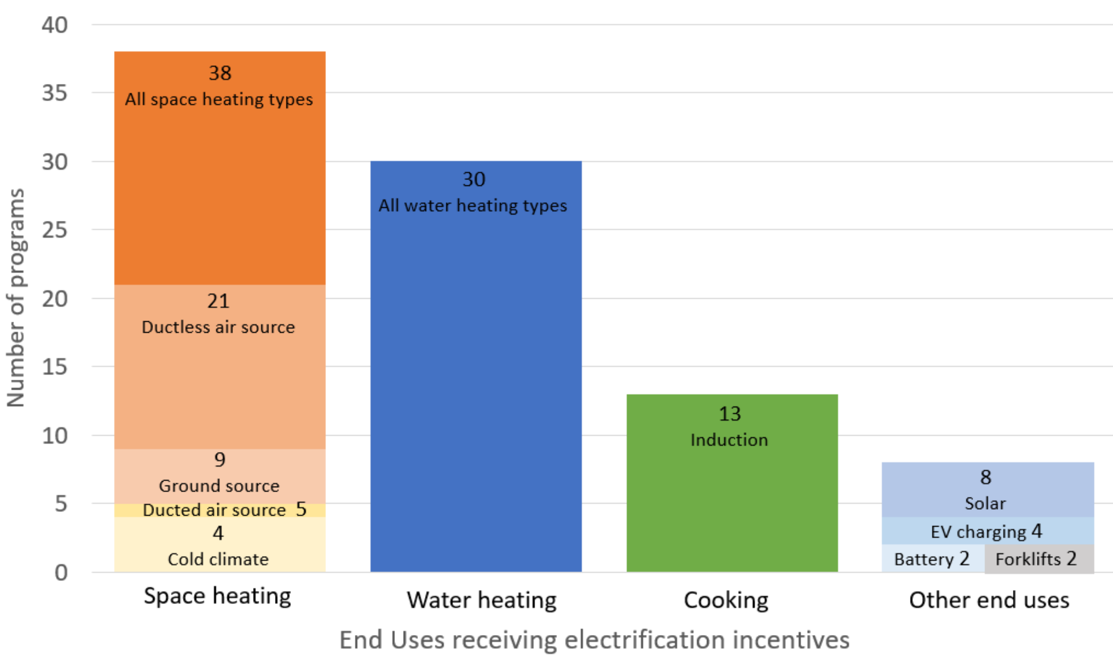

Figure 5. Targeted end uses across 42 electrification programs. Note: For space heating, many programs included more than one equipment type or did not specify the type of equipment included.

Most programs in this study targeted space-heating electrification. Out of 42 programs, 38 (90%) provided incentives for space heating via heat pumps of various types, and some of these 38 programs offered specific incentives for certain heat pump technologies and/or applications. The most common type of heat pump incentive was for ductless/mini-split systems, with 21 programs offering this type. Nine programs offered incentives for ground-GSHP systems. Ducted systems received specific incentives in five programs.

Some programs offered scaling incentives based on factors such as equipment efficiency, ability to perform in cold climates, or customer income level. In these cases, more efficient equipment and/or cold-climate equipment was typically eligible for a higher incentive. Four programs specifically incentivized ccASHP through this method. A more detailed breakdown of measures and rebates can be found in the "Measures and Incentives Breakdown" section, below.

Water heating was the second-most targeted end use, included in a total of 30 programs (71%). Many programs provided incentives for both space and water heating with heat pumps. These two end uses consume the largest share of energy in buildings. On a total Btu basis, space heating represents 43% of all residential site energy consumption, and water heating 19% (EIA 2018). This makes these uses the highest priorities for electrification from both carbon and energy standpoints.

Thirteen programs offered incentives for efficient electric cooking equipment in the form of induction stovetops. While induction stoves offer multiple advantages over both gas and electric resistance stoves, program managers noted challenges with overcoming some customers' preference for gas stoves and ovens and their unfamiliarity with induction cooking equipment.[10] To address this barrier, some program administrators, such as Sonoma Clean Power, offered equipment loan programs that allowed customers who had never used induction stoves before to familiarize themselves with the technology.

Only one program, run by the City of Ashland Conservation Division, targeted clothes drying as an end use for electrification. Dryer conversions were not included in most programs likely because electric dryers (using electric resistance heating elements) already represent almost 80% of the existing market for clothes dryers (Statista 2011) and are often less

[10] Induction stoves require specialized cookware (pots and pans) that many customers do not have in their kitchens. Customers may assume induction cooktops are like electric resistance stoves, which can take a long time to heat up, and that they provide less precise control of the heating element (Bartholomy et al. 2020). Induction cookware is more precise and is quicker to heat than electric and cools off rapidly after use, providing a much safer cooking environment.

expensive than gas dryers without incentives.[11] Heat pump clothes dryers are still new to the market.

Certain programs combined electrification of space and water heating with other clean energy technologies. These were often "whole-home" programs whose aim was to reduce overall building energy consumption and GHG emissions. The most common technology incorporated in these programs was solar power, with eight programs providing incentives for rooftop installations or off-site community solar subscriptions. Combining solar with electrification can help make up for the higher electric consumption that results from fuel switching, reducing customer energy bills in the long run. However, it also contributes to a higher upfront cost. Some of these programs combined incentives for solar and battery storage, such as the PG&E/SCP Advanced Energy Rebuild (AER) program, which offered customers an additional $5,000 (on top of $7,500–12,500 for electric space and water heating) to install solar and battery storage on newly rebuilt homes that had been damaged by wildfire. More details on the AER program can be found in the "Program Examples and Experience" section.

Although transportation electrification is another vital avenue for energy and GHG savings, electric vehicle service equipment (EVSE) was beyond the scope of this study, except where both building electrification and EVSE were offered in the same program. Many programs that offered EV incentives, such as Burlington Electric Department Net Zero City and Mountain Parks Electric's *Electrify Everything*, worked with customers to get their homes as close to net zero as possible through incentives for EV charging and electric lawn mowers in addition to air-source heat pumps and HPWH incentives.

Likewise, forklifts are another electrification opportunity that was beyond the initial scope of this study but were included in two cases where incentives were offered in addition to other building electrification measures. Two program administrators (Burlington Electric and the Tennessee Valley Authority) offered incentives for electrification of forklifts used in large commercial and industrial applications. This equipment offers numerous benefits over conventional, propane-powered forklifts, including reduced noise and air emissions, both of which create a safer and healthier environment for forklift operators and other workers. Electrification of heavy equipment is beyond the scope of building electrification. We include this information in this report because it presents a novel perspective on utility's role in promoting a broad range of end use electrifications. In this example, electric forklifts have a

[11] Heat pump clothes dryers are not widely available in the market and currently have disadvantages compared with electric resistance, including longer run times and needing more space. However, they can also reduce energy use by at least 28% compared with standard dryers. www.energystar.gov/products/heat_pump_dryer.

higher upfront cost but a lower overall cost of ownership compared with propane lifts, so utility rebates may be effective in this sector.

Source Fuels

Electrification requires conversion from fossil fuels to electricity. Some programs had specific fuel requirements or limitations on which fuels were eligible to receive incentives for their replacement. Figure 6 shows the targeted source fuels across the 42 programs. Many programs aim at more than one source fuel. In cases where the source fuel did not matter or apply, such as in new construction programs, we describe them here as having "no specific source fuel."

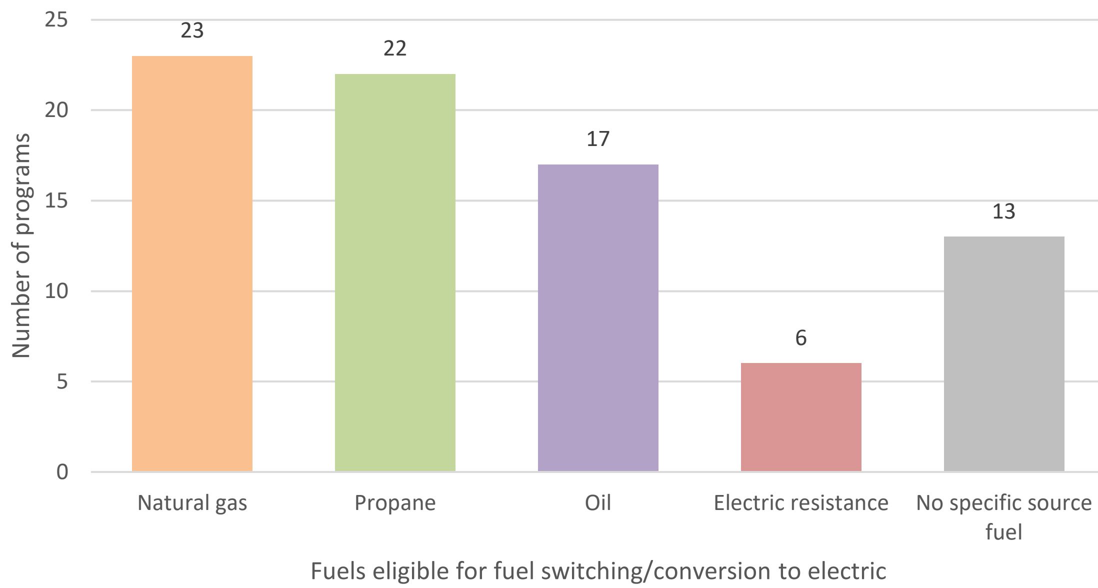

Figure 6. Source fuels for replacement in electrification programs

Electrification programs covered a variety of source fuels, depending on which ones were common in the service area, feasible for conversion, and permitted by regulation. Natural gas, oil, and propane were all frequent targets for replacement. Some programs offered incentives for replacing multiple source fuels or for electric-to-electric conversions.[12] Every program that offered oil conversions covered propane as well. Thirteen programs had no specific requirements for eligible source fuels. These programs were focused either on new

[12] While programs that offer incentives for conversion of fossil fuels are the focus of this study, six programs offered electric conversions in addition to fossil fuel replacement incentives. Note that we include the electric-to-electric programs only when they are offered as part of the fossil fuel replacement programs. The stand-alone electric-to-electric programs are not included in our study because they are often considered as efficiency programs.

builds or purely on technology (such as promoting heat pumps via a midstream incentive to the merchant).

A small number of programs provided incentives for partial load displacements or dual-fuel systems, particularly in cold climates. For example, promoting partial load mini-split heat pumps has helped drive adoption of heat pump technologies in regions like Maine, where the high price of electricity compared with natural gas makes the economics of an all-electric conversion challenging. Although there are still concerns with continuing to invest in fossil fuel infrastructure to support dual-fuel systems, dual-fuel heat pumps generally offer reduced operating costs in regions where the price of electricity is higher than the price of natural gas, and lower emissions than a purely fossil-based system. Dual-fuel heat pumps can offer a compromise for customers who are hesitant to adopt an all-electric heat pump system in colder climates, although cold-climate air-source heat pumps are proven to be effective in temperatures as low as –13°F (Mitsubishi 2020).

The availability of a fossil fuel backup system during extremely cold weather may additionally help relieve pressure on the grid during a winter peak (Hopkins, Takahashi, and Nadel 2020). However, as more jurisdictions face gas capacity constraints and gas peak demand days become an increasing concern in some regions (e.g., Massachusetts), the potential value add from offsetting electricity demand is increasingly diminished. It is also important to note that while dual-fuel systems may help reduce greenhouse gas emissions, they do not eliminate them. States that are committed to full decarbonization (such as New York) are first mitigating peak demand via envelope improvements, thus minimizing the size of the backup heating equipment needed to maintain comfort, rather than investing in full-load dual-fuel equipment.

Target Sectors

Programs in this study reached a variety of distinct customer sectors. Figure 7 shows the specific sectors targeted.

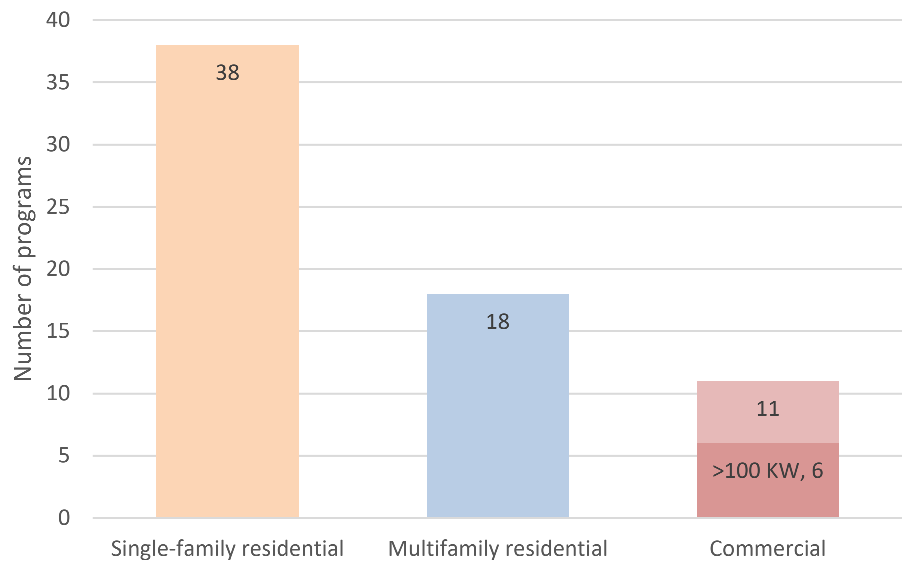

Figure 7. Target sectors for electrification programs in the study. Some programs target more than one of the listed sectors.

Single-family residences were the most targeted sector, with 32 programs offering electrification incentives. This is likely because it is relatively easy to work with owner-occupied units, where the residents have full control over their home energy environments. Multifamily residences were targeted in 15 programs, the majority of which provided incentives for both single- and multifamily electrification. Only two programs aimed at multifamily units exclusively: AEA LIWP and SMUD Multifamily. Ten programs were for the commercial sector, with six programs specifically targeting large commercial users (those with more than 100 kW demand).

Multifamily building electrification has unique challenges and barriers that often require specialized program designs. Because multiunit dwellings are often complex systems and may involve hundreds of residents, programs serving them, such as the Low Income Weatherization Program offered by the Association for Energy Affordability, must and work with property managers to deliver a combination of measures including energy efficiency, electrification, and distributed energy solutions in order to maximize carbon reductions and energy savings. We provide further details of opportunities and barriers for multifamily households in the "Discussion" section below.

Electrification in the industrial sector, while beyond the scope of this study, can achieve significant GHG reductions and cost savings in many applications (Rightor, Whitlock, and Elliott 2020). These solutions are often highly specific to the industry in question and require custom-tailored technologies.

Incentive Delivery Pathways

Incentives for electrification were delivered at numerous points in the supply chain, as shown in figure 8.

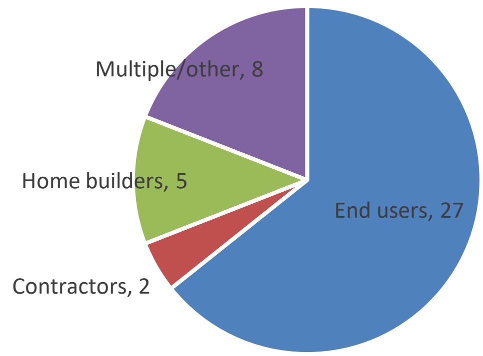

Figure 8. Recipients of electrification incentives in 42 programs

Twenty-six programs offered incentives directly to end users, the most frequent recipients. Six programs delivered incentives to home builders who construct all-electric new builds or major renovations. New construction is sometimes considered the low-hanging fruit of electrification since builders do not have to work around an existing home's structure and energy system and can design the house specifically to work with a heat pump–based space and water heating system (Bartholomy et al. 2020). Some programs offered incentives to multiple targets; for instance, the DCSEU Low Income Decarbonization Pilot provided simultaneous incentives to low-income end users and direct-install contractors.

While the largest target sector was end users and the most frequently used delivery mechanism was rebates, program managers employed numerous strategies and approaches to electrification. These included providing rebates at the point of sale; bundling measures for ease of delivery; combining electrification with home energy audits, weatherization, and solar installation; and providing incentives and education for contractors and upstream distributors. A wide variety of alternative and complementary implementation mechanisms went beyond those approaches. We provide a more thorough look at program incentives in the section below.

