Electrification in Mobile and Manufactured Housing: Barriers and Opportunities

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ABSTRACT

Mobile and manufactured homes are an important part of the U.S. housing stock, yet remain largely overlooked in building electrification research and policy. This paper presents findings from a twelve-month pilot in San Luis Obispo, California, funded by the U.S. Department of Energy's (DOE) Buildings Upgrade Prize, including recommendations for program implementers and service providers. The paper evaluates the installation of weatherization and electric heat pump water and space conditioning equipment and examines: (1) the physical feasibility of heat pump equipment installation given constrained footprints and electrical systems; (2) on-bill cost impacts; and (3) regulatory and programmatic barriers such as permitting, park rules, and subsidy eligibility. Findings suggest that weatherization paired with water heater and space-conditioning electrification results in on-bill cost parity or increases. "Plug-in" solar and battery equipment installed in one of the test homes provides a potential path to offset these costs and yield net on-bill savings.

Introduction

Mobile and manufactured homes (herein referred to as "manufactured homes"), are a critical segment of the United States' and California's affordable housing stock. Manufactured homes make up approximately 5% of the total U.S. housing stock and face persistent challenges related to energy inefficiency *(Talbot 2012, Bell-Pasht 2023)*. This paper provides manufactured home characteristics, describes the scope of the research conducted to evaluate the feasibility of electrification retrofits in manufactured homes, provides analysis and findings from the research, and concludes with findings related to the post-study installation of "plug-in" solar and battery storage equipment at one of the test sites.

Manufactured Home Characteristics[1]

Physical Characteristics of Manufactured Homes

Manufactured homes typically have enclosure issues such as poor insulation, less structural opportunity for insulation due to wall assemblies featuring 2x2 or 2x3 framing lumber, and limited, if any, attic space, outdated wiring, and poorly functioning HVAC systems *(McGrath et al. 2000).* Manufactured homes in California are typically dual fuel with natural gas or propane providing fuel for water heating and HVAC systems. Electrical capacity can vary widely, with some homes having as low as 30A service. The U.S. Department of Housing and

[1] For a comprehensive overview of manufactured home characteristics, see Talbot (2012) and McGrath (2000). This section provides a brief overview of characteristics relevant to the research presented in the paper.

Urban Development (HUD) regulates manufactured home construction and first introduced manufactured home regulations in 1976. HUD implemented further regulations in 1994 however the HUD Code has lagged site-built energy efficiency code measures (*McGrath et al. 2000)*. Manufactured homes built before the adoption of the HUD Code in 1976 typically have very little insulation, presenting a theoretically greater opportunity for energy savings. As noted in Bell-Pasht (2023), "Improving air and duct sealing, upgrading insulation in the underbelly of the home, and installing a moisture barrier to protect ductwork can lead to annual energy savings of $400–800, and payback in under four years" *(Bell-Pasht 2023; Dayem 2019).*

Regulatory and Energy Utility Characteristics of Manufactured Housing Communities

There are several legal and regulatory arrangements that make doing electrification retrofit work in manufactured homes unique. For instance, building permits for improvements to manufactured homes are regulated in California by the Department of Housing and Community Development (HCD) and not by the local jurisdiction the homes are located in. Additionally, park ownership structures can vary widely from a co-op style structure where occupants own the park to a structure where a private entity owns the park. In nearly all cases, the manufactured homeowner owns the building they live in but are only leasing or renting the land the building is located on. This has implications for financing home improvements; nearly half of manufactured home loans are high-interest personal property loans, which limit access to capital for energy upgrades and can put community members at risk of predatory lending *(Bell-Pasht 2023).* Most manufactured housing communities are "master-metered" with one utility interconnection for the whole community and sub-meters at each home. As noted later in the research, this meter arrangement locks residents into the one rate available for master meter communities, which includes a low electric baseline allowance and is generally unfavorable for electrification retrofits. This is especially important given that roughly 40% of manufactured housing residents are housing cost burdened (spending more than 30% of household's income on housing) and spend more of their income on housing than residents of single-family detached homes *(Bell-Pasht 2023)*.

Research Scope

The City of San Luis Obispo, Diversity Coalition of San Luis Obispo County, and the Community Action Partnership of San Luis Obispo County (CAPSLO) partnered to test the feasibility, scalability, and cost-effectiveness of electrification upgrades in local manufactured homes. The Project Team prioritized manufactured homes for research because: 1) manufactured homes account for approximately 60% of owner-occupied low-income housing in the community, and 2) they are an especially complicated building stock to decarbonize yet have received very little research or programmatic support. To ensure residents of manufactured homes are included in citywide electrification efforts, the Project Team proposed to identify the conditions under which manufactured home retrofits can be cost effective, and to convene community members to co-design a home electrification concierge service that reduces complicated technical, financial, and administrative barriers.

To fund the case study, the Project Team applied for the Department of Energy's (DOE) Buildings Upgrade (Buildings UP) Prize in 2022. The Prize, managed by the DOE's National Renewable Energy Laboratory (NREL), focused on innovative approaches to retrofitting buildings to include high-performance technologies, namely heat pump HVAC and water heating systems. The funded study, referred to as The SLO Green and Healthy Homes Technology Demonstration Plan, laid out the following scope for home upgrades:

- Completion of energy audits, weatherization measures, electrical panel upgrades, and the installation of heat pump water heaters (HPWHs), and/or air source heat pumps in double wide and single wide manufactured homes sited in a master-metered manufactured housing community in the city of San Luis Obispo.
- Monitoring of post-installation energy and utility bill impacts for twelve months.
- Provision of a bill-protection program to ensure bill neutrality for program participants.

