# Radical Affordability for Residential Electrification

*Meghan Harwood, VEIC*
*Jake Marin, VEIC*

## ABSTRACT

Residential electrification is key to reducing building greenhouse gas emissions, but affordability remains a significant barrier to equitable, widespread adoption. Many programs try to address this through upfront incentives and equipment subsidies; however, these approaches alone often fail to sufficiently support financially vulnerable households and are unsustainable at the scale needed. This paper contends that affordability in accessible, scalable energy upgrade programs is not just about upfront cost, but a broader system design challenge shaped by delivery models, ownership, capital needs, and how financial and performance risks are allocated.

Drawing on program experience and emerging evidence, the paper explores why conventional, contractor-focused and equipment-centric models often fall short, especially for low- and moderate-income households, renters, manufactured housing residents, and those needing emergency replacements. It specifically examines low-cost, scalable program interventions and introduces a "radical affordability" framework built around four complementary pathways: innovative service delivery models, alternative ownership and financing structures, integrated decarbonization strategies, and expanded flexibility in eligible measures and technologies. These pathways open opportunities to reduce non-equipment costs, lower participation barriers, and shift risk away from households, while improving scalability and fiscal sustainability.

In conclusion, scaling equitable electrification requires programs to move beyond one-size-fits-all designs. By redesigning delivery—not just increasing subsidies—administrators, utilities, and policymakers can expand access, enhance resilience, and accelerate the clean energy transition.

## Introduction

Residential electrification programs often treat affordability as a first-cost problem, but the term itself lacks a consistent definition across clean energy, housing, public health, and social policy. While metrics such as energy burden—the percentage of household income spent on energy—and lifecycle cost-effectiveness are commonly referenced, these definitions often miss the many compounding factors that influence utility bill costs and energy upgrade accessibility for an individual household. Recent work also documents how definitions and metrics of energy affordability vary across institutions and contexts, reinforcing the lack of consensus (Drehobl et al. 2020; LBNL 2025). Common metrics such as energy burden and lifecycle cost-effectiveness do not fully capture household-specific conditions—such as medical equipment needs, household size and age composition, deferred maintenance, or climate-driven heating and cooling demand—that shape whether upgrades are practically affordable

Most energy upgrade programs focus on reducing upfront costs for low- and moderate-income (LMI) households, with some programs going so far as to cover the entire cost of equipment and installation. Many of these programs are also primarily designed for owner-occupied households, creating barriers for renters because of split incentives and limited authority to approve upgrades (Wisconsin Division of Energy Services 2012). Although no-cost appliance incentive programs can drive uptake and increase access for some income-constrained households that are easier to retrofit, they often prove unsustainable over time for programs, policymakers, and program funding sources. In plain terms, finite budgets are stretched as early projects serve the easiest homes first and later projects often require more costly enabling work, while administrative systems and contractor networks can struggle to keep pace. Over time, these dynamics can also weaken ratepayer and political support if per-project costs rise and programs appear harder to sustain at scale.

Additionally, higher-incentive allocations for income qualified or equity-focused programs are often criticized for driving up costs for taxpayers or ratepayers. This tension underscores the limitations of current models, and the need for fundamentally new approaches that reduce friction and drive down non-appliance costs as well, making residential electrification scalable and truly affordable. Non-appliance costs include additional “hard” costs (such as electrical upgrades, relocation costs, upgrading ductwork) as well as “soft” costs (such as installation labor, permitting timelines, program marketing and outreach) (Less et al 2021).

To move beyond the prevailing focus on first-cost reduction, it is essential to rethink the entire system, shifting our perspective from affordability as simply an equipment-price issue to understanding it as a broader system-design challenge. Instead of concentrating solely on lowering the prices of heat pumps or other electrification technologies, the objective must be to **redesign how solutions are delivered, how capital is structured, and how risk is distributed, and center individual human experiences and comfort in their homes**—especially for LMI households. By designing solutions for these interconnected elements, we can unlock widespread adoption and ensure that the benefits of electrification are accessible to all, rather than just those with the means to contribute upfront capital or absorb financial risks.

This paper focuses specifically on alternatives to conventional electrification upgrade delivery models. While this paper primarily centers on affordability of electrification, it does not delve into other valuable aspects such as procedural equity in program design, elevated household comfort, and several additional important considerations. Today, contractor-centric installations dominate the market, resulting in high labor costs and limited flexibility. Furthermore, the current system places the burden of upfront capital investment and the risk of performance variability almost entirely on households. These persistent affordability barriers not only slow the adoption of electrification but also make selecting an electric solution during emergency replacements—such as when a heating system fails in the middle of winter—more difficult for those who need the support most.

This paper examines four distinct innovative pathways for affordable, scalable electrification programs—Innovative Service Delivery, Alternative Ownership Models, Integrated Decarbonization, and Measure Flexibility. Each of these pathways is explored in detail, with specific program recommendations. Before presenting these strategies, it first explains why current approaches fall short and identifies the drivers of unaffordability that program design must address.