MEASURES AND INCENTIVES BREAKDOWN

The specific measures and incentives that program administrators offered customers for electrification varied from program to program in terms of both value and type. Table 2 lists the financial incentives provided by the programs included in this study. Some incentives were not fixed but rather varied according to factors such as the equipment's efficiency, the customer's income level, whether the unit was for full or partial heating load, and other factors. For incentives with a fixed value rather than a range, we list the "minimum incentive" metric as n/a (not applicable). For programs that did not provide information on a given metric, we use n/d (no data).

Table 2. List of measures and incentives by program

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
AEA LIWP	CA				
Whole-home audit, weatherization, retrofits, on- or offsite solar		$3,000	$5,000	per $MTCO_2e$	81 (properties)
AK Heat $mart	AK				
Air-source heat pumps (ductless)		n/a	n/d	per home	n/d
APS Reserve Rewards	AZ				
Heat pump water heaters		n/a	$6,000[13]	per unit	200
Avangrid Energize CT	CT				
Air-source heat pumps (ductless)		$300	$500	per ton	n/d
Heat pump water heaters		n/a	$750	per unit	n/d
Air-source heat pumps		n/a	$1,000	per ton	n/d
BayREN Home+	CA				
Air-source heat pumps		n/a	$1,000	per system	68
Heat pump water heaters		n/a	$1,000	per unit	171
Residential induction ranges		n/a	$300	per unit	171
Heat pump clothes dryers		n/a	$300	per unit	31
BED Net Zero City	VT				
Electric lawn mowers		n/a	$100	per unit	n/d

[13] Instant rebate of up to 100% of cost, including installation costs. Part of a pilot study of grid-connected water heaters.

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
Electric vehicles		$800	$1,200	per unit	n/d
Cold-climate air-source heat pumps		$2,100	$2,500	per system	n/d
Electric forklifts		$4,000	$6,500	per unit	n/d
Heat pump water heaters		$300	$600	per unit	n/d
City of Ashland	OR				
Air-source heat pumps (ductless)		$500	$1,200	per system	n/d
Windows		n/a	$8,000	per home	n/d
Solar		n/a	n/d	per home	n/d
Heat pump water heaters		n/a	$600	per unit	n/d
ComEd Electric New Homes	IL				
Whole home		n/a	$2,000	per home (new builds)	n/d
Comfort365	CA				
Air-source heat pumps (ductless)		$250	$400	per unit	30
Ground-source heat pumps		n/a	$650	per ton	12
Cold-climate air-source heat pumps		$250	$400	per home	12
Heat pump water heaters		n/a	$250	per unit	n/d
Non-cold-climate measures (air-source heat pumps mini-split, ducted, HPWH, insulation, and air sealing)		n/a	$250	various	164
DCSEU LIDP	DC				

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
Air-source heat pumps		$6,750	$22,350[14]	per system (low income)	10
Heat pump water heaters		$1,850	$4,900	per system (low income)	8
Weatherization		$1,100	$5,825	per home (low income)	9
Residential induction ranges		n/a	$1,050	per unit (low income)	4
Solar		$4,961	$8,750	per system (low income)	6
Efficiency VT	VT				
Air-source heat pumps (ductless)		$350	$450	per unit[15]	9,825
Air-source heat pumps (ducted)		$1,000	$2,000	per system	233
Heat pump water heaters		$300	$600	per unit	233
Other space heating		n/a	$1,000	per ton	10
Ground-source heat pumps		$1,000	$2,100	per ton	n/d
Air-to-water heat pumps		n/a	$1,000	per ton	n/d
EFG Hudson Valley HP	NY				
Air-source heat pumps (ductless)		n/a	$350	per ton	n/d
EFG MA Solar Access	MA				
Air-source heat pumps (ductless)		n/a	n/d	per home	55
Solar		n/a	n/d	per home	49

[14] Covered 100% of the cost of equipment replacement for low-income customers in a multiunit dwelling.

[15] Ductless air-source heat pump systems frequently consist of multiple units, one for each separate heating zone in the home or indoor space. Because of this, some customers may claim more than one rebate for a multiunit system if the incentive structure allows it.

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
EFG Zero Energy Now	VT				
Air-source heat pumps (ductless)		n/a	n/d	per home	55
Heat pump water heaters		n/a	n/d	per home	15
Ground-source heat pumps		n/a	n/d	per home	15
Solar		n/a	n/d	per home	45
EMT HP Rebate	ME				
Air-source heat pumps (ductless)		$400	$800	per unit	n/d
Heat pump water heaters		n/a	$850	per unit	n/d
EWEB Smart Electrification	OR				
Air-source heat pumps (ductless)		n/a	$1,000	per home	n/d
Air-source hat pumps (ducted)		n/a	$800	per home	n/d
Heat pump water heaters		n/a	$800	per home	n/d
Air-source heat pumps (ductless)		$1,000	$3,800	per home (low income)	n/d
Holy Cross BE Rebates	CO				
Air-source heat pumps		n/a	$850	per ton	n/d
Heat pump water heaters		n/a	$1,450	per unit	n/d
Induction cooktops		n/a	$80	per unit	n/d
MA CEC ASHP Pilot	MA				
Air-source heat pumps (ducted)		n/a	$2,500	per home	169
MA DOER Home MVP	MA				
Air-source heat pumps		$2,000	$12,000	per system	n/d
Weatherization		$1,000	$9,000	per home	n/d

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
Ground-source heat pumps		$6,000	$20,000	per system	n/d
Mass Save Fuel Optimization	MA				
Air-source heat pumps (ductless)		n/a	$1,250	per ton	n/d
Air-source heat pumps (ductless)		$1,250	$1,250	per ton	n/d
Ground-source heat pumps		n/a	$2,000	per ton	n/d
Heat pump water heaters		n/a	$600	per unit	n/d
MN ASHP[16]	MN				
Air-source heat pumps		$50	$2,200	per system	n/d
MPE Electrify Everything	CO				
Air-source heat pumps		n/a	$1,000	per ton	n/d
EV charging		n/a	n/d	n/d	n/d
Insulation		n/a	n/d	n/d	n/d
Solar		n/a	n/d	n/d	n/d
Air-source heat pumps (ductless)		n/a	$7,200	per system	3 (pilot)
NG RI HVAC	RI				
Air-source heat pumps (ductless)		n/a	$1,000	per ton	n/d
Air-source heat pumps (ducted)		n/a	$1,000	per ton	n/d
NYS Clean Heat	NY				

[16] The Minnesota ASHP collaborative does not offer incentives to customers directly. Instead it provides information and connections to local utility incentives for heat pumps, which range from $50 to $2,200 depending on customer location and equipment type.

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
ccASHP (partial-load heating)		$500	$800	per ton	n/d
ccASHP (full-load heating)		$1,000	$2,000	per ton	n/d
Ground-source heat pumps		$1,500	$2,850	per ton	n/d
NYSERDA HP Rebate	NY				
Air-source heat pumps		$500	$1,000	per unit	n/d
Ground-source heat pumps		n/a	$1,500	per ton	n/d
OPALCO Switch It Up!	WA				
Air-source heat pumps		n/a	$15,000[17]	per home (financing)	n/d
Heat pump water heaters		n/a	$3,500	per home (financing)	n/d
EV charging		n/a	$2,500	per home (financing)	n/d
Palo Alto HPWH	CA				
Heat pump water heaters		$1,200	$1,500	per system	69
PG&E/SCP AER	CA				
Whole home		$7,500	$12,500	per home (new build)	66
Solar + battery storage		n/a	$5,000	per home (new build)	22
Renewable Juneau	AK				
Air-source heat pumps (ductless)		n/a	$5,000	per system	21
SCAQMD CLEANair	CA				

[17] Costs of electrification upgrades are financed via on-bill payment program over a period of 10 years.

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
Air-source heat pumps		n/a	$1,500	per system	2,000
SCE CLEAR	CA				
Whole home		$7,500	$12,500	per home (new build)	n/d
Solar + battery storage		n/a	$5,000	per home (new build)	n/d
SCE Residential Upstream	CA				
Air-source heat pumps (ducted)		n/a	$300	per ton	n/d
Air-source heat pumps (ductless)		$300	$600	per ton	n/d
Heat pump water heaters		n/a	$1,000	per unit	n/d
SMUD Advanced Homes	CA				
Heat pump water heaters		n/a	$2,500	per system	2,674
Air-source heat pumps		n/a	$3,000	per system	3,286
SMUD Home Appliance	CA				
Residential induction ranges		n/a	$750	per unit	432
SMUD Low Income	CA				
Air-source heat pumps (ductless)		n/a	$13,000	per system (low income)	2,600
Heat pump water heaters		n/a	$3,800	per system (low income)	500
Residential induction ranges		n/a	$3,000	per unit (low income)	500
Tri State Heat Pump	CO				
Air-source heat pumps		$350	$450	per ton	n/d
Ground-source heat pumps		$250	$500	per ton	1,799
Tri State HPWH	CO				

Administrator and measures	State	Minimum incentive	Maximum incentive	Unit	Number of incentives issued
Heat pump water heaters		n/a	$350	per unit	133
TVA C&I	TN				
Air-source heat pumps (ductless)		n/a	$230	per ton	750
Commercial electric cooking equipment		n/a	*varies*	*varies*	n/d
Electric forklifts		n/a	$2,000	per unit	n/d
WVPA Power Moves	IL				
Ground-source heat pumps		n/a	$1,500	per unit	75
Air-source heat pumps		$750	$1,500	per system	54
Heat pump water heaters		n/a	$400	per unit	54

The average incentives for measures described above are presented in table 3 below.

Table 3. Range of incentives for electrification measures

Measure	Minimum incentive	Maximum incentive	Median	Total no.
Air-source heat pumps (all)				43
per home	$250	$400–2,500	$700	6
per home (low income)	$1,000	$3,800	$2,400	1
per system	$50–2,100	$1,000–12,000	$1,500	11
per system (low income)	$6,750	$13,000–22,350	$13,000	2
per ton	$300–1,250	$230–2,000	$800	17
per unit	$250–500	$400–1,000	$425	4
Air-source heat pumps (ductless)				20
per home	$-	$1,000	$1,000	4
per home (low income)	$1,000	$3,800	$2,400	1
per system	$500	$1,200–7,200	$1,200	3
per ton	$300	$230–1,250	$500	9
per unit	$250–400	$400–800	$400	3

Air-source heat pumps (ducted)				5
per home	$-	$2,500	$2,500	1
per system	$1,000	$800–2,000	$1,000	1
per ton	$-	$650	$650	2
Air-source heat pumps (cold climate—ducted and ductless)				4
per home	$250	$400	$325	1
per system	$2,100	$2,500	$2,300	1
per ton	$500–1,000	$800–2,000	$900	2
Ground-source heat pumps				8
per system	$6,000	$20,000	$13,000	1
per ton	$250–1,500	$500–2,850	$1,500	6
per unit	$-	$1,500	$1,500	1
Heat pump water heaters				18[18]
per home	$-	$800	$800	1
per system	$1,200	$1,500–2,500	$1,500	2
per system (low income)	$1,850	$3,800–4,900	$3,800	2
per unit	$300	$250–6,000	$600	13
Induction cooktops				4
per unit	$-	$300–750	$525	2
per unit (low income)	$-	$1,050–3,000	$2,025	2
Whole home				4
per home	$7,500	$2,000–12,500	$7,500	3
per $MTCO_2e$	$3,000	$5,000	$4,000	1

As the data in table 3 demonstrate, certain technologies tended to be associated with specific incentive types. Air-source and ground-source heat pumps frequently received

[18] Programs that provided incentives on a whole-home basis, including heat pump water heaters, induction cooktops, and other measures, are listed under "whole home."

incentives per ton of heating/cooling capacity, whereas heat pump water heaters and induction stoves were most often incentivized on a per-unit basis.

Programs that subsidized the replacement of an entire system had the highest incentives. For example, MA DOER Home MVP provided income-qualified participants up to $20,000 for installation of a GSHP system in a one- to four-unit residential building. Some whole-home programs offered different types of incentives depending on various home types and existing HVAC systems. One program, the AEA LIWP, provided whole-home incentives based on the total GHG impacts of electrification measures, weatherization and efficiency upgrades, and solar installation. Because this state-run program was funded through California's cap-and-trade market, program administrators could ensure that investments were correlated directly with climate impacts (Hill, Dirr, and Harrison 2020).

INTEGRATION WITH OTHER CLEAN ENERGY TECHNOLOGIES

Certain programs combined electrification with other demand-side management and clean energy resources. We sought to identify the programs that integrated weatherization, demand response, distributed solar, battery storage, and EV charging in addition to building electrification.

Envelope Efficiency and Weatherization

Figure 9 shows the extent to which electrification programs encouraged or required weatherization in conjunction with other incentives.

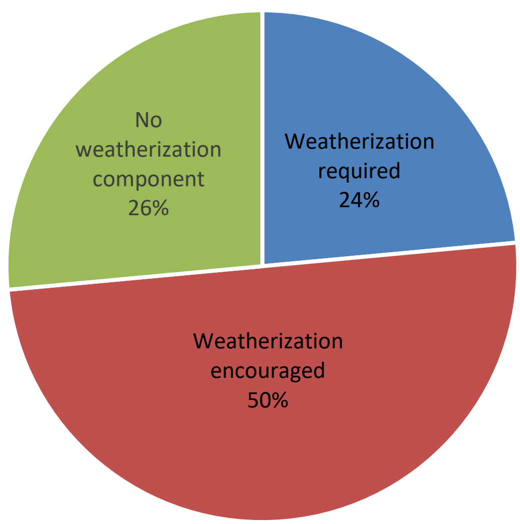

Figure 9. Program approaches to integrating weatherization with electrification (N = 34)

Many program administrators encouraged or required customers to implement weatherization measures, such as insulation and air sealing, as a component of building electrification efforts. A tighter thermal envelope means less energy is needed to maintain the desired indoor temperature, resulting in lower customer energy bills. A reduced heating load also means property owners can down-size the necessary HVAC equipment to meet a full heating load, leading to lower purchase and installation costs as well as reduced grid system demand. Managing peak demand is especially critical during the winter where space heating is a large contributor to both gas and electric demand.

A quarter of the programs required participants to undergo some form of weatherization or efficiency upgrade to receive the incentive. In many cases, these were whole-home programs that combined electrification incentives with energy audits and more conventional efficiency measures such as air sealing.

Half of the programs did not directly require customers to weatherize their homes but strongly encouraged it to maximize savings. They often did this by connecting customers to resources such as funding for upgrades or referrals to home energy professionals, or by collaborating with a preexisting program. For example, NYSERDA developed the Comfort Home program to complement the NYS Clean Heat program by providing incentives to make homes "heat pump ready" via envelope improvement packages. Some programs targeted customers with high energy use or load factors. These included the Burlington Electric Department program, which offered weatherization incentives to customers using more than 50 kBtu per square foot of heated space.

The remaining quarter of the programs had no weatherization component. Some program managers noted that they would have liked to include weatherization if schedules and budgets had permitted, but they had to focus on meeting their targeted number of installations. A more detailed breakdown of how each program integrated weatherization measures in its offerings can be found in table A4 in Appendix A.

Demand Flexibility

Five programs included a demand response component among their measures. This incentivized in-home electric devices such as connected water heaters and smart thermostats to adjust equipment power consumption at peak hours of the day or months of the year to mitigate stress on the grid. By shifting demand away from peak times, grid operators can reduce both the cost of electricity generation and marginal carbon emissions because peaking plants are mostly fossil fuel based and expensive to operate. As discussed in the “Barriers and Opportunities” section later in this report, large-scale electrification may lead to an increase in base load and peak electricity demand. Although this impact has not yet been seen due to the relatively small scale of electrification efforts to date, certain program administrators are combining grid interactivity measures with electrification strategies to prepare for future grid impacts.

Water heaters, particularly those with large tanks, can preheat water during times when demand for electricity is low. This makes them uniquely well suited for demand response (Delforge and Vukovich 2018). When paired with a special electricity rate or other financial incentive, this can produce cost savings for the customer. However, many of the programs that included demand response did so on an opt-in basis. As electrification becomes more widespread and its impacts on the power system more pronounced, we expect to see more programs integrating demand response as an optional or mandatory component.