Participant and Technology Selection

The Project Team worked with management staff at a local resident-owned manufactured housing community to host an outreach and enrollment event. Forty park residents attended, and of those who completed interest forms to participate in the research. Three homeowners and one renter were enrolled to receive upgrades.[2] Participants' homes, which served as installation locations for the Technology Demonstration, included three double-wide manufactured homes and one single-wide home. The double-wide homes were built in 1974, 1975, and 2016 respectively, and the single wide was constructed in 1970. As summarized in Table 1, the following technologies were installed:

- **Weatherization** was funded through DOE's Weatherization Assistance Program (WAP) prior to installation of heat pump equipment.
- **HPWH and Accessories**: A 40-gallon, plug-in dedicated circuit water heater (Rheem 32kBTU model-XG29T06MH32U1) was selected to fit the smaller water heater closets typical in manufactured homes. Because hot water runouts are a known risk with non-hybrid (i.e. lower heating capacity) HPWHs, especially where smaller storage tanks are present, the team elected to install thermostatic mixing valves on all water heaters. A thermostatic mixing valve blends hot and cold water to deliver water at a safe temperature. This allows for the water heater to be set at a much higher temperature set point, resulting in more readily available hot water that can be delivered without scalding. The Project Team also installed expansion tanks on each water heater to absorb extra water caused by thermal expansion which has many known benefits for protecting the water heater and home plumbing system from damage.
- **Heat Pump HVAC Systems**: For homes that had central ducted gas furnaces, the Project Team selected the Day & Night 3 Ton Fan Coil (model FTMA4X36L0BB) paired with the DLCURA Outdoor Unit Air Handler (model DLCURAH36AAK). The Project Team was mindful to select a heat pump HVAC system that accounted for the static pressure in the narrower duct systems of manufactured homes. The Project Team also installed a Gradient Comfort Window Saddle Heat Pump HVAC unit in one home to test the feasibility of a renter-friendly HVAC option. The Project Team was required to install the unit in a home that was eligible for window replacements, as most manufactured homes

[2] Participants were selected to ensure that the four research subjects covered a cross-section of vintages, sizes, and occupancy types.

have horizontally opening windows and the Gradient Comfort unit can only be installed in windows that open vertically.

- **Smart Thermostats**: Each participant who received a central ducted heat pump HVAC system also received an Ecobee 3 Lite Smart Thermostat.
- **Electrical Panels**: All participants who received both a central ducted heat pump HVAC system and a HPWH upgrade were provided with 100-Amp panel upgrades where existing service was less than 100 Amps. These upgrades were required in most homes as part of a larger electrical capacity upgrade, as some of the homes hosted aging electrical panels with service as low as 30 Amps.

Table 1. Home characteristics and selected technology

	Resident 1	Resident 2	Resident 3	Resident 4
Size	Double-Wide	Double-Wide	Single-Wide	Double-Wide
Vintage	2016	1974	1970	1975
Tenure	Own	Own	Rent	Own
Weatherization	X	X	X	X
Panel Upgrade		X	X	
HPWH	X	X	X	
Central HVAC	X	X	X	
Window HVAC				X

Equitable Program Design and Community Benefits

The benefits that the Project Team proposed delivering included: serving residents with need, covering 100% of upgrade costs, offering options for renters, advocating for more robust programs and services offered to manufactured-housing communities, providing qualified contractors, and offering technical support and energy coaching throughout the Technology Demonstration, as described below:

- **Serving Residents with Need:** The Technology Demonstration was offered to income-eligible subscribers. Income eligibility was determined by 2024 Low-Income Home Energy Assistance Program thresholds which allowed the team to leverage existing weatherization programs implemented by CAPSLO. Installs were completed in October through December of 2024. All homes were single-occupant, and all residents were over 55 years of age.
- **Options for Renters**: Making clean energy upgrades available to renters is essential to achieving an equitable energy transition and meeting greenhouse gas reduction targets. Gradient Comfort window heat pumps are a renter friendly option that plugs in to a 120V

outlet, do not require installation by a contractor, and are less expensive than ducted and mini-split options.[3]

