CALIFORNIA ENERGY COMMISSION

ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

Enabling a Customer-Centric Approach to Scaling Integrated Demand-Side Management Retrofits

Achieving Zero-Carbon Retrofits in Existing Low-Income Multifamily Housing

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission, and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation, and bring ideas from the lab to the marketplace. The EPIC Program is funded by California utility customers under the auspices of the California Public Utilities Commission. The CEC and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas and Electric Company, and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the Energy Research and Development Division at ERDD@energy.ca.gov.

ABSTRACT

This research was initiated to more fully understand how to implement deep energy efficiency in existing affordable housing while overcoming barriers such as customer discomfort, inconvenience, and asbestos mitigation that bedevil energy efficiency projects in homes. California's Senate Bill 350, Clean Energy and Pollution Reduction Act of 2015 (de León, Chapter 547, Statutes of 2015), requires the state to double statewide energy efficiency savings in electricity and natural gas end uses by 2030 and is helping the policy side achieve a zero-carbon built environment (CEC n.d.). As part of this effort, the team focused on answering the following questions:

- What are the barriers to comprehensive retrofits for decarbonization in multifamily housing?
- What are the key emerging efficient retrofit package technologies? What data were collected and are important for data analytics? What are the data analytics results? Which technology worked and why?
- What are the customer economics, perceived benefit, and noneconomic benefits of decarbonization?

Based on these questions, it was possible to achieve a substantive and significant reduction in operating carbon emissions of 40 percent in the 80-unit Seasons at Ontario community in Ontario, California, and 18 percent in the 60-unit Pleasant View community in Fresno, California, through both energy efficiency and electrification. These improvements were achieved while demonstrating an economically viable pathway that, if financed, could be conducted within a 15-year time frame to qualify for tax credit refinancing.

This work also illustrated barriers to electrification, in particular how California's current electric distribution systems might not be ready for building electrification and its cost to customers to upgrade inadequate electricity infrastructure. Working to mitigate these costs led to evaluation and demonstration of unique emerging technologies such as the first United States installation of 120-volt heat pump space conditioning units, smart panels to cap electrical demand, and centralization of heat pump water heating to reduce the need for electrical upgrades.

Keywords: California Energy Commission, low-income family housing (LIMF), 120V heat pumps, heat pump water heating, decarbonization, construction industry, low-carbon economy, integrated demand side management (ISDM), building electrification, electrical upgrades, energy efficiency

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Background

Low-income, multifamily communities comprise a significant proportion of California's residential energy consumers, and a considerable number of multifamily residential buildings are energy inefficient. Low-income families require comfortable, safe, and healthy housing with both affordable rent and low energy costs. Low-income families pay a much higher portion of their incomes for energy than average-income families. Owners and managers of low-income multifamily housing buildings lack basic information to consider energy efficient retrofit packages. Even if they are interested, most lack the means to design, finance, and implement anything but the most basic retrofits. With well-designed programs supporting efficient retrofit packages, multifamily property owners could at least partially offset efficient retrofit package financing costs and contribute to California's mandate, as expressed in Senate Bill 350, the Clean Energy and Pollution Reduction Act of 2015 (de León, Chapter 547, Statutes of 2015), to double statewide energy efficiency savings in electricity and natural gas end uses by 2030 while also working toward a zero-carbon built environment.

Prior efforts show that while a technology-centric approach may reduce energy consumption at one or two test sites, market barriers still limit the scalability of retrofits. These barriers include cost, occupant acceptance, physical space availability, building layout, and the ability to identify rental housing units with high energy-savings potential. For this project, the Electric Power Research Institute, Inc. research team focused on a customer-centric approach to energy savings in low-income multifamily communities by identifying pools of willing participants and developing retrofit packages that:

- Are not intrusive to residents' lifestyles.
- Are developed based on an advanced metering infrastructure.
- Do not create additional expenditures from a specific construction style.
- Can be incorporated into existing programs.
- Lead to participation in energy reduction activities and adoption of behavior changes.
- Lead to deployment of advanced efficiency tools.

The goal of this project was to demonstrate how to best scale energy efficiency in existing buildings with targeted retrofit packages that reduce the cost of upfront audits and calibration while enabling energy-efficiency contractors to install retrofits at scale. Another goal was to leverage lessons learned from the scaling of solar photovoltaics through a combination of standardization, replication, guaranteed results, and lack of encroachment from inside the home.

Project Purpose

The purpose of this project was to develop and demonstrate an innovative approach to decarbonization by scaling residential retrofits in low-income, multifamily communities. Efficient retrofit packages are hybrids of traditional technology- and customer-centric approaches. This project focused on two communities: the 80-unit Seasons at Ontario in Ontario, California, and the 60-unit Pleasant View in Fresno, California. This choice of communities was particularly meaningful given the need to address affordable housing and compatible financial structures for new retrofit models. The project goal was to demonstrate a package of interactive energy-efficiency and self-generation retrofits using emerging technologies that minimize net carbon emissions and cost for retrofits as well provide opportunities for tax benefits and reduce operating costs.

Project Approach

As a demonstration project, this project's primary stakeholder was Linc Housing, a non-profit organization with affordable housing portfolios in California. Linc owns or operates more than 80 properties and more than 8,000 tenant units in the state. The project team worked with 140 homes representative of Linc's portfolio as well as with existing affordable housing stock. Other project contributors included:

- Linc's financing partners for tax credit financing and construction.
- Manufacturers of emerging technologies and equipment such as Sanden™, Innova, and Lumin.
- Workforce partners such as Villara for heating, ventilation, and air conditioning; Sundowner Insulation Company, Inc., for insulation; and Walton Construction, Inc., as a general contractor.
- BIRAenergy for modeling and analysis and University of California, Davis, for customer engagement, air quality monitoring, and analysis.

The research approach was to:

- Evaluate current community energy use and develop a package of energy-efficiency improvements across multiple technology categories, including emerging technologies.
- Develop cost estimates and obtain financing for upgrades.
- Implement energy efficiency and electrification improvements, with a focus on emerging technologies, and install extensive data-monitoring technologies.
- Conduct data analyses and develop technical impact and performance evaluations of emerging technologies and develop cash-flow models to scale retrofits.

This process was developed to overcome both technical and nontechnical barriers. An important part of the research was identifying both where current technologies existed and where new technologies were needed. At the same time, the overall retrofit had a budget that ultimately determined solution scalability across the property portfolio. Finding practical solutions to nontechnical barriers was an essential component of scaling emerging technologies to fill technical gaps.

As the project progressed, the team's approach was slightly modified to focus more closely on decarbonization through electrification (in addition to the original core intent of the application of energy-efficiency technologies). This also meant that carbon savings became as important a metric as energy savings, and cost-effectiveness had to be treated differently as electrification economics did not always reflect energy-efficiency economics.

The project's technical advisory committee reflected the diversity of project participants: multiple low-income affordable housing property developers, the California Public Utilities Commission, utilities, and product manufacturers.

Project Results

The project results successfully demonstrated a pathway for scaling retrofits for decarbonization using a combination of energy efficiency, electrification, and local self-generation. Project highlights include:

- Comprehensive understanding of residential energy use in the state's affordable multifamily housing market, which in turn enabled creation of the accurate baselines that ultimately determined the impacts of emerging technologies
- Comprehensive energy retrofits across all energy uses: heating, ventilation, and air conditioning; lighting; water heating; appliances; and building envelope such as insulation, upgraded windows, and cool roofs in both Ontario and Fresno communities
- Identification of a new technology for electrification and installation of an integrated, first-of-its-kind heat pump system in the United States for heating, ventilation, and air conditioning that was Underwriter Laboratories (UL) certified
- Demonstration of a heat pump water heater using additional power at the building level. The new water heaters used carbon dioxide as their natural refrigerant, which has the low global warming potential of 1.
- Engagement with the construction and field workforce, which provided valuable insights into scaling emerging technologies and comprehensive retrofits
- Development of new financial models for comprehensive retrofits focusing on financing cash flow, including tax credit financing that provided the means to pay for the cost of the upgrades that, in addition to program rebates, offset some of the cost

In the Seasons at Ontario, the Electric Power Research Institute, Inc. research team overcame the split incentives barrier by reducing operating costs for both owners and tenants, which also reduced carbon emissions by 40 percent. This was achieved by both electrifying space heating and installing roof insulation and energy-efficient windows, lowering electricity usage. If water heating had simply been electrified instead of adding those efficiencies, the project would not have been able to deliver energy cost savings to residents.

At Pleasant View in Fresno, the project team ran into significant technical issues because of the lack of electric distribution capacity, both on the Pacific Gas and Electric Company side of the meter and inadequately sized building electric panels on the customer side. The cost of those distribution upgrades would have been more than $15,000 per apartment, so the team switched to alternative emerging technologies including 120-volt heat pumps, which are gaining popularity across the country for building electrification retrofits and are now

Underwriter Laboratories certified in the United States. Based on bill data information the project team received from LINC, the team compared 2022 (full year of measures and solar situation stabilized) and 2019 (last year before project measures installation and first year of full solar implementation) and noted that there was an increase of $11,600 (+24.7 percent) in Pleasant View's electricity bill and a decrease in their gas bill of $23,900, a net savings to LINC of $12,300 per year in total gas/electricity comparing 2022 and 2019. This is backed up by the data the EPRI team reported: a 45 percent gross decrease in gas consumption and 23 percent gross increase in electricity usage. The team attributed increased electricity usage to the tenants' increased use of the packaged terminal air conditioner (PTAC) units attributed to comfort reasons as well as a fuel switch to community heat pump water heaters in three buildings.

Finally, extensive customer surveys were conducted to fully understand how occupants perceived the energy upgrades. Surveys in both the Pleasant View and Seasons at Ontario communities showed that what mattered to residents were comfort and convenience — in this case improved air quality through window replacements and new appliances for cooking and cooling, which were included in the energy upgrade package.

Technology/Knowledge Transfer/Market Adoption (Advancing Research to Market)

This project focused on both emerging technologies and scalable approaches to decarbonization. The EPRI team therefore focused on how to collaboratively scale solutions with property owners, work forces, and other participants.

The team has been applying the project template across the country, including:

- Working with National Core Renaissance in San Diego on two low-income communities on water heating and 120-volt heat pumps, similar to those implemented in the Fresno project.
- Working with Seattle's Community Roots Housing and the New York City Housing Authority to include findings from this project in the U.S. Department of Energy's Connected Communities Award.
- Working with utilities nationwide to replicate the project's technical and financial models.
- Providing data and information on customer acceptance of emerging technologies to codes and standards organizations and to affordable housing providers throughout the United States.
- Communicating project results through multiple channels: reports, white papers, and conference publications. These efforts have so far increased awareness of the project. For example, the San Diego Building Electrification Coalition (comprised of environmental justice, labor, and faith-based organizations) contacted Electric Power Research Institute for possible project collaboration.

Benefits to California

As a result of this project, the Electric Power Research Institute research team developed technology packages and technical pathways that reduce greenhouse gas emissions by 40 percent or greater even before considering community solar. This project also identified and demonstrated key emerging technologies that will enable cost-effective electrification and heat pump installations in existing buildings.

The next step is managing costs to make projects like this one scalable. This project featured several financing mechanisms, including "gap financing" that could potentially reduce the overall cost of decarbonization for both residents and property owners. Gap financing is a bridge or interim financing that refers to a short-term loan for the purpose of meeting an immediate financial obligation until sufficient funds to finance the longer-term financial need can be secured. However, work remains to further reduce costs to the goal of $3 per square foot to make deep retrofits truly affordable. At Fresno, the total cost of electrification per square foot was $21.95 before incentives and with the Low-income Weatherization Program incentives was $17.65. The average square foot cost of electrification (total divided by the measure) was $8.12 before incentives; with the Low-income Weatherization Program incentives, it was $7.21.

Finally, the project provides both ideas and a program framework for utility and non-utility energy efficiency programs that can make retrofits cost-effective at market scale.

The integration of various zero-net-energy buildings, distributed-energy resources, and storage together achieved mandatory savings set forth in California Assembly Bill 32, the California Global Warming Solutions Act of 2006 (Pavley, Chapter 488, Statutes of 2006). Building efficiencies and controls also provided a number of benefits, including:

- Greater electric reliability concerning the integration of efficient retrofit packages, demand response, and distributed energy resources with grid operations.
- Savings from the project's retrofit packages totaling roughly 30-40 percent.
- Increased safety through improved ability to control and integrate a building's use of renewable power, storage, and electric-vehicle charging.

CHAPTER 1: Introduction

California's building energy retrofit goals include reducing existing building energy use by 50 percent by 2030. California also has aggressive goals to move buildings closer to zero net energy (ZNE). Low-income multifamily (LIMF) communities are important retrofit targets but require both public support and innovation since there are no cost-effective pathways for this sector to achieve deep energy retrofits.

Multifamily housing is a difficult market segment to incentivize for energy upgrades for a number of reasons. The issue of split incentives means that retrofits are the responsibility of a property owner who typically does not pay the energy bill. Furthermore, affordable housing owners cannot recover retrofit costs through rent increases. Multifamily housing owners also sometimes forego routine property maintenance, ultimately leading to greater building inefficiency and increased energy use.

In addition to incentive issues, limited technical and financial knowledge among multifamily building owners (as with owners of other building types) can also be a barrier to retrofits. Overcoming these limitations is a resource-intensive process. Specifically, an owner wishing to pursue energy efficiency improvements must contract with an energy auditor, a design engineer, a construction manager, one or more contractors, a lawyer or accountant (to handle subsidies or debt financing), and a consultant to educate residents and train maintenance staff.

To support California's ambitious building energy goals, the California Public Utilities Commission's (CPUC) ZNE Action Plan highlighted the need for cost-effective, integrated demand side management (IDSM) retrofit strategies and packages (CPUC 2015). The Electric Power Research Institute (EPRI) obtained a grant from the California Energy Commission (CEC) to lead a project to develop and demonstrate an innovative approach to scale residential retrofits, using energy-efficient retrofit packages (ERPs) for low-income communities. Together with its subcontractors – the University of California, Davis (UC Davis), BIRAenergy, and Itron – EPRI is developing, implementing, and evaluating site-optimized IDSM packages for multifamily buildings in California. The IDSM packages include energy-efficiency upgrades to both residential units and common areas.

Linc Housing, a non-profit, low-income housing organization, invited the EPRI research team to conduct a field study at two of its communities – one at the 80-unit Seasons at Ontario and one at the 60-unit Pleasant View in Fresno. The former provides housing for income-eligible seniors, while the latter is a mixed-age community for individuals, couples, and families in 1-, 2-, 3- and 4-bedroom apartments. At Seasons at Ontario, residents individually pay their utility bills, while at Pleasant View utilities are included in the rent. All field work for the study was conducted at these two sites.

The project had three phases: baseline, retrofit, and post-retrofit. The study measured energy consumption, indoor air quality, and residents' experiences with household energy both before and after energy upgrades were installed to determine which retrofit packages best saved energy, improved indoor air quality, and provided other benefits to owners and residents. The goal was to show the potential for a hybrid approach that combines traditional technology-centric and customer-centric solutions. Altogether, the project demonstrated the technical, commercial, and practical feasibility of turnkey, cost-effective IDSM retrofit solution packages to implement scalable energy efficiency improvements in low-income multifamily housing communities.

The knowledge gained from these demonstrations is incorporated into IDSM retrofit guidelines for multifamily residences in low-income communities found in Chapter 4of this report, providing pathways for ZNE communities. IDSM packages that are cost-effective, customer-centric, and acceptable to residents can provide maximum and continuing energy savings. This study addresses the following questions:

- What are the barriers to comprehensive retrofits for decarbonization in multifamily housing?
- What are key emerging technologies? What data were collected and proved important for data analytics? What were the results? What technology worked, and why?
- What are the customer economics, perceived benefit, and noneconomic benefits of decarbonization?
- What guided the electrification process in the LIMF segment?
    - How to Target Buildings
    - Optimal Performance Packages
    - Economics and Financing for Multifamily Housing
    - Technology Application Notes from Field Demonstrations (e.g., what to do and what to avoid)
- How should decarbonization targets in affordable communities be structured?

CHAPTER 2: Project Approach

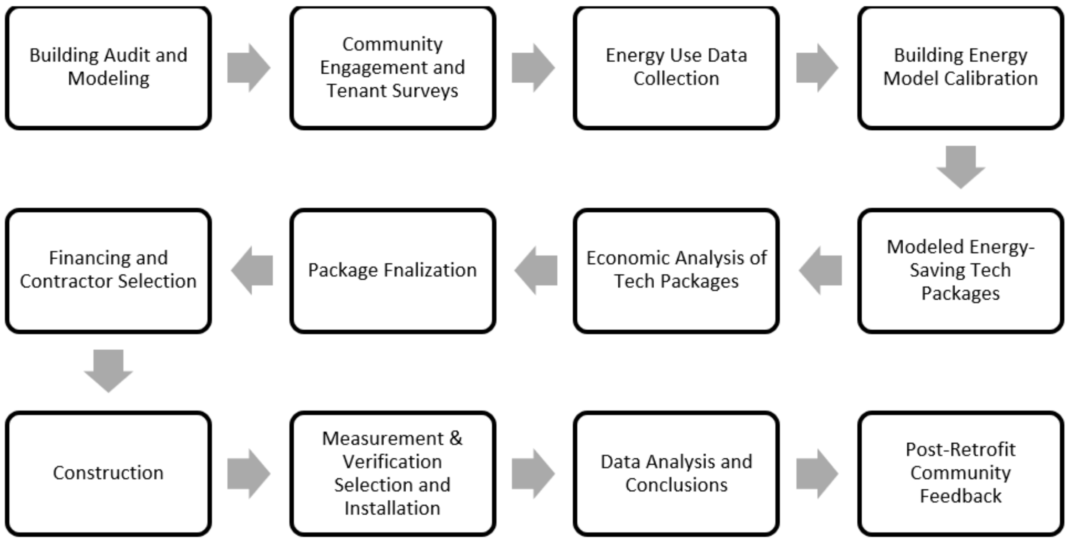
This project is essentially a customer-centric approach to decarbonization retrofits in existing buildings. Customer focus was a core element of the project that drove selected energy measures. One example was the decision to install cool roof and roof insulation instead of duct insulation because of the latter's intrusive nature. As shown in Figure 1, a customer-centric project balances efficiency and electrification with customer economics, health, and comfort.

Figure 1: Customer-Centric Retrofit Requirements

Source: Electric Power Research Institute

The overall approach began with baseline energy use and proceeded to technology identification, financing, construction, and results analysis. Each step contained significant analysis for energy use, technology readiness, and cost evaluation. Figure 2 provides a quick summary of the steps involved in developing, implementing, and evaluating the retrofit packages.

Figure 2: Overall Retrofit Process



Source: Electric Power Research Institute

Building Audits and Modeling

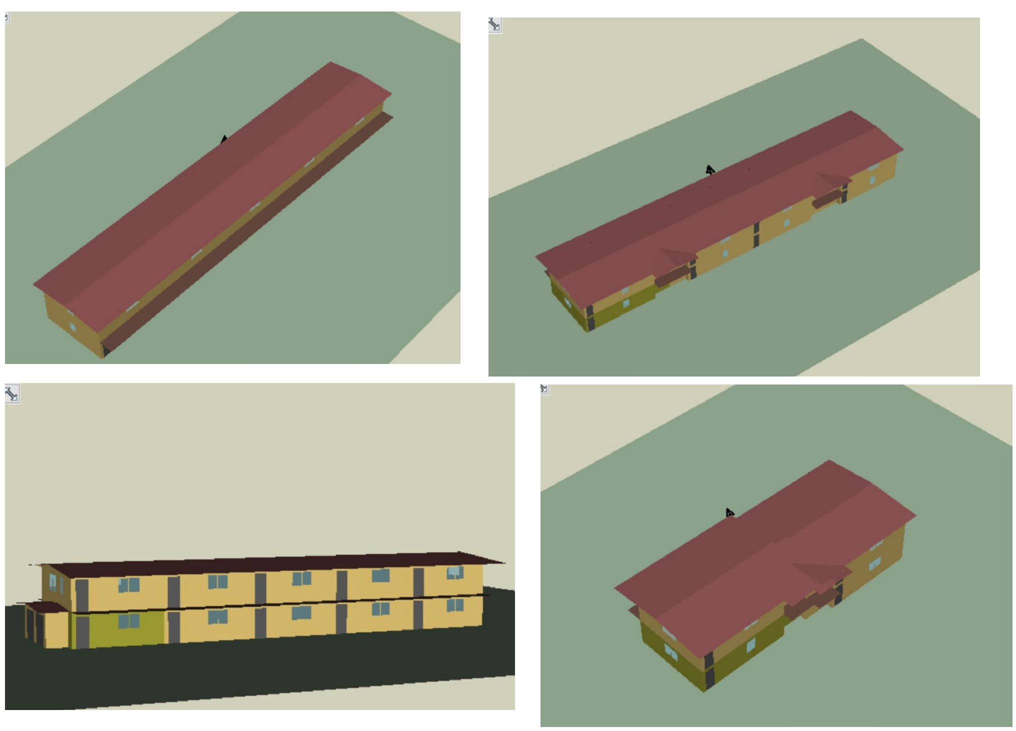
Linc Housing performed energy and water audits with support from the Low-Income Weatherization Program (LIWP) for large multifamily (LMF) buildings for both the Pleasant View and Seasons at Ontario communities. The project team used these audit reports as baseline information for existing conditions, recommended appropriate energy measures and savings, and estimated LIWP incentives. LIWP technical support staff also assisted with solar photovoltaic (PV) evaluations and designs at both sites. PV systems were installed by Spring 2017, ahead of ERPs installed for the project. Several visits to the two demonstration sites were required to confirm audit report information, provide more detailed information, view site conditions, evaluate the useful lives of vintage equipment, and meet with Linc Housing community managers to discuss owner and tenant needs and behaviors.