Solar, Battery Storage, EVs

Distributed generation and storage resources such as rooftop and community solar provide additional benefits, carbon reductions, and resilience when paired with electrification efforts. Solar was the most common clean energy solution that was combined with electrification, with eight programs providing incentives for solar installations. These were largely whole-home or new-build programs such as the AEA Low Income Weatherization Program, DCSEU Low Income Decarbonization Pilot, and PG&E/SCP Advanced Energy Rebuild. For the income-based programs, solar was included as a part of a holistic building conversion package designed to minimize participant energy costs. In the case of Advanced Energy Rebuild and others, participants could receive a higher incentive if they installed solar and/or battery storage along with electrification measures.

Battery storage and electric vehicle charging were less commonly incentivized as part of a package with building electrification measures. Many utilities consider transportation electrification separately from building electrification. The two programs that did include EV measures were whole-home programs that aimed to reduce GHG emissions on a household basis. Two programs, both located in California, provided incentives for battery storage. One of these, PG&E/SCP Advanced Energy Rebuild, combined building electrification, battery storage, and solar to maximize reliability while mitigating grid impacts. Additional programs and incentives for these other measures can be found in some regions but were not fully captured in this survey because they do not include a building electrification or fuel-switching component.

BUDGETS, PARTICIPATION, AND GHG IMPACTS

Electrification programs varied widely in terms of sources of funding, budget, number of participants, and impacts on greenhouse gas emissions and customer energy use. We collected data on program budgets, including incentives and administrative costs. Table 4 lists programs by total budget in descending order. These include budgets for ongoing programs as well as programs that are concluded. Budget data were not available for 10 programs, including some that had only recently started at the time of our data collection. A full list of annual and total spending by program, including incentive and administrative costs, may be found in table A4 in Appendix A.

Table 4. Program budgets

Program	Total budget to date (incentive + administration)	Annual budget (incentive + administration, most recent year)
AEA LIWP	$63,900,000	$17,900,000
NYS Clean Heat	$36,600,000	$36,600,000

Program	Total budget to date (incentive + administration)	Annual budget (incentive + administration, most recent year)
NYSERDA HP Rebate	$22,800,000	$22,800,000
SMUD Advanced Homes	$20,400,000	$7,700,000
SCE Residential Upstream	$17,000,000	$17,000,000
Avangrid Energize CT	$16,523,241	$10,676,893
Mass Save Fuel Optimization	$14,580,000	$9,705,000
BayREN Home+	$12,500,000	$8,700,000
EMT HP Rebate	$12,118,849	$12,118,849
SMUD Low Income	$10,400,000	$3,400,000
Efficiency VT	$7,700,000	$4,100,000
SMUD New Homes	$6,200,000	$3,300,000
SMUD Commercial	$3,300,000	$2,700,000
MA DOER Home MVP	$2,666,667	$1,333,333
SMUD Multifamily	$2,600,000	$1,200,000
Tri State Heat Pump	$2,452,417	$790,000
SCE CLEAR	$2,025,000	$1,600,000
EFG MA Solar Access	$1,492,067	$1,492,067
EWEB Smart Electrification	$1,000,000	$500,000
BED Net Zero City	$905,374	$277,469
EFG Zero Energy Now	$830,516	$164,641
SMUD Home Appliance	$800,000	$400,000
Palo Alto HPWH	$553,500	$300,000
MA CEC ASHP Pilot	$500,000	$500,000
EFG Hudson Valley HP[+]	$396,900[+]	$396,900[+]
DCSEU LIDP	$346,000	$346,000
AK Heat $mart	$300,000	$140,000
WVPA Power Moves	$205,838	$205,838
NG RI HVAC	$190,000	$190,000
Comfort365	$175,000	$50,000
Renewable Juneau	$167,500	$85,500
Tri State HPWH	$46,520	$15,400

Program	Total budget to date (incentive + administration)	Annual budget (incentive + administration, most recent year)
APS Reserve Rewards	n/d	n/d
City of Ashland	n/d	n/d
ComEd Electric New Homes	n/d	n/d
Holy Cross BE Rebates	n/d	n/d
MN ASHP	n/d	n/d
MPE Electrify Everything	n/d	n/d
OPALCO Switch It Up!	n/d	n/d
PG&E/SCP AER	n/d	n/d
SCAQMD CLEANair	n/d	n/d
TVA C&I	n/d	n/d
Total*	$261,278,489	$166,290,990
Average*	$8,177,356	$5,208,997

*** Among 32 programs reporting budget data.**

+EFG Hudson Valley HP budget is excluded from the total due to being funded through grants provided via the NYSERDA HP Rebate program.

The 32 programs with budget data available varied widely from small-scale pilots to far-reaching initiatives; hence, total and annual spending varied widely as well. The program with the highest overall budget to date was also the largest low-income program: the Low Income Weatherization Program, a statewide initiative in California run by the Association for Energy Affordability. The AEA LIWP has spent nearly $64 million on comprehensive building retrofit and decarbonization projects since its beginning in fiscal year 2014–15 and has provided services to 81 large multifamily properties encompassing more than 8,200 households. The average annual budget for the 32 programs was $5.2 million, and the average total expenditure to date was just shy of $8.2 million.

The program with the largest annual budget was the NYS Clean Heat program, which serves all of New York State with an annual budget of more than $36 million through 2025. In addition to the rebate program, NYSERDA is investing $230 million through 2025 to support a comprehensive market engagement portfolio to accelerate adoption of heat pumps and clean heat technologies. The NYS Clean Heat program is the continuation of the NYSERDA Heat Pump Rebate Program, which ended in 2020. The new program provides rebates for heat pumps and for contractor education and certification. Another significant program administrator is the Sacramento Municipal Utility District, which runs multiple programs with a combined annual budget of more than $18 million. These various programs serve different sectors in the greater Sacramento metropolitan area, including residential, low-income, new construction, and multifamily. More details on the programs run by these administrators can be found in the "Program Descriptions and Experience" section below.

Smaller-scale programs include pilots and demonstration projects, such as the Low Income Decarbonization Pilot from DCSEU in Washington, D.C., and market development efforts like AK Heat $mart and Renewable Juneau in Alaska.

Total annual spending from the 32 programs that provided these data topped $166 million, or approximately $5 million per program. This average is consistent with the amount reported in Nadel (2020), which included 23 programs totaling $108 million annually with an average of $4.7 million per program. We anticipate total spending on building electrification will rise in the future due to policy mandates and GHG reduction targets. Multiple large-scale building electrification initiatives are currently in the planning stages, such as California's TECH and BUILD programs and Xcel Colorado's forthcoming building electrification strategy.

Spending on building electrification is considerably smaller than the average spending for utility energy efficiency programs in general, which in 2019 was $64 million per year per state (Berg et al. 2020). Spending on energy efficiency was slightly higher for investor-owned utilities, with an average of $77.5 million per year for the 52 largest U.S. utilities in 2019 (Relf et al. 2020). On the basis of these data, we can see that electrification program annual budgets are relatively small compared to overall state and utility spending on demand-side management.

Sources of Funding

We collected data on how programs were funded and looked at the breakdown of budgets based on major sources of support. Figure 10 summarizes the most common methods of funding building electrification programs in this study.

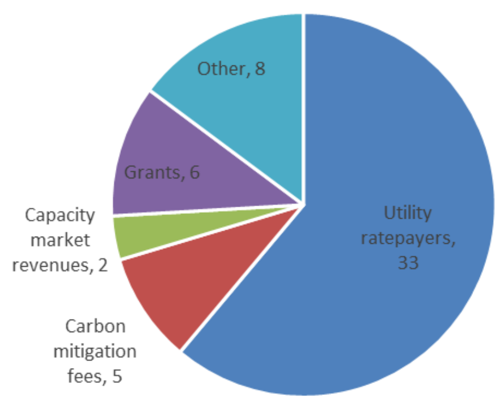

Figure 10. Sources of funding for electrification programs. Carbon mitigation fees include cap-and-trade funds and air emissions compliance fees by manufacturers. "Other" funding sources include local taxes, donations, and partner utility programs. Some programs utilized multiple funding sources.

The most common source of funds was utility ratepayers, who provided primary funding for 33 of the 42 programs (78%). Federal and state grants provided funding for six programs (14%), largely those focused on demonstration projects, R&D, or market development. Seven programs were funded all or in part by energy market–based mechanisms, such as capacity market revenues or cap-and-trade allocations from regional carbon markets. These mechanisms are in some ways ideal for electrification programs because displacing fossil fuels correlates directly with a reduction in carbon emissions. Regional cap-and-trade funds are currently limited in their distribution, and some states have placed restrictions on their ability to generate revenue. If more regions were to join carbon markets such as the Regional Greenhouse Gas Initiative (RGGI), it could lead to greater opportunities for funding electrification in the future. However, these market-based funding sources can be inconsistent where policymakers make allocation decisions, and program administrators that rely on these funds could be forced to seek additional funding, such as grants, to cover any budget gaps (S. Hill, director of low-income programs, Association for Energy Affordability, pers. comm., July 16, 2021).

Figure 11 displays the breakdown of budgets by funding source. Nearly all large-scale programs we could obtain budget data for were funded all or in part by utility ratepayers.

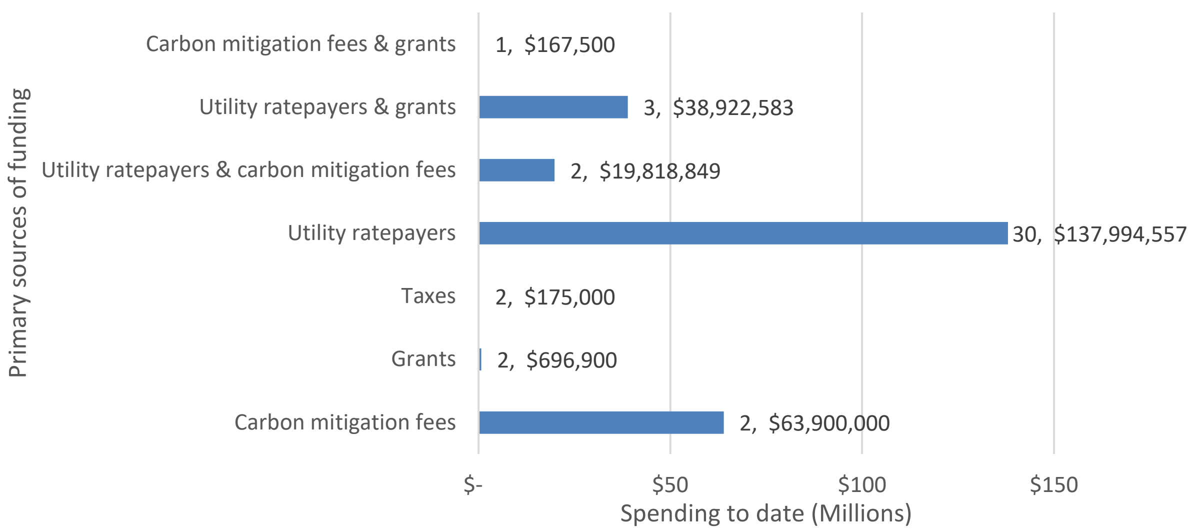

Figure 11. Program budgets by sources of funding, sorted by primary funding source(s) indicated by survey respondents. (Data labels indicate the number of programs followed by the total amount of funds.)

In general, programs administered by utilities were funded entirely through standard cost-recovery mechanisms. Programs run by a non-investor-owned program administrator such as an energy efficiency utility (e.g., Efficiency Vermont, DCSEU) or a municipal government or utility (e.g., City of Boulder, CO) were more likely to utilize additional funding sources like taxes, grants, and carbon mitigation fees. Some programs used multiple funding sources; for these, we did not have data on the relative contribution of each.

Incentive and Administrative Costs

Where it was available, we collected data on program administration costs (operations, staffing, customer support, etc.) and incentive costs (money paid to participants). Figure 12 shows the proportion of total program budgets that went toward administrative costs on both an annual and total basis.

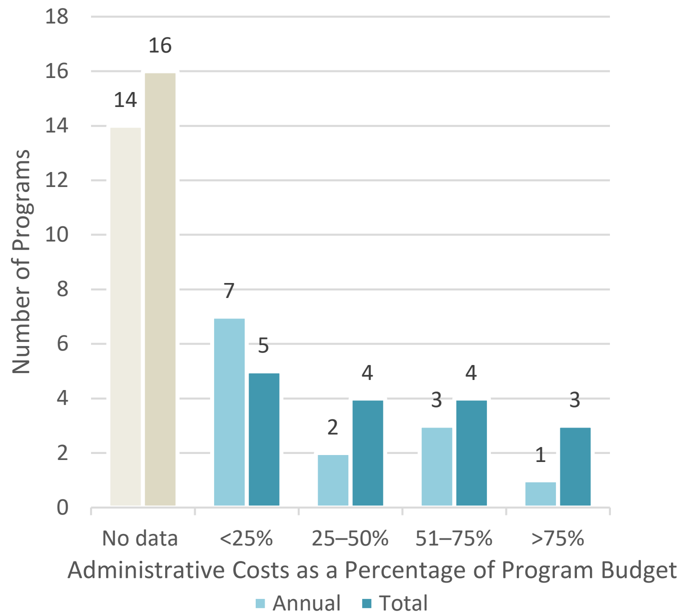

Figure 12. Administrative costs as a percentage of total program budget; among the 32 programs that reported budget data, only programs reporting separate administrative/incentive cost data are included

Although we were missing data for administrative costs, incentive costs, or both for more than half of the programs in this data set, those that did report both costs indicated a wide variation depending on program model and delivery strategy. In general, average annual administrative costs relative to total program budgets were higher in the first year of program administration and lower once programs were established, averaging 49% in the first year as opposed to 34% overall. This may be due to having a high number of pilots and early-stage programs in this data set, where new programs have higher upfront administrative costs (staffing, etc.) and lower annual operating costs once under way.

Some program models have higher operating expenses than others. Whole-home, income-qualified, and multifamily programs tended to have higher administrative costs, on average, than one-time rebate programs. These programs generally required additional technical and administrative support and staff to provide ongoing customer service. Additional support from staff and contractors was also important to manage experiences of customers participating in a more comprehensive retrofit program (P. Boyd, senior technology strategist, DCSEU, pers. comm., July 9, 2021).

Participation, Energy Savings, GHG Impacts

As with program budgets, we found that participation, energy savings, and greenhouse gas impacts varied widely among the 42 programs. Many of the programs did not have energy and climate impact data available. Some were still awaiting evaluation results; others had been launched too recently to gauge impacts. We were able to obtain participation data for 19 of the 42 programs. Data we collected on total and annual customers and annual spending per customer are listed in table 5 in descending order of total participants. Only programs that had participation data are included; for a list of which programs reported this data and which did not, see table A5 in Appendix A.

Table 5. Participation and average spending per customer

Program	Participation to date (customer households)	Annual participation (most recent 12 months)	Annual spending/customer
NYSERDA HP Rebate	21,500	6,520	$3,497
AEA LIWP	8,268	n/d	$-
SCAQMD CLEANair	2,000	2,000	$-
Tri State Heat Pump	1,799	649	$1,217
AK Heat $mart	600	200	$700
BED Net Zero City	390	390	$711
NG RI HVAC	378	378	$503
BayREN Home+	329	187	$46,524
EWEB Smart Electrification	268	268	$1,866
MA DOER Home MVP	250	250	$5,333
PG&E/SCP AER	207	105	$-
Comfort365	180	39	$1,282
Tri State HPWH	133	44	$350
Palo Alto HPWH	69	24	$12,500
EFG MA Solar Access	49	n/d	$-
EFG Zero Energy Now	45	8	$20,580
Renewable Juneau	21	6	$14,250
EFG Hudson Valley HP	20	n/d	$-
DCSEU LIDP	10	10	$34,600
Total participation and average spending per customer	**36,516**	**11,078**	**$6,198** (avg.)