- **Providing Qualified Contractors**: The Green and Healthy Homes Program partnered with Tri-County Regional Energy Network (3C-REN) to offer a training exchange between CAPSLO, who is an experienced HPWH installer, and Pacific Heating and Air, a local HVAC installer that specializes in heat pumps. The training occurred on-site of the first technology demonstration in October 2024.
- **Covering 100% of Upgrade Costs**: All equipment and labor costs were paid for with Buildings Upgrade prize funds.[4]
- **Energy Coaching**: Throughout the Technology Demonstration period, subscribers had access to an Energy Coaching service offered by Artemisia Energy. Residents were able to call with any questions they had about their new appliances or other aspects of home energy usage. All subscribers reported issues with operation initially, however after receiving support, participants reported positive feedback about the upgrades. Energy coaching successfully flipped equipment operation complaints into positive opinions.
- **Bill Protection Plan**: Artemisia Energy developed a Bill Protection Calculator and ran a monthly assessment of subscribers' energy bills based on their monitored and historical energy use. The Bill Protection payment was designed to absorb the monthly cost increase associated with fuel switching from gas to electricity, resulting in a net neutral impact on the participants' monthly expenses.
- **Home Comfort Check-Ins**: During the Technology Demonstrations, Diversity Coalition staff scheduled quarterly check-ins with subscribers. The Home Comfort Check-In served as a recurring opportunity for the team to have conversations with the residents and collect qualitative data about their experience, gauge level of satisfaction with their upgrades, and offer education on behavioral changes to improve familiarity and comfort with new technology and lower energy bills. These check-ins resulted in most of the qualitative data collection conducted during the demonstration.
- **Product and Labor Warranties**: The team provided warranties on equipment and labor to protect residents from any equipment malfunctions or failures.
- **Equitable Transition Contingency Fund**: $15,000 was set aside in case residents decided they were unhappy with the installed technology or could not afford to take on the bill impacts at the end of the 12-month research period. All four participants chose to retain their electric equipment. Unspent funds were reinvested into an addition phase of research detailed later in this report.
- **Consumer Protection and Disclosure Forms**: All subscribers who enrolled in the Technology Demonstration agreed to a Consumer Protection and Disclosure Form that outlined the terms, benefits, and agreements of their participation. This form transparently summarized the risks and benefits of the offerings listed above, as well as information about the specific appliances being installed and contact information for submitting energy bills, reporting problems, asking for information, or elevating grievances.

[3] In a follow-up to this research, the Project Team was able to fund a "plug-in" solar and battery storage system for one of the participants. This technology has substantial potential to benefit renters and will be the focus of subsequent research.
[4] The focus of this research is on the operational cost effectiveness. Subsequent research should focus on opportunities to bring down capital costs.

Data Collection

The Team used Emporia Vue 3 energy monitoring tools and software to collect real-time energy use data by circuit. Shared circuit equipment (such as the Gradient units) data was disaggregated from circuit-level monitoring as best as possible. The energy monitors were installed by a CAPSLO electrician after all other electrical work was completed. Bill savings and customer impacts were estimated using a Normalized Metered Energy Consumption (NMEC) model developed from four years of pre-retrofit billing and weather data. The model was used to create a weather-normalized counterfactual estimate of post-retrofit energy use: in other words, what the customer would likely have consumed if the retrofit had not occurred, under the actual weather conditions experienced after the retrofit. The counterfactual energy use and the observed post-retrofit energy use were then both converted into bills using current gas and electric rates. Estimated bill impacts were calculated as the difference between the modeled counterfactual bills and the actual observed bills.

Actual bills were collected from residents where possible as well as a means of tracking ancillary charges and verifying accuracy of monitored energy use. Starting one-month post upgrade, Diversity Coalition scheduled quarterly Home Comfort Check-ins with each participating household to collect data on each resident’s experience with the new technology. Check-ins were an opportunity to learn about the impacts of noise levels, ease of operation, comfort, and customer satisfaction. Each visit was supplemented with personalized Energy Use Reports co-developed by Artemisia Energy and Diversity Coalition to review each user's energy habits and tips on ways they could reduce their bill.

Technical Analysis and Findings

Financial Offerings Analysis

The Project Team conducted financial analysis identifying the cost of weatherization, heat pump installation, and associated electrical panel and wiring upgrades in a single-wide and double-wide manufactured home. The Project Team originally intended to fund most of the equipment and labor costs with rebates and incentives offered to other residential housing types in the region. However, the Team ended up needing to fund the installations directly for the following reasons:

- **TECH (Technology and Equipment for Clean Heating) Clean California** is funded by the California Public Utilities Commission and administrator of Federal HEEHRA funds and is an initiative to accelerate the adoption of clean space and water heating technology across California homes. At the time of the Technology Demonstration, TECH offered rebates up to $1,000 for heat pump HVAC upgrades. TECH does not serve master-metered communities. Most of the manufactured housing communities in San Luis Obispo are master-metered, which makes them ineligible for rebates disbursed by the TECH program.
- **Tri-County Regional Energy Network (3C-REN)** offers a Home Energy Savings program which, at the time of the Technology Demonstration, provided rebates up to $20,000 for energy efficiency and electrification upgrade projects. 3C-REN does not offer rebates to master-metered communities, making most of the manufactured housing communities in San Luis obispo ineligible for 3C-REN incentives. 3C-REN did provide

$15,000 in funds to support the Technology Demonstration, including the delivery of a contractor training for installing heat pumps and HPWHs in manufactured homes.

