ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

Lead Locally, an Innovative Program Designed to Increase the Number of Energy Efficiency and Electrification Retrofits in Sonoma and Mendocino Counties

October 2024 | CEC-500-2024-100

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ACKNOWLEDGEMENTS

The authors wish to acknowledge the many contributions to this report made by colleagues, members of the Technical Advisory Committee (TAC), and Lead Locally partners summarized below. We especially thank Jackson Thach, Kadir Bedir, and David Hungerford of the California Energy Commission for continued leadership and financial support for the project, the home and business owners that volunteered to serve as test sites for technology field evaluations, and the installers and vendors who worked very hard to ensure quality retrofit installations.

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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 report documents results and lessons learned from the Lead Locally grant led by Sonoma Clean Power and funded by the California Energy Commission. The objective of Lead Locally was to accelerate the adoption of energy efficiency and electrification technologies in Sonoma and Mendocino Counties. The project included field and laboratory evaluations of several emerging or underutilized residential and commercial retrofit technologies, including air-to-water heat pumps, ducted mini-split heat pumps, grid interactive heat pump water heaters, aerosol sealing, radiant ceiling panels, phase change materials, nighttime ventilation, induction cooking, enhanced daylighting, and heat recovery dishmachines. The Advanced Energy Center, consisting of a physical storefront in Santa Rosa and an interactive website, was created to help deploy these and other promising retrofit technologies to the local community in Sonoma and Mendocino Counties. The Advanced Energy Center has been the cornerstone of Lead Locally deployment and educational activities and has stimulated over 1,390 energy retrofits in Sonoma Clean Power service territory. As of November 2023, Lead Locally has provided over $3.1 million in retrofit incentives to building owners, financed projects worth over $1.3 million through the zero interest on-bill financing program, hosted 120 events and 29 contractor training courses at the Advanced Energy Center, published 20 deliverable reports, and communicated results at six conferences. Customers who participated in the Lead Locally Program reduced their annual energy consumption by 11 percent overall, 23 percent among residential customers, and 3 percent among commercial customers across more than 300,000 square feet of building space. Lead Locally has made many important contributions toward California's decarbonization efforts, including the goal of doubling the efficiency of existing buildings by 2030.

Keywords: applied research, technology demonstration, technology transfer, knowledge transfer, deployment, incentives, financing, Advanced Energy Center, existing buildings, commercial, residential, retrofit, Lead Locally, Sonoma Clean Power, energy efficiency, air-to-water heat pumps, ducted mini-split heat pumps, grid interactive heat pump water heaters, aerosol sealing, radiant ceiling panels, phase change materials, nighttime ventilation, induction cooking, enhanced daylighting, heat recovery dishmachines

Please use the following citation for this report:

Simonson, Rebecca, Scott Salyer, Robert Hendron, Claudia Pingatore, Conor Moar, Geoff Barker, Amit Kanungo, David Avenick, Chris Williams, and Yitian Liang. 2023. *Lead Locally, an Innovative Program Designed to Increase the Number of Energy Efficiency and Electrification Retrofits in Sonoma and Mendocino Counties* . California Energy Commission. Publication Number: CEC-500-2024-100.

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Background

The State of California has established many vital yet challenging goals for improving the efficiency of the building stock in California, reducing greenhouse gas emissions, and decarbonizing the energy infrastructure (CEC, 2017).[1] Substantial potential for efficiency improvements remains untapped in the existing building stock, but effective strategies that generate widespread consumer interest and adoption have been elusive. The specific programmatic approaches necessary to meet statewide goals include:

- Expanded adoption of energy efficiency upgrades that go beyond existing codes and standards.
- Advancements in technologies to increase performance and reduce equipment and labor costs.
- Innovative deployment and funding strategies, business models and private/public partnerships and informed decision-making to spur mass adoption and scale-up.

In 2017, the California Energy Commission introduced a comprehensive research and development program that would help double the efficiency of existing buildings by 2030. In 2018, Sonoma Clean Power's (SCP's) Lead Locally Program was funded under the California Energy Commission solicitation entitled "Programmatic Approach to Existing Buildings Research, Development and Demonstration Program." The tasks for this program were designed to span the full innovation pipeline—from technology improvement and strategy development (applied research and development) to customer demonstrations (technology demonstration and deployment) to addressing market barriers (technology transfer). The project brought together technical research and development experts, program design specialists, clean energy finance experts, and industry partners to overcome the cost and implementation barriers that hinder achievement of the state's goals for energy efficiency in existing buildings.