Base Case Energy Models

Basic steps in developing the building energy modeling setup shown in Figure 3 included:

- Acquiring floor plans and construction details from sites, including a site visit.
- Translating floor plans into the Building Energy Optimization Tool (BEopt™) v2.6.0.2 graphical user inputs.
- Extracting current installed feature information from energy audits.
- Performing site visits and met with Linc Housing community managers.
- Developing BEopt base case energy models from construction details and energy audits and vintage tables.
- Calibrating and testing the BEopt base case energy models.

Figure 3: Setup for Multifamily Model



Source: Electric Power Research Institute

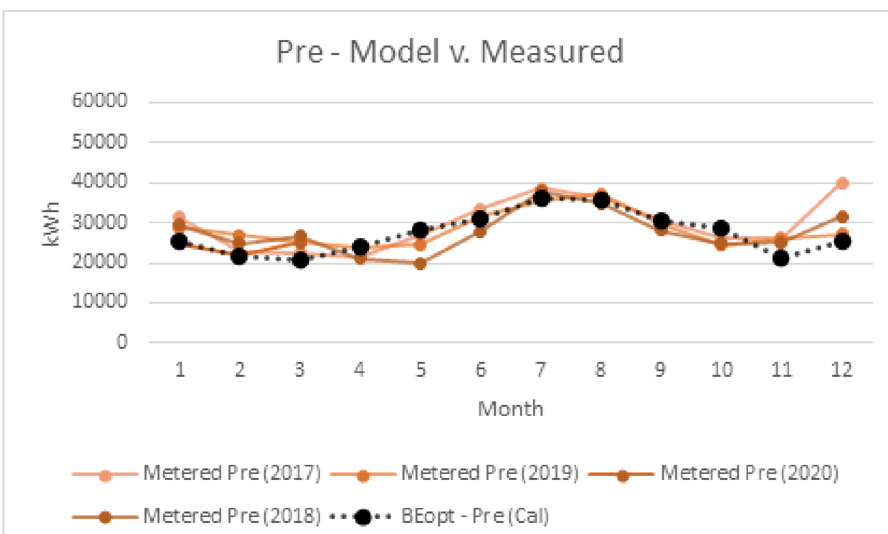
Calibration of Base-Case Models

Initial calibration of the BEopt building energy models compared modeled energy use with estimated energy use from recent LIWP-LMF building energy audits. This initial calibration for the Pleasant View apartments in Fresno, California, shown in Figure 4, show that the BIRAenergy model and the LIWP-LMF building energy audit were in 83 percent agreement. There is no confirmation of the accuracy of the LIWP-LMF building audit estimate, but overall agreement within 20 percent is a reasonable match in the absence of solid metered energy baselines for the buildings.

As EPRI moves into development of the initial ERPs, additional information on miscellaneous electric loads (MELs) and associated customer preferences and behaviors will also be developed. Existing data show that improving MEL estimates and customer data, along with calibrating historic utility use, will help achieve approximately 5 to 10 percent model agreement. The team monitored the sites to collect both end-use and overall energy data as part of the project's measurement and verification effort.

For Pleasant View, the BEopt model was calibrated to monthly data collected by WegoWise® monitoring devices. Most buildings had PV installed during June 2018, and all buildings had energy efficiency upgrades beginning in December 2019. The pre-retrofit period provided limited monthly data combined with 12-month consecutive data. The data ranged from January 1, 2013 through December 31, 2017. The resulting aggregated community-level modeling calibration, compared with metered community-level electricity consumption, is shown in Figure 4.

Figure 4: Community-Level Calibrated Pre-Retrofit Model vs. Measured Electricity Consumption



Source: Electric Power Research Institute

Customer Engagement and Surveys

The field surveys determined the extent to which retrofit packages saved electricity, improved indoor air quality, and benefited owners and residents. The surveys also identified likely barriers to owner and resident participation in similar programs.

Methodology

The objective of the baseline survey was to document residents' attitudes and experiences before retrofit installation. This section describes the approach and methods used to collect baseline data from households at the two project sites.

Survey Instrument Development

Before energy efficiency upgrades were installed, a household survey was created to collect information on residents' knowledge, attitudes, and behaviors about household energy use and sustainability. Preliminary questions were developed by behavior experts at UC Davis in accordance with project objectives and specific upgrades. To minimize burdens on participants, the majority of questions were close-ended, but a handful of open-ended questions were also included to gather more exploratory information. The final version of survey questions was programmed using Qualtrics, an online survey software platform.

Survey Implementation

Surveys were implemented at Seasons at Ontario December 6–8, 2017, and at Pleasant View February 20–21, 2018. In both cases, two UC Davis researchers traveled to the community to collect field data. Residents met with researchers either in the common area of the housing office or in their homes. UC Davis researchers conducted the survey — in English and Spanish — by reading survey questions aloud to participants and typing their responses into the Qualtrics survey. From start to finish, consent and survey implementation took between 12 and 20 minutes, depending on how much participants had to say, particularly on open-ended questions. Insights from the survey results follow.

Seasons at Ontario

Most respondents were reasonably satisfied overall with their apartments and community, as well as with individual features like cooling, heating, and air quality. There was room for improvement in the heating, ventilation, and air conditioning (HVAC) systems, particularly with respect to even distribution of cooling, heating, and indoor air quality (e.g., stuffiness, odors, and dirt). The hot water supply was deemed acceptable (with the exception of slow delivery to the bathrooms). A notable proportion of respondents reported inadequate lighting in their units (30 percent), at their front door (45 percent), or in the communal areas outside (59 percent). Most who used the pool were satisfied with its temperature in the summer.

Most respondents at Seasons at Ontario reported that they pay close attention to their energy bills (68 percent) and try to save energy at home (81 percent) for a variety of reasons, including cost. Fewer, though still most, expressed an interest in receiving information on how much energy their household uses (57 percent) and advice on how to save energy at home (60 percent).

Pleasant View in Fresno

Most respondents were dissatisfied with their apartment and community as well as individual aspects of their home (cooling, heating, air quality). Many problems were reported. The cooling systems (evaporative coolers) largely did not work, and the heating systems (gas wall heaters) in most apartments heated the rooms unevenly and some were unsafe. For these reasons a notable fraction of respondents did not use their evaporative coolers or heaters at all. There were reports of poor indoor air quality (stuffiness, odors, and dirt) by more than two-thirds of respondents. A large proportion of respondents reported inadequate lighting in the units (80 percent), at their front door (41 percent), or in the communal areas outside (54 percent). The hot water supply was the only feature that appeared to be working well for most respondents.

Despite the fact that utilities are not directly paid by residents at Pleasant View, most respondents (83 percent) reported that they try to save energy at home; reasons included environmental concerns, habit, and setting examples for their children. Most expressed an interest in receiving information on how much energy their households use (63 percent) and advice on how to save energy at home (68 percent).

Energy Efficiency Modeling and Development of Energy Retrofit Packages

This section first describes how ERPs were selected, with some non-adopted measures. This list of measures and their approximate energy savings, costs, and cost-effectiveness was developed collaboratively by the project team. Furthermore, based on a review of historical simulation data and cost-effectiveness analyses, it was possible to narrow down the initial list of measures. Table 1 is a list of initial measures that were considered for the Pleasant View site. The initial list of measures for the Seasons at Ontario site was determined to be the same except that the Seasons HVAC system is a combined hydronic heating system instead of a gas wall heater.

Table 1: Results Showing Initial EPRs Considered for Pleasant View in Fresno

	Currently Installed	Send to Bid for Upgrade	Estimated LIWP Rebates	IOU Incentives	First Cost/ Incremental Cost	Cost Source	$/yr Savings	Simple Payoff	HPWH Package	Gas DHW Package
Air Leakage	15 ACH50	7 ACH50, Hand-Sealing, Best Practice			$13,440	BIRA	$672	20.0	Yes	Yes
Evaporative Cooler	Yes	Remove ducting			$6,250	BIRA	$268	1.9	Yes	Yes
Thermostat	Standard	Programmable			$500	BIRA	$600	0.8	Yes	Yes
Water Savings	None	Low-flow faucets, showerheads	$715		$511	BIRA	$268	1.9	Yes	Yes
Lighting, Interior	Mostly CFLs	100% LED	$200		$500	BIRA	$274	1.1	Yes	Yes

	Currently Installed	Send to Bid for Upgrade	Estimated LIWP Rebates	IOU Incen-tives	First Cost/ Incre-mental Cost	Cost Source	$/yr Savings	Simple Payoff	HPWH Package	Gas DHW Package
Heat Pump	None	14 SEER HP/ 12.2 EER, 8.2 HSPF	$5,785	$750	$16,500	BIRA	$463	23.1	Yes	Yes
Water Heater (alt 1)	Gas Standard	HPWH (COP = 3.25)	$10,755		$9,500	BIRA	$28	Instant	Yes	No
Water Heater (alt 2)	Gas Standard	Gas Tankless, condensing, 0.96 EF or better			$5,500	BIRA	$237	23.2	No	Yes

Source: EPRI Analysis

The project team considered a number of other energy efficiency measures, but they were judged to be either insufficiently energy efficient or their costs were too high to meet the minimum cost-effectiveness threshold.

For Pleasant View, the team updated models to predict the impacts of installed measures:

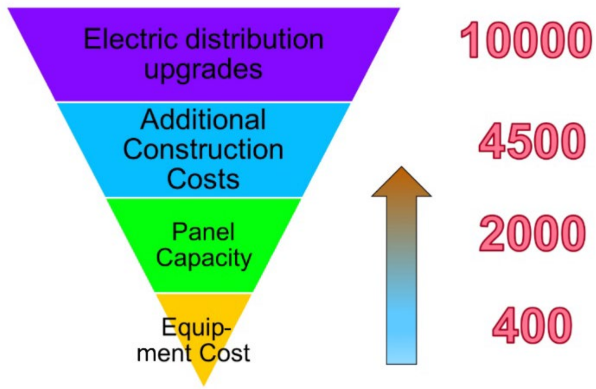
1. Wall Insulation: R-7 → R-13
2. Attic Insulation: R-19 → R-38
3. Air Leakage: 15 ACH50 → 7 ACH50
4. Space Conditioning: Evaporative Cooling/Furnace → Innova
    a. Increased cooling capacity proportional to # Innova units/# evaporative units per building
5. Lighting: 60 percent CFL hardwired → 60 percent LED hardwired
6. Water Heater for Applicable Buildings:
   Gas 0.57 EF, 40 gal → HPWH 3.25 EF, 50 gal
7. Miscellaneous Gas Loads (1/3x MELs):
    a. 1/3x accounts for heat pump electrification savings
8. Cooling Setpoints: Calibrated value of >70°F (21°C) → 70°F (21°C):
    a. Accounts for occupant ability to cool apartments to lower temperatures

In general, driven by reductions in gas usage, the retrofit packages predicted a decrease in overall source energy consumption. Only minor increases in electric consumption resulted due to the electrification of space and water heating, as well as increases in cooling load from improved cooling capabilities over the pre-retrofit evaporative coolers.

Understanding Cost Impacts for Electrification Technologies

This project was one of the first to identify barriers to building electrification on the electric infrastructure side. Multifamily buildings face unique infrastructure challenges, shown in the inverted cost pyramid in Figure 5. This is because, unlike in more dispersed single-family homes, multi-unit buildings undergoing electrification increase demand on the power grid at a single point of connection.

Figure 5: Inverted Cost Pyramid for Electric Infrastructure Upgrades



Source: Electric Power Research Institute

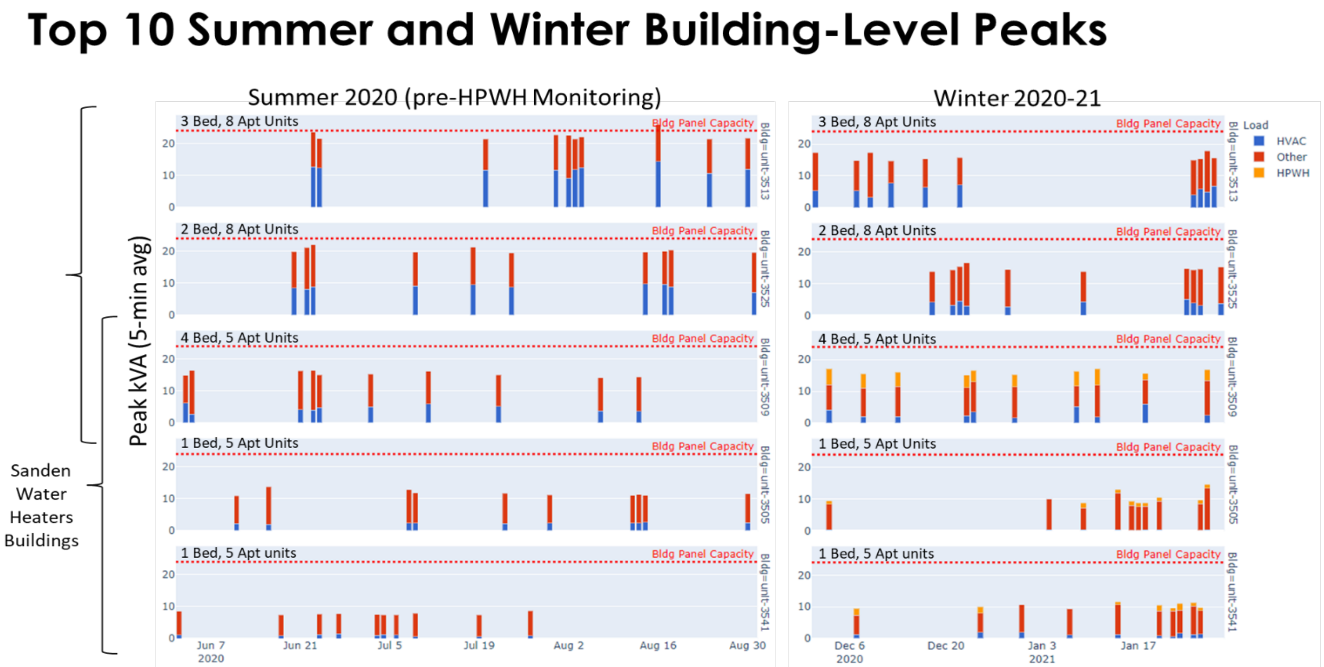
Seasons at Ontario

In Seasons at Ontario, space-heating electrification was aided by air conditioners that could be converted to heat pumps (but without backup resistance heating elements). To eliminate backup resistance with heat pumps, the units were insulated to reduce peak-heating loads. This strategy also avoided winter peaks. However, the water heating units could not be electrified since there was neither sufficient panel capacity in the apartments nor sufficient distribution capacity in Southern California Edison Company's (SCE) transformers. When electrical infrastructure upgrades were considered, costs rose to more than $15,000 per apartment — excluding the higher cost of heat-pump water heaters (HPWHs) when compared with tankless gas. Estimated costs were: $1,800 for panel upgrade, $2,000 to run a 240 V line to the location of the water heater, $1,500 for upgrading the advanced metering infrastructure (AMI) meter socket at the building level, about $3,000 for trenching and running larger wires from the transformer to the building, and about $7,000 for upgrading the service transformer.

Pleasant View

The situation at Pleasant View for electrification was even more challenging. The community consists of 10 apartment blocks with between 4 and 10 apartments in each block. Each block was served by a 200A main building panel, which meant an inadequate allocation of 20A per household. This meant that neither a standard heat pump nor an HPWH could be installed since each required 240V, 40A (or at least 240V, 15A), a capacity level unavailable at the building level. In addition, upgrading building electrical panel capacity would have required rewiring of Pacific Gas and Electric Company's (PG&E) distribution wiring at customer cost due to direct buried cable. The total cost of all building electrical upgrades required in this community was estimated at $12,000 per apartment, which was again a nonstarter. This led to investigations of different heat pump options to reduce power draw as well as options to provide HPWHs with reduced power-loading requirements. These analyses accounted for EPRI's circuit-level metering of the community, which provided very accurate power availability, as shown in Figure 6, and enabled installation of low-power heat pumps.

Figure 6: Peak Power Draw Analysis for Pleasant View Community in Fresno

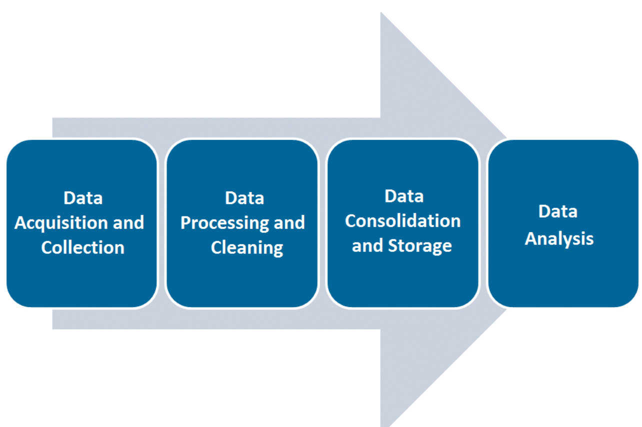


Source: Electric Power Research Institute

Data Acquisition and Monitoring

Data acquisition workflow has four major stages: data acquisition and collection, data processing and cleaning, data consolidation and storage, and data analysis. The workflow is shown in Figure 7.

Figure 7: Data-Acquisition Workflow



Source: Electric Power Research Institute

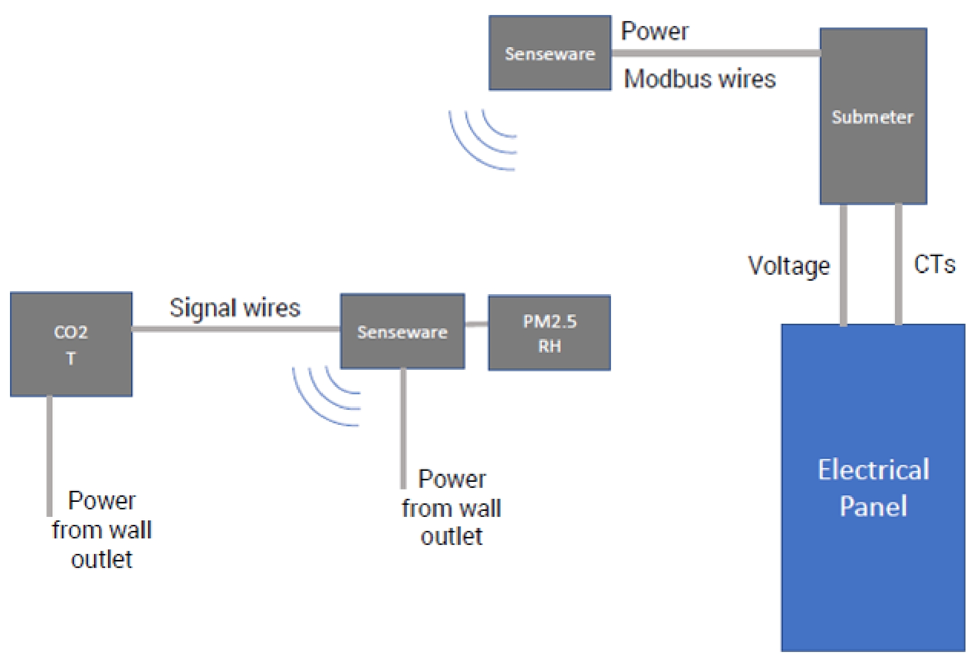
Data-System Architecture

EPRI's team adopted circuit-level metering to gain full and complete understanding of the two communities' energy use, combined with indoor air quality monitoring. This required collection of 30 data points at one-minute intervals from each apartment, meaning that the project would ultimately collect a total of 4.2 ***billion*** data points over the two-year life of the data acquisition.

An extensive set of requirements was developed for the data acquisition systems, and multiple products — SiteSage, Sense, Senseware, and Energy360 — were evaluated. Following this analysis, the team selected the Senseware system (shown in Figure 8)(Attune n.d.) for the following reasons:

- The system is a networked self-healing 50-MHz mesh network, which could potentially reduce set-up times and data dropouts.
- Senseware included a full range of sensors, including for indoor air quality, which were networked into a low-cost hardware system.
- Senseware hosted data management that reduced the burdens of data transfer and data storage.
- Senseware provided unified data communications and formats, with a good user interface for data access.
- The Senseware data architecture was designed to optimize Senseware's cloud data stack with the analytics data server.