## Background

### Why Current Programs Fall Short

Current residential electrification programs have improved access, but most still rely on rebates, incentives, or no-cost offers that primarily reduce upfront equipment and installation costs. These approaches can increase uptake among income-constrained households, but they often work best for easier-to-retrofit homes and can be difficult to sustain at scale. Higher incentive allocations, particularly in equity-focused or income-qualified programs, are frequently scrutinized for increasing costs for taxpayers or ratepayers. This tension highlights the shortcomings of prevailing models, which struggle to balance affordability, equity, and long-term viability (Drehobl et al. 2020).

Underlying these challenges are structural issues that current programs rarely address. Contractor bottlenecks drive up labor costs and delay installations, making it difficult for programs to meet demand efficiently. Strict technology requirements and limited site-specific flexibility restrict the ability to tailor solutions, leaving many households unserved. Moreover, most programs overlook enabling costs—such as repairs, remediation, weatherization, permitting, and electrical upgrades—that can add substantial burdens for households facing deferred maintenance or limited financial capacity. Weatherization and electrification efforts are also frequently delayed by deferrals tied to unresolved health and safety or major repair needs (ACEEE 2025b).

A further concern is the heavy capital and risk exposure placed on individual households. Conventional models require homeowners to contribute upfront capital and bear the uncertainty of future performance or bill volatility. In emergency replacement scenarios, where a heating system fails suddenly, the complexity and expense of an electric retrofit can be prohibitive, particularly when time and resources are most limited. Collectively, these factors impede widespread adoption, revealing that while existing programs provide meaningful help, they do not fundamentally solve the challenges of affordability or scalability. Addressing these persistent obstacles will require a systemic rethinking of delivery models, rate design, capital structuring, and risk allocation, laying the foundation for truly accessible and scalable residential electrification (ACEEE 2025a).

Recent research further suggests that traditional affordability metrics often fail to capture household exposure to financial risk in a rapidly changing grid, particularly as electrification intersects with rising electricity prices, new rate structures, and climate-driven load growth (LBNL 2025). What these metrics often miss is whether a household can reliably absorb month-to-month cost swings, avoid arrearages or disconnection risk, and still meet other essential expenses such as food, transportation, or medical needs. Even if average annual costs appear manageable, short periods of higher bills can destabilize already fragile budgets. Program design should therefore account not only for average costs or modeled savings, but also for financial risk exposure and the household's practical ability to pay over time.

**Drivers of Unaffordability**

**Installation barriers and cost pressures.** Costs associated with installation (aka "first costs") are a major contributor to affordability challenges. Programs often focus on the "incremental cost" of a more efficient over a baseline piece of equipment. Here, "incremental cost" means the difference in upfront purchase and installation cost between the efficient electric option and the conventional baseline option, not the full set of enabling or downstream costs. However, in addition to the price tag of the equipment itself, homeowners face other installation-related expenses such as high (and rising) costs of labor and preparing both their own electrical system and the surrounding grid for upgrades. Emergency replacements exacerbate these challenges. Emergency fees and accelerated labor costs can send bills soaring.

**Ongoing bill uncertainty.** Even after a heat pump is installed, uncertainty remains about whether it will truly lower a household's energy bills. This ambiguity can be paralyzing and makes the transition feel risky. Small increases in monthly costs can have an outsize impact on already tight household budgets. Underlying this challenge is the reality that, in many regions, natural gas remains relatively cheap while electric rates continue to climb. That means a family hoping to save money with a heat pump may instead face higher bills, especially if they rely on electric heating or cooling during expensive peak periods, or if rate structures are confusing or poorly communicated. This uncertainty is often exacerbated by evolving electricity rate designs—including time-of-use and demand-based rates—which can unintentionally increase bill volatility for newly electrified households if not paired with enabling technologies and clear customer education (NEEP 2025). This unpredictability undermines confidence in electrification and can prevent those who would benefit most from making the switch.

**Performance risk exposure.** Too often, current models place the entire weight of the real cost and risk of electrification on the homeowner—requiring them to invest upfront and accept uncertainty of future energy usage and system performance. For example, homeowners must pay for new equipment, specialized labor, and permits, and are responsible for preparing their electrical systems for upgrades. If a system fails unexpectedly or without prior planning, they may face emergency replacement costs, higher labor fees, and other penalties. Once installed, homeowners are exposed to unpredictable energy bills, which can fluctuate based on rate structures, seasonal usage, or peak pricing. If the system underperforms or electric rates rise, they may end up paying more than anticipated. These risks are especially acute for LMI customers, who often lack the financial cushion to absorb surprise expenses or higher monthly bills. For LMI households, even small increases in energy costs or unexpected repair bills can strain tight budgets, making electrification feel out of reach and potentially destabilizing.