Of the programs that reported participation, the level of spending per participant varied dramatically, from only the cost of the rebate itself (with very little overhead) to expansive programs and demonstration projects that provided comprehensive home assessments, weatherization, and retrofits, such as the EFG Zero Energy Now and DCSEU LIDP whole-home retrofit programs. Some programs have higher administrative costs and/or are testing innovative technologies, such as BayREN Home+, which included weatherization alongside electrification and focused on reaching difficult to serve homeowners and renters who were left out of other program delivery methods and creating a scalable program targeting residents, homeowners, contractors, and other market barriers. Low-income programs also may have higher costs due to the multiple barriers that exist for this customer class, which we explore further in the "Discussion" section. Spending per customer is here to provide context only and should not be used as an indicator of which programs and technologies were cost effective.

Table 6 lists total and annual energy savings and estimated greenhouse gas impacts for the programs that provided energy saving information. We normalized all energy savings to MMBtu (million British thermal units) to compare savings across different fuel types. Greenhouse gas impacts are measured in TCO_2e (metric tons of carbon dioxide equivalent). Most GHG emission reduction, except NYS Clean Heat and EFG MA Solar Access, was calculated by the authors using an average GHG emissions equivalence factor of 0.0053 TCO_2e/therm (0.053 TCO_2e/MMBtu) published by the EPA (EPA 2022). Just 9 of the 42 programs reported energy savings, an indication that energy savings are not yet universally recorded across programs of this type, or that many programs are still in an early stage and have yet to evaluate or publicize this data.

Table 6. Energy savings and GHG impacts from electrification programs

Program	Total energy savings (MMBtu)	Annual energy savings (MMBtu)	Total GHG emissions reduction (TCO_2e)	Annual GHG emissions reduction (TCO_2e)
NYS Clean Heat	1,400,000	66,300	72,300*	2,600*
AEA LIWP	58,914	6,520	3,122	346
Tri State Heat Pump	16,161	n/d	857	n/d
Comfort365	2,852	2,000	151	106
BayREN Home+	2,432	649	129	34
EFG Zero Energy Now	1,210	200	64	11
Palo Alto HPWH	973	390	52	21
Renewable Juneau	727	378	39	20
Tri State HPWH	469	187	25	10
PG&E/SCP AER	n/d	268	n/d	14
EFG MA Solar Access	n/d	n/d	1,192	498

Total savings	1,483,738	76,892	77,931	3,660

*** Source:** www.nyserda.ny.gov/Researchers-and-Policymakers/Clean-Energy-Dashboard/View-the-Dashboard

Even with only a fraction of programs reporting data on energy savings and GHG impacts, electrification programs are resulting in significant savings in terms of both energy and air emissions. Every 1,000 TCO_2e is equivalent to the emissions produced by 217 passenger vehicles or 120 homes' energy use for one year. These values are bound to increase over time as efficient decarbonization locks in savings for many years, and the estimated values are likely far lower than the total impact of electrification from the programs in this study that did not report these data. The lack of information highlights the infancy of programs and supports the need for continuous program evaluations with consistent methodologies. These improvements will enable program administrators to utilize evaluation results and publicize impacts that can then be used to advocate for more adoption of efficient building electrification programs.

Program Examples and Experience

In this section, we offer detailed descriptions of four electrification programs that use different strategies to reach various customer sectors in markets across the country. We chose these programs in particular because of their unique delivery models, strategies for overcoming barriers for hard-to-reach populations or use of specific technologies to achieve desired outcomes. The information in this section comes from the data we collected on the programs as well as detailed interviews we conducted with program administrators. For each program, we describe key measures, implementation strategies, obstacles to implementation, and lessons learned in the process. The four programs we selected are based in Washington, D.C.; New York; Tennessee; and California. They include a low-income retrofit program from the DC Sustainable Energy Utility, a midstream contractor education and incentive program from NYSERDA, and a new-build electrification program from Pacific Gas & Electric and Sonoma Clean Power. Our fourth program administrator example actually comprises six electrification programs from the Sacramento Municipal Electric Department for the residential, commercial, and low-income sectors.

DC Sustainable Energy Utility: Low-Income Decarbonization Pilot

This pilot program, which ACEEE highlighted in its beginning stages in a 2020 space-heating brief (Nadel 2020), concluded its initial run with 10 total units receiving partial or full conversion to all-electric heating, hot water, and cooking, with distributed solar on the single-family units and a community solar subscription for the four-unit multifamily complex. These whole-home conversions were provided at no cost to income-qualified participants. The projects were managed by the DCSEU, and while owners were consulted on decisions, the DCSEU handled most of the work with contractors. Program managers noted high satisfaction rates among participants, with 9 out of 10 reporting entirely positive outcomes in surveys after the pilot concluded. Beyond energy savings, customers responding to these surveys indicated that they experienced improved air quality and greater comfort in their homes because of the electrification and weatherization measures. The program managers cited clear communication from the contractor as key to ensuring that participants were well informed and satisfied with the process.

Program administrators encountered some complexities during program administration. The COVID-19 pandemic created multiple unexpected challenges and required the planned participant group of 20+ households to be reduced by more than half. Other issues included the expense and complexity of wiring and panel upgrades. The cost to upgrade to a 200-amp panel is approximately $2,750 in D.C., and wiring can increase the price even higher if no dedicated circuit exists for a new all-electric appliance. Additionally, the relatively short time frame for the project placed stress on the contractors, permitting process, unit delivery, and other factors. Most projects were completed in less than 45 days, whereas a typical full-unit conversion will often take between four and six months (P. Boyd, senior technology strategist, DCSEU, pers. comm., July 9, 2021). Last, administrators learned the importance of clearly communicating program goals and outcomes upfront so that clients know what to expect. At the start, it was unclear to certain participants that this was an energy-oriented program rather than a whole-home renovation. Once program administrators explained, customers were able to proceed smoothly with the process.

With the success of the pilot, the DCSEU is moving forward with more building decarbonization incentives in 2022. One of these is an HVAC Replacement Program that provides for the installation of high-efficiency electric heat pumps, high-efficiency electric water heaters, and advanced thermostats in single-family homes owned or rented by low- and moderate-income District residents. The other is an Affordable Housing Retrofit Accelerator, a comprehensive energy retrofit program that provides technical and financial assistance to affordable multifamily building owners who are required to comply with the District's Building Energy Performance Standards.

NYSERDA Heat Pump Incentive: Air-source Heat Pump and GSHP Programs

In service of meeting the state's ambitious carbon reduction policy goals, NYSERDA from 2017 until December of 2019 ran two separate but parallel programs to provide incentives for cold-climate air-source heat pumps and ground-source heat pumps. In both programs, the incentives were paid to qualified participating contractors. Air-source heat pump contractors had the option to keep the entire incentive amount or pass a portion on to the customer/end user. GSHP contractors were required to pass the entire incentive on to the customer/end user. The air-source heat pump program served only the residential and multifamily sectors, while the ground-source heat pump program was open to any residential, commercial, or industrial application.

Program administrators selected a contractor-based delivery mechanism because it allowed them greater control over and insight into the installation process. Participating contractors were required to undergo training and agree to certain terms and conditions, including periodic inspections of completed installations to guarantee quality. This training and inspection process allowed administrators to promote understanding of heat pump technologies among the contractor workforce in the area. Over the course of the program's run, NYSERDA reported increasing participation and a doubling of installations every year.

The incentive program run by NYSERDA sunsetted in March 2020, transitioning over to a similar delivery mechanism run by the New York State Utilities under the umbrella "NYS Clean Heat." Increasing contractor capacity, educating and driving consumer interest, setting state policy targets, and identifying supply chain opportunities, in particular supporting development of new technologies, improving distribution and stocking for heat pumps, are all aspects of the market development groundwork for growing adoption of heat pump technologies and retrofits.

Some contractors and customers are installing heat pump technologies while leaving in place the existing fossil fuel system to use as a backup. While this approach is eligible for incentives, the NYS Clean Heat program encourages sizing heat pumps to meet a building's full heating load. To this end, program administrators at NYS Clean Heat offer specific, higher incentives for installing integrated controls aimed at prioritizing and optimizing use of the heat pump system, or for decommissioning the existing fossil fuel heating system.

Over time, by increasing adoption and growing contractor capacity and sale of heat pump equipment relative to fossil fuel heating systems, program administrators expect upfront costs to come down, particularly as the price of natural gas increases relative to electricity in the region. Ensuring that air-source heat pumps will function cost effectively, especially in cold climate zones will help to fully decommission legacy fossil fuel systems at the end of their useful life.

Pacific Gas & Electric, Sonoma Clean Power: Advanced Energy Rebuild

Following the wildfires that destroyed thousands of homes in Sonoma County, California, in 2017, Sonoma Clean Power (SCP), Pacific Gas & Electric (PG&E), and the Bay Area Air Quality Management District (BAAQMD) collaborated to create the Advanced Energy Rebuild program (Opinion Dynamics 2019). Its purpose was to incentivize homeowners to adopt energy-efficient, low-carbon technologies and building practices in accordance with above-code standards when reconstructing homes that were damaged or destroyed by fire. The program provided incentives of up to $7,500 for partial electrification with a dual-fuel backup and up to $12,500 for all-electric homes. An additional $5,000 incentive was available for adding solar panels or battery storage to either type of project. Due to regulatory restrictions, PG&E was unable to directly fund electrification measures, so Sonoma Clean Power and BAAQMD provided the funding for homes to convert to all-electric. Out of the 66 customers who participated, 22 rebuilt homes to be all-electric and the remainder chose dual-fuel backup.

Using the results from this program as a case study in promoting zero net energy and decarbonization efforts, managers identified a variety of best practices to be used in future programs of this type. A crucial element of this program's success was its use of existing program infrastructure and established relationships with customers via social media and other messaging pathways. This helped establish legitimacy early on and led to streamlined marketing strategies. Another aspect of success was the program's use of multiple funding streams from the three different program implementers, which enabled funding of various specific measures while presenting a single, unified customer-facing program. Additionally, the program enlisted local advocates (termed "block captains") in specific neighborhoods to act as champions for energy efficiency and decarbonization among their peers, expanding communication, understanding, and enrollment in the program.

An obstacle that program managers encountered was consumers' and contractors' lack of knowledge and comfort around all-electric technologies, particularly induction stoves (Opinion Dynamics 2019). To overcome this, SCP established an induction cooktop lending program that offered customers a 30-day free trial of the equipment to build familiarity and garner feedback at the end of the trial period. Additionally, because this was a program focused primarily on rebuilding homes affected by wildfire, managers noted customer priorities were more often focused on their immediate needs of comfort and safety, and less on carbon impacts or long-term energy costs.

Sacramento Municipal Utility Department: Electrification Programs

SMUD, a municipally owned, not-for-profit utility in Sacramento, California, has one of the most aggressive carbon reduction targets in the country, aiming to reach net-zero emissions by 2040, five years ahead of California's statewide goal (SMUD 2021). Building decarbonization is a critical aspect of meeting this goal, with the utility aiming for 80% of buildings in its service area to be all-electric by 2040 (Wang and Menonna 2020). SMUD aims to achieve this cost effectively and equitably by employing smart technologies and focusing on including under-resourced communities and hard-to-reach sectors. The utility currently offers six pathways for building electrification incentives. We describe each of these programs below.

Advanced Homes—SMUD offers rebates for electrification and energy efficiency upgrades in residential single- and multifamily homes. Using a whole-house approach, a certified contractor will inspect the home and recommend improvements, rebate packages, and financing options. In addition to providing incentives for efficient HVAC and HPWH, the utility offers incentive packages for air sealing and insulation as well as funding for prewiring homes to be "electrification-ready."

Commercial—SMUD offers incentives for small and large commercial building electrification. These include rebates for energy-reduction upgrades on HVAC systems, and a custom retrofit Go Electric package to incentivize gas-to-electric conversions at a rate of $0.30/kWh-equivalent site energy reduction, with payments of up to 50% of project costs, capped at $100,000.

Home Appliance—SMUD offers end-user rebates for induction cooktops, providing up to $750 for gas-to-electric replacements. Applicants are required to submit "before" and "after" photos demonstrating that the conversion has taken place in order to qualify for the rebate.

Low-Income Electrification—To ensure that low- and moderate-income customers are not left behind in the energy transition, SMUD embedded electrification incentives in its existing direct-install energy efficiency program. All customers enrolled in SMUD's energy assistance program are qualified for in-home energy audits and weatherization services. Electrification measures are combined with this service at no cost to the customer. Since adding this component, SMUD has conducted fuel switching in more than 80% of the homes receiving incentives and services through this program (Gerdes 2019). These conversions may additionally require upgrading 100-amp electrical service panels to a 200-amp unit. Full electrification project costs for low-income customers can range from $10,000 to $15,000, depending on the extent of upgrades required.

Existing Multifamily—SMUD's Go Electric incentives for existing multifamily properties with five or more units are designed to promote switching to electric space-heating, water-heating, and cooking appliances. This program also offers incentives for wiring and electrical panel upgrades, EV charging, and energy efficiency measures. Property owners can receive a per-appliance incentive and an additional 25% incentive for apartment complexes where a majority of tenants are income-qualified. Project managers work with property owners to deliver incentives but also engage directly with building tenants to provide education and guidance through the upgrade process.

New Homes Electrification—This program targets home builders with incentives to construct all-electric and energy-efficient single-family and multifamily residential houses. SMUD provides a per-home incentive of $4,000 per single-family home and $1,250 per multifamily home, with an additional bonus for including induction cooking appliances. To qualify for incentives, builders must construct homes with all-electric appliances and mechanical systems, with no gas service or infrastructure. The program also includes a demand response component in the form of an optional add-on incentive for connected heat pump water heaters.

Discussion

BARRIERS AND OPPORTUNITIES FOR BUILDING ELECTRIFICATION

In this section, we discuss the barriers that exist for multiple actors in the building electrification supply chain, including homeowners, contractors, manufacturers, low-income residents, and policymakers. For each actor, we identify key barriers based on our survey, interviews with program administrators and subject matter experts, and a review of existing literature. We then discuss various strategies that program implementers in this study have successfully employed to address these barriers. Table 7 gives a summary of key issues by actor, along with strategies to address these barriers and accelerate electrification. Each of these issues and opportunities are discussed in greater detail below.

Table 7. Barriers and opportunities for electrification

Key barriers by actor	Pathways to expand electrification
Homeowners and building managers	
• Higher upfront costs relative to fossil fuel equipment • High operating costs in areas with steep electricity rates • Lack of knowledge about heat pump technologies • No motivation to replace equipment before the end of its useful life	• Program administrators can offer point-of-sale incentives to contractors and homeowners to address the cost differential • Lenders, utilities, and states can provide access to financing for home energy upgrades • Federal, state, and local governments and utilities can create customer education campaigns • Contractors and dealers can encourage replacement of equipment that is nearing the end of its useful life and likely to fail
Low- to moderate-income (LMI) customers and communities	
• Low-income homeowners may not pay income tax, which prevents them from accessing tax credits. • Low-income homeowners may lack the upfront capital needed to purchase new equipment and therefore will not benefit from rebates.	• Where state and federal programs offer tax credits for electrification, they should provide alternate methods for customers who lack the tax equity to access these incentives • Program administrators can incorporate electrification incentives into existing LMI programs to streamline delivery

Key barriers by actor	Pathways to expand electrification
• Many LMI customers are renters, who typically do not control the infrastructure serving their homes (gas versus electric). • Energy burdens must be monitored and managed given that operational costs for heat pumps are higher than gas prices in many regions.	• Program implementers must develop electrification strategies specific to the multifamily housing sector
Contractors	
• Making a like-for-like fossil fuel replacement is easier than introducing and installing a new type of system, especially for contractors unfamiliar with heat pump technology. • Limited capacity and availability of qualified installers • Narrow dissemination of specialized knowledge, such as how to set up dedicated controls • Lack of a standard set of proficiencies for heat pump installers and technicians	• State and federal governments and industry organizations can establish certification pathways to create standardized knowledge and skills for heat pumps and other electrification technology installation and maintenance • Using established certification pathways, educate and train heat pump installers so that all have a standard set of proficiencies. • Develop peer networks for information sharing among contractors • Offer contractor incentives and partnerships with utility programs to encourage heat pump sales and deployment
Manufacturers and distributors	
• Shortage of heat pumps in distribution networks and supply depots • Higher cost to manufacture heat pumps than unitary A/C units	• Federal programs can offer incentives to manufacturers to address price differential between heat pumps and A/C units • State and utility programs can offer midstream incentives to distributors to encourage consistent stocking of heat pumps and parts. • Consider phasing out preexisting utility incentives for air conditioners and gas furnaces in favor of heat pumps that function as both, improving economies of scale

Key barriers by actor	Pathways to expand electrification
Policymakers—legislators, regulators, utility administrators	
• Limits on fuel switching in certain jurisdictions • Traditional cost-effectiveness tests do not fully value the benefits of electrification (such as reduced emissions and improved indoor air quality) • Conflict of interest with natural gas utilities	• States should Incorporate building electrification into climate plans • Jurisdictions can update building codes to require new and renovated structures to be all-electric or "electrification-ready" • States and local jurisdictions can establish moratoriums on gas infrastructure in new construction • Regulators can update cost-effectiveness testing methods to value environmental impacts and nonenergy benefits of electrification • Federal and state governments can create mechanisms to price carbon and allocate CO_2 mitigation funds for weatherization and electrification

HOMEOWNERS AND BUILDING MANAGERS

Every day, approximately 16,000 HVAC systems are installed in the United States (Pantano et al. 2021). Currently most of these systems utilize conventional one-way air conditioners coupled with fossil-based heating systems instead of efficient bidirectional electric heat pumps. The decision to install a particular type of system is often made by the homeowner and the contractor, which means that understanding and meeting the needs of homeowners and engaging with both owners and contractors are vital to scaling up electrification in homes and buildings.