- **Central Coast Community Energy (3CE),** the City's Community Choice Aggregator, offered an Electrify Your Life rebate program. At the time of the Technology Demonstration, rebates up to $14,300 for heat pump and electrical panel upgrade projects were offered to enrolled customers. Conversation with 3CE administrative staff revealed that master-metered communities are eligible to enroll as 3CE customers, but no local manufactured housing community had enrolled, and no programs existed to support their enrollment. To date, no manufactured housing communities in the City are enrolled as 3CE customers and therefore do not qualify for Electrify Your Life program incentives.
- **Financing options** for manufactured home retrofits are extremely limited. All identified financing programs are only available for manufactured homes constructed after 1976, on a permanent foundation, that have never been moved beyond the initial move from the factory to the residential lot and elevated above the 100-year return frequency flood elevation.
- **California Energy Commission's Equitable Building Decarbonization** (EBD) provides decarbonization retrofits for low- and moderate-income households through California Energy Commission's Direct Install Program. Program funds were not yet available at the time of the Technology Demonstration.

In summary, at the time of the Technology Demonstration, the local home energy upgrade incentive landscape could deliver up to $35,300 per project for single-family homeowners in San Luis Obispo. Due to restrictive eligibility requirements for master-metered communities and none of the communities being enrolled as 3CE customers, residents of manufactured housing did not qualify for any residential home energy upgrade rebates or incentives in 2024 and 2025. Other than the $15,000 contribution from 3C-REN, the Project Team covered the remainder of Technology Demonstration costs with funds from the Buildings Up prize funds and CAPSLO's Weatherization Assistance Program.

Technology Selection and Feasibility

Panel amperage and physical space was often a constraint. In cases where 60A panels were present, they were upgraded to 100A. While 100A is typically sufficient for a fully electrified home of this size (confirmed after a year of monitoring power draw), it did require some forethought in terms of power-efficient design (proper sizing of HVAC equipment, HPWH selection) especially if full electrification were to be achieved eventually.

The feasibility of heat pump HVAC installations largely depended on the year the home was constructed and the electrical system's capabilities. None of the carriages had central AC prior to program participation and so all central heat pump systems added new electrical load. Installing the window HVAC unit required removal and replacement of windows due to window orientation being incompatible with the unit where they were installed. Window units are shared-circuit devices and do present the risk of tripped breakers depending on which circuit they are plugged into, but this was not a problem in the unit where they were installed.

HPWHs had more considerations affecting installation feasibility. Water heaters were installed in existing water heater closets, at times requiring work to expand access to the space through the removal of doors and associated trim and needing to run electrical wiring for a dedicated outlet. In addition to being taller than equivalently sized gas or resistance electric water heaters, thermostatic mixing valves and compression tanks also took up space. Exterior closet installation only allowed for 40-gallon models to fit. These volume constraints informed which equipment was chosen. Opting for dedicated circuit (rather than shared circuit) 120V water heaters improved performance greatly. 1.2kW compressors triple the recovery time of heat pumps in both shared circuit models and hybrid 240V units (both have 400W compressors). This allowed for faster recovery on moderate usage days where resistance backup or hot water runouts would have otherwise occurred, without requiring 240V upgrades and therefore saving panel space. Larger compressors are also louder. This was only noted to be a problem with one resident, but careful programming (simplified in part by greater thermal storage enabled by the thermostatic mixing valves) mitigated noise impacts.

Rheem has since discontinued their 40-gallon dedicated circuit HPWH. In subsequent installations beyond the scope of the Technology Demonstration, CAPSLO found that 50-gallon HPWHs were feasible to install but required the added expense of expanding the opening of the water heater closet. Both the central ducted heat pump HVAC system and window saddle heat pump HVAC units were feasible to install and performed effectively.

The most relevant housing characteristic determining upgrade feasibility were the year of construction, sufficient closet space, and sufficient electrical system capacity. Homes that already had these characteristics required fewer upgrades and alterations. Newer manufactured homes notably have more closet space and generally better electrical systems. While heat pump technologies were successfully installed and operated in older homes, the team determined that such retrofits in homes built before 1976 (when the HUD code was established) were more complicated and expensive than in newer homes.[5]

User Experience and Feedback

The team conducted post-installation interviews in the first weeks after the equipment was installed. The weeks following equipment installation were the most critical in addressing residents' concerns, with the first visit after installation being the best opportunity to address concerns early on. Returning to check-in with residents allowed the team to program equipment according to their needs and help them adjust to the new technology. Solutions to common concerns are described in Table 2.

[5] Although there is only one post-1976 home in the research cohort, the Team has visited a large number of other newer homes and have largely found the characteristics of larger utility closets and more electrical capacity to be present.

Table 2. Common concerns and project team's solutions

Concern	Solution
HPWH hot water runouts	Temperatures were raised to accommodate hot water demand schedules.
Water heater noise (typically during sleeping hours)	Technicians installed sound barriers between the water closet and bedroom; equipment was also programmed to run hotter during the day with nighttime setbacks.
Resident confusion operating smart thermostats leading to extended runtimes and waste	Technicians and Energy Coaches provided one-on-one assistance (typically in person) to guide residents through use and help adjust settings to their specific needs.
Utility bill increases	Delivery of 12 months of bill protection payments paired with education on bill reduction strategies and future bill impact projections. Residents were given the option of a no-cost conversion back to natural gas appliances if they were not interested in/capable of covering the costs.