Figure 8: Senseware System Architecture



Source: Senseware

Data Acquisition and Collection

Four specific areas are associated with the data acquisition and collection processes: (1) installing connected devices and associated monitoring hardware, (2) procuring legal agreements associated with each device and monitoring hardware manufacturer, (3) integrating software communication, and (4) obtaining customer agreements for access to respective home and device-level data.

Data Processing and Cleaning

Any large-scale data collection encounters anomalies in the data streams. Anomalies arise due to installation errors, loss of internet connectivity, software coding errors, and other miscellaneous errors. Each data stream is processed and cleaned, which requires subject matter expertise to both assess and correct the error. These procedures are performed through exploratory and automated scripting, with the goal of more automation as the project progresses.

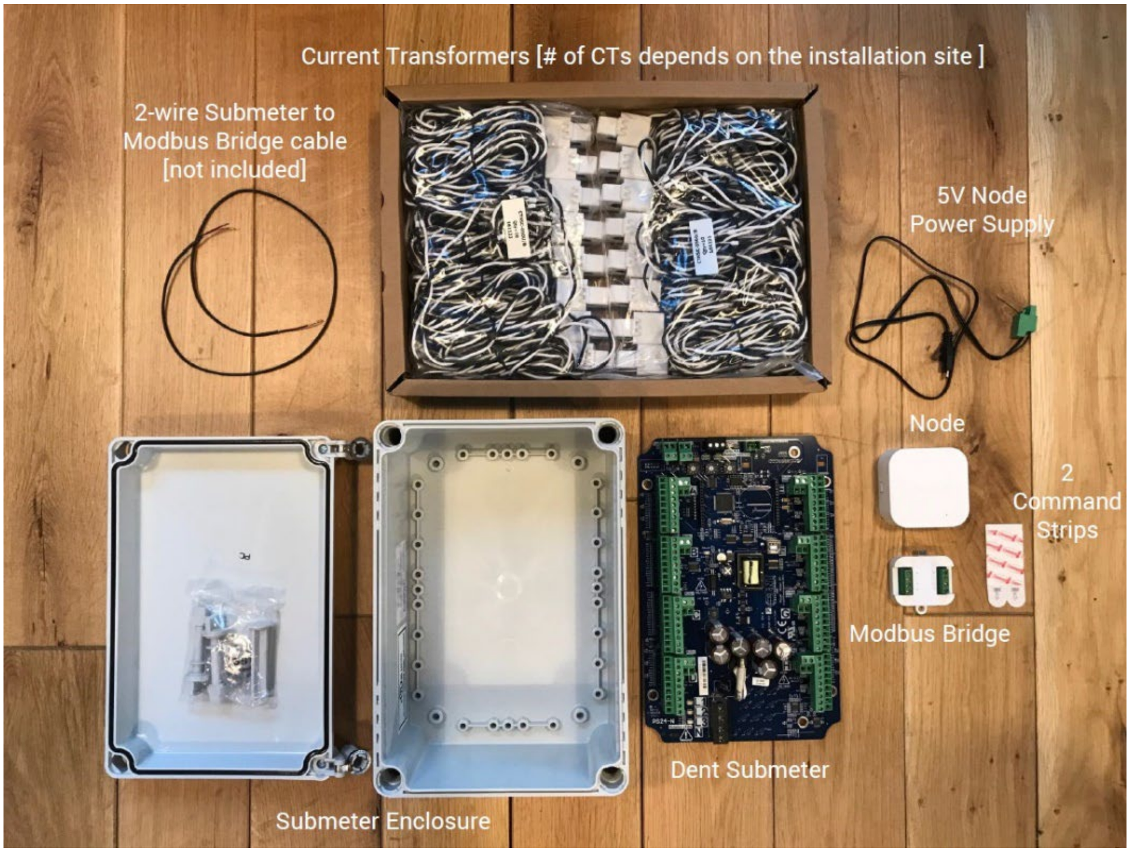
Data Consolidation and Storage

Following the data cleaning process, data is aggregated in two different ways. The first involves consolidating devices in groups that make sense for analysis by device type: home, circuit level, and whole premise. The second method of aggregation involves collecting data streams into a single repository so that they do not exist in silos. Having a single repository, as outlined in the data architecture section, streamlines analysis.

Data Acquisition Hardware Stack

The hardware stack consists of three main systems: submeter, thermistor, and gateway. The submeter system includes one Dent printed circuit board (PCB) submeter, one Modbus bridge, one gateway node, one 5 V power supply, and multiple current transformers (CTs) within a large National Electrical Manufacturers Association (NEMA) plastic enclosure, as shown in Figure 9 (Attune n.d.). The CTs measure the current flowing through individual breakers, and the PCB submeter calculates the power usage. The Modbus bridge and gateway node transmit results to the gateway.

Figure 9: Senseware System Components



Source: Senseware

CHAPTER 3: Procurement, Installation, and Commissioning

Procurement

An initial list of ERPs was identified for Seasons at Ontario in early 2017. Although 14 ERPs were initially identified, 10 final components were ultimately selected: HVAC replacements, smart thermostats, condensing tankless water heaters, indoor LED lamp replacements, outdoor LED lighting fixture replacements, installation of retrofit windows, sprayed applied polyurethane foam roofing, solar PV systems, water-saving devices, and kitchen appliance upgrades. Beginning in November 2017, the project team installed the HVAC upgrades, thermostats, tankless water heaters, outdoor lighting, appliance upgrades, and window retrofits. Indoor LED bulbs, low-flow aerators, and low-flow showerhead wands were replaced at no cost through the Energy Savings Assistance Program (ESAP). Installation of the spray foam roof and solar PV systems was contracted directly between Linc Housing, Arithane Roofing, and Cal Solar. The ERP measures were funded by multiple sources: CEC EPIC (Electric Program Investment Charge) Grant EPC 15-053, ESAP through SoCalGas, LIWP, Low-Income Housing Tax Credit (LIHTC) Program, and the Multifamily Affordable Solar Housing (MASH) Program. LIHTC program funds were temporarily available as the property was going through a tax credit refinancing process. It was estimated that 5–10 percent of the property portfolio goes through this process every year, each of which is an opportunity for deep retrofits. Funding sources and installation contractors are shown in Table 2.

Table 2: Summary of Selected Energy Retrofit Packages for Installation at Seasons at Ontario

Energy Retrofit Packages	Funding Source	Cost	Installing Contractor
HVAC Replacement	EPIC/LIHTC	$487,544	Walton Construction
Smart Thermostats	EPIC	Included in HVAC	Walton Construction
Condensing Tankless Water Heater	LIHTC	$193,178	Walton Construction
Outdoor LED Lighting Fixture Replacement	EPIC/LIHTC	$93,227	Walton Construction
New Appliances	EPIC	$92,158	Walton Construction
Window Retrofit	LIHTC	$203,930	Walton Construction
Indoor LED Lamp Replacement	ESAP	0	TELACU
Low Flow Aerators	ESAP	0	TELACU
Low-Flow Showerhead	ESAP	0	TELACU
Spray Foam Roof	LIHTC/LIWP	$132,810	Arithane Roofing
Solar PV	LIWP/MASH	$404,553	Cal Solar

Source: Electric Power Research Institute

Financial Analysis of Retrofits

Table 3 is a chart of efficiency retrofits performed on the homes as well as costs and rebates available during the design stage of this project. Table 3 provides per-dwelling unit costs and incentives as well as the total costs for retrofitting all 80 dwelling units, both with and without incentives.

Table 3: Costs and Incentives for All 10 Electrification and Energy-Efficiency Features for Seasons at Ontario

	Costs		Incentives	
EE Measure Upgraded	**Estimate Total Gross Costs: Community**	**Cost Estimate Per Unit**	**IOU, ESA, & LIWP Incentives per Unit**	**IOU, ESA, & LIWP Incentives for Community**
HVAC[1] 16 SEER, 8.6 HSPF	$ 426,000	$ 5,325	$ (748)	$ (59,840)
Smart Thermostats	In HVAC	In HVAC	$ -	
Outdoor LED lighting (Fixture	$ 49,120	$ 614	$ (1,374)	$ (109,920)
Kitchen Appliances	$ 92,158	$ 1,152	$ -	$ -
Attic Insulation	$ 82,000	$ 1,025	$ (713)	$ (57,040)
Weatherstripping	$ 15,000	$ 188	$ (115)	$ (9,200)
Water saving devices	$ 8,160	$ 102	$ (633)	$ (50,640)
Condensing Tankless W/Hs	$ 191,600	$ 2,395	$ (530)	$ (42,400)
Indoor LED lighting (Lamps)	$ 80,167	$ 1,002	$ (688)	$ (55,040)
Glazing	$ 210,930	$ 2,637	$ (607)	$ (48,560)
Total Cost (Community)	**$ 1,155,135**		**$ (5,408)**	**$ (432,640)**

Source: Electric Power Research Institute

The total cost of the recommended electricity-saving features (excluding gas water heating and solar-gas community pool heating), or the full, gross cost (including removal and installation of the retrofits, but excluding all incentives), was $1,155,135, as detailed in Table 3. This total is the cost to remove existing features and install upgraded versions of all 10 listed features in all 80 apartments. All recommended features were at or beyond their normal life spans and needed replacement, regardless of participation in this project. The baseline cost to replace existing features with minimum-efficiency versions was more than $750,000. Subtracting the baseline cost from the total upgrade cost provided the incremental or net cost of the efficiency upgrades, which totaled $404,000. Writing this out as an equation, the upgrade costs were:

$1,155	–	$751,000	=	$404,000
Total Cost		Baseline Costs		Net Upgrade Cost (Absent Incentives)

Numerous incentives are available for some upgrades — some to encourage upgrading energy efficiency and some to encourage carbon reduction. These incentives are provided on a per-dwelling unit basis in the fourth column of Table 3; the fifth column provides the full amounts of incentives for all 80 units. The potential incentive for installing these upgraded features was $5,408 per unit, totaling about $433,000.

If all upgrades were installed and all incentives awarded, the upgrade cost would be negligible. Every effort should be made to secure commitments for incentives for these upgrades. Table 4 shows cost estimates for each step, beginning with the construction bid (or gross cost) before netting out costs for minimum-efficiency replacements and the final net recovery cost for exceeding the minimum to high-efficiency replacements and additions.

Table 4: Cost Estimates for Each Measure

			Baseline value (min cost to replace features beyond Useful Life)	
EE Measure Upgraded	**Estimate Total Gross Costs: Community**	**Estimate Baseline Replacement Cost**	Net Upgrade Cost (+Gross - Baseline - Incentives)	Upgrade Costs: (Diff from Baseline, no incentives)
HVAC[1] 16 SEER, 8.6 HSPF	$ 426,000	$ 400,000	$ (33,840)	$ 26,000
Smart Thermostats	In HVAC			
Outdoor LED lighting (Fixture	$ 49,120	$ 20,000	$ (80,800)	$ 29,120
Kitchen Appliances	$ 92,158	$ 46,079	$ 46,079	$ 46,079
Attic Insulation	$ 82,000		$ 24,960	$ 82,000
Weatherstripping	$ 15,000		$ 5,800	$ 15,000
Water saving devices	$ 8,160	$ 8,160	$ (50,640)	$ -
Condensing Tankless W/Hs	$ 191,600	$ 95,800	$ 53,400	$ 95,800
Indoor LED lighting (Lamps)	$ 80,167	$ 40,084	$ (14,957)	$ 40,084
Glazing	$ 210,930	$ 140,620	$ 21,750	$ 70,310
Total Cost (Community)	**$ 1,155,135**	**$ 750,743**	**$ (28,248)**	$ 404,393

Source: Electric Power Research Institute

Installation

Installation was managed by Walton Construction, the project's prime contractor. Individual contractors were hired for different parts of the work. Of note, the installed cost of the heat pumps was only marginally higher than replacing air conditioners, and after accounting for the LIWP rebate, it was cheaper to install a heat pump than an air conditioner.

Other construction is shown in Figure 10, which also shows a sprayed foam roof and the final elastomeric coat; granules were installed by Arithane.

Figure 10: Full Coverage of Sprayed Foam Roof (left) and Final White Elastomeric Coat with Granules (right)

Source: Electric Power Research Institute

Heating and Cooling Systems

As shown in Figure 11, each unit was provided with its own central heating and cooling equipment, which consisted of a hydronic fan coil unit connected to the water heater and a 20-year-old air conditioner (original to property).

Figure 11: Pre-Retrofit Condenser Unit (left) and Fan Coil Unit (right)

Source: Electric Power Research Institute

Installation of the new HVAC system began in January 2018 and was completed by the end of April 2018. As shown in Figure 12, the retrofit included removal of the existing condenser and fan coil and replacing them with a Goodman model GSZ16 heat pump (16 SEER, 9 HSPF, 13 EER) and an AirMark high-efficiency electronically communicated motor-cased ceiling-mounted electric heat DX cool air handler. The thermostat was replaced with a seven ESA-day programmable WiFi thermostat by Venstar. The ductwork within the unit remained. A new fresh air intake was added above the front entry; the existing condensate lines were reused.

Figure 12: Installation of New Fan Coil Unit, Condensate Lines, and Split System Heat Pump

Source: Electric Power Research Institute

Domestic Hot Water System

Each unit was provided with its own natural gas 40-gallon water heater, located in an exterior closet on the balcony or patio. However, this space was not sufficient for a new HPWH, which required a closet that was 2 inches (~5 cm) larger. In addition, the units did not have sufficient electrical capacity for HPWHs. Instead of electrification, it was decided an energy efficiency upgrade would be performed with a very high-efficiency tankless water heater, which provided multiple financial benefits. In late March 2018, replacement began of the existing individual storage type natural gas water heater with a Navien NPE-150 condensing tankless gas water heater. Installation was completed by the end of April 2018.

Common Area Lighting Improvements

Common area lighting was predominantly high-intensity discharge (HID) wall packs. It was decided to switch them entirely over to LEDs. Many of the outdoor lights, and in some cases the poles themselves, were replaced with LED fixtures to future-proof the retrofit, as shown in Figure 13. Common area lighting improvements began in early June 2018 and were completed by late August 2018.

Figure 13: New Post Light, Pole Light, and Wall Pack

Source: Electric Power Research Institute

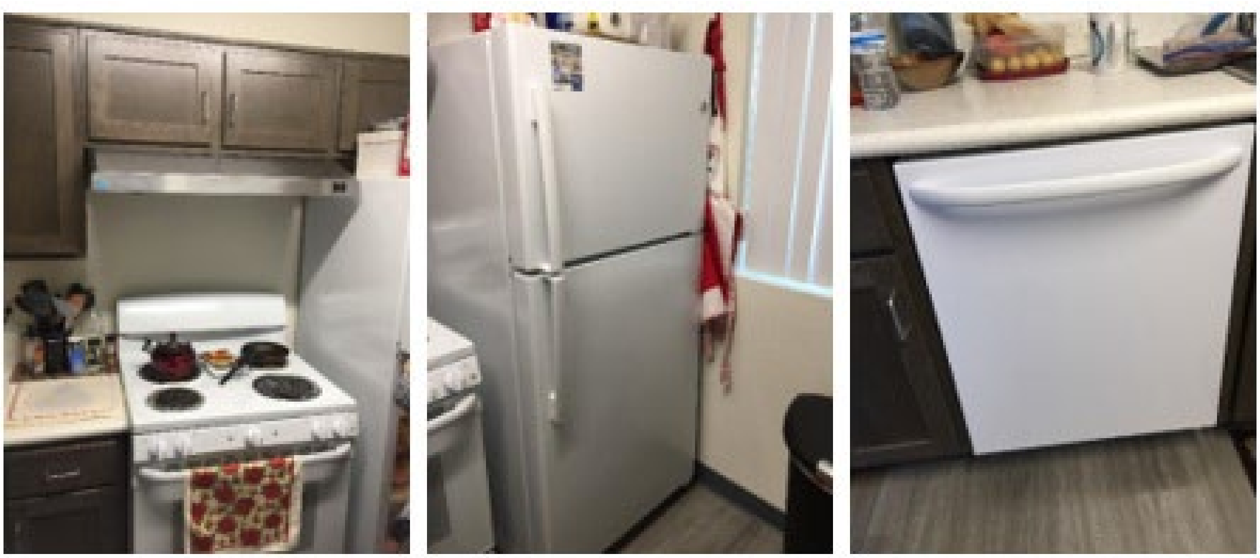
Individual-Unit Lighting Improvements

Each residential space contains a combination of wall- or ceiling-mounted permanent light fixtures. There was very little fixed lighting in the apartments, so most of the lighting was plug loads, with very little energy efficiency to be gained from switching CFLs to LEDs. SCE's ESAP allowances, in this case, meant that only the kitchen light fixtures were replaced.

Appliances

Appliances in apartment units and the community room were replaced with EnergyStar compliant General Electric models, as shown in Figure 14. This was the best-received upgrade from tenants since these appliance replacements resulted in immediate quality-of-life improvements. Ranges were replaced with higher-efficiency electric ranges. Induction cooktops were considered, but there were resident concerns about cookware compatibility.

Figure 14: New Range and Hood, Refrigerator, and Dishwasher



Source: Electric Power Research Institute

Water Fixtures

Between March 2018 and August 2018, both kitchen and bathroom fixtures were replaced with water-saving models. Showerheads and wands were replaced through the ESAP in January 2018. Toilets were not replaced due to budgetary constraints.

Community Solar

Linc Housing (in collaboration with its subsidiary company, Solar Energy and Economic Development [SEED] Partners) installed new solar photovoltaic systems at five Linc properties by aggregating them for financing through a power purchase agreement (PPA). A 140.075 kW photovoltaic system was installed on the roofs of the residential buildings and on some of the existing carport structures, as seen in Figure 15. Permits were pulled in early August 2017 and signed off by the city of Ontario in late January 2018 with a permit to operate issued in February 2018.

Community solar plays a significant role in electrification since it can offset tenants' costs of switching to electric heating systems given electricity cost increases and that natural gas is a community rather than a tenant expense.

Figure 15: Solar PV Panels on Residential Building Rooftop (left) and on Carport (right)

Source: Electric Power Research Institute

Commissioning

Installation verification of all ERPs was conducted weekly during site visits by the project architect, construction manager, building inspector, and EPRI project team members to ensure that all upgrades were performed according to project objectives, design intent, and owners' operational requirements.

In addition to weekly site visits to review installation, the HVAC installing contractor completed the Air Conditioning Contractors of America HVAC *Installer/Startup Technician Checklist* (ACCA n.d.) for each residential unit. To complete the checklists, EPRI observed the in-field testing.

All units met the airflow, refrigerant charge, superheat, subcooling, electrical measurements, and the post-installation duct leakage criteria.

Window water testing observation was conducted on eight residential units. Testing was performed by applying water to the exterior of windows with a water-hose nozzle at a pressure of approximately 6 pounds per square foot. No water intrusion was observed. In addition to water testing, compartmentalized single blower door testing was conducted on the eight units.

The solar PV system was commissioned by a third party.

CHAPTER 4:
Data Analysis and Customer Surveys

Overview

The EPRI team collected a substantial amount of both quantitative and qualitative data over the course of this project. Quantitative data consisted of energy assessment data, along with indoor air quality data, while qualitative data were mostly collected in customer energy surveys. Table 5 provides a description of the data analysis use cases for this project.

Table 5: Data Analysis Use Cases

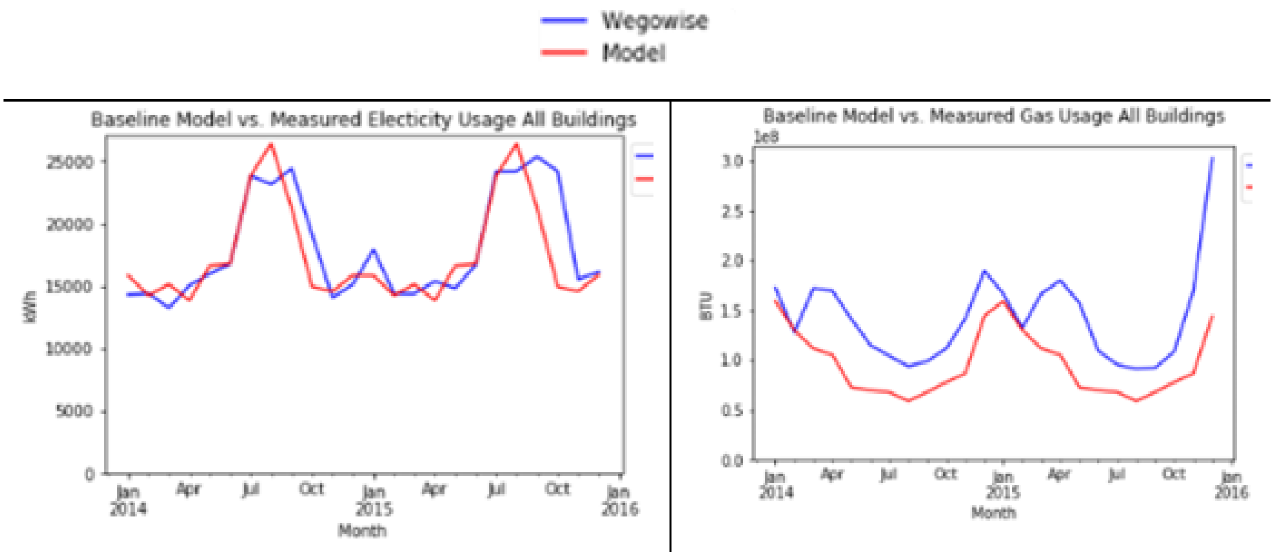
Use Case	Use Case Description
Baseline Model Calibration	The BEopt model was calibrated to emulate total energy consumption at the community level using WegoWise data.
Baseline Model Gas Calibration	The BEopt model for gas use at the building/community level was calibrated using WegoWise gas data.
Model vs. Measured Electricity Use	Building level comparisons of modeled vs. measured were made from May 2018 onwards.
Model vs. Measured Gas Data	It is possible to perform building/community-level comparisons of model vs. measured with WegoWise building level gas data. Moreover, given that active gas usage controls are direct controls and may not be used, application of the model may be the best case achievable.
Load-Level Load Shapes	Community-, building-, and unit-level HVAC, lights, plugs, and range loads energy use for a 24-hour period was averaged on a monthly basis.
Peak Load Attribution	Peak load attribution refers to which loads contribute most to the peaks occurring over a 24-hour period each month.
HVAC DR Performance	Baseline HVAC use was compared to use during DR events at the unit/building/community level.
Building-Level Current Distribution	Building-level current distribution refers to a distribution of building- level 5-minute average currents on a monthly basis.