**Deployment friction and accessibility.** Electrification is often obstructed by bottlenecks and logistical barriers. Renters, in particular, struggle to benefit from upgrades they cannot authorize or own, reflecting a classic split-incentive problem in which landlords and tenants do not capture the same costs and benefits (Wisconsin Division of Energy Services 2012). In addition, the permitting process itself can be complex and time-consuming, requiring homeowners to navigate a maze of local codes and approvals before work can even begin. Finding a reputable contractor with heat pump experience adds another layer of difficulty, as homeowners must compare qualifications, check references, and secure competitive bids to ensure quality work. Coordinating schedules between multiple contractors—such as electricians, HVAC specialists, and inspectors—can further prolong the project and introduce additional stress. On top of these logistical hurdles, accessing funding often means applying to complicated incentive programs, sometimes requiring homeowners to combine (or "stack") multiple sources of financial support. This process can be overwhelming, involving extensive paperwork, eligibility checks, and follow-up communications, which can discourage participation and delay much-needed upgrades for those who stand to benefit most.

**Deferred maintenance and retrofit challenges.** Aging wiring, outdated panels, or hazards like mold must often be addressed before any electrification can take place, with no guaranteed funding to help cover those costs. A family whose home requires extensive remediation may find the cost of electrifying simply out of reach. Without dedicated resources for these foundational fixes, many homes remain locked out of electrification benefits (ACEEE 2025b).

## Program Strategies – Making Electrification Truly Affordable

### Innovative Service Delivery Approaches

Advancing the affordability and accessibility of residential electrification requires a departure from traditional, contractor-centric program structures. Program administrators must adopt innovative, customer-oriented models that lower financial and operational barriers, directly engage households, and adapt program delivery to the realities of the retrofit journey. By rethinking installation roles and leveraging alternative service pathways, electrification initiatives can reduce costs, expand participation, and enhance program effectiveness. The following sections examine emerging strategies that collectively address these objectives.

**DIY / guided installation**. Research across states has shown that between 25 to over 50 percent of households are taking a do-it-yourself (DIY) approach to replacing water heaters in their homes (Harwood et al. 2025). The prevalence of this approach presents both a challenge and opportunity for policymakers and program administrators. Many of these DIY installers are unable to participate in traditional rebate and incentive programs, where use of a pre-approved contractor network or proof of a professional installation is required. As a result, they may be less likely to purchase a HPWH without being able to take advantage of an incentive – exacerbated by potential lack of familiarity with heat pump technology, and the increased complexity of a HPWH installation. However, these DIY installers also present an opportunity in the form of an additional installer "workforce" due to the much lower costs of a non-professional install (DIY or assisted by a General Contractor or non-licensed plumbing contractor). Finally, while many DIY installers choose to go the non-professional route for cost saving reasons – expediency is another commonly cited motivator. This is particularly prevalent in rural areas, where it can take a long time to get a licensed contractor who has HPWH experience out to a site (Harwood et al. 2025).

Assessing data from California's TECH Clean California program demonstrated that homeowners achieved an average of $3,776 in savings by pursuing a DIY path for a 240V HPWH installation compared to TECH Clean California contractor-led installations, and, for a 120V project, saw an average of $1,169 in savings. These figures reflect upfront installed-cost differences observed at the time of installation, not lifetime operating savings (Harwood et al. 2025). Those numbers represent 30-60% reduction in installed costs (Harwood et al. 2025).

While DIY pathways should not be encouraged in every instance – such as for particularly complex installations where electrical upsizing or panel upgrades is needed, or the HPWH is located in a space-constrained indoor closet – the increasing prevalence of DIY-friendly products (e.g., window HPs, 120 V HPWH, digital QA tools) can enable high-quality, low-cost, low-skill installs. Ideally, a program provides incentives available to DIY installers that is contingent on some sort of virtual and streamlined quality assurance process to minimize poor installations. Elements of the following recommendations are informed by Harwood et al. (2025), with additional items reflecting author synthesis. DIY pathways and installers can be supported by programs through:

- Targeted education around the benefits of electrification technologies direct-to-homeowners;
- Support concierge-like services that support homeowners directly in mapping their decarbonization pathways, such as volunteer and community-based organizations (CBO's) led efforts (AIE 2026);
- Continued investment in and support for DIY-friendly products (including window HP and 120V HPWH) (Harwood et al. 2025);
- Making instant rebates and point-of-sale zero- or low-cost financing available;
- Create tool rental libraries for pieces of equipment that are expensive and most households aren't likely to own – such as a dolly for transporting a water heater in and out of a home, or a Pro Press Tool if it is being used on copper pipes and fittings;
- Investing in streamlined, clear, and no-cost permitting pathways, including enabling quality assurance through remote/photo-based verification and paid post-install inspections (Harwood et al. 2025).

**Networked or bundled decarbonization projects.** Decarbonizing buildings at scale requires new approaches that reduce costs, streamline implementation, and expand equitable access. One promising strategy is to "bundle" or network geographically proximate projects—such as a neighborhood, a mobile home park, or a single street—so that multiple households or buildings move through electrification or retrofit upgrades together. By working in clusters rather than individual, stand-alone projects, programs can unlock cost efficiencies, accelerate deployment, and strengthen community engagement.