In addition to the concerns listed above, residents also shared positive feedback, including:

- Residents appreciated smooth, professional, and timely installation.
- Residents reported HPWHs providing faster and more comfortable hot water after slight temperature adjustment. Residents found HPWHs more reliable and comfortable compared to their previous natural gas equipment.
- Residents reported heat pump HVAC systems as being much quieter and easier to maintain than previous natural gas equipment (central ducted furnaces). Residents who took advantage of now having cooling during the summer appreciated the change. They also noted improved air quality and less dust on surfaces within the home.
- All residents opted to keep their heat pump technology past the end of the demonstration, knowing they would take on responsibility for related bill increases.

HVAC Energy Performance

Performance varied substantially across the four homes, driven by a combination of behavior and building characteristics (Figure 1):

- **Resident 1 (central ASHP):** The resident operated the unit manually (turning on and off with no programming). Response times were longer due to lower capacity than the pre-existing furnace, but the mobile home was reasonably well weatherized due to its age (built 2016). Energy reductions were substantial and matched predictions based on assumed efficiencies. No cooling was noted.
- **Resident 2 (central ASHP):** This carriage is older (circa 1980s) and less efficient. The resident also operated the heat pump largely without significant nighttime setbacks. As a

result, runtimes were much longer and energy savings reduced. A small amount of cooling was noted, as well as apparent occasional summer heating.

- **Resident 3 (central ASHP):** This resident lived in a much older, leaky home. The heat pump was almost never used for either heating or cooling. Based on conversations with the resident it is suspected that they rarely used the furnace prior to retrofit and this behavior continued with the heat pump in place.
- **Resident 4 (2 Gradient Window Units):** This resident was the only resident that retained a central gas heating system and supplemented the Gradient systems with the central furnace. The bedroom Gradient unit was used most frequently (largely replacing nighttime heating with the central system). The Gradient located in the living room was used occasionally for heating and cooling, but the gas furnace provided most of the daytime heat.

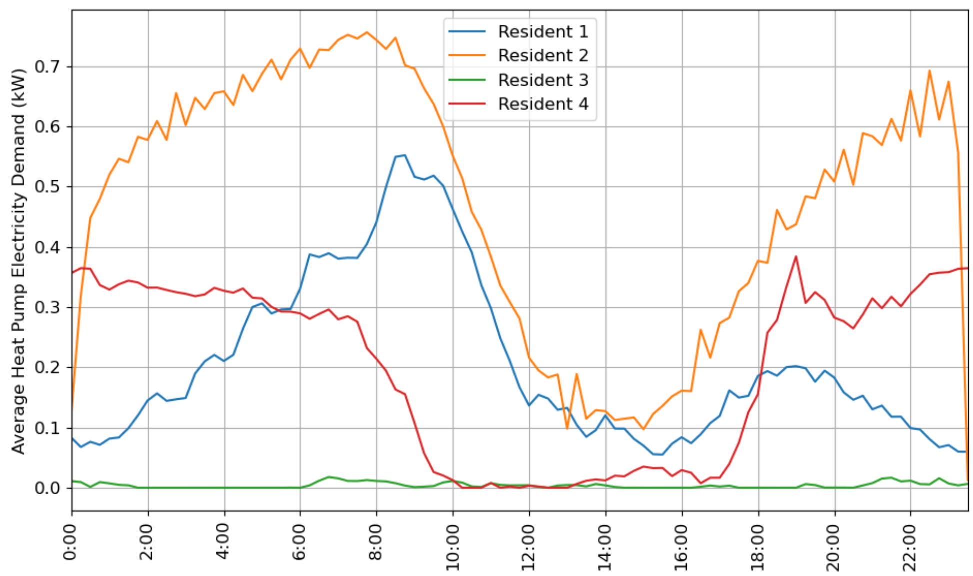

Figure 1. Average load shapes for winter heat pump use (space heating)

Figure 2 shows the annual site energy impacts (MMBTU) pre- and post-retrofit (from December 2024 - December 2025). The pre-retrofit gas represents the gas counterfactual (heating gas that would have otherwise been present based on weather during this period). Note that Resident 4 was retrofitted in January 2025, and the post-retrofit data is therefore an incomplete year. Note also the presence of gas in the post-retrofit period for Resident 4 as a result of reliance on both the Gradient units and central furnace. The diversity in outcomes in both comfort and performance demonstrates that performance is not as straightforward as nameplate efficiencies or the level of weatherization in the home. Thermostat settings (and resident thermostat familiarity) combined with lower capacities can lead to longer daily runtimes and greater usage during shoulder seasons (i.e. Resident 2). This can be particularly impactful in leaky homes. Still, the amount of site energy offset for Residents 1 and 2 represents expectations based on efficiencies, with an annual reduction of 70-80% when compared to counterfactual gas use. Resident 4 was able to reduce nighttime heating by 90% by heating just the bedroom with the Gradient.