Source: Electric Power Research Institute

Baseline Analysis for Seasons at Ontario

A baseline analysis calibrated the energy models with the AMI data. This calibration was important as it helped correlate savings by technology rather than just by bulk level, for both pre- and post-retrofit. At an aggregate level, the following figures and tables show preliminary results of baseline calibration for measured (from WegoWise) versus model data (from BEopt) of annual kilowatt-hours and therms (by building). In addition, the EPRI team conducted measure-level load shape analyses that compared modeled versus measured performance. Overall, the timing of peaks strongly correlated; however, the project team had to scale HVAC and plug loads to fit the magnitude of those peaks. Figure 16 shows the data for summer HVAC load, lighting load, and appliance load data. With the calibration, the team reduced deviations in the model to less than 7 percent on an hour-by-hour basis throughout the year.

Figure 16: Monthly Analysis of Baseline Modeled vs. Measured Comparison of Electricity (left) and Gas Usage (right) for Seasons at Ontario

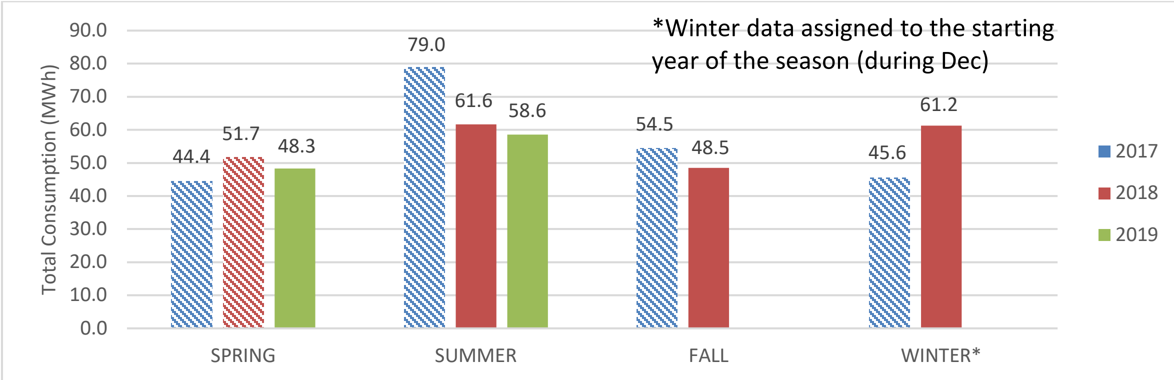


Source: Electric Power Research Institute

Pre-Retrofit vs. Post-Retrofit Comparison

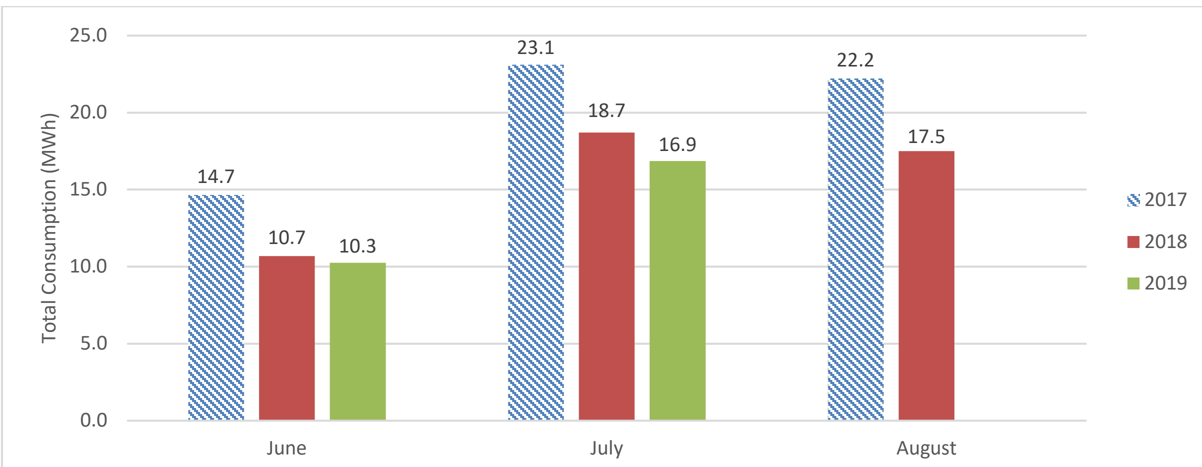
Figure 17 and Figure 18 compare electric energy usage at the unit level before and after retrofits. The decrease in summer energy use can be attributed to more efficient air conditioners, which offset the increase in electric usage in the winter through electrification of the heating systems. Fresno's total energy reduction was 21 percent (243.1 MWh); gas was a 45 percent reduction (11,200 Therms); and electricity was a 23 percent increase (85 MWh). Ontario's total energy reduction was 50 percent (460.53 MWh); gas was a 55 percent reduction (15,704 Therms); and electricity a less than 1 percent reduction (405 MWh).

Figure 17: Seasons at Ontario Living Space Scaled AMI Consumption Pre- (striped) vs. Post-Retrofit (solid) Seasonal Comparison



Source: Electric Power Research Institute

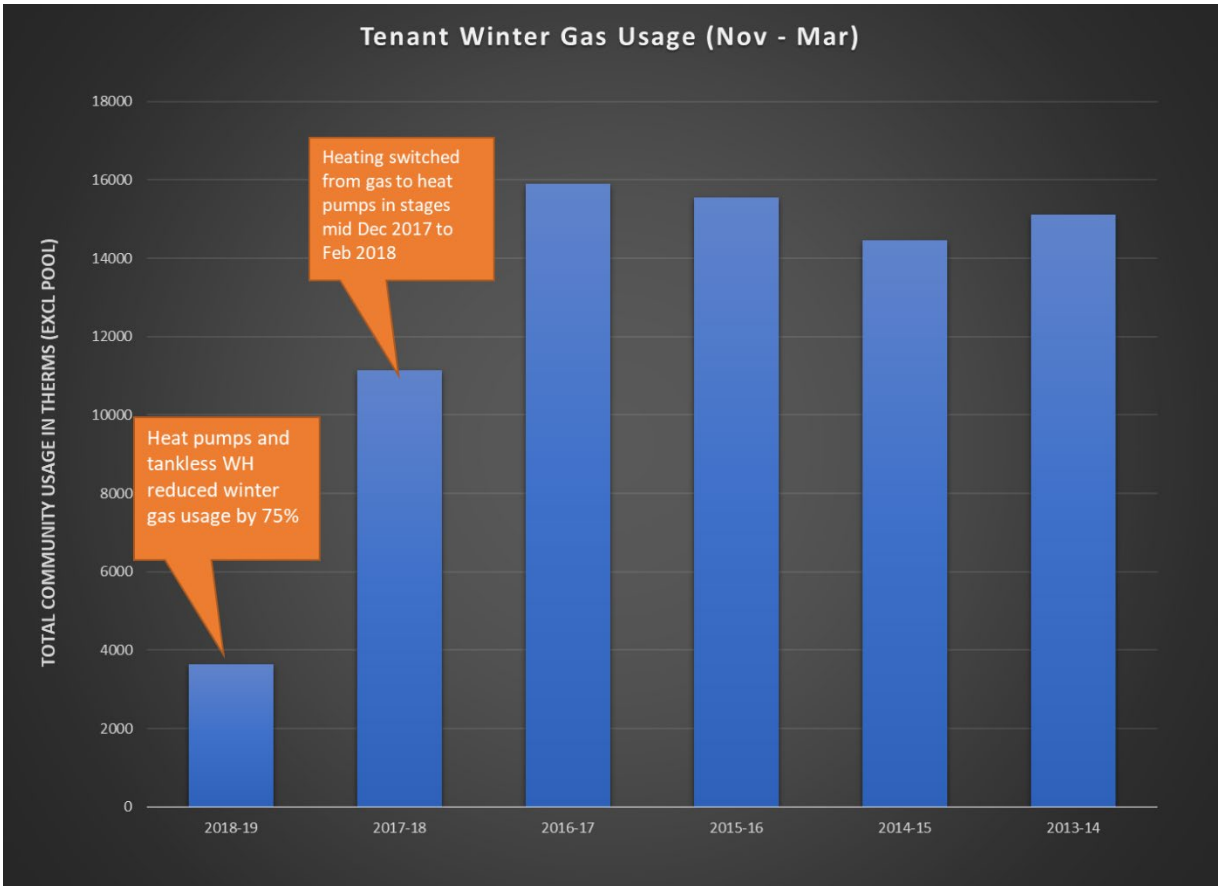
Figure 18: Seasons at Ontario Summer HVAC Monthly Consumption Pre- (striped) vs. Post-Retrofit (solid) Comparison



Source: Electric Power Research Institute

Figure 19 illustrates gas consumption for Seasons at Ontario pre- and post-retrofits and shows that improvements reduced gas usage by more than 70 percent.

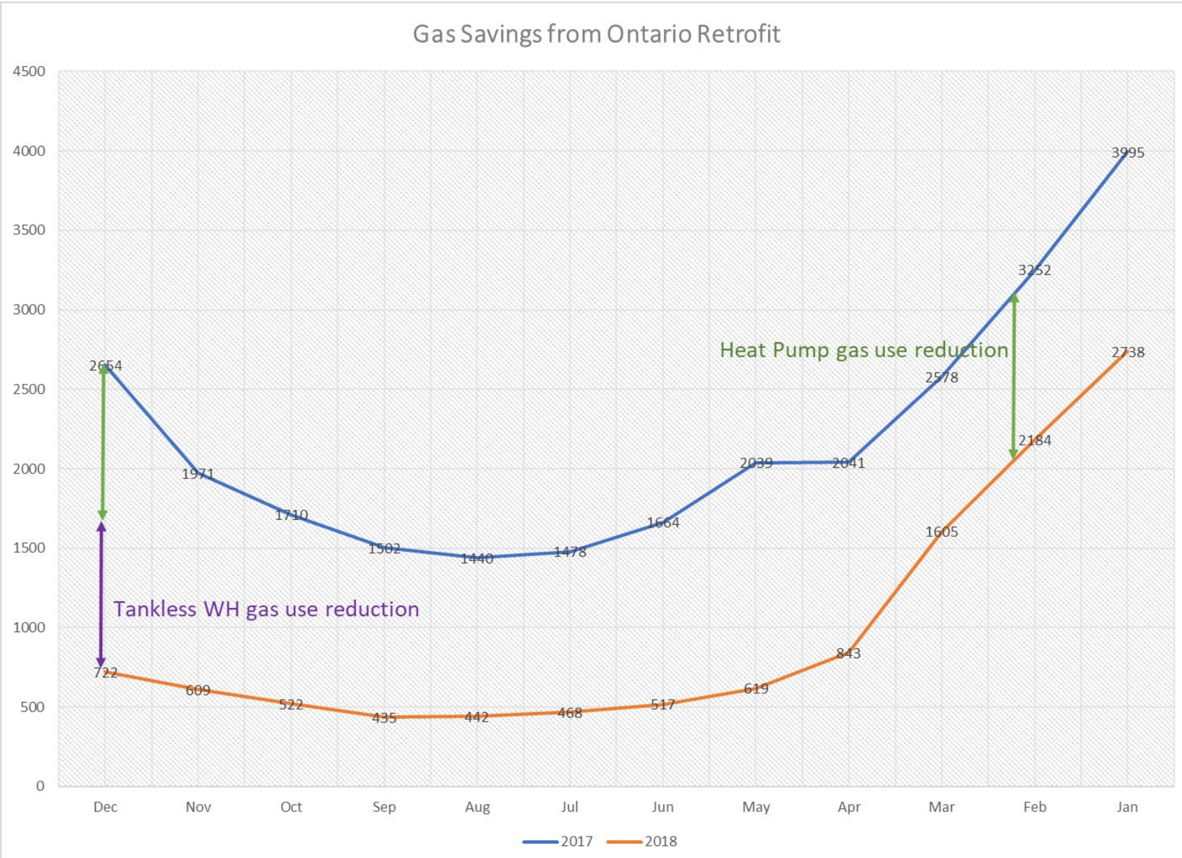
Figure 19: Seasons at Ontario Community Gas Usage Pre- and Post-Retrofits



Source: Electric Power Research Institute

Figure 20 shows gas usage reductions through the space-heating electrification and water-heating tankless replacement processes, indicating that the savings were split evenly between electrification and efficiency. These numbers reflect the high consumption of natural gas for water heating in Southern California.

Figure 20: Attribution of Gas Savings Between Electrification and Energy Efficiency



Source: Electric Power Research Institute

Energy savings from both electric and gas usage were converted to carbon savings to measure the success of decarbonization goals. Results from this analysis (using hourly carbon models from the California Independent System Operator showed a 40-percent reduction in carbon emissions from the community. After accounting for the electricity offset from the solar-PV system, savings increased to 81 percent when compared with baseline emissions pre-retrofits.

Pleasant View in Fresno

A similar analysis to Seasons at Ontario was conducted for Pleasant View in Fresno to identify energy and carbon savings from community retrofits. Table 6 provides a snapshot of summer electricity usage at the community level and shows that the cooling system contribution is about 30 percent of usage; plug loads were the predominant load in the community (including torchieres and window air conditioners).

Table 6: Pleasant View Senseware Data Site Total (5/1/18 – 7/31/18)

End Use	kWh
Swamp Cooler	22,379
Range	7,548
Water Heater	145

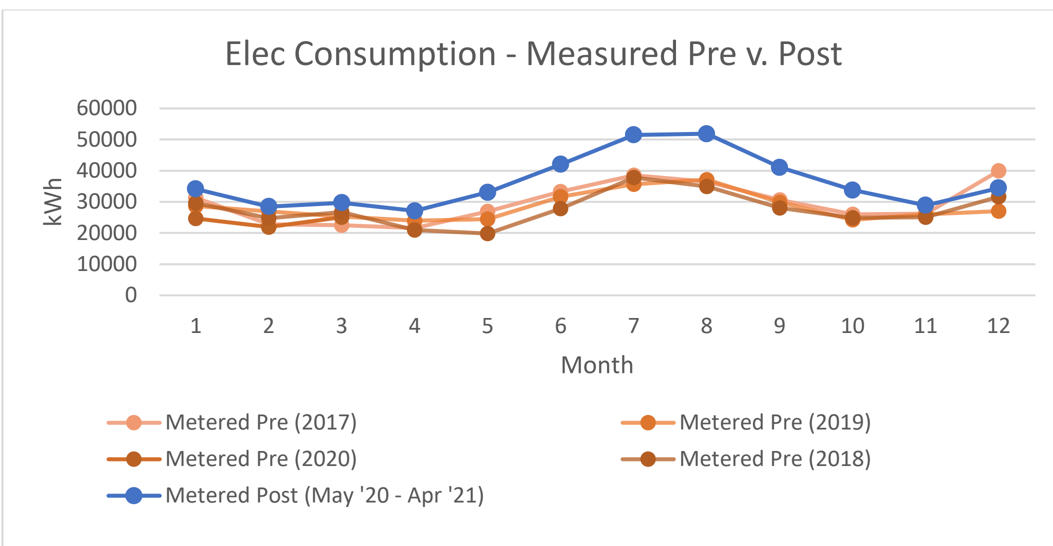
End Use	kWh
Lights	9,868
Plugs	36,733
Total	76,673

Source: Electric Power Research Institute

A weather-based regression analysis normalized pre-retrofit and post-retrofit monthly usage billing data to evaluate the energy impacts of the technology packages, independent of weather effects. The monthly weather normalization regression was carried out using the OpenEEmeter implementation in Python to implement CalTRACK measurement and verification methods (CalTRACK 2018).

Based on the measured impacts of pre- and post-electricity consumption, cooling load in the summer drove a larger increase in electricity consumption than was predicted by modeling, as shown in Figure 21. This is likely due to the inaccuracy of models to fully capture the improved ability of the upgraded cooling systems to reach cooler setpoints in the home. Prior to the upgrades, units were unlikely to be able to reach 70°F on a hot day even if the thermostat was set to this temperature. However, the simplification of cooling setpoints in BEopt does not allow for cooling setpoints in the summer that are below heating setpoints used in winter heating. Therefore, model limitations likely could not accurately reflect the achieved reduction in ambient room temperatures that provided improved comfort to occupants but resulted in increased cooling load. In summary, summer electricity use increased more than predicted. Winter and shoulder electricity consumption aligned well with model predictions.

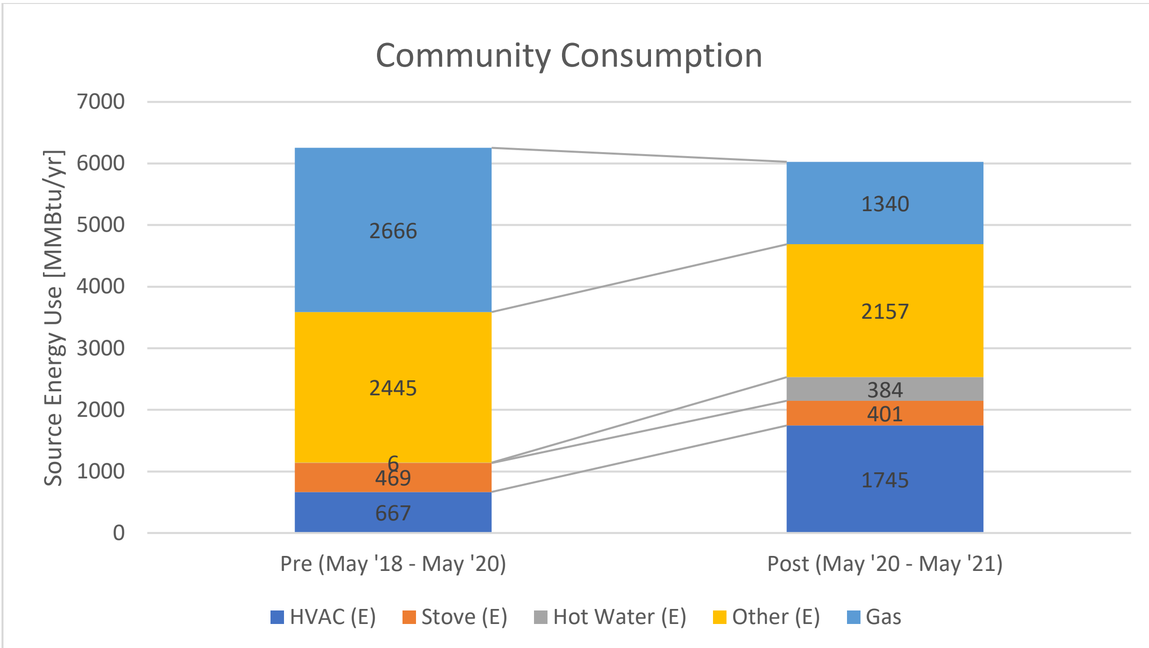
Figure 21: Community Electric Consumption, Measured Pre- and Post-Retrofit



Source: Electric Power Research Institute

Model predictions of gas consumption aligned well with observed impacts at the meter. Some weather-correlated variability in gas consumption was not captured in the modeled consumption, likely due to simplified assumptions about miscellaneous gas consumption during model calibration. However, this discrepancy is minor relative to the magnitude of impacts and variability captured by the transition from pre-retrofit to post-retrofit gas consumption, shown in Figure 22. These findings align with the model showing pre- versus post-gas retrofit gas consumption at Seasons at Ontario (see Figure 16).

Figure 22: Comparison from Pre-Retrofit To Post-Retrofit Pleasant View Community Electricity and Gas Consumption



Source: Electric Power Research Institute

The results revealed that:

- Winter and shoulder electricity consumption tracked closely with BEopt models.
- Summer measured electricity consumption was significantly higher than BEopt predicted. BEopt predicted only a slight increase in summer cooling load.