Cost of Electrification Upgrades

The higher upfront cost of heat pumps relative to oil, propone, and natural gas–based heating systems is a major barrier to adoption of heat pump technologies in buildings. Table 8 shows cost comparisons of different space-heating and water-heating systems derived from a study by Rocky Mountain Institute on the economics of electrifying buildings. Note that the table presents the most challenging scenario—upgrading the existing heating systems only. (When a new air conditioner needs to be added, a heat pump system has the lowest upfront cost compared with the combined cost of an air-conditioning and fossil fuel heating system.) The lower upfront cost of natural gas–based heating systems, plus the current low price of natural gas itself, makes these systems more attractive from a cost standpoint for homeowners who have access to the fuel.[19] Many programs in this study seek to address this upfront cost barrier with incentives.

Table 8. Heating system retrofit costs comparison

Equipment type	Upfront equipment cost (before incentive)	Annual operating/ fuel cost ($)	Net present cost
Space heating			
Natural gas space heating (w/existing AC)	$3,156–3,581	$130–782	$12,933–17,310
Fuel oil or propane space heating (w/existing AC)	$3,004–3,323	$1,582–2,703	$21,844–28,019
Air-source heat pump	$7,522–8,816	$136–1,240	$15,350–20,886
Water heating			
Natural gas water heating	$1,228–1,426	$90–251	$2,141–3,710
Fuel oil or propane water heating	$1,359–2,175	$353–641	$5,387–7,199
Heat pump water heater	$2,062–2,416	$48–342	$3,072–5,916

Data source: Billimoria et al. 2018. Estimates are based on a model of a typical 2,401-square-foot single-family home in four cities: Oakland, Chicago, Houston, and Providence. Values represent a range from lowest to highest cost of various installations in the four locations.

In our review of incentives, the average incentive for air-source heat pumps was between approximately $429 and $897 per ton of heating/cooling capacity and between $1,434 and $4,330 for a whole-home system. This is not always sufficient to make up the difference in cost between electric and natural gas systems (the difference depending on equipment choice and other factors). Additionally, there can be other project costs associated with electrification of existing buildings which are excluded in the cost estimates in table 8, such as wiring and panel upgrades (typically not included in utility rebate programs). While these costs vary by project and region, the typical cost to upgrade an electric panel from 100 amp to is $1,300 to $1,600 (HomeGuide 2021). The cost of installing new wiring and circuits can increase expenses further. These additional potential expenses may further widen the cost gap between fossil fueled equipment and electric equivalents for homeowners.

[19] At the time of writing, the average price of natural gas in the United States was $20.96 per thousand cubic feet (EIA 2021b). These cost comparisons are for building retrofits with preexisting gas infrastructure. For new builds, the added cost of installing gas service may equal or exceed the cost of a heat pump, making electrification the most economical option for new builds in most parts of the country (Billimoria et al. 2018).

Some program administrators are addressing the cost barrier by packaging retrofit upgrades with other incentives. For instance, SMUD's Advanced Homes program offers customers a package of rebates for electric space- and water-heating measures, combined with a Go Electric bonus package of up to $2,500 to cover wiring and panel upgrades. However, more generous utility incentive programs may have trouble passing some cost-effectiveness screens, depending on the testing protocols employed by that state's regulatory commission. Just one in four states considers environmental benefits in the cost-effectiveness evaluation of demand-side programs (York, Cohn, and Kushler 2020). If the benefits from electrification and carbon reduction are not quantified in cost-effectiveness assessments, aggressive utility incentives for electrification may not receive approval by regulators.

Financing for Electrification Upgrades

An effective way to address cost barriers may be to provide access to financing for home energy upgrades. Although many programs deliver benefits through equipment rebates, these may not cover the entire extra cost of an electric system, leaving the customer to make up the difference. Loans and financing can help address the cost barrier that remains. Access to affordable financing may also lower the barrier to entry for customers who wish to see environmental and financial benefits of converting to an efficient all-electric system but do not have the capital to cover the upfront costs. Entities such as green banks that offer low-cost loans to assist with home energy upgrades may spur development in this area, as well as create local jobs and lasting economic growth. Examples of program administrators in this study that include financing options for heat pumps are the Minnesota ASHP Collaborative, the Eugene Water and Electric Board, and AK Heat $mart.

One method of financing upgrades that is more accessible for customers who lack savings or a strong credit history, or who are unable or unsure of how to access traditional financing, is on-bill financing. This strategy has existed for more than 30 years and is beginning to see greater implementation today (Yañez-Barnuevo 2021). With on-bill financing, the cost of upgrades is repaid through a charge on the customer's monthly energy bill. It is best suited for projects that are cash flow positive from the outset, so that savings can be realized on customer bills immediately. If the home is sold, any remaining debt can be easily transferred to the new owner. Because of the complexities involved with taking on customers' debt, these programs often require enabling statutory or regulatory action, and many investor-owned utilities are hesitant to run such programs at scale. One program administrator in this study, Orcas Power and Light (a customer-owned cooperative utility in Washington State), provides on-bill financing for fuel conversion upgrades, heat pump water heaters, and EV charging with its Switch It Up! program.

Factors Beyond Cost: Knowledge, Trust, and Motivation

Beyond cost, there are other reasons why heat pumps might not be the first choice for many customers. One is a lack of general knowledge and awareness about heat pump technologies among the public. To address this information barrier, some utilities and program administrators are running education and marketing campaigns to increase public awareness about efficient electric technologies. The Bay Area Regional Energy Network

(BayREN) reached customers through digital advertising and by partnering with local municipal utilities to offer webinars and send mailers to eligible customers. Other programs, such as the PG&E/Sonoma Clean Power Advanced Energy Rebuild program, used peer networks to disseminate knowledge among customers. This program engaged with customers at public events and appointed customer representatives to serve as "block captains" in each neighborhood (Opinion Dynamics 2019). Using these existing social networks, particularly through social media, allowed Sonoma Clean Power and PG&E to effectively message residents.

A major misconception among contractors and property owners is the idea that air-source heat pumps are unable to deliver heat reliably and efficiently in cold temperatures.[20] It is crucial to address this misconception because, according to program managers, comfort is a key factor in the customer experience and a critical part of what motivates people to upgrade or replace their HVAC or water heating system. If customers lack confidence in a heat pump's ability to provide consistent and reliable thermal control, they will favor the familiar and ask their contractor to install a like-for-like replacement or a dual-fuel system where fossil-based heating is left in as a backup. For total building electrification to be achieved, program administrators and contractors need to demonstrate that heat pumps are just as reliable, comfortable, and affordable as fossil fuel–based systems.

Finally, for electrification retrofits to be a viable option, equipment must be available, affordable, and attractive so that property owners will be sufficiently motivated to adopt heat pump technology. Many system replacements occur only when existing equipment breaks or reaches the end of its useful life. This requires heat pump equipment to be in stock at supply centers for emergency replacement scenarios. Homeowners also need to be informed (by contractors and/or marketing and education efforts) so that they can plan for replacement well in advance of a system's failure. Otherwise, in an emergency, a like-for-like replacement will often result, locking in fossil fuel use and carbon emissions for an additional 20 years or more. These replacements should target equipment that is very old and nearing the end of its useful life, since replacing prior to that is often not economically feasible.

LOW- AND MODERATE-INCOME (LMI) CUSTOMERS

The challenges discussed in the section above mainly concern market-rate customers, homeowners whose annual income is at least 80% of area median income. However, a substantial percentage of the population does not fit within this category. The needs of low-

[20] Due to recent innovations in refrigerants that can work in very low temperatures, as well as defrosters that can prevent ice from accumulating on the heat pump system, cold-climate air-source heat pumps can provide full-load heating in temperatures as low as 5°F and partial-load heating for temperatures as low as –13°F (Mitsubishi 2021). Studies in cold regions such as Minnesota have found that this technology can provide an effective space heating option on its own or when paired with a backup heating system (McPherson, Smith, and Nelson 2020).

and moderate-income homeowners and renters cannot be ignored in the process of decarbonizing the buildings sector. In fact, these groups often stand to benefit the most from home retrofits, since they are more likely to live in older buildings with poor heating, ventilation, and indoor air quality and are likely to struggle with higher energy burdens.[21] Beneficial electrification can address some of these issues by reducing energy costs and improving comfort and health. However, there are additional equity concerns, such as housing affordability and higher electricity rates, that can arise if the needs of these customers are not considered holistically within building decarbonization plans. This section details key barriers to electrification for low- and moderate-income customers and describes how program administrators in this study addressed these issues.

SYSTEMWIDE COSTS OF ELECTRIFICATION

A major issue that affects LMI customers is the impact of electrification on electricity rates, and by extension energy burdens. LMI homeowners are also at higher risk of bearing the brunt of damage caused by climate change–induced extreme weather events. If building decarbonization is not implemented equitably and with due consideration of systemwide cost impacts, it could exacerbate the burdens on an already under-resourced group of people. Seventy-nine percent of the programs in this study were funded partially or entirely by utility ratepayers. If the benefits from these programs are not allocated equitably among the population, then there is a risk that utilities will raise costs for everybody to create benefits for a smaller, wealthier subset of customers.[22] To ensure that low-income customers are not left behind in the building energy transition, several programs in this study offered higher incentives to income-qualified customers, carved out a portion of program funding for income-qualified customers, or offered entire programs designed specifically to address the barriers that LMI customers face.

Another key issue relates to keeping housing affordable for LMI renters and homeowners. Due to the higher costs of heat pump equipment discussed above, home builders and landlords may seek to recover those costs by charging higher prices for homes and rentals. Providing electrification specifically for the affordable housing sector is critical to ensure that building upgrades do not price residents out of their neighborhoods. One approach is to offer incentives to home builders to reduce the costs of equipment in all-electric new builds. Commonwealth Edison provides specific incentives to home builders who construct all-

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[21] *Energy burden* is the percentage of annual income a given household pays for energy (electricity and fuel). On average, low-income households spend 8.1% of their annual income on energy, while non-low-income households average 2.3% (Drehobl, Ross, and Ayala 2020).

[22] The effect of electrification on electricity rates is complex due to creating both upward and downward pressure on rates simultaneously. A Ratepayer Impact Measure (RIM) test can evaluate the specific rate impacts of a given program; however, RIM should not be used as a substitute for a true cost-effectiveness test.

electric homes that integrate a holistic package of energy efficiency upgrades, including distributed solar. The utility also offers rebates for affordable housing new construction.

A recent pilot study by Commonwealth Edison compared two multifamily units constructed under the affordable housing program. One was built to ENERGY STAR certification with a natural gas heating system, and the other had all-electric systems and was constructed to more stringent passive house (PHIUS+) certification standards. The efficient, all-electric home was more expensive to construct ($214 per square foot compared with $178 per square foot) but reduced the delivered energy requirement for space heating by 76% and lowered resident annual energy costs by 19% relative to the other home (Slipstream 2021). The authors of the study suggest that as market capacity increases over time, with more qualified contractors who are able to install efficient HVAC and meet passive house standards, the costs to implement these efficient building decarbonization measures will decline.

Multifamily Electrification: Renters, Landlords, and the Split Incentive

For customers who live in rental units, the first barrier of access is that they do not own or control their home's energy system. Renters and landlords face a *split incentive* when it comes to paying for home energy upgrades. In the case where renters pay their own energy bills, energy savings provide little to no motivation to landlords to invest in energy efficiency or heating system upgrades, given they will see little to no financial return on their investment. For this reason, they are less likely to take advantage of rebates or participate in many building electrification or energy efficiency programs based on energy saving benefits alone.

Because of this split incentive, several programs in our study—notably the AEA's Low Income Weatherization Program (AEA LIWP) and the SMUD Multifamily program—targeted the low-income multifamily sector. Each of these programs combined electrification equipment retrofits with other measures, such as wiring and panel upgrades, weatherization, and distributed generation (in the case of AEA LIWP). Both programs provided incentives to the property owners for upgrades, while simultaneously engaging with tenants and providing educational materials. In SMUD's program, all multifamily properties were eligible for incentives, and an additional 25% incentive was provided for properties with more than 50% of tenants who are enrolled in the utility's low-income rate. AEA LIWP had slightly higher requirements, providing incentives to properties with more than 66% of tenants at or below 80% of area median income. AEA LIWP program managers recommend aligning program eligibility criteria with other common funding mechanisms for income-based programs, such as the Low Income Housing Tax Credit (LIHTC), to streamline the enrollment process for similar programs (Hill, Dirr, and Harrison 2020).

Of the two multifamily-specific programs, the AEA LIWP made a dedicated effort to address the split incentive issue by offering significantly higher incentives (an extra $1,000–1,500 per $MTCO_2e$ reduced) for buildings where the tenants paid for their own electricity. This was designed to offset the out-of-pocket investment for property owners making building decarbonization upgrades. The lower incentives that were offered to master-metered properties also proved effective in encouraging comprehensive work scopes, allowing property managers to tackle deferred maintenance and upgrade aging systems with new, efficient, carbon-free versions (Hill, Dirr, and Harrison 2020).

Electrification and Weatherization

Another issue is that some LMI customers occupy homes requiring major repairs or weatherization before electrification upgrades can be installed. To overcome this barrier and deliver equitable electrification solutions, approximately half of the programs in this study encouraged weatherization on top of electrification by connecting customers to incentives or parallel programs providing insulation, air sealing, and other building envelope measures. A quarter of programs required customers to weatherize in order to receive incentives or offered more generous incentive packages to customers who weatherized. For example, Energize CT required customers to weatherize if they were receiving incentives for displacing delivered fuels (oil or propane) or if they were participating in the income-based Home Energy Savers (HES) parallel program. Other program administrators, such as BayREN Home+, created a "one-stop shop" for program delivery so that customers could access a holistic package of efficiency and electrification upgrades. Delivering incentives in this way lowers barriers to entry and allows time-limited customers to easily access information about incentives and home improvements.

Natural Gas Infrastructure Stranded Costs

Finally, there remains a key equity issue concerning LMI customers on the natural gas delivery system. As with electricity, the costs of gas heating are allocated among all customers on the delivery system, including both variable and fixed costs. When customers leave the gas system by electrifying buildings, the remaining fixed costs to maintain the system are allocated across a smaller number of customers. While there is little to no evidence at the time of writing that this has led to substantially higher costs for customers, these costs may rise sharply at high levels of building electrification; one study projects the yearly increase to be $31 per customer at 15% electrification; $116 per customer at 40% electrification; and $1,565 per customer at 90% electrification (Davis and Hausman 2021). This should not be used as a reason to avoid pursuing electrification, but it does represent an equity issue, since not every homeowner or resident is able or willing to pay the price of conversion or move to another unit. Future program planners should be mindful of the cost of stranded gas assets and pay special attention to providing incentives for LMI and energy-burdened customers on the natural gas system to access building electrification upgrades.