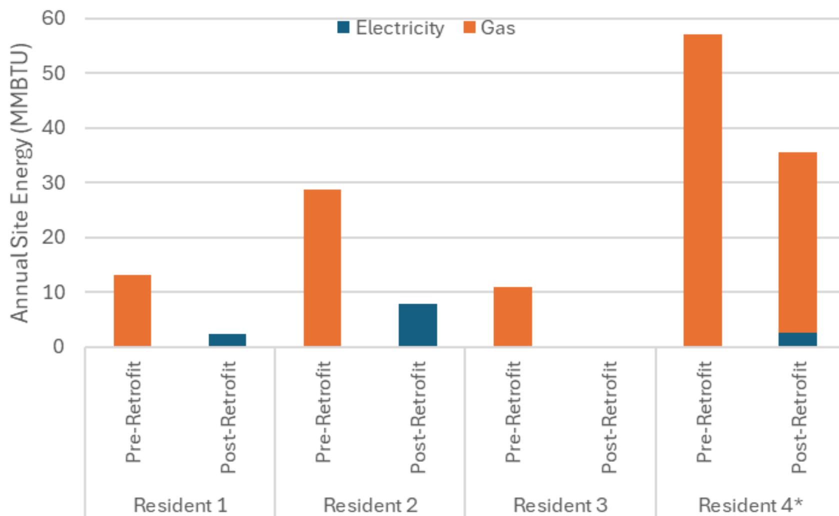

Figure 2. Annual space heating energy consumption pre- and post- retrofit

Water Heater Energy Performance

HPWH performance is not as susceptible to seasonal variation as space heating; behavior is a primary driver of consumption and due to research constraints, no hot water flow data was collected. In general, pre-retrofit summer usage over the five years of bills obtained was quite constant, so it can reasonably be assumed that hot water demand pre- and post-retrofit is similar. Average daily energy usage varied widely across the three residents. Discussions with residents confirmed this variability is largely driven by hot water demand patterns such as volume and timing of bathing and clothes washing. Winter electricity usage increased 20-30% (depending on resident) because of lower Coefficients of Performance (COPs), higher standby losses, and colder incoming water temperatures. The exact contribution of each cannot be determined.

While daily use on average is modest, residents 2 and 3 had highly variable hot water demand, with HPWH energy consumption occasionally exceeding 6kWh/day. This underscores the advantage of having larger compressors with better recovery times in 120V units that lack resistance backup elements. Additionally, added thermal storage availability made possible by thermal mixing valves (higher setpoint temperatures) reduces risk when hot water demand uncertainty is present. Two examples show the value of the selected equipment:

- In the case of resident 2, a hot water runout occurred within a week of install (initially set to 125°F). Setting to 135°F solved this problem.
- In the case of resident 1, the unit was oversized for the resident's hot water demand. However, the water heater closet was located next to the primary bedroom and random compressor operation kept the resident up. Pre-charging the unit before bed allowed for a reservoir of hot water available in the morning without nighttime operation.

Table 3. Energy use and setpoint temperature by resident

Resident	Average Daily Energy Use (kWh)	Setpoint Temperature (°F)	Notes
1	1.1	120°F	130°F at 8PM; night setback to 110°F until 10AM
2	2.5	135°F	Occasionally laundry usage required higher setpoint
3	2.5	130°F	Set higher initially; resident takes long showers

Figure 3 shows the average daily load shape for each resident during the monitoring period. Resident 1 was programmed to charge at 10AM, avoiding noisy nighttime operation.

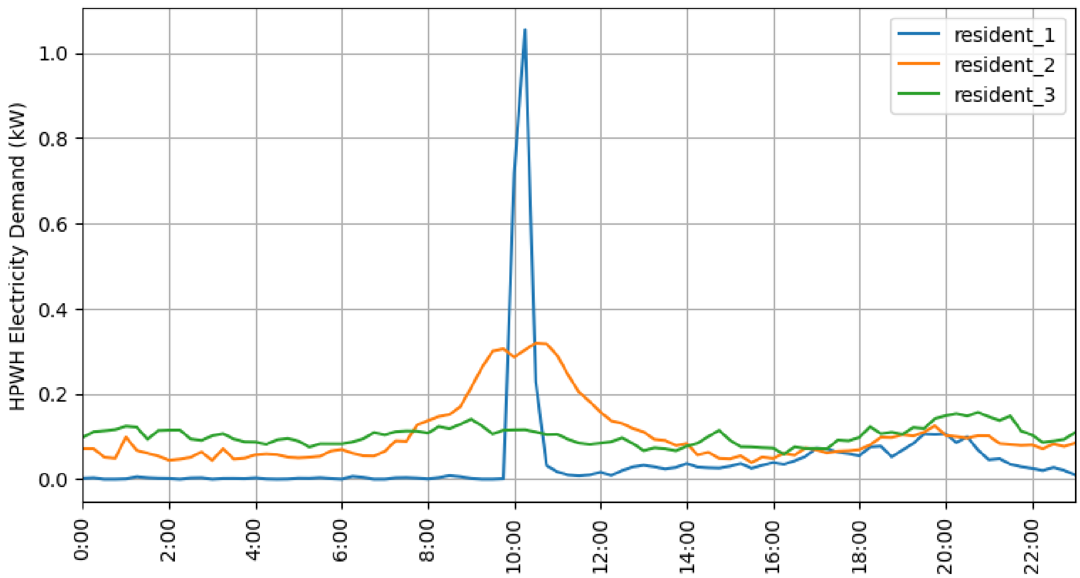

Figure 3. Average daily HPWH load shape by resident

On-bill Utility Cost Impacts

To evaluate the on-bill utility cost impacts of the installed measures, the Team analyzed the sum of impacts given a year's worth of data and bills.[6] Conclusions made regarding impacts to bills must be tempered to some extent with qualitative observations (conversations with residents, etc.) especially for a small number of individuals. This research finds that for the participants on the program, from December 2024 to December 2025, total energy utility bills increased post-electrification, and that most of these increases occurred during the winter. HPWHs were approximately breakeven on cost, and bill impacts from HVAC electrification