Bundled approaches take several forms. Zonal electrification initiatives aim to fully electrify an entire defined area, enabling utilities to decommission segments of gas infrastructure entirely and reinvest avoided pipeline maintenance costs. Other models coordinate similarly scoped projects across neighborhoods, HOAs, or manufactured housing communities, allowing entire groups of customers to pursue heat pump installations or other retrofits simultaneously. Thermal Energy Networks (TENs) expand this concept further: buildings within a shared geographic area are connected to a common underground thermal loop served by geothermal boreholes, wastewater heat, or other sources. Each building uses a ground-source heat pump, but the shared loop allows them to exchange heating and cooling, increasing efficiency and lowering long-term costs (VCTN 2025). Similar place-based and community-led electrification models—emphasizing coordinated planning, bulk procurement, and trusted local partnerships—have been documented in municipal and community-based organization collaborations across the United States (RMI 2024).

The expected benefits of bundling are significant. Bulk procurement and group-buying models can reduce equipment costs—studies show heat pump bulk purchases can lower prices by 3–20% (TAF 2023), and some self-organized residential groups are seeing reductions of around 7% in equipment costs (Island Institute 2025). Contractors can price more competitively when they bid on multi-home scopes of work, and programs can manage budgets at a portfolio level, balancing higher-cost homes with lower-cost ones. This flexibility to manage toward a portfolio average is especially important for historically underserved households that often face deferred maintenance or repair barriers that would exceed traditional program caps if evaluated in isolation. Bundled approaches also create social momentum. Community-led outreach, peer effects, and trusted neighborhood "champions" have proven highly effective in spreading awareness and motivating participation in clean energy programs. When groups of neighbors make decisions together—supported by local organizations, capacity grants, and tailored education—adoption becomes easier, more inclusive, and better aligned with community needs.

To realize these benefits, programs should intentionally design pathways for bulk purchasing, standardize procurement of best-fit technologies, and provide technical assistance for communities that want to self-organize. Cost-containment strategies should blend "bottom-up" mechanisms that ensure fair labor standards with "top-down" expectations that guard against price inflation. Finally, program administrators should be empowered to manage a portfolio-wide average project cost so that higher-need homes can be served alongside more straightforward ones, expanding access while maintaining fiscal responsibility.

Bundled decarbonization approaches offer a practical, community-centered, and cost-efficient path toward scaled, equitable electrification. Because TENs are generally owned and operated by a third-party, they also incorporate another concept described below, leveraging third-party ownership models.

**Financing and Ownership Models**

An additional way of thinking innovatively and creatively about the affordability of electrification is looking at who owns or finances upgrades, with a goal of moving capital off household balance sheets altogether. Opportunities to rethink this include Tariffed On-Bill Finance – or Inclusive Utility Investment (IUI) – where upgrades are financed with no-upfront-cost as a portion of (and dependent upon) customer bill savings; third-party ownership models, such as subscription HVAC approaches; and loaner programs for certain permanent or interim equipment, such as portable induction hobs or plug-in 120V heat pump solutions. These solutions are increasingly being piloted to minimize financial burdens on customers. Tariffed on-bill and IUI structures can be particularly important for renters because the charge is tied to the meter rather than an individual occupant, allowing investments to remain in place even as tenants change. When paired with strong consumer protections, these structures can also reduce split-incentive barriers by creating a mechanism for repayment that does not depend on a single tenant financing an upgrade they may not control for long.

Multiple IUI programs exist and have been implemented, providing concrete examples that range from programs run by rural electric cooperatives, to community choice aggregators, to larger investor-owned utilities. For IUI frameworks, challenges include ensuring adequate consumer protections and bill savings such that a portion of those savings can be allocated to paying for the upgrade, which is not always a simple guarantee when it comes to electrification (depending on climate zone, rate structures, equipment type, and more). For third-party ownership and loaner models, there are challenges related to trust building, equipment maintenance and warranties, and more that need to be considered. Federal guidance and implementation resources for Inclusive Utility Investment frameworks underscore the importance of consumer protections, transparent billing, and administrative oversight to ensure these models deliver durable affordability outcomes (ENERGY STAR 2025).

Opportunities presented by these models include that they might be more accessible for renters who don't have autonomy over their equipment but may pay their utility bills directly. With IUI, if set up with adequate consumer protections, program administrators are incentivized to oversee quality and high-performing installations, as performance and bill volatility risk shifts toward utility/third-party asset owners rather than the consumer. Third-party ownership models are also interesting for retrofits that might be high-upfront-cost but yield significant energy savings, such as geothermal systems or thermal energy networks (TENs). For ground-source heat pump systems in particular, research indicates that third-party ownership of the ground loop can significantly improve long-term economics by spreading capital costs across multiple customers while ensuring consistent maintenance and performance (IGSHPA 2025). Loaner models can also be a neat solution to deploy in cases of emergency replacement of existing fossil fuel equipment, where program administrators might want to deploy a temporary unit before a full retrofit is possible, or where customers might want to test an appliance before committing to it (such as an induction stovetop).