Project Purpose/Approach

Lead Locally is an innovative program designed to greatly increase the number of energy efficiency and electrification retrofits in Sonoma and Mendocino Counties. This included lab-based research, demonstration, and field studies of technologies installed in real homes and businesses to determine technologies ready for deployment. Deployment was supported through a physical marketplace, the SCP Advanced Energy Center (AEC), a 9,400 square-foot space in downtown Santa Rosa. An accompanying website (https://scpadvancedenergycenter.org) was designed and built for Lead Locally. Evaluation, measurement, and verification (EM&V) was conducted to determine overall program savings and performance.

[1] Content for this section was partially drawn from the original EPIC solicitation.

Knowledge from this project is being published and shared with other utilities and program administrators to advance California's carbon reduction goals beyond this pilot program.

The goal of Lead Locally was to reduce annual energy consumption by 10 percent for participating residential customers and 20 percent for participating commercial customers across at least 300,000 square feet of building space overall and to develop new methods for accelerating the regional adoption of building electrification.

No technology improvements were made or attempted by Lead Locally, but each application was customized to some extent using commercially available products. The applied research and demonstration technologies consisted of residential and commercial retrofit technologies, including ducted mini-split heat pumps, grid interactive heat pump water heaters, induction cooking, heat recovery dishmachines, aerosol sealing, radiant ceiling panels, air-to-water heat pumps, enhanced daylighting, phase change materials, and nighttime ventilation (see Table ES-1).

The range of innovative approaches used by Lead Locally included evaluation of emerging technologies, creation of new incentive and financing programs, and implementation of outreach strategies to engage new customers, contractors, and vendors.

Table ES-1: Overview of Technologies Evaluated by Lead Locally

Technology	Description
Ducted mini-split heat pumps (residential)	Space heating/AC using heat pump technology; a smaller, variable speed version of a ducted split system (separate indoor and outdoor units); includes whole-house supply ventilation
Grid-interactive heat pump water heaters (residential and small commercial)	Tank water heaters using heat pump technology with electric resistance "backup;" potential to communicate with electric grid for load shifting and optimal efficiency
Induction cooking (residential and commercial)	Rangetops that use electromagnetism to heat cookware instead of a flame or electric resistive elements
Heat recovery dishmachines (commercial)	Commercial dishmachines that retrieve heat from the steam exhaust via a heat exchanger and redirect to the water pre-heating compartment
Aerosol envelope sealing (residential)	Solution sprayed into a space that can plug small gaps due to its aerosol particle size and pressurized application. Different product/application used for building envelope vs. ductwork
Radiant ceiling panels (residential)	Hydronic (circulated water) heating and cooling system using cross-linked polyethylene pipes mounted to ceiling panels and served by an air-to-water heat pump. Panels replace existing ceiling drywall.
Air-to-water heat pumps with fan coils (residential)	Integrated space heating, cooling, and hot water system with central fan coil for distribution

Technology	Description
Daylighting (commercial)	Measures to increase the amount of free natural light available to commercial spaces, and control of electric lighting to maintain visual comfort
Phase change materials (residential and commercial)	Materials that absorb and release heat via melting/freezing. Material can be selected based on melting point to suit particular space conditioning needs. Flexible mats in attic for residential buildings, rigid panels above drop ceilings for commercial buildings
Nighttime ventilation (residential)	Addition to ducted space conditioning system that brings in cool outdoor air at night, pre-cooling the house before rising daytime temperatures. Can supplement existing AC systems or avoid the need for AC

Source: Frontier Energy

Key Results

Most applied research demonstration technologies performed well in the field from a technical standpoint. The exception was residential phase change material, which did not result in clear energy savings, and the product showed severe durability issues.

The technologies selected for deployment from the applied research stage were heat pumps for space conditioning, heat pump water heaters, induction cooking, and commercial dishmachines. Financial incentives were provided by SCP to its customers to accelerate the market adoption of these technologies. SCP also provided incentives for heat recovery ventilation devices that transferred heat from exhaust air to fresh air being brought into a home to reduce the amount of energy required to condition the fresh air. Heat pump space conditioning, heat pump water heating, and induction cooking were the most popular. As of November 30, 2023, a total of 1,391 projects were deployed through the program and $3,165,484 incentives were issued.