HVAC CONTRACTORS

In interviews with program administrators and experts, many of them emphasized the scarcity of qualified contractors as an important barrier to overcome in the effort to advance heat pumps and other electrification measures. A contractor's relative level of experience and comfort with heat pump heating and hot-water systems is critical when it comes to communicating the value of electrification technologies to customers and homeowners. If a contractor lacks the skills, knowledge, and confidence to install a heat pump for space and water heating, it will not be presented as a viable option to customers who are looking for HVAC solutions. Underinformed contractors may even try to discourage potential buyers from installing an electric home heating system (Pontecorvo 2021).

Market development efforts can address this obstacle by training contractors to install heat pumps and educating them on the value of these technologies and how to communicate that to customers in terms of comfort, health and safety, and cost savings. In markets where a lack of contractor availability and willingness to install heat pumps and other electric technologies is a major barrier, some program implementers are promoting and supporting education and job training for installers through investments in workforce development. This is particularly crucial for technologies like heat pump water heaters, which require contractors who have both plumbing and electrical experience. Organizations such as Efficiency Maine, NYSERDA in New York, the Minnesota ASHP Collaborative, the Beneficial Electrification League of Colorado, and the Massachusetts Clean Energy Center are investing millions of dollars in education and training for heat pump contractors.

Certification programs and procedures can create a common language of competencies that job training programs can use for teaching and evaluation. While the North American Technician Excellence (NATE) organization does include certification pathways for specialty in installation and service of air-source heat pumps (NATE 2021), these certifications are not universally required for contractors in all jurisdictions, so the reliability and consistency of heat pump contractors varies from region to region. A standard definition of and curriculum for green HVAC contractors would help guide job training programs around the country. Additionally, the training and certification programs must extend beyond standard heat pump installation and maintenance to grow contractor expertise in specific technologies and issues, such as selecting and installing cold-climate heat pumps, hot-water heat pumps, and ductless mini-split systems. Market transformation groups like the Minnesota ASHP Collaborative are publishing guides for installers that include key information on product choice, sizing of systems, integrated controls, and installation best practices for achieving optimal energy savings and homeowner satisfaction.

If utilities target contractors with incentives for specific technologies such as cold-climate heat pumps, contractors will then be able to offer those products and services to their customers at a competitive rate. These incentives need to be combined with accountability measures, such as site inspections, to ensure that equipment is installed correctly and to gather feedback and results that can be communicated back to utilities, installers, and product manufacturers (McPherson, Smith, and Nelson 2020).

Online Resources for Heat Pump Information and Education

Our research identified several online resources that can be used freely for informing and educating contractors, customers, and other key decision makers on the demand side of building electrification. The Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air-Source Heat Pump List is a searchable database of more than 28,000 heat pump products (as of November 2021) that includes details such as maximum throughput rating in

Btus per hour, coefficient of performance in cold climates, ducting configurations, and other valuable information to help guide buyers of these technologies.[23] Another virtual resource is the HVAC 2.0 consulting process for contractors, which provides guidance and training in a specialized sales process for installers of heat pumps and information for potential buyers of these technologies.[24]

MANUFACTURERS AND DISTRIBUTORS

As mentioned earlier, for contractors to sell heat pumps to customers, it is vital that the necessary equipment be stocked and available at distribution centers. This is particularly true for emergency replacement retrofits. Otherwise, even when contractors and customers are interested in heat pump technologies, a shortage of supplies in the manufacturer-distributor pipeline will probably result in a like-for-like replacement. In late 2021, many markets for heat pumps reported having supply chain issues with air-source heat pumps and water heaters (Anderson 2021). These shortages may have been exacerbated by additional factors, such as the COVID-19 pandemic and high demand in certain markets.

Four programs in this study engaged with manufacturers of heat pumps in order to reduce costs and/or address supply chain issues. The Energy Futures Group ran two direct-install demonstration projects, one in New York (leveraging grant funding by NYSERDA) and Massachusetts (leveraging grants from the MA Clean Energy Center and Dept. of Environmental Resources). These projects provided incentives at multiple levels, including to end users, to contractors, and to distributors of heat pumps to streamline the delivery process to retrofit 20 homes in Hudson Valley, New York, and 49 homes in western Massachusetts. Administrators of the Mass Save Fuel Optimization program also engaged with manufacturers in developing a set of rebates, although financial incentives were ultimately offered to end users. The Southern California Edison residential upstream incentive program, also known as Plug Load and Appliances, built on relationships with retailers to incorporate incentives for efficient electronics (including HVAC) and appliance recycling programs.

These four programs represent a small fraction of incentives and spending across all programs in this study. However, a nationwide study from CLASP suggests that providing incentives at the manufacturer and distributor level may be one of the most cost-effective methods to accelerate heat pump deployment in many markets (Pantano et al. 2021). This research proposes a manufacturer-based solution to addressing supply chain, cost, and

[23] The list can be found at ashp.neep.org/.

[24] For information, visit www.hvac20.com/.

availability concerns for heat pumps in buildings.[25] The authors of the study recommend offering incentives to manufacturers to produce air-source heat pumps (which are $200–500 more expensive to manufacture) rather than air conditioners.[26] By targeting manufacturers, state and federal program administrators could streamline distribution networks and bring prices down at the distributor, installer, and consumer levels. By simply replacing all central A/C installations with heat pumps, program administrators could substantially accelerate partial or full electrification of centrally ducted homes throughout the United States. The study authors find that this type of incentive would have cascading effects down the supply chain, delivering the equivalent of $1,000 in per-unit cost reduction for the customer for every $373 spent on manufacturer incentives; it would also alleviate supply shortages and simplify a complex sales process from the point of view of a contractor.

A federal funding mechanism would likely be the most effective approach to achieve this outcome, both because the scale of funds required would be massive and because manufacturers and distributors operate primarily on a multistate level. The DOE has announced a partnership with industry allies to improve the efficiency and affordability of cold-climate heat pumps (DOE 2021). This partnership appears to consist primarily of peer-to-peer information sharing and education; at the time of writing, it was not clear whether it would include per-unit incentives for manufacturers to prioritize air-source heat pumps over air-conditioning units. This may be an area where federal leadership can lead to significant impact and a reduction in price for heat pump units across the entire market.

REGULATORS AND POLICYMAKERS

State policy and utility regulation play a significant and essential role in advancing building electrification in the United States. The states that have made the most substantial electrification efforts to date are the ones with explicit policy goals for decarbonization, including California, New York, Colorado, and Maine. By removing barriers to building electrification, providing incentives and mandates for utilities to deliver services to their customers, and creating sustainable funding streams for electrification programs, state leadership can catalyze rapid change in this nascent market. This section outlines key policy barriers and opportunities for decision makers to advance policies that favor rapid scaling and decarbonization of buildings.

FUEL SWITCHING

State policies that enable or discourage fuel switching can be a critical driver or barrier for building electrification. In 2020 ACEEE identified 11 states that prohibited or strongly

[25] Details can be found at www.clasp.ngo/research/all/3h-hybrid-heat-homes-an-incentive-program-to-electrify-space-heating-and-reduce-energy-bills-in-american-homes/.

[26] Except in cases of specialized applications, such as cold-climate equipment.

discouraged fuel switching in state policy or regulation (Berg and Cooper 2020). This number has changed recently, with more states, such as Minnesota, amending their rules to allow policies that directly subsidize conversions of fossil fuels to electricity. However, in states where prohibitions remain (e.g., Pennsylvania, Georgia, Texas, and Washington), utility-funded electrification programs will be unable to gain much traction. Working to have these prohibition policies repealed should be a priority for electrification proponents in those states. Conversely, states where policies encourage fuel switching through guidelines or fuel-neutral goals include California, Alaska, Vermont, Tennessee, New York, Massachusetts, and Vermont. To date, these tend to be states with high reliance on delivered fuels and/or constraints on gas distribution systems (such as in the Northeast), making electrification an especially effective tool for emissions and cost reductions.

Building Codes

New and renovated buildings represent one of the most straightforward opportunities to deliver electrification measures at a cost that is equal to or lower than the cost of installing fossil fuel equipment. Building codes, which are adopted at either the local or state level, depending on jurisdiction, set mandatory baselines for new construction and can include stretch codes or other compliance pathways for above-code additions, such as passive house and net-zero certification. Stretch codes are an opportunity to grow a nascent market in green buildings and are currently present in multiple jurisdictions such as Vermont, Massachusetts, New York, Maryland, and Washington, D.C. (NEEP 2021). While most building energy codes concern energy efficiency (envelope, lighting, hot water, and HVAC systems), the 2021 IECC is the first model code to include zero-energy appendixes for residential and commercial new construction. States and jurisdictions can adopt these codes as they are or pass amendments to require higher standards of efficiency or strategic electrification.

An “electrification-ready” proposal to require electrical outlets near fossil fuel–powered appliances was rejected in the latest IECC code development cycle. This would have reduced conversion costs for existing units by avoiding the need to install new wiring and circuits for all-electric appliances. It was removed after pushback from home builders and other industry lobbyists, who cited higher costs. However, states and local jurisdictions may still include such a provision in their own building energy codes.

Cost-Effectiveness Testing: Valuing Fuel-Neutral Energy Savings

For utilities to begin offering electrification programs and incentives at scale, they will need to undergo evaluation, measurement, and verification (EM&V) by state regulators. At present, only 29% of states conduct EM&V of electrification or fuel-switching programs (York, Kushler, and Cohn 2020). For these cost-effectiveness tests to fairly measure the impacts of electrification programs, they will need to consider energy impacts from a fuel-neutral standpoint. Cost-effectiveness tests should also seek to quantify nonenergy benefits of electrification such as emissions reduction, improved indoor air quality, and potentially increased property values. Metrics such as the social cost of carbon may be used to quantify environmental benefits in the context of climate change mitigation (Cho 2021).

If done correctly, EM&V practices that are integrated throughout a program on a procedural basis can lead to robust program designs and consistent outcomes. State evaluators and program administrators should consider reporting and evaluation practices when designing new electrification programs and/or adapting ongoing ones.

Natural Gas Utilities

Of the fossil fuels eligible for replacement in electrification programs, only one fuel—natural gas—is generally rate-regulated at the state level. In some regulatory environments, natural gas utility companies are separate entities from electric utilities; this makes them a natural opponent of electrification because electrification stands to negatively affect their profits. The interests of the natural gas lobby have led certain states, such as North Carolina, to pass policies that prohibit local and state governments from banning new gas connections, whether or not such bans were being considered at the time (Ouzts 2021). Balancing the interests of regulated natural gas utilities will be a challenge for regulators and policymakers who are seeking to rapidly scale building decarbonization as a climate solution.

One state that has enacted policies that include natural gas as well as electric utilities is Colorado, which requires all utilities (including natural gas utilities) to develop decarbonization plans using a fuel-neutral approach (Colorado Energy Office 2021). Gas utilities can meet the statutory target through efficiency or electrification measures for their customers. However, the bill also prohibits the PUC from banning new gas hookups or requiring customers to replace gas-fueled equipment in existing buildings. This middle-of-the-road approach is the first of its kind in the nation and may represent an example for other politically mixed states seeking to drive beneficial electrification through proactive policies. Another example of such a policy is the Natural Gas Innovation Act, which was passed in Minnesota in July 2021. This law encourages gas companies to file "innovation plans" that introduce renewable natural gas and hydrogen-based fuels and fund energy efficiency, carbon capture, and geothermal heating (Jossi 2021). By broadening the ability of gas companies to invest in electrification and decarbonization and recover their costs, the authors of this policy hope to foster cooperation, rather than competition, with natural gas utilities.

There have been some initial efforts, such as the GeoMicroDistrict pilot study in Massachusetts, to explore the use of stranded gas infrastructure as a geothermal heat distribution method (HEET 2019). Although this model shows promise as a way for gas distribution companies to pivot their business model to a decarbonized solution, current examples of real-world applications of this technology are limited, and the upfront costs are significant, especially in a retrofit context. Substantial investment and workforce development would be necessary for this to be a commercially viable approach, but utilities in states like Massachusetts that currently depend on natural gas infrastructure may have much to gain by exploring this approach.

Pricing Carbon Emissions

The current low price of natural gas compared with electricity makes it challenging for building electrification to compete with fossil fuels on a cost-of-energy basis in many markets. There are indications that the market price of natural gas and other fuels may rise in 2022 and future years (EIA 2021e). However, the domestic supply chain is set up to continue extracting and distributing fossil fuels in the United States for decades to come. This favorable market position is likely to continue as long as the public (and marginalized communities in particular) bears the health and environmental burdens of fossil fuel extraction and combustion. If legislators and regulators were to impose a per-ton tax on carbon emissions, the downstream price of natural gas and other fuels would more accurately represent the societal impact of their use. Such a policy would help equalize the market environment between electric end uses and fossil fuels and could be the single most impactful policy to drive building electrification forward on the federal and state levels (High-Level Commission on Carbon Prices 2017).

Though the present political landscape makes enacting a nationwide carbon tax in the United States challenging, if not downright infeasible, state carbon market programs like RGGI in the Northeast and the cap-and-trade program in California have utilized a market-based mechanism to achieve a similar effect. With enabling legislation, these programs can be structured to generate revenue based on selling emissions allowances. States can direct these revenues toward decarbonizing hard-to-reach sectors. A good example of this method in practice is the AEA LIWP in California, the largest low-income decarbonization program we identified in this research. The initial wave of funding through this program was distributed to low-income multifamily buildings and communities on a per-MTCO_2e reduced basis. This effectively resulted in carbon emitters subsidizing decarbonization and clean energy for communities that would otherwise be unable to afford these measures.

Conclusions and Recommendations

Decarbonization in the buildings sector is a vital step to address global climate change, with electrification an important strategy to decarbonize. The market for electrification in the United States is still small but growing rapidly, driven mainly by state policy directives and technological improvements in heat pump performance. ACEEE has tracked the landscape of programs and incentives for building electrification over the past several years. In 2020 we identified 22 space-heating electrification programs with a total annual budget of almost $109 million. This year, we expanded our survey to include 42 incentive and market development programs. Thirty-two of these programs reported budget data, with an average of $5.2 million per program and a total budget of $166 million per year.

Our nationwide scan shows that electrification programs are still in their infancy, with most programs clustered in certain regions (e.g., California, Colorado, New York, and Massachusetts) that have explicit policy goals and targets for building electrification. Most programs in this study (90%) focused on space heating with air-source heat pumps. Water heating with heat pumps was also included in 71% of programs. Because our study was limited to programs that specifically incentivized fuel switching away from fossil fuels or all-electric new construction, this survey excluded many utility incentives for heat pumps replacing electric resistance, a pure energy efficiency upgrade, unless they are part of an electrification program that focuses on fossil fuel replacements. Some programs in our study offered tiered incentives based on the fuel being replaced, with higher incentives for fossil fuel conversions.

We observed a wide range of incentives. Rebates for space heating were frequently provided on the basis of unit capacity, ranging from $165 to $1,600 per ton, whereas other incentives (for water heating, cooking) were offered on a per-unit basis, ranging from $91 to $800 per unit. Only one program in our study (AEA LIWP) delivered incentives based on the total GHG impacts of electrification measures. This unique incentive structure allowed program administrators to strategically target the highest-impact measures when it comes to carbon reduction in buildings.

Data on energy and GHG impacts from electrification programs were relatively scarce, owing to the newness of many programs with inadequate time to go through a full evaluation, measurement, and verification process. This scarcity of data highlights the need for more evaluation studies of electrification programs in order to clearly quantify and publicize the climate benefits of building electrification. Moreover, more efforts are needed to help utilities align their programs with local carbon reduction goals and to track the actual outcomes.

Energy efficiency and weatherization should be paired with space- and water-heating retrofits whenever possible to reduce upfront cost and ongoing energy requirements for electric heating and cooling systems. Most program administrators (76%) acknowledged the importance of energy efficiency by combining electrification and energy efficiency measures, either by offering both in the same program or by referring customers to home energy audits and weatherization assistance. A quarter of the program implementers even required participants to take actions to improve their home efficiency before receiving the full incentives from the electrification program.