[6] The impacts of individual equipment cannot reliably be calculated since the total bill is a mix of fixed charges, multiple tiers, and annual credits. Behavior, weather, and usage among other appliances is also constantly changing, which affects the marginal change in cost for any electrified appliance.

generally increased with increased use of the equipment. There are a few critical reasons for this not that are not related to performance, including:

- **Large "spark gap" between gas and electricity:** San Luis Obispo is one of the few areas where dual fuel residents have PG&E for electricity and SoCalGas for gas service. Gas prices in SoCalGas territory are generally cheaper than PG&E, making electrification less attractive. As of December 2025, SoCalGas baseline gas prices are approximately 42% cheaper than in PG&E. In other words, for this given month, a gas MMBTU is four times cheaper for residents who have PG&E for both gas and electricity, but *seven* times cheaper for residents who have PG&E for electricity and SoCalGas for gas. It is worth noting that towards the end of the project gas prices began to rise again and the operational cost-effectiveness of electric appliances improved substantially.
- **Sub metered mobile home residents are not eligible for better rates:** Most mobile home parks in California, including the one in this study, are master metered. PG&E and SoCalGas have only one rate schedule (PG&E and ES and SCG GS) available for master metered complexes. Residents are not eligible for TOU-C, EV2, E-ELEC, or other potentially more favorable residential rates that reduce the cost of winter heating.
- **Sub metered mobile homes cannot individually get an electric heat baseline designation:** Typically, individually metered residents on certain rate plans (such as E1) get a larger baseline allowance in the winter if they have electric heating. However, this is not available for ES as the rate is set at the master meter (park) level. As a result, increases in winter load even for modest energy consumers is almost all above baseline.
- **Fixed charges are still present**: For those who electrified heating and water heating, gas cooking (and laundry, where relevant) was often <1 therm/month. Fixed charges (meter fees, etc.) are still \$4-5/month (5-10% of the total bill).

The result of the last two bullets is a 25% higher heating cost compared to baseline (under PG&E electric rate EM) or a 40-60% higher heating cost compared to PG&E's Electric Home Rate Plan (electric rate E-ELEC). Of course, the total bill impacts depend on a multitude of other factors, but for residents with otherwise low usage and negligible cooling, their bill is most sensitive to increases in winter heating costs. Increases as a percentage of the bill are generally felt the most by residents with large heating loads that increase their above-baseline consumption. The California Alternate Rates for Energy (CARE) program provides a small amount of decrease in annual electrified bills since the CARE gas discount is 20% but the electricity discount is 35%. However, this was not enough to offset the difference between gas and electricity costs.

As previously noted, this increase represents just a snapshot in time. Increases are representative of the study period's high electricity rates and relatively cheap gas under SoCalGas. Bill increases/savings would have looked very different a few years prior (before major increases in volumetric costs) and will undoubtedly look different a few years from now as electricity prices are projected to stabilize in PG&E territory while gas prices continue to rise. Rate restructuring (such as Income Graduated Fixed Charges) and other changes lead to uncertainty in cost impacts, but in general we can assume that the on-bill cost-effectiveness of electrification in this situation will improve.

Table 4. Utility bill cost change by resident

Resident	Annual Gas Savings ($)	Annual Electricity Increase ($)	Total Annual Savings ($)	Annual Bill Change (%)	Notes
1	$310.56	$355.39	$ (44.83)	+4%	Cost increases from space heating were mostly offset by water heating savings.
2	$614.39	$1,080.99	$ (466.60)	+35%	Substantial increases in heating energy, particularly at night, was the primary reason for cost increase. Some summer cooling is also noted that was not present before and increased summer costs slightly.
3	$274.47	$412.45	$ (137.98)	+12%	Low baseline heating use. Substantial behavioral variation. Cost increases due to increase in water heating cost.
4	$427.99	$258.49	$ 169.50	-8%	10 months of post-retrofit data. No water heater retrofit. Savings achieved through reduced nighttime furnace heating of the entire home via bedroom use of the Gradient.

The Role of Solar in Cost-Effectiveness

In utility territories where energy rates make electrification increase total energy bills, the addition of solar can substantially improve the lifecycle cost. This depends highly on up-front costs, net metering structure, rates, and other factors. Conventional solar was explored as an opportunity to reduce cost increases resulting at the retrofitted homes but a variety of factors made this untenable:

- Carriage submetering requires that back-feeding not occur as a safety measure. Curtailment significantly reduces the value of installed solar (up to 80% in these residences, depending on the size of system installed), and batteries add significant cost.
- Roofs are often not suitable for installation, especially in older manufactured homes where increased heating costs make solar the most beneficial.
- Challenges with permitting and interconnection on master-metered parks add time, complexity, and cost.

Ultimately, Resident 1 was selected for solar as the newer structure (2016) could support a photovoltaic system. However, even fully electrified, annual use was modest: <3000 kWh pre-electrification, with an addition of approximately 1500kWh after fully electrified, depending on weather. Annual usage of 4500kWh could be fully offset (on net) by a 2.4kW system, but with overhead and added battery costs the cost was over $14/Watt before incentives (as low as $7/Watt after). At this cost, a system would never achieve cost-effectiveness.