Source Energy and Emissions Impacts

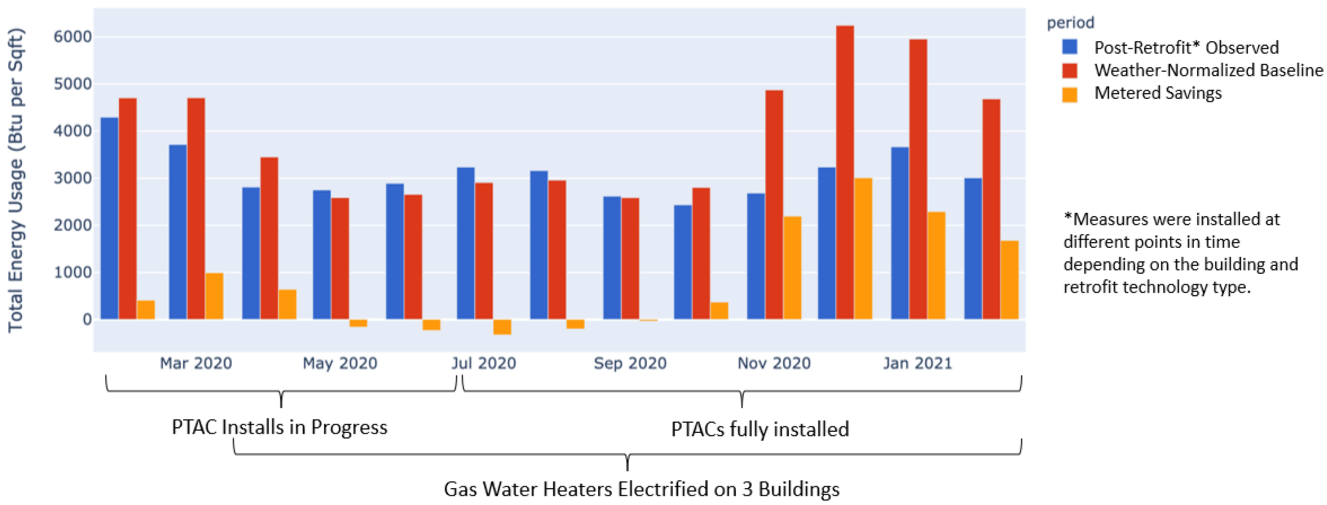
In general, measured impacts of the installed upgrades did not significantly reduce energy use, primarily due to higher-than-predicted growth in cooling loads, as shown in Figure 22. There was an overall net decrease in source energy consumption; however, this decrease was not significant.

The upgrade impacts improved when the cooling season was removed from the analysis and only impacts from electrifying heating during the November to March time frame were considered. During this time frame, when baseline source emissions were greatest, the community achieved a 41 percent energy reduction.

Total Energy (Gas and Electric)

As shown in Figure 23, total energy usage has decreased by 21 percent (10,600 Btu per ft2) over baseline usage since February 2020, with savings of 22 percent (10,200 Btu per ft2) in the last 12 months (March 2020 through February 2021). While energy usage typically decreases (on average) over the course of the year, these savings fluctuate on a month-to-month basis. COVID-19 stay-at-home orders in summer 2020 also negatively impacted energy savings, especially for cooling.

Figure 23: Monthly Pleasant View Community-Level Total Energy (Gas and Electric) Impact



Source: Electric Power Research Institute

Minor increases in energy usage during cooling season were significantly offset by savings in total energy usage in the heating season beginning in October 2020. These savings can be attributed to efficiency savings from heat-pump-based technologies over gas baselines for space heating, and water heating for 3 of the 10 buildings.

Electricity usage has increased by 23 percent (85 MWh) over baseline usage since February 2020, with increases of 26 percent (87 MWh) over baseline usage in the last 12 months (March 2020 through February 2021).

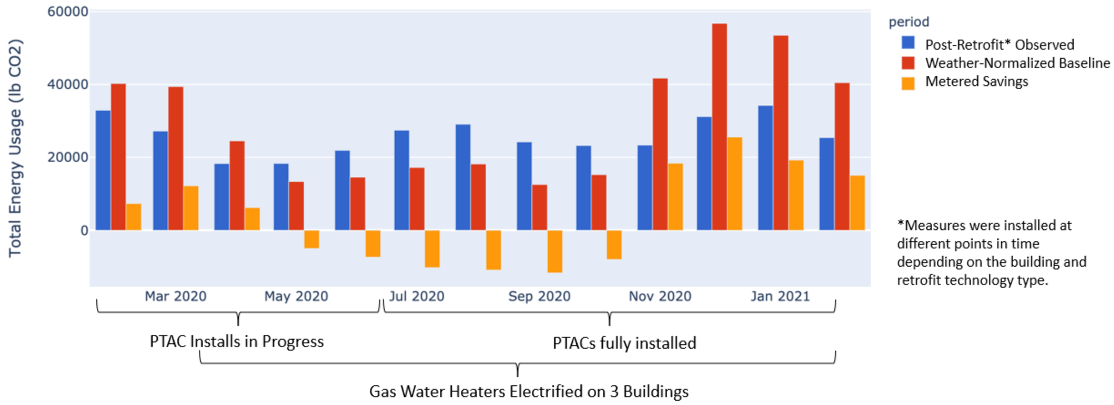
Greenhouse Gas Emissions (Gas and Electric)

Greenhouse gas (GHG) emissions are associated with the community's total energy usage.[1] As shown in Figure 24, GHG emissions from energy usage have decreased by 13 percent (50,000 lb CO_2) over baseline usage since February 2020, with savings of 13 percent (43,500 lb CO_2) in the last 12 months (March 2020 through February 2021). Gas usage decreased by 40 percent (11,200 therms) over baseline usage since February 2020, with savings of 44 percent

[1] GHG emissions attributed to energy usage are defined as a combination of scope 1 and scope 2 emissions for purposes of this analysis, which are combined on-site emissions from gas end uses and source emissions attributed to electricity generation.

(11,000 therms) over baseline usage in the last 12 months (March 2020 through February 2021).

Figure 24: Monthly Pleasant View Community-Level GHG (Gas and Electric) Impact

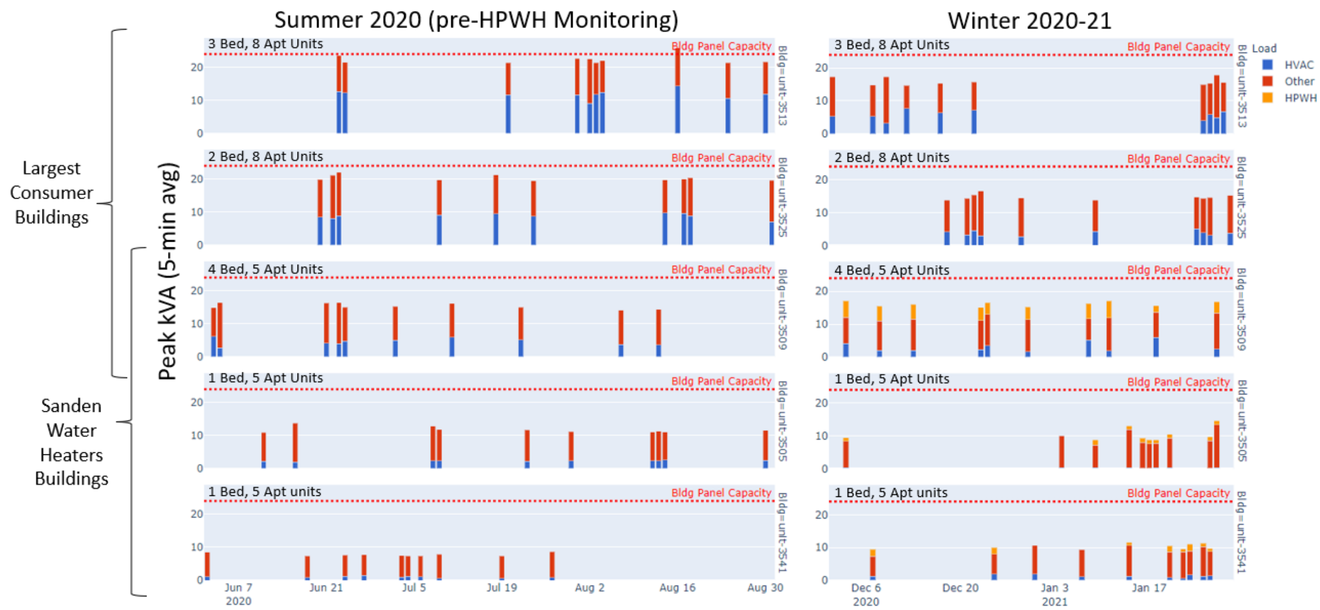


Source: Electric Power Research Institute

Peak Electric Load for Infrastructure Management

The sizing of infrastructure and the subsequent need for upgrades at multiple levels of the grid were determined in large part by peak demand. Because of constraints at multiple levels of the power system in the Pleasant View community, the impacts of electrification measures on peak loads were of interest throughout the project. Unforeseen impacts to peak loads could have triggered a number of upgrades, ranging from building electric panels and feeders to transformers. Upgrades to any of these components would have introduced significant incremental costs above the planned upgrades. For purposes of electric-panel sizing considerations, Figure 25 shows the top 10 building-level peaks of the winter and summer seasons for a subset of the community with either relatively large demand or installation of HPWHs. Buildings not included did not encounter any peaks approaching the building-panel limit.

Figure 25: Pleasant View Building-Level Top 10 Peak Loads of Summer 2020 and Winter 2020–2021



Source: Electric Power Research Institute

Peak consumption was measured based on five-minute average electricity consumption at the building level, using circuit-level monitoring. Other than a single 15-minute period in one building (in August 2020), no events were recorded where circuit-level monitoring exceeded building-level panel limits lasting longer than five minutes. These observations were verified by the lack of observed events in the project's performance period.

Customer Surveys and Engagement

Customer surveys were administered to all residents at Seasons at Ontario (December 6–8, 2017) and Pleasant View (February 20–21, 2018) to determine their needs. The survey was completed by 64 percent of Seasons residents and 71 percent of Pleasant View tenants. This was another part of the project's "customer-centric" retrofit approach and was intended to incorporate customer needs into technology selection. Results are shown in Table 7.

Table 7: Customer Survey Results of Residents at Seasons at Ontario and Pleasant View in Fresno

Complaint	Seasons at Ontario	Pleasant View at Fresno
Dissatisfied with Cooling	21%	74%
Dissatisfied with Heating	11%	51%
Major Problem with Dirty Air	28%	55%
Dissatisfied with Hot Water	15%	27%
"Too Dark" in Apartment	30%	76%
Inadequate Outdoor Lighting	59%	54%

Source: Electric Power Research Institute

It is interesting to note that, except for the quality of outdoor lighting, the problems expressed by residents were very different at each location. Also apparent was that the Pleasant View community (with its significant evaporative cooling problem) was in much greater need of improvements than the Seasons site. This drove the decision to install compressor-based cooling, even though it increased energy use and detracted from project goals for energy-use reductions. A number of problems identified by Pleasant View residents related to HVAC:

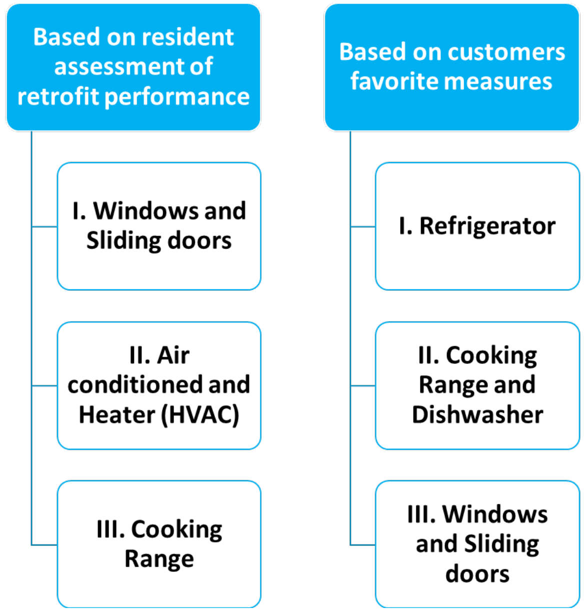
- AC does not cool apartment down quickly (78 percent) or cool all rooms evenly (95 percent), and the system emits dirt and dust.
- Heater does not heat all rooms evenly (76 percent).
- Indoor air is stuffy/stale (68 percent), dirty (63 percent), has odors (73 percent) (e.g., smoke, cooking odors).
- Interior lighting is inadequate (almost no overhead lighting).

After all upgrades were completed, resident responses significantly improved, with most citing significant improvements in their quality of life. Key findings associated with perceived impacts following retrofits at Seasons at Ontario included:

- Customers responded positively to energy-efficiency upgrades.
- More than 65 percent of respondents reported lower energy bills post-retrofit.
- Resident satisfaction levels rose from 88 percent (pre-retrofit) to 97 percent (post-retrofit).
- Community satisfaction increased from 37 percent (pre-retrofit) to 55 percent (post-retrofit).
- There has been a marked increase in residents' approval of HVAC retrofit performance.
- Tenant satisfaction increased for cooling and heating, both pre- and post-retrofit.

Figure 26 compares resident assessments for both retrofit performance and immediate quality-of-life improvements.

Figure 26: Seasons at Ontario Resident Reception for Energy Efficiency Measures

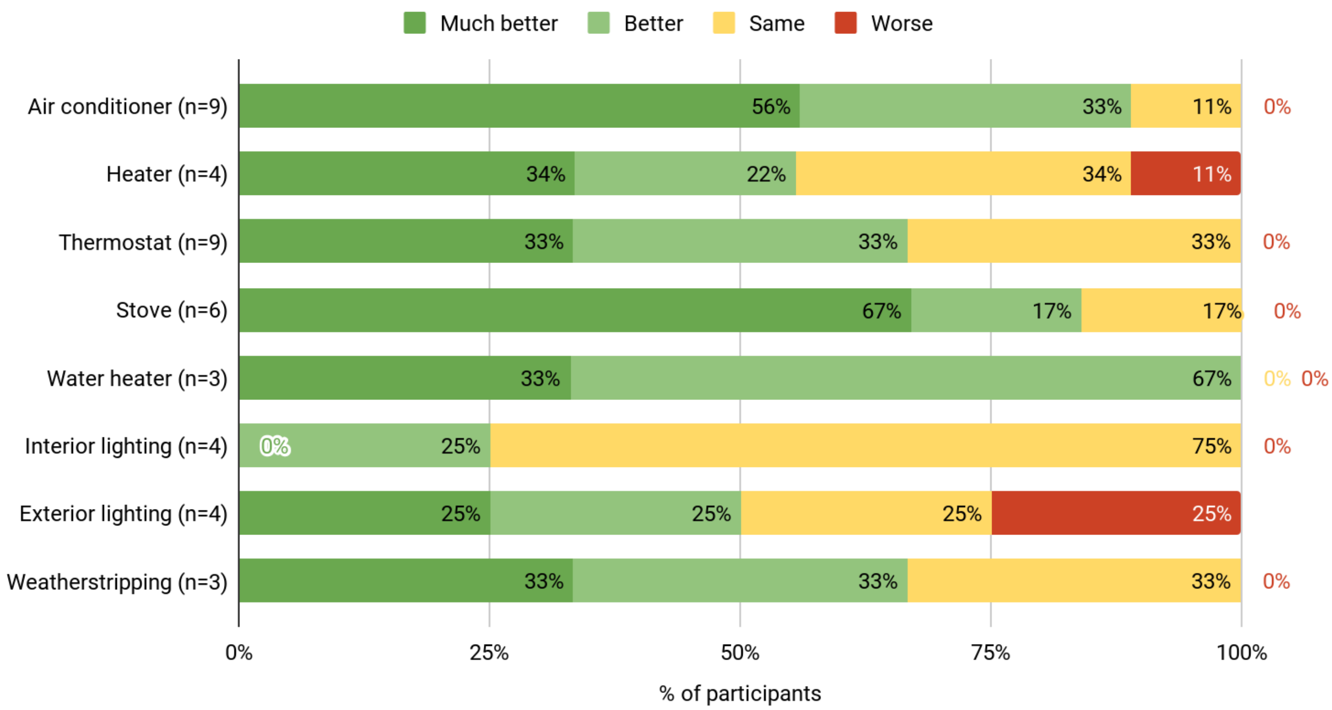


Source: Electric Power Research Institute

At Pleasant View, post-retrofit surveys were conducted remotely during the COVID stay-at-home period; there was a much lower response rate on remote, post-retrofit surveys. Figure 27 presents these assessments for each retrofit measure among only the sample subset that reported receiving each upgrade (sample sizes shown in Figure 27). Note that three groups were excluded from this analysis: those who did not receive a retrofit that was installed selectively in some units (such as a water heater), those who may have received the upgrade but did not remember it, and those who moved in after the retrofit was installed.

Based on bill data information received from LINC, the research team compared 2022 (full year of measures and solar situation stabilized) and 2019 (last year before project measures installed and first year of full solar implemented) and noted that there was an increase of \$11.6k (+24.7 percent) in residents' electricity bill and a decrease in their gas bill of \$23.9k, a net savings to LINC of \$12.3k per year in total gas/electricity bill comparing 2022 and 2019. This is backed up by the data that the team reported: a decrease in gas consumption (45 percent gross decrease) and an increase in electricity usage (23 percent gross increase). The team attributed increased electricity usage to the tenants' increased used of the PTAC units attributed to comfort reasons as well as a fuel switch to community HPWH in three buildings.

Figure 27: Pleasant View Post-Retrofit Survey Results



Source: Electric Power Research Institute

CHAPTER 5:
Achieving Affordable Decarbonization: A Summary

As California progresses toward its decarbonization goals, it is now clear that how existing buildings evaluate their needs must substantially change. This project began as a deep energy-efficiency retrofit but ultimately morphed into a full-scale decarbonization retrofit. Decarbonization, in this case, was a combination of both energy-efficiency measures and heating-system electrification. Lessons learned through the process are widely transferable. The impact of the retrofits can be measured three ways: in primary energy savings, customer cost savings, and carbon savings.

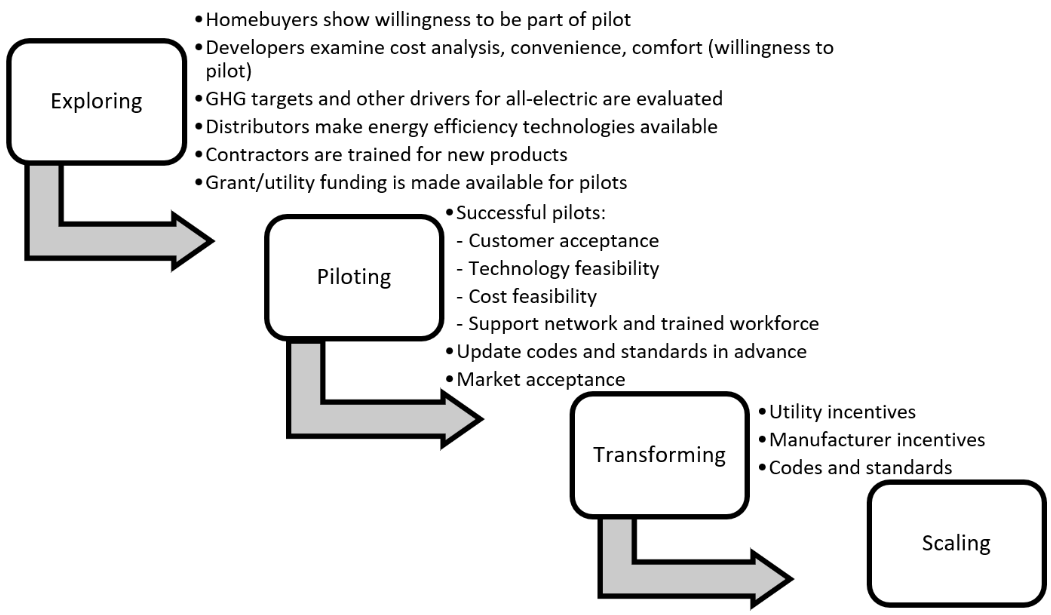
While electrification and fuel substitution have not been widespread practices in California, this project was one of the first to evaluate and implement electrification at community scale in existing multifamily communities. Specific lessons were learned from electrification efforts since they had not yet been programmatically applied. Such lessons could prove useful for future electrification programs. Looking both backwards and forward 20 years, it is time to update the processes that significantly reduce carbon impacts from existing buildings. Current strategies, however, are usually dependent on a "trickle down" approach where the affluent first adopt new technologies and access to technology is either uneconomical or unavailable to low-income populations. Significant downsides of greater decarbonization of existing buildings, especially in affordable housing, follow.