All three scenarios should be considered as creative avenues for supporting decarbonization retrofits, in parallel to other program investments or even as their own stand-alone initiatives. Policymakers and program administrators should support IUI pilots and programs, with a particular focus on customers likely to see bill savings or to support high-efficiency but high-cost retrofits (such as geothermal or ground-source heat pumps). Additionally, third-party ownership models and loaner programs should be piloted and tested in conjunction with programs, in particular to support challenging emergency replacement scenarios. All three innovations in ownership models should be paired with robust community engagement to ensure adequate consumer protection and trust building.

**Integrated Decarbonization as a Program Strategy**

Integrated decarbonization is an ambitious programmatic approach that systematically combines multiple energy interventions—such as electrification, efficiency upgrades, and distributed renewable generation—within a single project or customer touchpoint. Rather than deploying discrete measures in isolation, integrated decarbonization leverages the synergistic effects of simultaneous implementation to amplify greenhouse gas reductions, drive deeper cost savings, and accelerate equitable market transformation. However, it is essential to be strategic in how these programs are implemented, since expanding the scope can make projects more disruptive and challenging to execute. Thoughtful planning and sequencing are needed to minimize inconvenience for participants and ensure that the benefits outweigh any logistical complexities. The strategy's core value lies in its capacity to transcend incrementalism: by bundling solutions, programs can optimize system performance, streamline customer experience, and unlock financing innovations that lower barriers for hard-to-reach populations.

**Comprehensive weatherization + electrification + rooftop solar offerings.** One of the most impactful forms of integrated decarbonization is to combine weatherization with electrification to enhance energy savings and bill impact outcomes from electrification. This can take the form of coordinated weatherization and electrification programs, where customers are cross-referred and, ideally, the two funding streams can layer to support a singular and coordinated offering and contractor service to a customer. An example of this includes programs such as the Efficiency Vermont Weatherization Assistance Program referral into low-income fuel switching offerings. Additionally, combining rooftop solar installations or community solar program enrollment with electrification measures such as high-efficiency heat pumps and heat pump water heaters (HPWH). By incorporating battery storage into this bundled approach, households can optimize when power is drawn from the grid versus when it is supplied by their own stored solar energy. This strategy leverages clean, fixed-price solar generation to offset on-site electricity demand, enables direct powering of electrified end uses with renewable energy, and provides greater flexibility to manage utility rates and peak demand.

The approach of pairing electrification measures with weatherization investments and rooftop solar yields three major benefits: it significantly lowers household energy expenses, insulates participants from utility rate volatility, and maximizes emissions reductions by ensuring that households are high-performing and that energy-consuming appliances are powered by renewables. This bundled strategy is especially transformative for manufactured housing communities, rural customers facing high utility rates, and homes with greater thermal loads, where incremental electrification may be insufficient to achieving household bill savings.

Program designers should prioritize making these weatherization-electrification and solar-electrification streamlined offerings accessible to a wider range of households. Policymakers can play a critical role here, drawing learnings from programs such as the New York State Energy Research and Development Authority Clean Energy Initiative (CEI), a collaboration between NYSERDA and the New York State Homes and Community Renewal, and the New York City Resilient & Equitable Decarbonization Initiative (REDi), to stack funding in a manner that is streamlined for end users. To avoid driving up investment costs, adopting innovative financing models like third-party solar ownership, green bank-supported loans, or Inclusive Utility Investment (IUI) frameworks, all of which shift upfront costs away from household budgets. These mechanisms not only improve affordability but also expand eligibility to renters and moderate-income families, thereby accelerating residential decarbonization and democratizing access to clean energy solutions. Implementing these approaches at scale will require coordination across federal, state, utility regulatory, and local permitting contexts, even when the program design itself is straightforward.

**High-Performance Manufactured Housing (HPMH).** High-performance manufactured housing (HPMH) represents a transformative approach to residential decarbonization. By integrating advanced building envelopes including factory-installed super-insulation, air sealing, and all-electric systems, HPMH significantly reduces thermal loads, allowing for the use of right-sized, lower-cost heat pump equipment. This results in an affordable, comfortable living platform that can be paired with rooftop solar to further reduce energy costs and emissions. Unlike traditional HUD-code mobile homes, HPMH aims to overcome legacy issues such as disproportionate energy burdens and poor indoor environmental quality, positioning manufactured housing at the forefront of the clean energy transition.

HPMH offers a scalable, long-term alternative to legacy manufactured homes, addressing inequities in affordability and indoor environmental quality. These homes are constructed to appreciate in value, in contrast to traditional mobile homes that often depreciate and saddle owners with high utility bills. Enhanced durability and superior building standards deliver lower energy expenses and improved living conditions for residents. The combination of super-insulated, all-electric homes with rooftop solar amplifies energy savings and emissions reductions, while also boosting resilience and comfort for homeowners. This shift in value perception encourages a broader adoption of HPMH, making manufactured housing a leader in clean energy solutions.