Low-income customers have additional barriers to accessing electrification for their homes, such as being unable to afford the upfront costs of conversion, a lack of access to financing, and an inability to control their built environment if they live in rental housing (market-rate renters face the same problem). Low-income homeowners are also at higher risk of bearing the brunt of damage caused by climate change–induced extreme weather events. Programs that were designed to reach this sector encountered much higher costs per participant due to upgrades often being provided at no cost, as well as the larger extent of improvements required for older homes and buildings. However, participants in income-qualified programs like DCSEU's Low Income Decarbonization Pilot cited substantial improvements to their indoor temperature, air quality, and comfort due to the conversion. More programs that provide specialized incentives for this sector are needed in order to deliver equitable decarbonization for marginalized groups and communities.

Integration of demand flexibility (through connected water heaters and thermostats) and renewable sources with electrification is an emerging area of interest. A small number of programs coupled electrification with other distributed energy resources such as rooftop and community solar, battery storage, and electric vehicle programs. As electrification continues to add more loads to the existing grid and changes energy use patterns (e.g., when peak time occurs), measures to manage peak load—particularly through using heat pump water heaters as a flexible load resource—are essential to scaling electrification to meet the needs of a changing grid, even if at present its impact is not being felt in many regions due to the small scale of building electrification efforts today.

The majority (78%) of these programs were funded all or in part through utility rates. In our examination of incentive and administrative costs, we found that total administrative costs were 34% of program budgets to date. On an annual basis, administrative costs were 49% of the total for the most recent year. Because so many programs were in the pilot phase, this indicates that new programs have a higher upfront administrative cost and lower ongoing administrative costs. In addition, certain types of programs such as whole-building retrofits required additional support from staff and contractors to manage participant experiences and ensure a smooth installation process. Effectively communicating with customers was critical to ensuring satisfaction and delivering high-quality installations.

Only a small number of programs emphasized the role of contractors and provided them with incentives and education to sell heat pumps and other electrification equipment. In interviews with program managers and subject matter experts, contractors were identified as key players and an underutilized resource in terms of scaling building electrification efforts.

To effectively scale building decarbonization, we recommend that policymakers, utilities, and program implementers expand upstream and midstream incentives for manufacturers, retailers, and installers to expand availability of equipment, reduce costs throughout the supply chain, and educate and empower contractors to deliver electrification measures to end users. Although these types of incentives (particularly manufacturer incentives) were infrequent in our study compared with end-user rebates, they address several major roadblocks in the electrification pipeline. Customers are likely to rely on contractors to communicate the value of home energy decisions. By providing training, certification, and incentives to contractors who prioritize heat pumps, water heating, and induction cooking measures, the building energy contracting workforce can become a vital partner in the effort to electrify every home and building in the United States.

State policies are a major driver of building electrification efforts. We found the most program spending and participation in states with clearly defined climate policies that prioritize electrification, such as California and New York. Additionally, some states still prohibit utilities from offering incentives for fuel switching or have enacted legislation that forbids the banning of new gas infrastructure. Planning for building electrification in climate policy and pushing back against policies that seek to further entrench our dependence on fossil fuels in buildings are necessary strategies to accelerate electrification and prepare for total decarbonization in every state.

Large opportunities remain for building electrification in the United States. The technologies that support the process are clean, efficient, and largely able to meet the needs of the American public without having to rely on burning fossil fuels for space heating, water heating, cooking, and other end uses. Given the urgency of addressing climate change, the potential for energy savings, and the improved quality of life (with exponential benefits for LMI and disadvantaged communities), building electrification should continue to be a priority for policymakers, utilities, program implementers, contractors, and customers. This research identifies key trends and lessons learned from past and current programs and practices to provide those key decision makers with the necessary tools to scale up programs and move the market away from fossil fuels. These lessons help show a pathway to broader understanding and acceptance of efficient electric technologies across the United States.

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Appendix A. Program Details

Table A1. End uses, source fuels, and target sectors

#	Program	End uses targeted	Source fuels for replacement	Target sector(s)
1	AEA LIWP	Space heating, water heating, cooking equipment, solar	No specific source fuel	Multifamily residential
2	AK Heat $mart	Space heating	Oil, propane, electric resistance	Single-family residential, multifamily residential, small commercial (100 kW demand or less)
3	APS Reserve Rewards	Water heating	No specific source fuel	Single-family residential
4	Avangrid Energize CT	Space heating, water heating	Natural gas, oil, propane	Single-family residential
5	BayREN Home+	Space heating, water heating, cooking equipment, solar	Natural gas, electric resistance	Single-family residential
6	BED Net Zero City	Space heating, water heating, EV charging	Natural gas, oil, propane	Single-family residential
7	City of Ashland	Space heating, water heating, cooking equipment	Natural gas	Single-family residential, multifamily residential, small commercial (100 kW demand or less)
8	ComEd Electric New Homes	Space heating, water heating, cooking equipment, solar	No specific source fuel	Single-family residential
9	Comfort365	Space heating, water heating,	No specific source fuel	Single-family residential, multifamily residential
10	DCSEU LIDP	Space heating, water heating, cooking equipment, solar	Natural gas, oil, propane	Single-family residential, multifamily residential
11	Efficiency VT	Space heating, water heating	Natural gas, oil, propane, wood, electric resistance	Single-family residential, multifamily residential, small commercial (100 kW demand or less), large commercial (over 100 kW demand)
12	EFG Hudson Valley HP	Space heating	Electric resistance, oil, propane, natural gas	Single-family residential
13	EFG MA Solar Access	Space heating, solar	Electric resistance, oil, propane, natural gas	Single-family residential
14	EFG Zero Energy Now	Space heating, water heating, solar	Natural gas, oil, propane, wood, electric resistance	Single-family residential

#	Program	End uses targeted	Source fuels for replacement	Target sector(s)
15	EMT HP Rebate	Space heating, water heating, EV charging	Oil, propane	Single-family residential
16	EWEB Smart Electrification	Space heating, water heating	Natural gas, oil, propane	Single-family residential
17	Holy Cross BE Rebates	Space heating, water heating, cooking equipment	Propane, natural gas, oil	Single-family residential
18	MA CEC ASHP Pilot	Space heating	Natural gas	Single-family residential
19	MA DOER Home MVP	Space heating, water heating	Natural gas, oil, propane	Single-family residential
20	Mass Save Fuel Optimization	Space heating, water heating	Electric resistance, oil, propane	Single-family residential, multifamily residential, small commercial (100 kW demand or less), large commercial (over 100 kW demand)
21	MN ASHP	Space heating	No specific source fuel	Single-family residential
22	MPE Electrify Everything	Space heating, EV charging, solar	No specific source fuel	Single-family residential, small commercial (100 kW demand or less)
23	NG RI HVAC	Space heating, water heating	Oil, propane	Single-family residential
24	NYS Clean Heat	Space heating, water heating	No specific source fuel	Single-family residential, multifamily residential, small commercial (100 kW demand or less), large commercial (over 100 kW demand)
25	NYSERDA HP Rebate	Space heating	No specific source fuel	Single-family residential, multifamily residential, small commercial (100 kW demand or less), large commercial (over 100 kW demand)
26	OPALCO Switch It Up!	Space heating, water heating, EV charging	No specific source fuel	Single-family residential, multifamily residential
27	Palo Alto HPWH	Water heating	Natural gas	Single-family residential, multifamily residential
28	PG&E/SCP AER	Space heating, water heating, cooking equipment	No specific source fuel	Single-family residential, multifamily residential
29	Renewable Juneau	Space heating	Oil, propane	Single-family residential

#	Program	End uses targeted	Source fuels for replacement	Target sector(s)
30	SCAQMD CLEANair	Space heating	Natural gas	Single-family residential, multifamily residential
31	SCE CLEAR	Space heating, water heating	Natural gas, oil, propane	Single-family residential
32	SCE Residential Upstream	Space heating, water heating	Natural gas	Single-family residential
33	SMUD Advanced Homes	Space heating, water heating	Natural gas, oil, propane	Single-family residential, multifamily residential
34	SMUD Commercial	Space heating, water heating, cooking equipment	Natural gas, propane	Small commercial (100 kW demand or less), large commercial (over 100 kW demand)
35	SMUD Home Appliance	Cooking equipment	Natural gas, propane	Single-family residential
36	SMUD Low Income	Space heating, water heating, cooking equipment	Natural gas, propane	Single-family residential
37	SMUD Multifamily	Space heating, water heating, cooking equipment	Natural gas, propane	Multifamily residential
38	SMUD New Homes	Space heating, water heating, cooking equipment	Natural gas, propane	Single-family residential, multifamily residential
39	Tri State Heat Pump	Space heating	No specific source fuel	Single-family residential, multifamily residential, small commercial (100 kW demand or less)
40	Tri State HPWH	Water heating	No specific source fuel	Single-family residential, multifamily residential, small commercial (100 kW demand or less)
41	TVA C&I	Space heating, cooking equipment, industrial forklifts	No specific source fuel	Small commercial (100 kW demand or less), large commercial (over 100 kW demand), other, industrial
42	WVPA Power Moves	Space heating, water heating	Natural gas, oil, propane	Single-family residential

Table A2. Program delivery strategies

#	Program	Incentive recipient	Delivery strategies	Notes on incentives beyond measures
1	AEA LIWP	End users	Audits, whole-home, performance-based	Home energy audits, community solar subscriptions, weatherization
2	AK Heat $mart	End users	n/d	n/d
3	APS Reserve Rewards	End users	Rebates	n/d
4	Avangrid Energize CT	End users	Rebates	n/d
5	BayREN Home+	End users	Rebates	n/d
6	BED Net Zero City	End users	Audits, rebates	n/d
7	City of Ashland	End users	n/d	n/d
8	ComEd Electric New Homes	Home builders	New builds	n/d
9	Comfort365	End users	n/d	$500 fuel-switching incentive per appliance up to $1,000 plus additional $500 if including solar
10	DCSEU LIDP	Multiple targets	Audits, whole-home	Electrical wiring and panel upgrades were included at each site.
11	Efficiency VT	End users	n/d	n/d
12	EFG Hudson Valley HP	Multiple targets	Rebates, manufacturer discounts, contractor discounts	Each customer received a free eGauge (and installation) to monitor their consumption and savings.
13	EFG MA Solar Access	Multiple targets	Manufacturer discounts, tax credits, rebates	Roof structural support and panel upgrades were provided for approximately 3 out of 49 projects.
14	EFG Zero Energy Now	End users	n/d	n/d
15	EMT HP Rebate	End users	End-user rebates	n/d
16	EWEB Smart Electrification	End users	End-user rebates, loans	n/d
17	Holy Cross BE Rebates	End users	n/d	n/d

#	Program	Incentive recipient	Delivery strategies	Notes on incentives beyond measures
18	MA CEC ASHP Pilot	End users	Audits, whole-home	n/d
19	MA DOER Home MVP	End users	Performance-based	n/d
20	Mass Save Fuel Optimization	Multiple targets	Workforce development, manufacturer discounts, education	n/d
21	MN ASHP	Multiple targets	Education, workforce, financing	Financing for home energy improvements
22	MPE Electrify Everything	End users	n/d	Smart thermostats
23	NG RI HVAC	End users	End-user rebates	n/d
24	NYS Clean Heat	Midstream installers	Audits, contractor rebates, workforce development, financing	Incentives for envelope improvements aimed at load reduction available through Empower (low income), Assisted Home Performance (moderate income), and Comfort Home (market rate)
25	NYSERDA HP Rebate	Midstream installers	Audits, contractor rebates, workforce development	n/d
26	OPALCO Switch It Up!	End users	Financing	n/d
27	Palo Alto HPWH	End users	Education, workforce	n/d
28	PG&E/SCP AER	Multiple targets	New builds, education	Prewiring of homes to be “electrification ready,” $5,000 incentive for onsite solar + battery or off-site community solar
29	Renewable Juneau	End users	Rebates, education, wiring	Installation and wiring
30	SCAQMD CLEANair	End users	Rebates	n/d
31	SCE CLEAR	Home builders	n/d	n/d
32	SCE Residential Upstream	Multiple targets	n/d	n/d
33	SMUD Advanced Homes	End users	n/d	n/d

#	Program	Incentive recipient	Delivery strategies	Notes on incentives beyond measures
34	SMUD Commercial	Home builders	n/d	n/d
35	SMUD Home Appliance	End users	n/d	n/d
36	SMUD Low Income	End users	n/d	n/d
37	SMUD Multifamily	Home builders	n/d	n/d
38	SMUD New Homes	Home builders	n/d	n/d
39	Tri State Heat Pump	Multiple targets	End-user rebates, installer rebates	n/d
40	Tri State HPWH	End users	n/d	n/d
41	TVA C&I	End users	End-user rebates	Wiring and electrical infrastructure upgrades for commercial kitchens; covers up to 50% of cost
42	WVPA Power Moves	End users	n/d	n/d

Table A3. Integration with weatherization, demand response, and other distributed energy resources

#	Program	Weatherization required?	Weatherization details	Demand response	Solar	Battery storage	EVs
1	AEA LIWP	Required	Program begins with a whole-home audit and proposes solutions including building shell improvements, conversions of heating systems, and distributed or community solar.		Yes		
2	AK Heat $mart	Encouraged	As part of the "Thermalize" program, contractor performs air sealing and attic and crawl space insulation at a discounted rate.				

#	Program	Weatherization required?	Weatherization details	Demand response	Solar	Battery storage	EVs
3	APS Reserve Rewards	No		Yes			
4	Avangrid Energize CT	Required	Required for displacing delivered fuels. Recommended for HES participants.				
5	BayREN Home+	Encouraged	The Home+ program rebates have both weatherization and electrification measures.		Yes		
6	BED Net Zero City	Encouraged	Dwellings using more than 50,000 Btus/heated square foot are offered Weatherization incentives of 33% for owner-occupied and 50% for rentals where tenants pays heating costs directly.	Yes		Yes	Yes
7	City of Ashland	Encouraged					
8	ComEd Electric New Homes	Required	Homes must integrate a holistic package of energy efficiency upgrades including ENERGY STAR appliances, weatherization, water conservation measures, and solar to exceed basic code requirements and achieve the DOE Zero Energy Ready certification.		Yes		
9	Comfort365	Encouraged	Incentives for insulation and air sealing, customer advising services				
10	DCSEU LIDP	Required	n/d		Yes		
11	Efficiency VT	Encouraged	Midstream programs make weatherization qualification very challenging.	Yes			
12	EFG Hudson Valley HP	Encouraged	Solar and weatherization were encouraged, but program focused on heat				

#	Program	Weatherization required?	Weatherization details	Demand response	Solar	Battery storage	EVs
			pump and monitoring to reach the target number of heat pump installations.				
13	EFG MA Solar Access	Encouraged	Encouraged but not required, due to funding limitations and the challenges with getting projects completed overall.		Yes		
14	EFG Zero Energy Now	Required	Must be a minimum of 10% reduction in air leakage.		Yes		
15	EMT HP Rebate	n/d	n/d			Yes	Yes
16	EWEB Smart Electrification	Encouraged	Financial barriers, but customers tend to weatherize without it being required, either at time heat pump installed or later.				
17	Holy Cross BE Rebates	No	n/d				
18	MA CEC ASHP Pilot	Encouraged	The whole-home pilot requires that customers have a home energy assessment and strongly encourages them to follow up on recommended measures.				
19	MA DOER Home MVP	Encouraged	Performance-based incentive encourages a combination of heat pumps and weatherization. There is an increased weatherization incentive when combined with heat pump electrification.				
20	Mass Save Fuel Optimization	Encouraged	In Massachusetts the program administrators do not require weatherization, but it is recommended.				
21	MN ASHP	No	n/d				

#	Program	Weatherization required?	Weatherization details	Demand response	Solar	Battery storage	EVs
22	MPE Electrify Everything	No	n/d	Yes	Yes		
23	NG RI HVAC	Required	Two separate tiers of incentives existed in 2019: Standard Rebate, which encouraged but did not require weatherization, and Enhanced Rebate ($1,000/ton), which required weatherization				
24	NYS Clean Heat	Encouraged	NYS Clean Program materials will promote weatherization to make homes and buildings "heat pump ready," which will include publicizing NYSERDA's Comfort Home Pilot. Expansion of weatherization programs offered in conjunction with heat pump programs will be explored as a potential program element to be added in the future.				
25	NYSERDA HP Rebate	Encouraged	Program manual highly recommends that site owners contact a home performance professional to assess and implement energy efficiency opportunities related to building envelope and HVAC distribution before, or in coordination with, installing a heat pump system, and refers to available incentives.				
26	OPALCO Switch It Up!	No	n/d				
27	Palo Alto HPWH	n/d	n/d				
28	PG&E/SCP AER	Required	To qualify for incentives, homes need to be built to	Yes	Yes		