- Decarbonization in a short time period requires an integrated approach of deep energy efficiency along with the electrification of existing buildings. Local or community renewable sources may be required to provide customers with affordable energy, while custom measures (like in this report) require a lengthy approval process that makes it challenging to install comprehensive building upgrades. EPRI recommends a more straightforward program for affordable housing, with incentives tied to meter-based savings that do not require time-consuming multiple levels of approval for each project.
- Decarbonization represents a significant change in how customers both consume and pay for energy. It is important that low-income customers who cannot afford retrofits are not stranded while their energy bills continue to rise from both transitioning to new technologies and from other reasons beyond their control.
- From a grid planning perspective, clear and timely communication with transmission managers about all changes to the building stock can reduce the cost of repetitive grid upgrades. Electric transportation and building electrification can then be implemented sequentially and without coordination at the community or regional scales.
- Many low-income customers pay their electric bills, while gas bills are master metered. Electrification may therefore shift their energy burdens to their individual expenses; an

integrated approach of deep efficiency with electrification is therefore required to reduce individual energy costs.

- The original concept was a pure focus on energy efficiency, where fuel switching was not envisioned. However, as California's mandated energy goals evolved to decarbonization, this project evolved with them. Carbon savings of greater than 40 percent were achieved at both project sites. Figure 28 shows the four key steps in the energy-efficiency retrofit process.

Figure 28: Key Steps in the Energy-Efficiency Retrofit Process



Source: Electric Power Research Institute

Affordable housing has unique features such as financing riders and tax credit refinancing, including integrative building retrofits. This financing provides the opportunity to integrate and scale promising technologies, as opposed to single-family homes where each technology must be addressed one by one. Ownership of large segments of affordable housing by government and affiliated agencies also provides opportunities for purchasing large quantities of retrofit technologies through centralized procurement as well as bulk installation, both of which reduce the cost of decarbonization.

This project examined how a new approach to decarbonization, with affordable housing as its beachhead, could work in a manner that improves energy costs for both property owners and residents while identifying and facilitating new technologies that further this transformation.

Categorization of Affordable Housing

Nationally, low-income housing residents have high energy burdens, of approximately 7 percent of their incomes, on average, about twice that of average renters (EPA 2018). This higher energy burden is not only due to low income, but also to poorer and less efficient housing stock with high energy costs per square foot. The U.S. Department of Housing and Urban

Development (HUD) is a key player in the affordable housing market; HUD spends about 15 percent of its annual budget on subsidies to low-income customers to offset utility costs. In California, the burden is slightly lower due to decreased demand for heating and cooling and smaller home sizes, reducing tenant burdens to 3–5 percent of income. HUD also supports rent for low-income households through support for local public housing authorities, as well as vouchers to help with low-income Section 8 housing. These vouchers provide property owners the difference between the rent required for operation of affordable housing units and household rent caps (set at 30 percent of income).

Some facts about low-income households include:

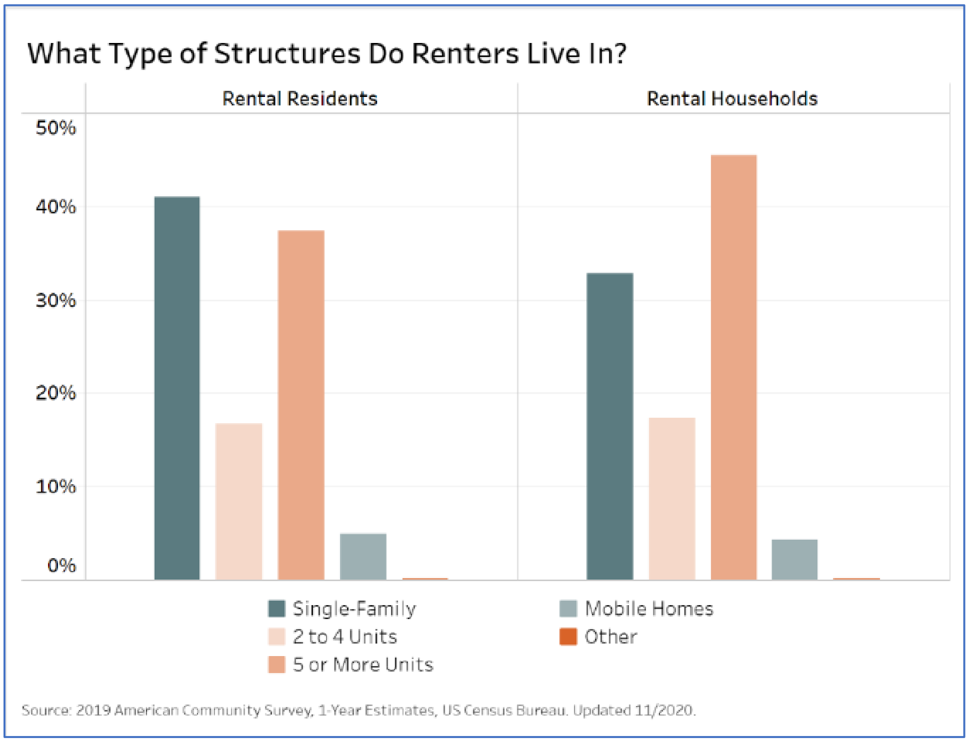
- Not all low-income households that qualify for rate discounts live in housing that is subsidized by or classified as affordable housing.
- Primary sources of housing subsidies are from HUD, both for rent and utility support.
- Manufactured housing is the largest segment of unsupported low-income housing. Manufactured housing is about 8 percent of the United States housing stock, and about 14 percent in rural areas.
- Low-income customers who live in single-family homes are harder to reach with utility programs.

Approaches for Addressing Decarbonization in Affordable Housing

Approximately 60 percent of low-income households live in rental units; 70 percent of those units are in multifamily buildings. Different approaches to decarbonization are therefore needed for each segment of the building stock for low-income households. As shown in Figure 29, these segments are broadly classified into:

- Rental Multifamily Units (~40 percent of low-income customers).
- Rental Single-Family Units and Manufactured Homes (~20 percent of low-income customers).
- Owned Single-Family Units (~20 percent of low-income customers).
- Owned Manufactured Homes (~15 percent of low-income customers).
- Owned Multifamily Units (~5 percent of low-income customers).

Figure 29: Types of Rental Properties and Occupancy



Source: Electric Power Research Institute

The technical approach is similar across each of these segments of the building stock, but regional variations could significantly change current building systems, energy rates, and grid infrastructure. Upgrades and improvements can be part of a standard package, a regional package, or a building segment package, as shown in Table 8.

Table 8: Summary of Upgrade and Improvement Packages

	Standard Package	Regional Electrification Package	Regional Efficiency Package
Approximate Package Cost in California	$9,000	$ 6,000–$11,000	$4,000

Source: Electric Power Research Institute

Utility programs currently cover about one-third of the cost of the standard package.

Standard Package

This set of measures applies to all types of buildings and across all ownership categories, and includes:

- Comprehensive energy audits.
- Home insulation, including insulated cool roofs for multifamily buildings, increased wall insulation for single-family buildings, and wall and underfloor insulation for existing manufactured homes.

- Air sealing and ducting upgrades.
- Window replacements.
- LED indoor lighting.
- Upgraded refrigerators.
- In multifamily buildings, replacement of lighting and appliances such as laundry equipment in common areas.

Regional Electrification Package

This set of measures applies to regions commonly using gas or other fossil fuels for heating. While there might be challenges with availability of electrical infrastructure, these measures include:

- Replacing all propane heating systems with heat pumps.
- Replacing propane water heating systems with heat pump water heaters (HPWHs).
- Replacing air conditioners with heat pumps, if heating is supplied by fossil fuel.
- Replacing natural gas storage water heaters with HPWHs if there is sufficient power.
- For multifamily buildings with 20 or more units, replacing central boilers or water heaters with a single or stacked series of central HPWHs with storage tanks.
- Using 120-volt (V) heat pumps if the building or units have only a heating system.

Regional Efficiency Package

This package applies to areas where electric heating systems are common. In addition to the standard package of weatherization measures, it includes:

- Replacing existing electric resistance heating with newer heat pumps.
- Replacing air conditioners with heat pumps if heating is supplied by fossil fuel.
- Replacing electric resistance water heaters with HPWHs.

EPRI recommends that utilities, at a minimum, cover building-envelope upgrades for insulation and windows, installed to current codes.

EPRI suggests creating a program that provides local renewables (such as community solar) to offset energy cost increases from electrification. California's *Solar on Multifamily Affordable Housing* program provides assistance for installing solar, including tools such as load shifting controls to reduce electricity usage during times of high energy rates.

In the long term, many utilities have goals to be either low-carbon or carbon free, including the decarbonization of building stock by 2040 through a combination of efficiency and electrification. However, for many customers electrification can lead to higher energy bills due to current energy rates for electricity and natural gas, as well as for master metering and submetering. Installing local renewables can also provide energy-cost relief in the medium term, depending on a utility's net metering rules.

Summary of Insights from Pleasant View and Seasons at Ontario

This section provides an overview of two case studies on decarbonized multifamily affordable housing. These case studies are based on large community-scale demonstrations conducted over the last several years where electrification was the pathway to decarbonization in rental units master-metered for gas and tenant-metered for electricity. The goal was to conduct customer-centric building retrofits that would:

- Reduce overall energy use.
- Reduce energy burdens for low-income customers.
- Improve customer comfort and indoor air quality.
- Evaluate economic models that enable integrated energy retrofits in existing buildings.
- Demonstrate a pathway for eliminating building carbon emissions by 2040.

Both demonstrations highlighted challenges with split incentives (common in upgrades in rental housing), as well as electrification challenges in areas with traditional fossil-fueled heating systems.

Case Study 1 – Seasons at Ontario

This case study is an 80-unit multifamily building for low-income seniors. The 80 units are arranged on an L-shaped shaped property with two 20-unit buildings, one 16-unit building, and one 24-unit building, shown in Figure 30.

Figure 30: Seasons at Ontario Senior Affordable Housing Community

Source: Electric Power Research Institute

The buildings were only 20 years old; however, at the same time, many older building systems were approaching needed end-of-life replacement. Table 9 shows the state of energy systems both before and after retrofits.

Table 9: Energy Efficiency and Electrification Upgrades for Seasons at Ontario

Energy System	Pre-Retrofit	Post-Retrofit
Wall Insulation	R-13	R-19
Roof Insulation	None with standard roof	Cool roof with 3 in. of blown foam insulation
Windows	Single pane	Double pane with low-E and frame sealing
Cooling	9 SEER air conditioner	15 SEER air conditioner
Heating	Hydronic with 40-gal gas water heater (combination system)	8.5 heating seasonal perform-ance factor (HSPF) heat pump
Water Heating	40-gal gas storage water heater	98% efficient gas tankless
Indoor Lighting	CFL	LED
Outdoor Lighting	Metal halide parking lot lights	LED integrated lamps, fixtures, and posts for parking lot lights
LED replacement in wall sconces		
Pool pumps	Single speed	Variable speed
Renewables	None	137-kW community solar

Source: Electric Power Research Institute

The total cost of the retrofits was $1.6 million, or around $20,000 per unit. Of this total, one-third of the costs were borne by utility and state programs for affordable housing, such as ESAP and LIWP. The property owner was obtaining tax-credit refinancing at the time, which enabled the owner to absorb the costs of additional improvements. Additional cost justification for the upgrades was based on end-of-life replacement of systems such as air conditioners and windows. Renewables were installed as part of a PPA developed by the property owner with a third-party financing entity that covered six different properties for 1.2 MW of PV solar.

The most challenging aspects of the building retrofits were the electrification measures. Electrification of space heating was not as difficult in this case because the installer was knowledgeable about heat pumps and able to find cost-effective replacement systems. In fact, after accounting for rebates from the LIWP, the heat pumps were actually a lower first cost than air conditioner replacement.

Water heater replacements, however, were extremely challenging due to lack of sufficient electrical capacity for HPWHs. All HPWHs widely available in the market as of 2018 were minimum 50-gallon units with a power requirement of 240 V, 30 A. These multifamily units had a total electric-capacity availability of 100 A. After accounting for electric cooktops and heat pumps, installation of HPWHs would require a panel upgrade to 200 A. In addition to the panel upgrade, it also required running the 240 V power to the water heater. On the construction side, the closet had to be expanded to accommodate HPWHs that were 3 inches (~7.6 cm) larger than the gas water heaters. Finally, upgrading the panels to 200 A would trigger an AMI meter socket upgrade. A socket upgrade of 80 meters would also require upgrades of the two neighborhood transformers, at an estimated cost of $600,000 for the property owner. Table 10 summarizes the cost of various upgrades per apartment. One option the team considered to avoid these upgrade costs was to use smart panels and batteries that could help manage peak load at the panel itself. However, EPRI was not convinced that these strategies would meet National Electrical Code requirements, so these measures were not installed. These technologies do hold great promise, however, and EPRI plans to work with its utility members to evaluate them. In the end, for economic reasons, it was decided to capture a substantial portion of GHG savings through energy efficiency by upgrading the gas storage water heater to a gas tankless water heater.

Table 10: Cost of HPWH Installation with Market-Available Products

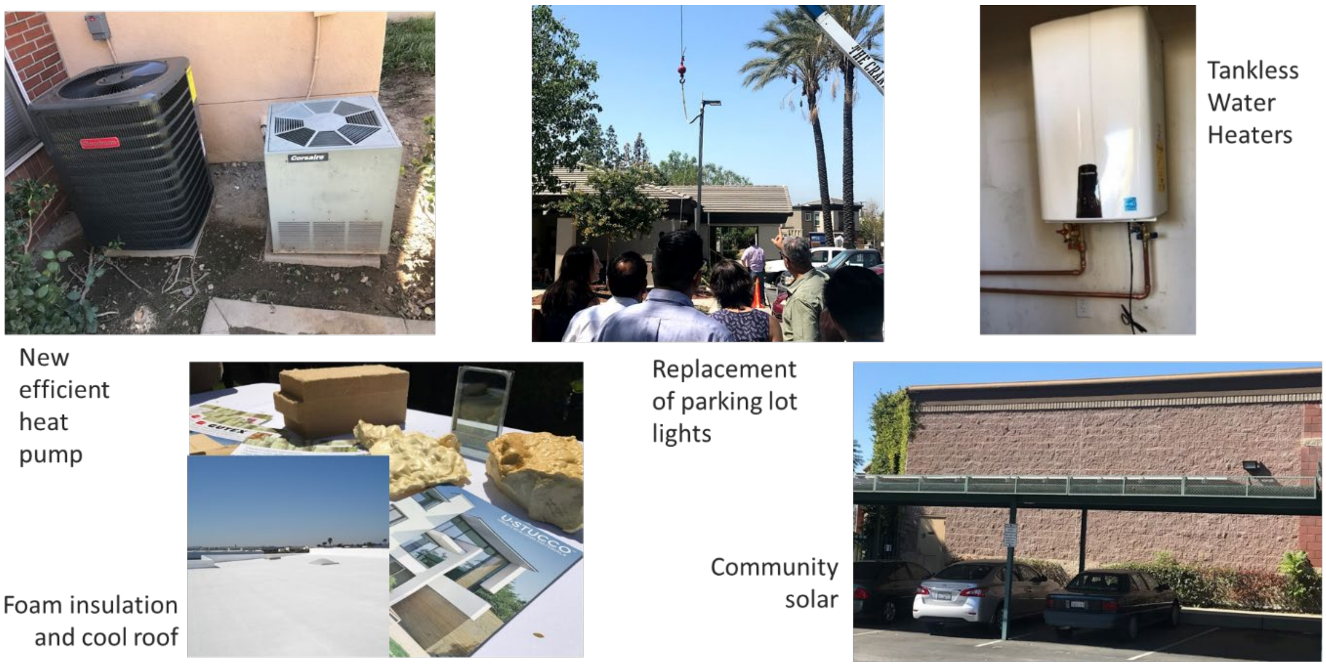
Cost Item	Cost Impact per Unit ($)
200A Panel Upgrade	1,800
Wire Run to Water Heater Location	2,000
Closet Construction Costs	2,200
Distribution System Upgrades	7,000
Total Cost per HPWH	13,000

Source: Electric Power Research Institute

The comprehensive building system upgrades shown in Figure 31 (aside from community solar), resulted in a triple net benefit, shown in Figure 32:

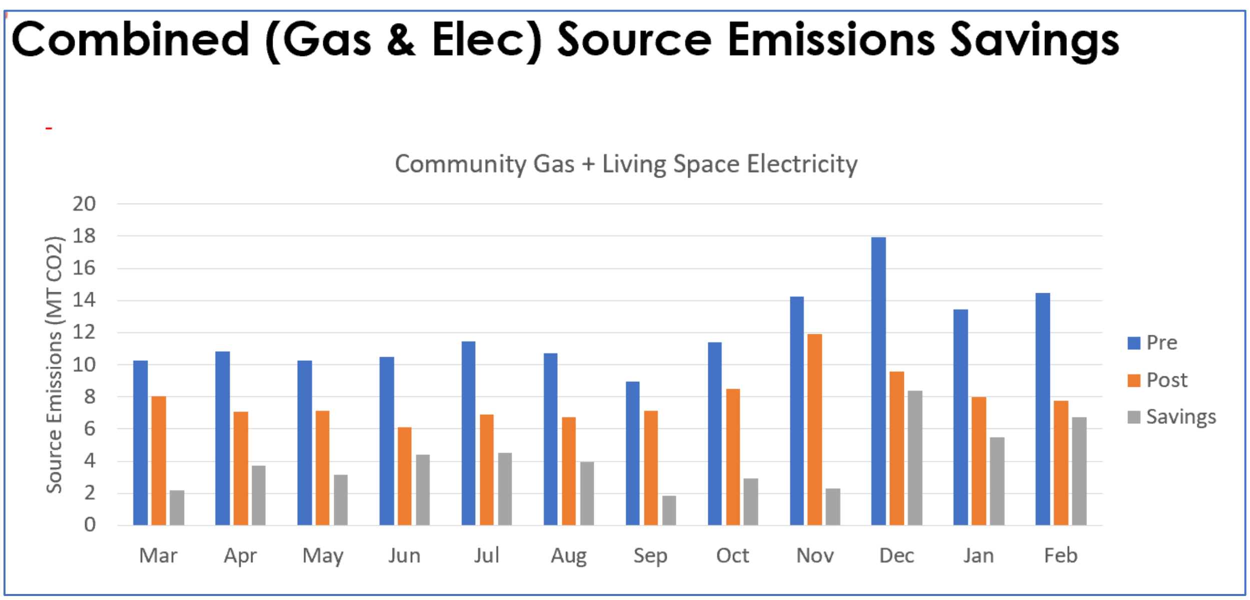
- 9 percent reduction in electricity use
- 70 percent reduction in gas usage
- 40 percent reduction in building carbon impact in 2020, which will increase as the electric grid decarbonizes

Figure 31: Upgrades Implemented at Seasons Ontario Community



Source: Electric Power Research Institute

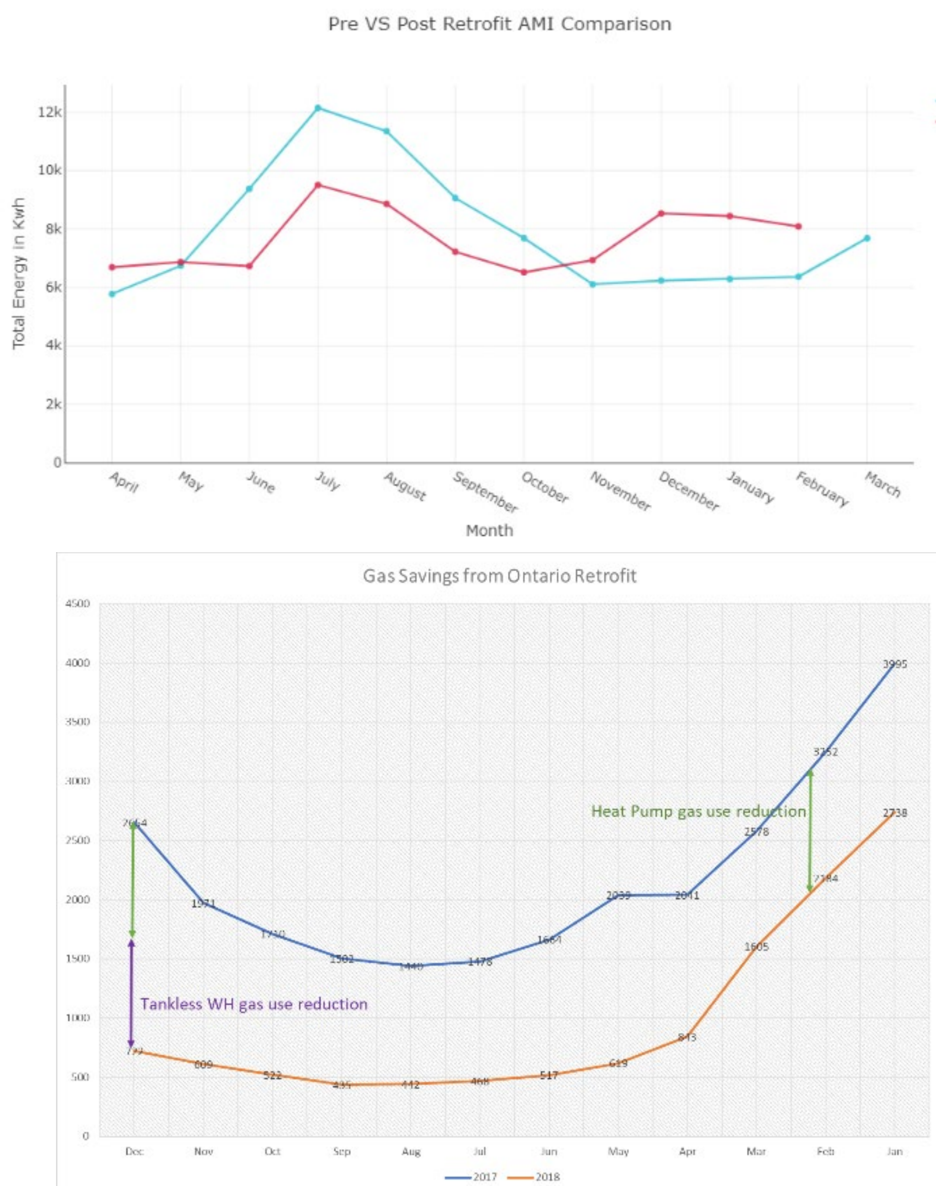
Figure 32: Combined (Gas and Electric) Source Emissions Savings Pre- and Post-Retrofit for Seasons at Ontario



Source: Electric Power Research Institute

This analysis underscores the importance of energy efficiency measures in electrification. Figure 33 shows that the increase in electricity usage during the winter heating season was offset by the reduction in cooling demand due to weatherization and air-conditioner efficiency. Without the weatherization measures, both winter and summer usage would have been substantially higher and would have increased tenant electricity usage and energy bills. The reduction in carbon intensity from electrification is also greater than the corresponding drop in energy usage since it accounts for the conversion from gas to electricity for heating.