Program administrators should prioritize the adoption of high-performance manufactured housing as a strategic imperative for market transformation. This can include supporting initiatives like those pioneered by Efficiency Vermont, which have demonstrated the effectiveness of targeted interventions in advancing factory-built, super-insulated, all-electric homes. Innovative financing approaches can expand access, such as through green bank loans and inclusive utility investments, to remove upfront cost barriers for moderate-income families and renters. Additionally, programs can promote pairing HPMH with rooftop solar systems to maximize energy savings and affordability. By doing so, stakeholders can address legacy inequities, deliver enduring value to consumers and the grid, and elevate manufactured housing as a viable, long-term solution in the clean energy transition.

**Measure Flexibility**

Measure flexibility refers to the willingness of energy programs to expand beyond conventional, prescriptive standards in their selection of energy-saving measures. Rather than adhering strictly to only the most efficient or traditionally favored technologies, measure flexibility encourages the thoughtful inclusion of solutions that might typically be overlooked due to perceived lower efficiency or departures from industry norms. This approach recognizes that broadening the range of eligible measures—such as considering sub-premium heat pump models in addition to ultra-premium options—can overcome affordability barriers and more effectively meet the diverse needs of households.

**Expanding access to heat pumps via sub-premium equipment inclusion.** To accelerate the adoption of heat pumps and advance residential decarbonization, program design should intentionally support and promote the inclusion of sub-premium heat pump models alongside ultra-premium options. This approach directly addresses affordability challenges—particularly for moderate- and low-income households—by broadening eligibility and lowering barriers to participation in electrification initiatives. By permitting a wider range of qualifying equipment, more households who might be cost-constrained can access the benefits of clean heating and cooling technologies.

Allowing sub-premium heat pumps as eligible program measures yields several important outcomes. First, it enables broader participation, especially among renters, manufactured housing residents, and those with limited capital, by making electrification upgrades more affordable. Second, while ultra-premium models provide maximum efficiency and lowest operating costs, sub-premium units still deliver significant emissions reductions and operational cost savings compared to fossil fuel heating, albeit at a slightly lower efficiency. Lastly, this flexibility supports fuel-switching, increases program decarbonization impact, and advances energy equity, even if not every installation achieves peak efficiency. Field and laboratory research on cold climate, multi-stage air source heat pumps demonstrate that even mid-tier systems can deliver reliable heating performance across a wide range of cold weather conditions, supporting their inclusion as viable electrification options (Shen et al. 2024).

Table 1: Ultra-Premium vs. Sub-Premium Heat Pumps

| Feature | Ultra-Premium Model | Sub-Premium Model |
|---|---|---|
| Heating Efficiency (HSPF2) | 13.3 | 8.5 |
| Cooling Efficiency (SEER2) | 26 | 18 |
| Cold-Climate Capability | Rated to -13F | Rated to -5°F |
| Voltage | 240V / Professional install | 115V / DIY possible |
| Price (Equipment Only) | ~$3,000 | ~$800 |

| | | |
|---|---|---|
| AHRI-Listed | Yes | Yes |

Lifecycle Cost Analysis:

- Ultra-Premium Heat Pumps: Higher upfront equipment and installation costs (e.g., ~$3,000 for equipment alone) but deliver superior heating efficiency (HSPF2 up to 13.3), resulting in lower operational costs over the system's lifetime. These units are especially cost-effective for homes with high annual heating loads or where energy prices are high and stable.
- Sub-Premium Heat Pumps: Much lower upfront cost (under $800), with good but not top-tier heating efficiency (HSPF2 around 8.5). Operational costs are higher per unit of heat delivered compared to ultra-premium models, but the lower initial investment reduces financial hurdles and makes heat pump adoption feasible for more households.

Assuming 20 MMBTU of heat generation per year, the more efficient unit will use about 1,500 kWh, while the less efficient unit will use 2,350 kWh. At the national average electricity rate of $0.1299/kWh, this is roughly $110/year difference in operating costs. This equates to a 20-year payback period for the equipment cost difference—before factoring in installation labor, which can further extend the gap. Homes with higher annual usage or higher electricity rates would see a shorter payback period, but under many circumstances, sub-premium units present a more accessible path to electrification.

Program eligibility should be broad, allowing sub-premium heat pumps to qualify for incentives and financing—crucial for affordability in LMI households, manufactured housing, and rentals. This expands program reach and boosts decarbonization, even if not all installations are top-tier efficiency. Support for sub-premium heat pumps should include clear, accessible consumer education on operating costs and model selection, tailored to local climate and energy prices, so households can make informed, budget-friendly choices. The rise of 115V plug-in models enables DIY installation, further reducing up-front costs and increasing access for renters and manufactured home residents. Ultra-premium heat pumps are best for high heating needs, high electricity costs, or long-term residents who can realize operational savings. Sub-premium models are better where initial cost is the main barrier, heating loads are moderate, or occupants may move before premium savings accrue. A flexible, tiered program approach balances lifecycle cost efficiency with immediate affordability, enabling more households to participate in the clean energy transition.