A secondary option of plug-in ("balcony") solar was considered for Resident 1. While the full annual load could not be offset with a smaller plug-in system, a smaller system with far less cost overhead and installation complexity could be selected to minimize curtailment and optimize for cost. Ultimately, a small 820W system with 2kWh of battery storage was selected, with current transducer monitoring employed to eliminate back-feeding. The installed cost of this small system was <$4/Watt without incentives. This system would roughly offset 40% of total annual electricity consumption in the fully electrified home.

The system was installed in early 2026 and monitoring has confirmed a substantial bill reduction with relatively little curtailment (see Fig. 5). While active submetering ended in 2025, tracking bills and normalizing to weather yields a high degree of confidence that these savings come from the plug-in solar system, resulting in approximately $500-700 of forecasted savings through the end of the year. Note that 2026 costs represent 2026 utility rates and weather, so some uncertainty exists in absolute savings. The main takeaway here is that this resident almost achieved cost parity when fully electrified without solar but was able to increase savings significantly with a small solar system. This also results in an expected payback for similar installations in manufactured housing 5-7 years.

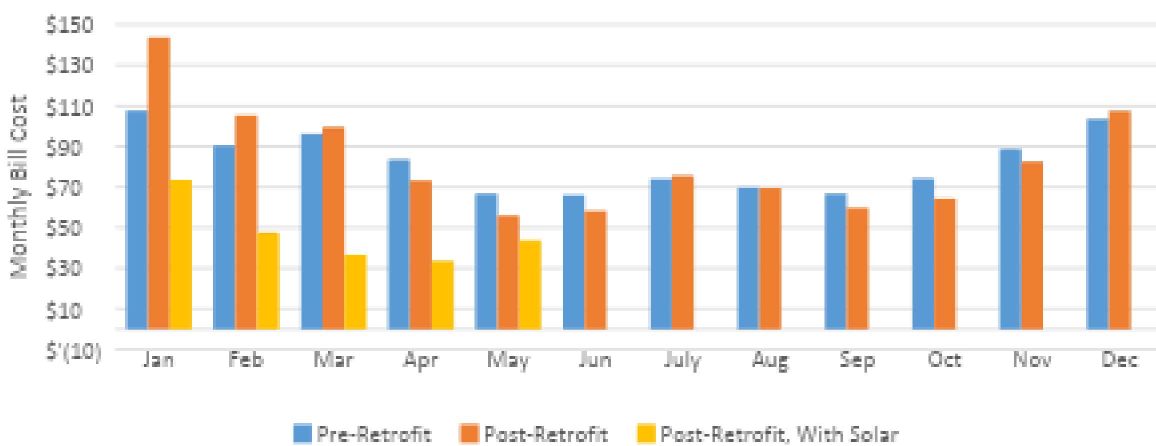

Figure 5. Total (gas and electricity) cost comparison of mobile home electrification with and without plug-in solar (820W and 2kWh storage). Pre-retrofit cost represents a total weather-normalized cost counterfactual for 2025 (based off data from 2020-2024, using 2025 utility rates). Post-retrofit cost represents observed 2025 costs. Post-retrofit, with solar represents 2026 costs so far.

This size of system would have been more than sufficient to close the electrification gap (where present) of all residents in this study and bring substantial cost savings compared to pre-retrofit bills ($300-$700/year depending on electricity usage patterns). In cases where higher usage was present, a larger system (up to 1600W) could increase these savings further. In the case of Resident 1, the Project Team was able to optimize fully by having submeter data at hand, but cost optimization is reasonably easily achieved with only monthly bills and a rough understanding of usage patterns.

Conclusion

When paired with weatherization and "plug-in" solar and battery storage equipment, water heating and HVAC electrification can be technically feasible and on-bill cost-effective in various types of manufactured homes. Given that many residents of manufactured homes are low-income, it is unlikely that the average resident of manufactured housing could afford heat pump upgrades without access to some form of incentive and would likely be unable to see on-bill savings without changes to the relative cost of gas, eligibility for electrification rates, and/or inclusion of solar installation. Given the small sample size of participants, more research is necessary on energy and bill impacts of heat pump retrofits in manufactured homes, including in newer vintages, which were not part of this study. To address the challenges to manufactured home electrification described in this research, the project team offers the following recommendations:

- The research should be replicated in climate zones with different winter heating and summer cooling needs to test for variation in performance and cost-effectiveness.
- Additional research should be done to understand how this work could be transferable to help retrofits in other types of under-studied building.
- Energy program administrators should implement incentives and rebate offerings that residents of master-metered communities can access.
- Manufacturers should bring back 40-gallon HPWH units. Split system HPWHs could also be feasible alternatives for manufactured homes.
- Programs serve people, not their homes. When identifying participants for retrofits it is important to meet them where they are. Program implementers should offer education, answer questions, and understand the practical concerns of communities and residents.
- Programs should consider the benefits of "plug-in" systems including solar and battery storage systems, as well as plug-in ASHPs.
- Regulators should consider master-metered manufactured community electricity rates that would better support cost-effective (on-bill) electrification.

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