Figure 33: GHG and Energy Savings from Integrated Efficiency and Electrification for Seasons at Ontario



Source: Electric Power Research Institute

A key part of this project was to ensure that tenants were able to save on energy costs and reduce their energy burden. This was achieved through the reduction in electric energy use (with the community solar providing additional bill relief). The property owner was able to save on both electric energy use for the common areas as well as gas energy use for the whole property. Community solar was paid for through the PPA, but the PPA costs for the property owner were higher than the owner's savings in electric bills. This is because the PV system was sized much larger than the current common area electricity usage, so a substantial portion of the economic benefits from the community solar accrued to the low-income tenants.

Case Study 2 – Pleasant View in Fresno

The second case study is for another affordable multifamily housing complex of 60 units, Pleasant View, located in Fresno, California. This multifamily community is more than 50 years old and is comprised of 1- to 4-bedroom units spread over 10 buildings, each containing 4–10 apartments, shown in Figure 34.

Figure 34: Pleasant View Affordable Housing Community

Source: Electric Power Research Institute

Each apartment is served by a 100 A electric panel, while each building is served by a 200 A mains panel (regardless of number of apartments). The community is master metered on both the electric and gas side, which means that the benefits of energy and energy cost savings accrue directly to the building owner. The existing electrical service infrastructure is a significant constraint to building electrification. Table 11 shows upgrades from the retrofit.

Table 11: Efficiency and Electrification Upgrades for Pleasant View in Fresno

Energy System	Pre-Retrofit	Post-Retrofit
Wall Insulation	None	R-19
Roof Insulation	R-13	R-25 with blown insulation
Patio Doors	Single pane	Double pane with low-E and frame sealing
Cooling	Direct evaporative cooler	120V Innova heat pump

Energy System	Pre-Retrofit	Post-Retrofit
Heating	Wall furnace	120V Innova heat pump
Water Heating	40-gal gas storage water heater	Sanden HPWH shared by 3/10 buildings
Indoor Lighting	CFL	LED
Outdoor Lighting	Metal halide parking lot lights	LED integrated lamps, fixtures, and posts for parking lot lights LED replacement in wall sconces
Appliances	Electric coil cooktop	Glass top electric cooktop
Renewables	None	137-kW community solar

Source: Electric Power Research Institute

The total cost of the retrofits, both net rebates and incentives, was $600,000. The utility ESAP covered some of the common area measures, but air conditioning upgrades were out of pocket for the property owner. A big challenge with this property was that the building level 200 A panels had almost no available additional capacity. This eliminated any new 240 V equipment at the unit level without taking on a huge cost penalty. The estimated cost for building and grid infrastructure for adding 240 V equipment was $9,000 per unit, which necessitated panel upgrade rewiring of distribution circuits and the upgrade of community transformers.

Emerging Technologies to Reduce Costs

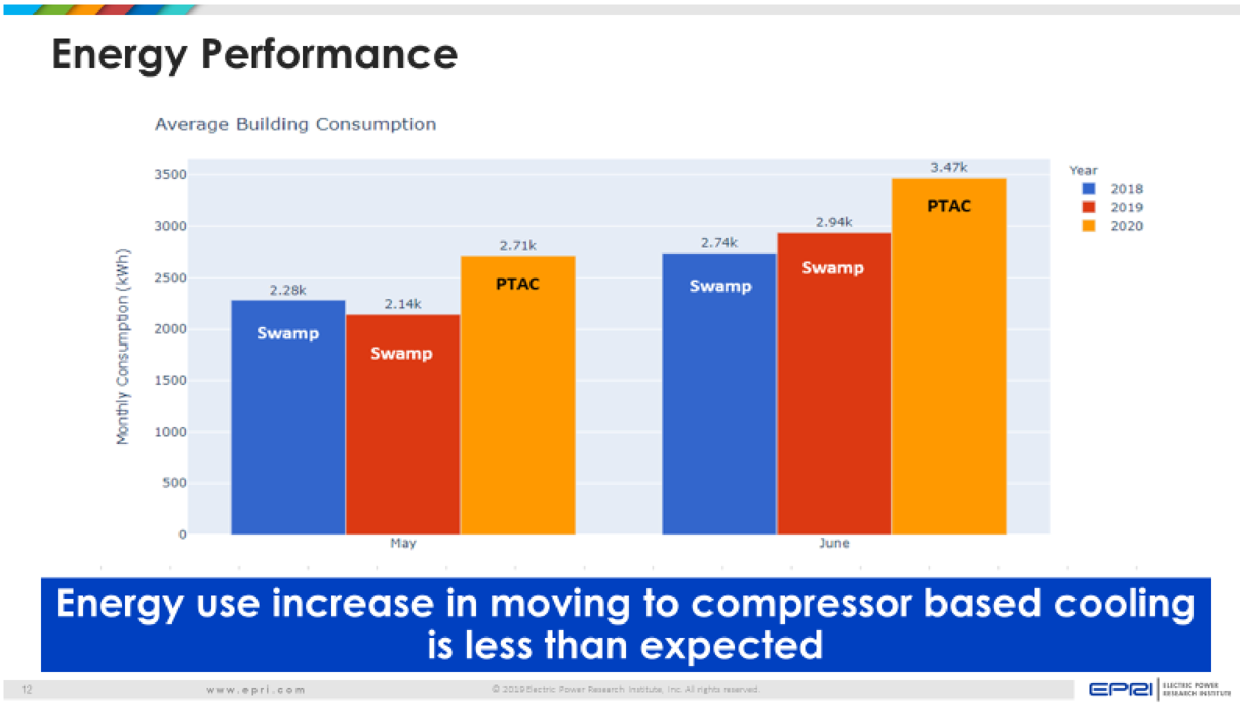
Two new emerging technologies were evaluated in this project to electrify without additional power.

120 V Innova Heat Pumps

A major electrification challenge was that existing systems were comprised of a wall- mounted furnace and an evaporative cooler. This meant that any heat pump conversion would eliminate the need for an evaporative cooler. While most tenants were unhappy with the performance of the evaporative cooler over the summer, changing out the evaporative cooler for compressor-based air conditioning meant a significant energy penalty in the summer for cooling. However, both wall furnaces and swamp coolers have significant indoor air quality impacts (NO_x, CO, mold issues), so from a customer-centric standpoint, the right thing to do was to incur a penalty with a newer heat pump. To overcome this increased energy use, it was critical to reduce air conditioner run times and recover some of the energy use and carbon impacts.

Innova heat pumps have been gaining greater market traction in California and beyond. In California, affordable housing developers are increasingly choosing this product for their communities due to its easy installation. Furthermore, as shown in Figure 35, the energy use increase in moving from evaporative coolers to compressor-based cooling is less than would be expected. Figure 36 shows comparison photos of gas wall-furnace replacement with 120 V heat pumps. The results will be provided to the codes and standards team at the CEC to provide better performance data for variable-capacity heat pumps.

Figure 35: Energy Use of Innova Variable-Capacity Heat Pumps Compared with Evaporative Coolers



Source: Electric Power Research Institute

Figure 36: Replacement of Gas Wall Furnaces with 120 V Heat Pumps

Source: Electric Power Research Institute

Heat Pump Water Heaters (HPWHs)

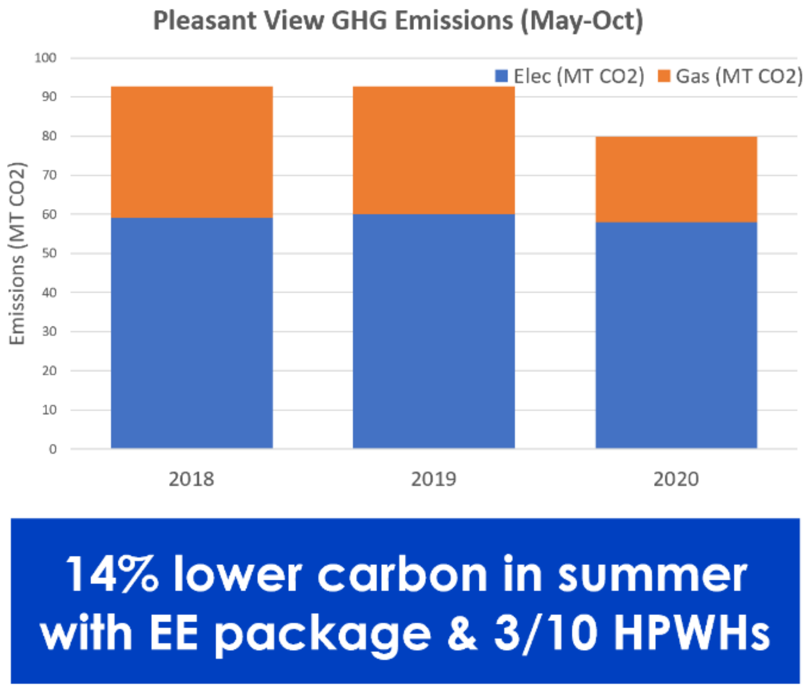
This community used 40-gallon gas storage water heaters in closets, each serving a single unit. Given that there is no power availability for standard 230 V HPWHs, the team needed to find an alternative solution for electrification of water heating. Two options were available: apply 120 V HPWHs or find a way to use central water heating. The solution chosen was to install Sanden water heaters using additional power at the building level, as seen in Figure 37. Sanden water heaters were chosen because their power draw is in the 1,100 W range (instead of 4,500 W) and because the 120 V HPWHs were not available for market evaluation. These Sanden units had sufficient capacity and were powered off the common area that also had solar inverters connected to the electrical panels. The new water heaters were installed in two configurations: 1-1 replacement for the 4-bedroom apartments and 1-2 replacement for the 1-bedroom apartments.

Figure 37: Replacement of Gas Water Heaters with Integrated CO_2 HPWHs

Source: Electric Power Research Institute

Results from the retrofits showed a 14 percent reduction in GHG emissions for the summer of 2020, as shown in Figure 38. These emissions reductions came from the electrification of water heating, which offset increased energy use on the cooling side. The cooling energy use increase was due to replacement of evaporative cooling with compressor-based cooling, as well as the stay-at-home factor during the pandemic. The carbon savings are expected to increase once electrification of the heating systems is accounted for during the winter.

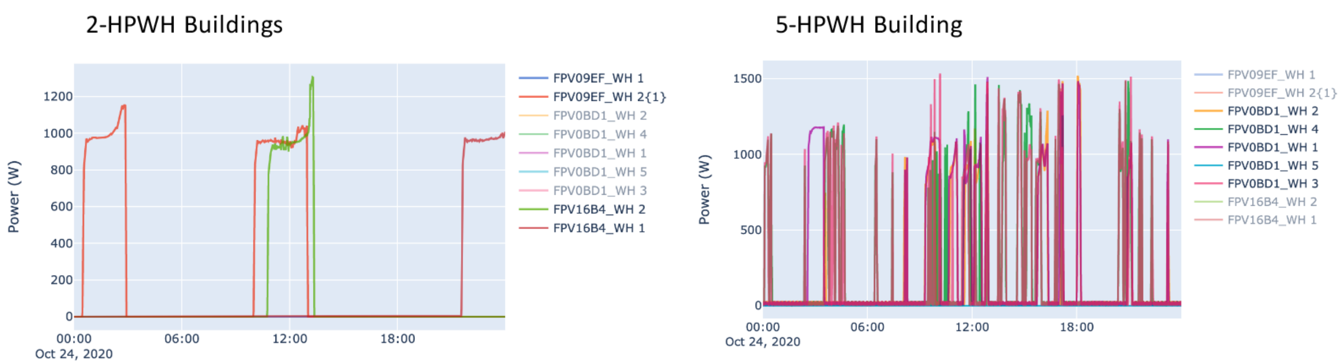
Figure 38: Annual GHG Emission Reductions from Building Retrofit



Source: Electric Power Research Institute

Another interesting outcome involved the comparison of performance of the 1:1 and 1:2 Sanden HPWH systems. The 1:2 systems, with greater thermal storage, showed a much flatter load curve and very low energy use from 12:00–4:00 p.m. The 1:1 systems were much more "peaky," with some peaks in the afternoon hours, as seen in Figure 39. This figure also shows potential for storage controls that can move most HPWH electric usage to hours outside the high-demand, late afternoon hours, reducing electric grid impacts. On the economics side, the total cost of the upgrades was $10,000 per home (after incentives and programmatic rebates), exclusive of community solar.

Figure 39: Comparison of CO_2 HPWH Operation with and without Thermal Storage



Source: Electric Power Research Institute

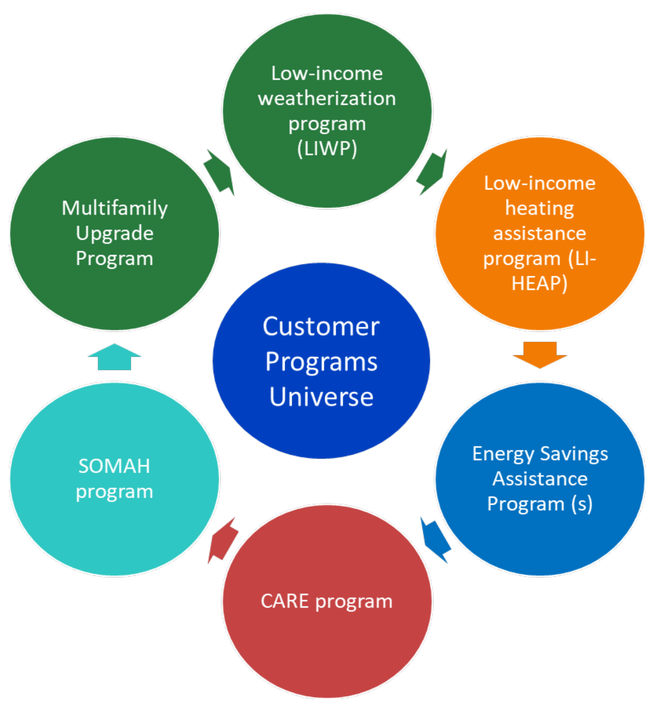
Addressing Programmatic Barriers

A consistent project challenge was "How can we make the cash-flow work?" Many programs, both taxpayer and ratepayer-funded, are designed to support energy upgrades or offset energy costs for low-income customers. Within these programs are sufficient funds to achieve decarbonization goals, as long as infrastructure-upgrade costs are not part of the equation.

As illustrated in Figure 40, program offerings commonly available across the country included:

- Utility energy-savings assistance programs, operated through ratepayer funds.
- Low-income weatherization programs operated by the states and funded by the U.S. Department of Energy (DOE).
- Multifamily upgrade programs through ratepayer funds.
- Low-income heating assistance programs operated by the U.S Department of Housing and Urban Development (HUD).
- Community solar programs usually paid for through ratepayer funds.
- Rate discounts for low-income customers through ratepayer funds.

Figure 40: Complex Matrix of Low-Income Customer Programs

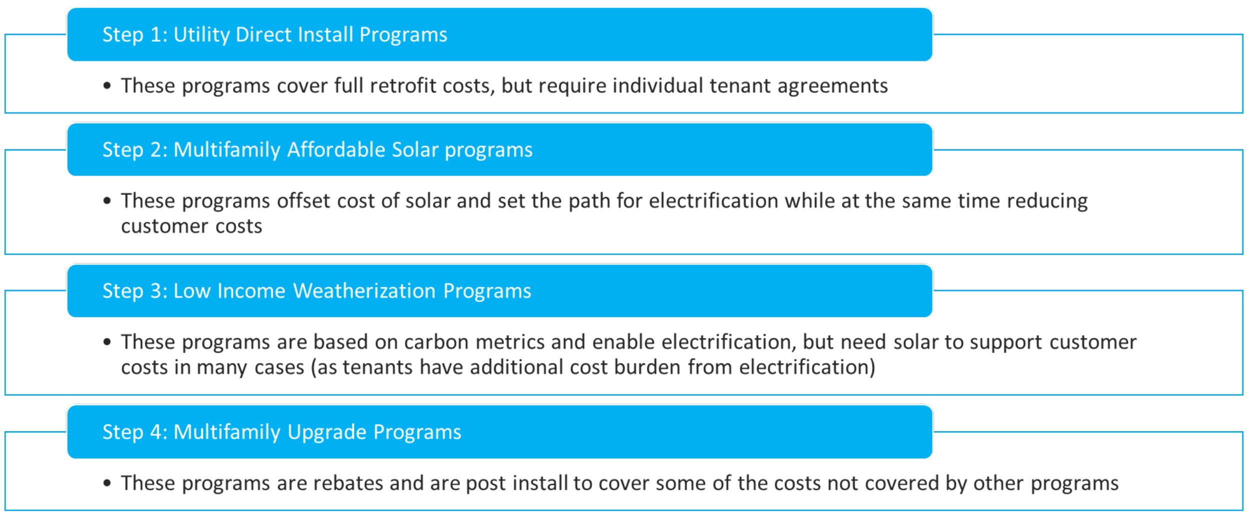


Source: Electric Power Research Institute

Both owners of low-income properties and low-income homeowners face daunting choices of programs, varying qualification criteria, implementation partners, and generally uncoordinated rebates and incentives. For example, insulation upgrades might be covered as a direct install in the ESAP and as a rebated incentive in the LIWP. However, incentives for electrification might only be available in the LIWP but not in the ESAP.

The key need here is not for more programs but rather for a concierge approach to help property owners navigate through multiple programs to achieve energy efficiency and the greatest carbon benefits while unlocking full financial benefits of these programs. One example is the flow chart in Figure 41, which shows a proposed methodology, followed by incentive and financing programs. This will also help utilities guide property owners through these programs. This process can be streamlined as tenants and owners implement no-cost, direct-install energy efficiency upgrades, leverage GHG-driven programs for electrification, and complete rebated upgrades to increase cash flow.

Figure 41: Process Flow for Property Owners to Implement Comprehensive Retrofits



Source: Electric Power Research Institute

Addressing Project Economics and Overcoming Split Incentives

The economics of decarbonization must ensure that both property owners and residents save on energy expenses following the transformation. The whole-building transformation required for decarbonization does not comfortably lend itself to past economic constructs like payback. This transformation requires pairing technology packages with financing mechanisms to change the discussion from payback to cash flow. Ultimately, in this sector, cash flow is more important and critical, as most housing agencies, non-profits, and homeowners operate on a cash-flow basis. For rental properties, it is additionally necessary to overcome the split-incentives barrier so that both property owners and tenants have positive cash flows.

Overcoming split incentives would require some form of master metering, with rents increased to offset reduced tenant utility costs. This approach lowers the tenant energy burden while still providing a positive cash flow for property owners. The example of the Seasons at Ontario, where partial electrification lowered energy bills for both the property owner and the tenants, is one approach to overcoming split incentives.

Cash Flow for Ratepayers

Ratepayers can be either homeowners or tenants. Their concerns center around cost. In many cases, this means that additional energy-cost burdens from electrification will need to be addressed with other energy-efficiency measures as well as distributed renewables, which can also reduce tenant energy costs. Table 12 shows the energy cost comparison of replacing a gas-storage water heater with an HPWH. Some areas of the United States have greater potential for energy cost savings than others. However, in some areas such as San Francisco and New York, energy costs could increase if not coupled with controls that optimize unit operating time periods. The additional cost of controls should be considered as a first cost to enable tenants and homeowners to save operating costs. The space heating analysis shows similar results, where the benefits of electrification were much greater due to the shift from propane or fuel oil.