**Strategic electric resistance.** Electric resistance heating paired with thermal storage provides a pragmatic and inclusive pathway for building electrification, particularly for households with limited access to capital. Deploying technologies such as ceramic brick storage heaters, water-based thermal tanks, and phase change materials allows for cost-effective heating approaches that mitigate the need for significant initial expenditure and circumvent expensive upgrades to distribution infrastructure.

The adoption of electric resistance systems with thermal storage can increase the affordability of electrification, as these technologies typically have lower equipment and installation expenses compared to premium heat pumps, broadening their accessibility.

Operational efficiency is improved through strategies that charge storage during periods of low-cost and clean electricity, enabled by time-of-use rates and targeted rate structures, resulting in reduced annual heating costs and strengthened grid reliability. These systems function as flexible grid assets, storing heat when renewable generation is plentiful and discharging during peak demand or periods of higher grid emissions, thereby enhancing energy use efficiency and reducing overall grid impact. Furthermore, their compatibility with existing distribution systems eliminates the necessity for extensive infrastructure upgrades, simplifying installation and minimizing complexity.

To maximize the benefits of these solutions, incentive and financing programs should explicitly include electric resistance heating with thermal storage, ensuring affordability for low- and moderate-income households, manufactured housing, and rental properties. Comprehensive consumer education is essential, offering tailored guidance on operational costs, technology selection, and rate optimization based on local climate and energy prices to empower informed decision-making. Policymakers should advance supportive rate designs—such as time-of-use and heat pump-specific structures—to drive cost savings and grid benefits. Promoting a diversity of storage solutions, including ceramic brick, water, and phase change materials, will accommodate varying installation constraints and performance requirements. Finally, prioritizing the inherent compatibility with standard distribution infrastructure will further lower barriers to electrification, enabling broader and more equitable adoption.

## Discussion

It is important to emphasize the levers related to affordability that are not captured in this paper, but that are equally crucial for enhancing equitable outcomes. These include utility regulatory levers such as equitable rate design to improve electrification economics and support TOU structures, and gas decommissioning planning to support investments from avoided gas infrastructure into decarbonization. It also includes other policy levers, such as tax credits (with upfront direct pay options), permitting streamlining, investment in quality and high-road workforce, and more.

Additionally, adjacent issues warrant further consideration to boost program effectiveness and equity. For example, strategies for addressing split incentives in rental properties, innovative financing mechanisms for low- and moderate-income households, and targeted outreach to underserved communities could significantly increase accessibility and participation. Codify DIY-safe product requirements (pre-charged lines, quick connects, 120V options), panel-avoidance technologies, solar-ready and HP-ready manufactured housing requirements, and digital QA protocols.

Opportunities for further research include evaluating the long-term impacts of decentralized electrification solutions on grid resilience, exploring behavioral drivers of heat pump adoption, and assessing how emerging technologies—such as advanced thermal storage or adaptive rate structures—can be integrated into affordability-focused programs. Examining the intersection of electrification with community health, landlord-tenant dynamics, and local job creation could also yield valuable insights for future policy development. These areas offer promising pathways to deepen affordability and equity in the clean energy transition.

## Conclusion

### Framework Shift Toward System Design Thinking

Residential electrification stands as a critical pillar in our pursuit of economy-wide decarbonization, yet persistent affordability challenges threaten to limit its impact and reach. This paper has illuminated that while reducing upfront equipment costs is necessary, it is not the whole solution. By framing affordability solely as a matter of subsidies, traditional program models often fail to address deeper, systemic barriers—those rooted in delivery methods, ownership structures, financial requirements, and the allocation of risk. The result is programs that struggle to reach the households most in need, lack resilience, and fall short of delivering the broad, equitable transformation essential for meaningful climate progress.

The framework offered here invites a shift in perspective: viewing affordability as a system-design opportunity, not merely a budgetary hurdle. By exploring innovative service delivery, alternative ownership and financing, integrated decarbonization, and flexible program measures, this paper highlights actionable strategies that cut costs, lower participation barriers, and protect households from undue risk. These approaches yield their greatest power when combined—when program administrators adopt a portfolio mindset, balancing diverse projects and tailoring solutions to match real household needs. This integrated vision replaces one-size-fits-all models with adaptive systems, welcoming renters, manufactured home residents, rural households, and those facing urgent replacement situations into the clean energy future.

### Implementation Priorities

In practice, this portfolio mindset should translate into a set of near-term implementation priorities. Programs and policymakers should align weatherization, electrification, and solar funding streams into a single customer pathway wherever possible, while regulators approve enabling rate designs and consumer protections for on-bill and IUI approaches. States, utilities, and local governments should also work toward standardized, low-friction permitting and quality assurance pathways that reduce soft costs without compromising safety. Clear participation pathways are needed for renters and manufactured housing residents, alongside sustained investment in workforce and contractor capacity. Finally, program evaluation should move beyond average savings alone to include bill volatility, arrearage risk, and practical ability-to-pay metrics that better reflect whether an intervention is truly affordable.