#	Program	Weatherization required?	Weatherization details	Demand response	Solar	Battery storage	EVs
			20% above 2016 title 24 energy code, with high-performance walls and windows, efficient plumbing, ENERGY STAR appliances, and other efficiency measures.				
29	Renewable Juneau	Encouraged	On occasion, a lack of adequate weatherization can disqualify a home. The program aims to reduce utility costs for an applicant. not increase them.				
30	SCAQMD CLEANair	No	n/d				
31	SCE CLEAR	Encouraged	n/d				
32	SCE Residential Upstream	Encouraged	n/d				
33	SMUD Advanced Homes	Required	For low income only	Yes			
34	SMUD Commercial	n/d	n/d				
35	SMUD Home Appliance	n/d	n/d				
36	SMUD Low Income	n/d	n/d				
37	SMUD Multifamily	n/d	n/d				
38	SMUD New Homes	n/d	n/d				
39	Tri State Heat Pump	No	Expanded weatherization program in 2021. Working with agencies to do more heat pumps.				
40	Tri State HPWH	n/d	n/d				

#	Program	Weatherization required?	Weatherization details	Demand response	Solar	Battery storage	EVs
41	TVA C&I	No	n/d	Yes			
42	WVPA Power Moves	No	n/d	Yes			

Table A4. Funding sources and program spending

#	Program	Funding source	Annual incentive cost	Annual admin. cost	Annual budget	Total incentive cost	Total admin. cost	Total budget to date
1	AEA LIWP	Cap-and-trade program, low-income housing grants	n/d	n/d	$17,900,000	$33,252,173	$30,647,827	$63,900,000
2	AK Heat $mart	City and borough of Juneau grants and DOE grant	n/d	$140,000	$140,000	n/d	$300,000	$300,000
3	APS Reserve Rewards	Utility ratepayers	n/d	n/d	n/d	n/d	n/d	n/d
4	Avangrid Energize CT	Utility ratepayers, cap-and-trade funds	$10,676,893	n/d	$10,676,893	$16,523,241	n/d	$16,523,241
5	BayREN Home+	Utility ratepayers	$3,700,000	$5,000,000	$3,700,000	$5,000,000	$7,500,000	$12,500,000
6	BED Net Zero City	Utility ratepayers	$277,469	n/d	$277,469	$905,374	n/d	$905,374
7	City of Ashland	Oregon clean fuels program, Bonneville Power Administration	n/d	n/d	n/d	n/d	n/d	n/d
8	ComEd Electric New Homes	Utility ratepayers	n/d	n/d	n/d	n/d	n/d	n/d
9	Comfort365	Local tax on electricity usage	$45,000	$5,000	$45,000	$140,000	$35,000	$175,000
10	DCSEU LIDP	Utility ratepayers	$277,000	$69,000	$277,000	$277,000	$69,000	$346,000

#	Program	Funding source	Annual incentive cost	Annual admin. cost	Annual budget	Total incentive cost	Total admin. cost	Total budget to date
11	Efficiency VT	Utility ratepayers, cap-and-trade funds, forward capacity market bids from EE, distribution utility direct funding	$4,100,000	n/d	$4,100,000	$7,700,000	n/d	$7,700,000
12	EFG Hudson Valley HP	Utility ratepayers, competitive R&D grant from NYSERDA	n/d	n/d	n/d	$10,000	$386,900	$396,900
13	EFG MA Solar Access	Utility ratepayers, Mass Clean Energy Center, and DOER competitive grant	n/d	n/d	n/d	$224,000	$1,268,067	$1,492,067
14	EFG Zero Energy Now	Utility ratepayers, grants	$60,000	$104,641	$60,000	$350,000	$480,516	$830,516
15	EMT HP Rebate	Utility ratepayers, cap-and-trade funds, forward capacity revenue	n/d	n/d	n/d	n/d	n/d	$12,118,849
16	EWEB Smart Electrifica-tion	Utility ratepayers	n/d	n/d	$500,000	n/d	n/d	$1,000,000
17	Holy Cross BE Rebates	n/d	n/d	n/d	n/d	n/d	n/d	n/d
18	MA CEC ASHP Pilot	Utility ratepayers	n/d	n/d	$500,000	n/d	n/d	$500,000
19	MA DOER Home MVP	n/d	n/d	n/d	$1,333,333	n/d	n/d	$2,666,667

#	Program	Funding source	Annual incentive cost	Annual admin. cost	Annual budget	Total incentive cost	Total admin. cost	Total budget to date
20	Mass Save Fuel Optimization	Utility ratepayers	n/d	n/d	$9,705,000	n/d	n/d	$14,580,000
21	MN ASHP	Utility ratepayers	n/d	n/d	n/d	n/d	n/d	n/d
22	MPE Electrify Everything	Utility ratepayers, other, rebates from Tri-State Generation and Transmission Association	n/d	n/d	n/d	n/d	n/d	n/d
23	NG RI HVAC	Utility ratepayers	n/d	n/d	n/d	n/d	n/d	$190,000
24	NYS Clean Heat	Utility ratepayers	n/d	n/d	$36,600,000	n/d	n/d	$36,600,000
25	NYSERDA HP Rebate	Utility ratepayers	n/d	n/d	n/d	n/d	n/d	$22,800,000
26	OPALCO Switch It Up!	Utility ratepayers	n/d	n/d	n/d	n/d	n/d	n/d
27	Palo Alto HPWH	Utility ratepayers	$250,000	$50,000	$250,000	$353,500	$200,000	$553,500
28	PG&E/SCP AER	Utility ratepayers; BAAQMD and SCP cover costs for fuel-switching upgrades in all-electric homes.	n/d	n/d	n/d	n/d	n/d	n/d
29	Renewable Juneau	Carbon offset purchases, donations, grants	$85,000	$500	$85,000	$165,000	$2,500	$167,500
30	SCAQMD CLEANair	Air Quality Investment Fund (mitigation fees from manufacturers)	n/d	n/d	n/d	n/d	n/d	n/d

#	Program	Funding source	Annual incentive cost	Annual admin. cost	Annual budget	Total incentive cost	Total admin. cost	Total budget to date
31	SCE CLEAR	Utility ratepayers	n/d	n/d	$1,600,000	n/d	n/d	$2,025,000
32	SCE Residential Upstream	Utility ratepayers	n/d	n/d	$17,000,000	n/d	n/d	$17,000,000
33	SMUD Advanced Homes	Utility ratepayers, utility shareholders	$6,000,000	$1,700,000	$6,000,000	$16,600,000	$3,800,000	$20,400,000
34	SMUD Commercial	Utility ratepayers	$1,900,000	$800,000	$1,900,000	$2,100,000	$1,200,000	$3,300,000
35	SMUD Home Appliance	Utility ratepayers	$200,000	$200,000	$200,000	$300,000	$500,000	$800,000
36	SMUD Low Income	Utility ratepayers	$3,400,000	n/d	$3,400,000	$10,400,000	n/d	$10,400,000
37	SMUD Multifamily	Utility ratepayers	$800,000	$400,000	$800,000	$1,000,000	$1,600,000	$2,600,000
38	SMUD New Homes	Utility ratepayers	$2,900,000	$400,000	$2,900,000	$4,600,000	$1,600,000	$6,200,000
39	Tri State Heat Pump	Utility ratepayers	$790,000	n/d	$790,000	$2,452,417	n/d	$2,452,417
40	Tri State HPWH	Utility ratepayers	$15,400	n/d	$15,400	$46,520	n/d	$46,520
41	TVA C&I	Utility ratepayers	n/d	n/d	n/d	n/d	n/d	n/d
42	WVPA Power Moves	Utility ratepayers	$158,337	$47,501	$158,337	n/d	n/d	$158,337

Table A5. Participation, energy savings, and GHG impacts

#	Program	Participation to date (customers)	Annual energy savings (MMBtu)	Total energy savings (MMBtu)	Annual GHG savings (TCO_2e)	Total GHG savings (TCO_2e)
1	AEA LIWP	8,268	58,914	58,914	8,823	8,823
2	AK Heat $mart	600	n/d	n/d	n/d	n/d
5	APS Reserve Rewards	n/d	n/d	n/d	n/d	n/d
6	Avangrid Energize CT	n/d	n/d	n/d	n/d	n/d
9	BayREN Home+	329	2,432	2,432	83	83
10	BED Net Zero City	390	n/d	n/d	n/d	n/d
12	City of Ashland	n/d	n/d	n/d	n/d	n/d
13	ComEd Electric New Homes	n/d	n/d	n/d	n/d	n/d
14	Comfort365	180	n/d	2,852	n/d	667
16	DCSEU LIDP	10	n/d	n/d	n/d	n/d
19	Efficiency VT	n/d	n/d	n/d	n/d	n/d
23	EFG Hudson Valley HP	20	n/d	n/d	34	34
24	NYS Clean Heat	n/d	66,300	1,400,000	2,600	72,300
25	EFG MA Solar Access	49	n/d	n/d	498	1,192
27	EFG Zero Energy Now	45	1,210	1,210	175	175
28	EMT HP Rebate	n/d	n/d	n/d	n/d	n/d
29	EWEB Smart Electrification	268	n/d	n/d	n/d	n/d
30	Holy Cross BE Rebates	n/d	n/d	n/d	n/d	n/d
39	MA CEC ASHP Pilot	n/d	n/d	n/d	n/d	n/d
40	MA DOER Home MVP	250	n/d	n/d	n/d	n/d
41	Mass Save Fuel Optimization	n/d	n/d	n/d	n/d	n/d
42	MN ASHP	n/d	n/d	n/d	n/d	n/d

Appendix B. Data Collection Sheet

Electrification Program Information

ACEEE Beneficial Electrification Programs 2021

Instructions

This form is to collect data about your organization's current and prior electrification program offerings for use in a forthcoming research report on building electrification. It should take approximately 20 minutes to complete. Please enter information in the blue cells.

If your organization offers more than one program, please fill out the other sheets in this document for each separate program. Thank you!

1 **Program Administrator / Organization**

2 **Program Name**

3 **Technology Categories**

Please select from the drop-down menu below which categor(ies) of technology are offered in your program.

a Technology 1

b Technology 2 (if applicable)

c Technology 3 (if applicable)

d If "Other", which technologies?

4 **Eligible Fuels**

Please select from the drop-down menus below which fuels are eligible for conversion in this program.

a Fuel 1

b Fuel 2 (if applicable)

c Fuel 3 (if applicable)

d If "Other", which fuels?

5 **Customer Sectors**

Please select from the drop-down menus which customer sectors are targeted in your program. If you use different program definitions/thresholds than the ones listed in the dropdown, please note that in "other."

a Sector 1

b Sector 2 (if applicable)

c Sector 3 (if applicable)

d If "Other", which sector?

6 **Program Timeline**

Please select the range of years during which this program has operated. If your program year does not line up with a calenday year please specify the months (e.g, March 2020-February 2021).

a	Program Start Date (month/year)	
b	Program End Date (month/year)	
c	Is this program ongoing? (Yes/No)	

7 **Budget**

Please enter the annual budget (most recent year) and the total budget to date. "Incentive Cost" refers to the total amount paid to recipients of program incentives (rebates, etc). "Admin Cost" refers to the cost to administer the program, including staffing, marketing, evaluation, etc.

		Annual Budget		Total Budget to Date
a	Incentive Costs	$0	c	$0
b	Admin Costs (incl. marketing)	$0	d	$0

8 **Funding Source**

Please select from the drop-down menus to indicate where the source(s) of your program funding originate. ("Cap and Trade Funds" refers to revenues from a regional carbon allowance market, such as RGGI in the Northeast or California's Cap & Trade program)

a	Primary Funding Source	
b	Secondary Funding Source (if applicable)	
c	Additional Funding Source (if applicable)	
d	If "Other", what source of funding?	

8 **Electrification Measures**

Indicate the most frequently adopted measures, the amount of incentive in dollars per measure (a range of values is fine), and the total number of units that have received incentives since the program began.

		Measure Type	Incentive per Measure ($)	No. of Units
a	Measure #1			
b	Measure #2			
c	Measure #3			
d	Measure #4			
e	Measure #5			
f		Measure Type	Incentive per Measure ($)	No. of Units
g	If your program includes measures not included in the list above, please enter them here:			

9 **Incentive Pathways**

Where in the value chain (upstream manufacturers, midstream distributors/retailers, downstream end users) are these incentives delivered?

a Choose the option that fits your program.

b If "Multiple targets" or "Other", please describe your program's delivery pathway.

10 **Additional Incentives**

Does your program include any electrification incentives aside from measures, e.g., electrical wiring and panel upgrades?

a Please include 1) type of non-measure incentive, 2) the value of the incentive per customer (in dollars), and 3) total number of non-measure incentives provided to date

11 **Strategies for Overcoming Barriers**

Beyond the upfront cost of measures, what other market barriers are you seeing for electrification in your programs? (e.g. consumer behavior, logistical / infrastructure concerns, workforce, etc.)

a Please briefly describe any significant barriers that you have encountered.

Aside from direct financial incentives, what strategies are you using to address existing market barriers to electrifcation, if any? (e.g. workforce development, marketing information campaigns, etc.)

b Please briefly describe the strategies this program has employed to address market barriers.

12 **Is there a connection between weatherization and electrification measures in this program?**

Please select the option in the drop-down menu that describes the extent to which your program incorporates weatherization. (ie. building shell improvements, air sealing, etc.)

a Weatherization approach

b Please elaborate on how weatherization is incorporated into your electrification programs, if at all:

13 **Demand Response**

Does your program include any demand-response capabilities (ie. load-shifting, grid interactivity, load control)?

a yes/no

b If yes, please briefly describe how demand response is integrated with the program design, and any incentives that exist for customers to participate.

14 **Participation**

Please list the number of customers that received benefits from your program in the most recent program year and in total since the program began.

	Participants in Most Recent Year	Total Participants to Date
a # customers		

Does this program have a low-income component? If so, what percentage of those who receive incentives are income-qualified? (approximate)

b % of income-qualified participants %

15 **Reporting and Evaluation**

Please enter in the boxes below the reported or evaluated energy, peak demand, and/or greenhouse gas savings from this program, if they exist. For energy savings, please record in MMBTU. If there are measured peak demand savings on the gas system, please note that.

		Annual Savings (most recent 12 months)		***Total Savings since program began***
a	Energy Savings (MMBTU)		d	
b	Peak Demand Savings (kW)		e	
c	Greenhouse Gas Emissions Savings (TCO2e)		f	

Has this program been evaluated for cost-effectiveness, either in a projection for a program filing or in retrospective evaluation? If so, what type of cost-effectiveness test was used, and what were the findings?

g Plesae note the type of test (UCT, TRC, jurisdiction-specific test, etc.) and cost-effectiveness result

If there is a source for the above data, such as an evaluation report, internal report or DSM filing, please link here or send via email to ccohn@aceee.org

h

16 **Additional Details**

Please use this space below to provide any extra information about the electrification program not covered in the questions above.

a

17 **Follow Up**

Are you willing to be contacted for a follow-up conversation about your program's progress to date and lessons learned?

a Yes/No

Are you willing to have your program identified in this forthcoming report and in the peer-to-peer information exchange faciliated by ACEEE?

Choose an option

Are you interested in connecting peer-to-peer with other electrification program manager(s) to share resources and information? (e.g. one-on-one or in a working group)

b Yes/No

18 **Your Contact Information**

a Name

b Email

c Role / Job Title

Thank you! Your time and information is very valuable to us. The data you provide will be used in a forthcoming report by ACEEE analyzing progress to date and lessons learned from building electrification programs. The full data set from this research will be available to respondents on request. If your organization has any other electrification programs, please fill out the other sheets in this document for each separate program.

Completed Forms are requested back by Friday, July 30.

Mail completed form to:

Charlotte Cohn ccohn@aceee.org