Table 12: Energy Cost Impacts of Replacing a Gas Storage Water Heater with an HPWH

Comparison of Opex: HPWH v. Gas Storage

City	Blended Rate	Time Optimized	Gas Rate	Saving from Blended Rate	Saving from Time Optimized
Austin, TX	$0.13	$0.13	$1.61	$161.67	$161.67
Sacramento, CA	$0.18	$0.12	$1.69	$98.92	$189.88
Los Angeles, CA	$0.15	$0.10	$1.20	$36.60	$112.40
Phoenix, AZ	$0.11	$0.07	$0.91	$33.44	$94.08
San Francisco, CA	$0.31	$0.17	$1.69	($98.16)	$114.08
New York, NY	$0.24	$0.14	$1.25	($88.84)	$62.76

Source: Electric Power Research Institute

Assumptions:

- Blended rates are based on tiered rate plans.
- Time-optimized rates are the lowest off-peak rates.
- Savings represent annual dollar values.
- Time-optimized rates assume all usage during off-peak hours.
- Application efficiencies are based on 0.58 for gas storage, 0.85 for gas tankless, and 2.5 COP for HPWHs.

Takeaways:

- Rates need to be aligned with electrification programs.
- Managing usage for time-of-use rates is imperative.

The challenging part is when the burden of energy costs shifts to tenants with electrification in rental properties; it will require a shift from master metering to tenant metering for gas or propane to reduce tenant energy burdens. Another way to reduce tenant energy burdens would be for owners to install community solar with virtual net metering options.

Economics for Property Owners

Property owners pay the first cost of building upgrades and the net of any incentives from customer programs. Property owner first costs are common throughout most of the United States. If the property owner is also the ratepayer, the cash-flow equation is more straight-forward; the cost of the building retrofit is converted to a cash flow equation at current interest rates of around 2.5 percent for a 20-year loan. Table 13 shows the approximate per-unit cost of an electrification retrofit under different circumstances and estimated monthly payments. Costs shown as zero are covered by customer programs.

Table 13: Approximate Cost of Per-Unit Electrification

Upgrade	Equipment Only Replacement Cost	Scenario 1	Scenario 2	Scenario 3
Wall and Attic Insulation	$2,000	0	$500	$2,000
Window Replacements	$1,500	0	$1,000	$1,500
Heat Pump Replacement	$6,000	0	$4,000	$6000
HPWH Replacement	$3,000	$1,000	$1,500	$3,000
Appliance Replacements	$3,000	$1,000	$1,000	$3,000
Cost of Electric Upgrades		$0	$2,000	$12,000
Total Cost of Upgrades		$2,000	$10,000	$27,500
Monthly Payments		**$11**	**$53**	**$146**
Community Solar	$8,000	$8,000	$8,000	$8,000
Monthly Payments		**$44**	**$44**	**$44**

Source: Electric Power Research Institute

A description of each scenario in Table 13 follows:

- **Scenario 1:** Best: Electric service available for heating system electrification and end-of-life equipment replacement, with program support
- **Scenario 2:** Medium: Minimal electric upgrades and replacement of operating equipment, with extensive program support
- **Scenario 3:** Difficult: Requires significant electric infrastructure upgrades along with in-service equipment replacement, with limited program support

These scenarios also represent different regions of the United States. Regions such as the Northeast, Midwest, and California, with available electrification infrastructure, will offer much lower first costs for property owners when compared with areas with traditional fossil-fueled heating systems. These scenarios should not be taken to represent extreme cases, and likely represent 20th, 50th, and 80th percentile cases, respectively, for whole-building decarbonization.

The monthly cash expense for each case can be wildly different for property owners. For the economics to work, both property owners and tenants must save money as a result of upgrades. Property owners save only on common-area bills, usually gas, parking lot lighting, and laundry. These expenses usually total between $400 and $800 per year, per unit, which makes the cash flow uneconomical in many cases (beyond Scenario 2).

In the case of the Seasons at Ontario apartment complex, the total common area electricity expense before retrofit was $676/month, and gas expense was $1,670/month, for a total of $352/year/unit. Following building retrofits and community solar installation, the total expense (including utility connection charges) decreased to $600/month, mainly for water heating, which converts to a total utility expense of $90/year/unit. The savings for the community were therefore only $262/year/unit, not enough for even the financing cost of the community solar system. Excluding solar, community bills would be $160/year/unit, a $130/year/unit reduction in energy costs. This means that Scenario 1 is the only viable choice for decarbonization to be cost-effective. This scenario depends on expansion of ratepayer-funded programs and grid improvements to achieve cost targets.

Recommendations for Programmatic Improvements

Customer programs must meet two needs for successful decarbonization: they need to provide a coordinated approach for property owners that undertake improvements, and they need to bridge the financial gap just described.

Program Coordination

While there is no shortage of customer programs, there is a lack of coordination between multiple programs designed to facilitate more comprehensive building retrofits. Many ratepayer-funded programs target the end customer with measures like direct install wall insulation or window replacements. In many cases, however, the ratepayer cannot take advantage of these benefits because, as tenants, they are unable to perform the required building upgrades. Other programs, like community solar and multifamily upgrade programs, address the property owner. However, if the programs are rebated instead of direct-installed, the property owner is unable to immediately recover the costs. An additional barrier is that programs that target the ratepayer directly must go through two levels of approval: one for the ratepayer and one for the property owner. The step-by-step method shown in Figure 41 would first take advantage of all available direct install programs, followed by programs offering midstream rebates, and finally by programs providing post-installation rebates.

Applying a coordinated process can lead to substantial reductions in the capital required to implement comprehensive building retrofit upgrades. Based on the earlier cost analysis, achieving the deep decarbonization at a viable cost might require significant program support as well as avoiding infrastructure upgrades. Following are several recommendations to bridge that gap.

- Avoid shifting infrastructure upgrade costs on customers and offset electric panel upgrade costs.
- Identify and test innovative technologies such as smart panels to avoid panel upgrades for electrification. Address code barriers for new technology adoption.

- Ensure weatherization is available as a no-cost direct install working directly with property owners.
    - Identify scalable, low-cost, replicable technologies for weatherization (such as retrofit wind films and sealants and the addition of roof insulation with every roof membrane replacement).
- Create either a “green fund,” on-bill financing program, or a marketplace of low-interest-rate green lenders that provide easily accessible financing for low-income property owners.
- Create bridge financing so that property owners are not left financially responsible for building upgrades as they await rebates.
- Set up a trusted energy advisor who can help the property owner navigate the sea of programs. Utilities could serve as trusted energy advisors alongside community self-help organizations.

CHAPTER 6: Conclusions/Recommendations and Technology Transfer

Conclusions

The overall results of this IDSM retrofit project show a triple net benefit by reducing tenants' energy use, property owners' energy bills, and more than 50 percent of operational carbon. If PV system impacts are included, operational carbon was reduced by 86 percent. Careful integration and management of the technologies, implementation, and incentive processes were essential for success. In addition, an economic benefits division process between the tenants and the owner successfully addressed split incentives in the LIMF market.

This project was one of the first integrated electrification/decarbonization retrofits at scale in California for an 80-unit LIMF community, the Seasons at Ontario. The IDSM integration included deep energy efficiency retrofits, electrification, community solar PV, and indoor environmental analyses. The results illustrated key technologies in space heating and water heating to fill the gap for retrofits, and a financial model to enable deep retrofits.

This project identified several significant barriers and solutions to the electrification and decarbonization of multifamily buildings, especially in LIMF communities. Chapter 5 provides an in-depth look at barriers and solutions. Because of electric panel and wiring limitations, the project worked with heat pump and HPWH manufacturers to develop solutions. These solutions included developing technical specifications for 110 V heat pumps and HPWHs and searching international markets for existing 110 V heat pump technologies. Project efforts with manufacturers have been especially productive in stimulating the market to provide enhanced technologies key to electrification and decarbonization goals.

Integration of the ERPs and IDSM included deep efficiency, electrification, community solar, and indoor environmental analyses to achieve comprehensive decarbonization. A benefit from this project is that it provided field data and experience for the analytics required for scalable decarbonization retrofits for additional LIMF communities.

Retrofit investments and savings for these LIMF communities have different impacts on both tenants and management companies, often called split incentives. An example is when electrifying HVAC and water heating cause higher tenant electricity usage. Community solar can mitigate these cost increases for low-income tenants. The two demonstration communities had different metering systems. At Seasons at Ontario, the tenants paid an electric bill, but gas and water were master metered. The Pleasant View community was all master metered. Each community presents a different customer economic model for deep decarbonization retrofits that combine tax-credit refinancing, state and utility programs, and solar PPAs. The project evaluates various LIMF economic models and provides guidance on how to best balance tenant and management investments and benefits for scaling electrification in LIMF communities.

Barriers and Solutions

The project reconfirmed that there are several vital barriers to integrated IDSM with the goals of electrification and decarbonization of LIMF buildings. Three primary barriers and solutions follow.

1. **Managing the Complex Process and Economics for Owners**

   This project navigated numerous support programs and funding organizations and integration of both the planning and installation of ERPs, with other upgrades for appliances, roof insulation, and solar PV. A model was developed for the sequence and coordination of how to best plan and install these scaled LIMF electrification retrofits. Several pathways are outlined in this report.

2. **The Need for Financing and Cash Flow Analyses**

   The retrofit process demonstrated a gap between the cost of upgrades and the funding available as well as the dispersed nature of funding between multiple program sources. A debt financing mechanism is required to successfully bridge cash-flow issues for property owners.

3. **The Need for Electrical Infrastructure Upgrades**

   The majority of existing LIMF communities use gas for space and water heating. It is vital to electrify these loads to meet California's GHG emission goals. Retrofitting heat pumps for these end uses often requires electric infrastructure upgrades. New panels and 220 V wiring are often required to support additional electric loads. These additional electrical infrastructure costs increase the overall HPWH costs by 50–100 percent. The upgrades require unit panels, building panels, service laterals, and even utility grid connections. Shifting to carbon-based incentives and metrics (such as LIWPs) will significantly increase HPWH incentives. Both policy and regulatory solutions are required for successful market adoption of scaled electrification retrofits for LIMF communities. A related barrier is the lack of heat pump and HPWH products that fit the retrofit markets. This project successfully collaborated with manufacturers and other stakeholders to develop or import high-efficiency central HPWH or 110 V heat pump technologies demonstrated at the Pleasant View community in Fresno.

Knowledge Transfer – Outreach Activities

Technology transfer to enable market scaling and adoption was conducted through various forums: invited presentations, engagement with customer programs, engagement with stakeholder groups such as the affordable housing community, and engagement with community-based organizations.

Presentations

EPRI team members have given more than a dozen presentations on the results from the work performed in the course of this project at the Seasons at Ontario site. Audiences included regulatory staff and commissioners from both the CPUC and the CEC, utility staff, builders, developers, engineers, and scientists. These presentations (some of which are listed in Table 14) focused on affordable efficiency and renewable energy retrofits, community-scale retrofits, electrification, and decarbonization. Information regarding those presentations are provided upon request.

Table 14: Presentations on the Seasons at Ontario Project

Title	Audience/Occasion	Date
Advanced Energy Community Demonstrations	San Diego Gas & Electric	December 1, 2019
Advancing Building Decarbonization: Costs and Overcoming Barriers	EPRI Fall Advisory Meeting	September 15, 2019
Advancing Decarbonization: Efficient Electric Water Heating	ACEEE Hot Water Forum	March 2018
Building Electrification: Costs, Benefits, and Lessons Learned	CPUC	August 30, 2018
Building Decarbonization Workshop	EPIC 4	September 5, 2021

Source: Electric Power Research Institute

Engagement with Customer Programs

EPRI has developed guidebooks that describe customer programs to adopt technologies such as 120 V heat pumps and central HPWHs. These guidebooks will help develop new programs for utilities nationwide, which will in turn further help scale the results. There were three EPRI reports that were developed that leveraged insights from this project. Two reports are available free to the public. The third is currently available for purchase:

a. Building Better: A Roadmap of Building Decarbonization Strategies to Reduce Global Greenhouse Gas Emissions - https://www.epri.com/research/products/000000003002022156[gcc02.safelinks.protection.outlook.com]

b. Affordable Building Decarbonization: A New Pathway to Reduce Customer Costs and Improve Quality of Life - https://www.epri.com/research/products/000000003002022207[gcc02.safelinks.protection.outlook.com]

c. Characterizing the Performance of 120V Monoblock Heat Pumps in Retrofit Applications - https://www.epri.com/research/programs/110345/results/3002024715[gcc02.safelinks.protection.outlook.com]

Recommendations

To meet California GHG goals, the majority of building gas loads will require electrification from renewable sources. The Seasons at Ontario IDSM retrofit package in this project reduced operational carbon use by more than 80 percent. If HPWHs could have been used to achieve an all-electric retrofit, the complex would have reached zero net carbon operation. All-electric IDSM retrofits can also play a significant role in other GHG reductions including transportation and embodied carbon. For future projects, electric charging and the embodied carbon of building materials should be integrated into solutions for meeting overall GHG reduction goals.

The following recommendations emphasize development of better pathways for scaling electrification retrofits of LIMF and other residential markets, with the goal of maximizing IDSM and decarbonization impacts.

Improved Planning and Implementation Models

The process for understanding and integrating the many support programs for the LIMF market is daunting. For example, coordinating solar PV, roof upgrades, and ERPs is essential for optimizing the electrical upgrades required for the IDSM retrofit. Additional demonstrations are recommended.

Economic Models for Split Incentives

For scaled community IDSM, electrification retrofits are newly emerging. IDSM retrofits are needed to accelerate market adoption of electrification, so improved models are needed to account for both split incentives and savings from community solar.

Upgrade Policy or Codes for Electrification and Decarbonization

The shift to carbon-based metrics and incentives is underway and essential for successful scaling of decarbonization retrofits for LIMF communities. Application of carbon savings metrics can increase incentives and cover up to 80 percent of HPWH costs, as shown by LIWP incentives.

Solutions for mitigating electric infrastructure costs are essential for stimulating electrification/decarbonization retrofits. New federal, state, and utility programs need to be developed and tested to cover these costs.

Work with Manufacturers and Stakeholders

A significant barrier to the electrification retrofits of LIMF communities is the lack of heat pump products for the retrofit market. New heat pump products designed for the retrofit market are needed. A sustained program working with domestic and international manufacturers, utilities, designers, installers, and government organizations is recommended.

Demonstrations to Evaluate Integrated Solutions

Development of demonstration programs and creation of test beds by utilities and stakeholders are essential for the rapid evaluation of new integrated electrification and decarbonization retrofit solutions and for faster market adoption of these new solutions.

Expand on Senate Bill 1477 Activities

Senate Bill 1477 established two programs: Technology and Equipment for Clean Heating (TECH) and Building Initiative for Low-Emissions Development (BUILD). These programs encourage and support the electrification and decarbonization of buildings. Government, utility, and nongovernmental organizations should be encouraged to participate in and leverage these activities.

Benefits to Ratepayers

This project provided many benefits to California including energy, carbon, and cost savings as well as non-energy benefits. This project was one of the first integrated electrification/ decarbonization LIMF community retrofits and revealed significant difficulties; this information will be essential for scaling future projects. Non-energy benefits included development of models for low-income housing groups, identification of barriers and solutions, development of customer-centric solutions for continued savings through behavioral changes, and customer education packages for low-income residents. This project also provided field data and groundwork for utility development of customer-centric IDSM solutions for low-income properties, with the goal of benefitting both occupant and property management groups. California ratepayers benefit with greater electricity reliability, lower costs, increased safety, and accelerated decarbonization of multifamily complexes that help meet California's environmental goals.

The project used a combination of customer education and recruitment to create voluntary pools of engaged customers for energy efficiency retrofits, including participant incentives for continued energy savings behavior following technology upgrades. Then, the project developed and installed standardized packages of non-intrusive, early commercial energy efficiency measures that include distributed energy resources (DER) and DER-capable systems. Continued engagement of occupants reinforced energy savings, encourage behavioral changes, and optimized the energy savings potential of these measures. EPRI leveraged experience from the previous scalable near-ZNE retrofit project, which indicated that incorporating occupant engagement could be as important as being precise about the analysis of energy efficiency potential and audits. Active occupant engagement led to higher tolerance and acceptance of disruption during ERP implementation. The project consisted of four primary technical tasks:

- Design of energy efficiency pools and ERPs
- Construction, implementation, and commissioning of ERPs
- Data acquisition, monitoring, and analysis
- Development of IDSM retrofit guidelines for residences in low-income communities, showing new pathways for meeting California's ZNE and decarbonization goals

One approach was to validate the ERPs and IDSM at two sites with different integration issues and ERPs. The demonstration sites and partnerships described in this report demonstrate scalable, cost-effective retrofit IDSM technologies. Integration of new technology combined with changes in occupant behavior resulted in maximum efficiency and sustainable savings. Critical project benefits included:

- A new model of customer-centric technology solutions expected to offer greater residual savings.
- Documented costs, savings, and customer satisfaction with the ERPs, based on field monitoring and tenant surveys.

- Identification of key barriers to electrification and decarbonization for LIMF communities: electric panel size, environmental remediation, and small gas water heater closets.
- Motivation for manufacturers that provide heat pump and HPWH solutions for multifamily building retrofits.

Overall Energy Savings and PV Electricity

The Seasons at Ontario demonstration project led to a statistically significant reduction in electricity and gas usage. Table 15 presents pre- and post-retrofit electricity, natural gas, and source energy (MMBtu) usage for the Seasons at Ontario project. The retrofits led to a 9 percent reduction in electricity usage (27,556 kWh) and a 50 percent decline in natural gas usage (8,255 therms). The percentage decline in natural gas usage exceeded the decline in electricity usage due to the electrification of space heating and cooking (replacing existing gas measures with high-efficiency electric measures). Converting the usage reduction to British thermal units (Btu), the project led to a 24 percent reduction in energy usage across the entire complex (2,792 MMBtu).

The complex also installed a 140.1 kW PV system that produced 164,481 kWh of electricity over the 12-month post-installation evaluation period. PV production contributed to a 65 percent decline in the complex's use of utility-provided electricity and a 60 percent decline in the complex's use of energy, measured in MMBtu.

The complex's reduction in electricity usage was 27,556 kWh, substantially less than the 133,579 kWh reduction anticipated prior to the evaluation (see Table 15). It is likely that the many measures impacting HVAC usage led to substantial double counting of anticipated electrical savings. It also appears that the forecasted estimates may not have accounted for the increased electricity usage associated with the complex's electrification of heating. Estimated natural gas savings of 8,376 therms were close to the observed savings of 8,255 therms.

Table 15: Total Usage Pre- and Post-Retrofit for Seasons at Ontario

	Electricity (kWh)		Natural Gas (therms)		Energy (MMBtu)	
	Pre	Post	Pre	Post	Pre	Post
Apartment Area	232,099	223,416				
Common Area	64,346	45,473				
Complex	296,445	268,889	16,504	8,249	4,686	3,578
PV Production		-164,481				-1,684
Total Utility	296,445	104,408	16,504	8,249	4,686	1,894
Usage Reduction		27,556		8,255		1,108
Utility Usage Reduction		192,037		8,255		2,792

Source: Electric Power Research Institute

These data indicate that when the PV generation is included in the analysis, the complex reduced its annual usage of electricity from the utility by 192,037 kWh (296,445 kWh – 104,408 kWh). Approximately 15 percent of the reduced utility electricity usage was due to the retrofits (296,445 kWh – 268,889 kWh = 27,556 kWh), with the remaining 85 percent due to electricity produced by the PV system.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
ACH50	air changes per hour at 50 Pascal
AMI	advanced metering infrastructure
BEopt™	Building Energy Optimization Tool
BUILD	Building Initiative for Low-Emissions Development
CEC	California Energy Commission
CFL	compact fluorescent lamp
COP	coefficient of performance
CPUC	California Public Utilities Commission
CT	current transformer
DER	distributed energy resources
DHW	domestic hot water
DR	demand response
EER	energy efficiency ratio
EF	energy factor
EPIC	Electric Program Investment Charge
EPRI	Electric Power Research Institute
ERP	efficient retrofit package
ESAP	Energy Savings Assistance Program
GHG	greenhouse gas
HP	heat pump
HPWH	heat pump water heater
HSPF	heating seasonal performance factor
HUD	U.S. Department of Housing and Urban Development
HVAC	heating, ventilation, and air conditioning
IDSM	integrated demand side management
IOU	investor-owned utility
LED	light-emitting diode
LIHTC	low-income housing tax credit
LIMF	low-income multifamily (community segment)
LIWP	Low-Income Weatherization Program
LMF	large multifamily (housing)

Term	Definition
MASH	multifamily affordable solar housing
MEL	miscellaneous electric load
NEMA	National Electrical Manufacturers Association
PCB	printed circuit board
PPA	power purchase agreement
PTAC	packaged terminal air conditioner
PV	photovoltaics
RH	relative humidity
SCE	Southern California Edison
SEED	Solar Energy and Economic Development
SEER	seasonal energy efficiency ratio
TECH	Technology and Equipment for Clean Heating
ZNE	zero net energy

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