For program leaders, utilities, and regulators, the message is clear and empowering: durable affordability demands a broader embrace of who can deliver, what forms electrification can take, and how success is measured. This means cultivating partnerships with community-based organizations, supporting nontraditional installation pathways, and managing programs as dynamic portfolios rather than rigid, project-by-project undertakings. While these shifts may require stepping outside administrative comfort zones, they unlock greater scale, resilience, and social equity—aligning the interests of households, implementers, policymakers, and more.

This paper does not claim programmatic innovation is a panacea; broader policy and regulatory reforms must also play their part. However, the evidence here shows that much can be accomplished today when programs are intentionally designed to minimize non-equipment costs, streamline participation, and share risk equitably. The path to affordable, inclusive electrification is not reserved for some distant future, it is available now to those bold enough to reimagine what is possible.

As we look ahead, the imperative is not only to measure and refine these strategies but to foster a spirit of experimentation and collaboration across communities. By expanding our toolkit and redefining success—not by the size of the subsidy, but by the reach and resilience of our systems—we can build a future where clean energy is truly accessible to all. Let this paper be an invitation: to think differently, act courageously, and help create a transformation as ambitious as the moment demands.

## References

ACEEE. 2025a. *Electricity Rates that Keep Bills Down after Electrification*. Washington, DC: American Council for an Energy-Efficient Economy. www.aceee.org/research-report/b2502

ACEEE. 2025b. *Estimating the Impacts of Weatherization Readiness Programs.* www.aceee.org/research-report/b2504

AIE (All In Energy). 2026. Energy Bill Check-Up. allinenergy.org/ebcu/

Drehobl, A., Ross, L., & Ayala, R. 2020. *How High Are Household Energy Burdens?* American Council for an Energy-Efficient Economy (ACEEE). www.aceee.org/research-report/u2006

EPA (Environmental Protection Agency). 2024. *Inclusive Utility Investments (Tariffed On-Bill Programs): A State and Local Implementation Guide.* Washington, DC: U.S. Environmental Protection Agency. www.epa.gov/statelocalenergy/inclusive-utility-investments-tariffed-bill-programs

ENERGY STAR. 2025. *Inclusive Utility Investment Program Resources for Residential Electrification.* www.energystar.gov/products/inclusive_utility_investment

Harwood, M., Erdman, S., Badger, C., Parker, S. 2025. *DIY Heat Pump Water Heater Installation and Market Study.* calnext.com/wp-content/uploads/2025/06/ET24SWE0044_DIY-Heat-Pump-Water-Heater-Installation-and-Market-Study_Final-Report.pdf

IGSHPA. 2025. “The Value of the Ground Loop Heat Exchanger for Third-Party Owners.” igshpa.org/igshpa-blog/the-value-of-the-ground-loop-heat-exchanger-glhe-for-interested-third-party-owners/

Island Institute. 2025. *Bulk Purchase of Heat Pumps.* Island Institute Solutions Library. www.islandinstitute.org/ii-solution/bulk-purchase-of-heat-pumps/

Jacobs, J., and Sachs, A. 2025. *Inclusive Utility Investment.* a-us.storyblok.com/f/1021068/x/4634e44aba/inclusive-utility-investment-rewiring-america.pdf

LBNL. 2025. *Energy Affordability in a Changing Grid: Trends and Metrics.* Berkeley, CA: Lawrence Berkeley National Laboratory. eta-publications.lbl.gov/sites/default/files/2025-10/energy_affordability_20251007_v2.pdf

Less, B., Walker, I., Casquero-Modrego, N., Rainer, L. 2021. *The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes.* https://bies.lbl.gov/publications/cost-decarbonization-and-energy

NEEP (Northeast Energy Efficiency Partnerships). 2025. *Modern Rate Design in the Northeast: Unlocking Efficiency, Affordability, and Electrification*. eta-publications.lbl.gov/sites/default/files/2025-10/energy_affordability_20251007_v2.pdf

RMI. 2024. *Electrify Your Community.* rmi.org/resources/electrify-your-community/

Shen, B., et al. 2024. *High-Efficiency Air-Source Multi-Stage Cold-Climate Integrated HP.* Washington, DC: U.S. DOE/BTO. www.energy.gov/sites/default/files/2024-11/bto-peer-2024-322262003_high-efficiency-air-source-multi-stage-cold-climate-integrated-hp-shen.pdf

The Atmospheric Fund (TAF). 2023. *Scaling Heat Pump Retrofits through Aggregation and Bulk Procurement.* taf.ca/custom/uploads/2023/04/TAF-HP-Aggregation-Final-Report_Final.pdf

Vermont Community Thermal Networks (VCTN). 2025. *Thermal Energy Networks as Key Energy Infrastructure in Vermont.* static1.squarespace.com/static/6329d214da4067742d066f7b/t/68d3cfa1cc18d571e1301cf9/1758711713917/TENs+as+Key+Energy+Infrastructure+in+Vermont.pdf

Wisconsin Division of Energy Services. 2012. *“Follow the Money”: Overcoming the Split Incentive for Effective Energy Efficiency Program Design in Multi-family Buildings.* www.aceee.org/files/proceedings/2012/data/papers/0193-000192.pdf