SCP also offered on-bill financing for select measures, consisting of zero-percent interest loans repaid by the customer through their energy bills. In total, the on-bill financing program financed over $1.35 million of work for 174 projects.

EM&V was performed for the applied research projects and deployed projects from September 2019 through June 2022. The EM&V covered over 305,000 square feet across 166 residential and commercial sites and yielded the following results:

- An 11-percent reduction in annual energy consumption overall
- A 23-percent reduction in annual energy consumption among residential customers
- A 3-percent reduction in annual energy consumption among commercial customers
    - Persuading commercial building owners to take action, even when retrofits were offered free of charge, was extremely challenging. The EM&V for commercial

building was almost exclusively conducted for applied research projects, which included technologies not proven for deployment.

Additional key results and findings from Lead Locally are detailed in Table ES-2.

Table ES-2: Additional Key Results and Findings from the Lead Locally Program

Research Topic	Findings/Conclusions
Summary of Energy Savings	The 166 sites over 305,000 square feet that were evaluated for energy savings achieved the following results: • Annual energy savings > 2.7 million kilobritish thermal units (kBtu) (814,000 kilowatt-hour equivalent) • 11-percent reduction in annual site-level energy consumption overall • 23-percent reduction in residential site annual energy consumption, which far exceeded the grant goal of 10 percent • 3-percent reduction in commercial site annual energy consumption, which fell short of the grant goal of 20 percent • Heat pumps and heat pump water heaters drove overall savings.
Greenhouse Gas Impacts	The 166 sites over 305,000 square feet that were evaluated for energy savings achieved the following results: • 2,250 metric tons of carbon dioxide (tCO_2) reduction in lifecycle carbon emissions (equivalent to 500 gasoline passenger cars driven for one year, or 284 homes' energy use for one year[2]) • Mini-split heat pumps and heat pump water heaters contributed to 67 percent of the total lifecycle GHG reduction.
Applied Research Technology Evaluations	• More than 20 emerging retrofit technologies were evaluated in the laboratory or in field applications, which included 62 field test sites. • Three technologies were eliminated from further evaluation during the lab testing stage. Efficiency optimizing controls for heat pump water heaters were not yet available in a commercial product; automated louvers for window blinds did not perform with enough reliability; and fiber optic daylighting was deemed too expensive and had issues with lighting quality. • Energy cost savings per technology ranged from -3 percent to 64 percent with paybacks ranging from immediate to 1,000 years (or no payback at all). • Several technologies showed great promise for future deployment, including aerosol sealing, nighttime ventilation, mini-split heat pumps, air-to-water heat pumps, and heat pump

[2] Greenhouse Gas Equivalencies Calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results)

Research Topic	Findings/Conclusions
	water heaters. Others require further technology development or lower installation costs. • Energy savings for emerging technologies were highly application dependent, depending on initial conditions of the building and mechanical equipment and the comfort preferences of the occupants. • Fuel substitution technologies were cost-effective if the improvement in efficiency overcame the cost of electricity, or if a photovoltaic system was present.
Deployment	• Over $3.1 million in incentives and over $1.35 million in on-bill financing were provided to SCP customers to stimulate deployment. • More than 1,390 incentives were issued, and 174 projects were on-bill financed. • Strategic incentives and on-bill financing helped increase customer access to energy efficiency and decarbonization technologies. • The AEC and website provided awareness and education, as well as connected customers with contractors that could install deployment technologies.
Knowledge Transfer	• The AEC hosted over 10,00 visitors and hosted over 120 events. • The AEC website has received 241,722 page views as of November 2023. • Lead Locally partners have made presentations at technical conferences and conducted direct meetings with numerous stakeholders to discuss the project. • Technologies and program strategies provided valuable strategies to help local governments, residents, and businesses in other California climate zones deliver on the state's energy efficiency and renewable energy goals. • Field trips and tours of the AEC provided opportunities to reach out to students from historically underserved populations and get them excited about working in the energy efficiency field.
Non-Energy Impacts	• Non-energy benefits resulting from Lead Locally included lower energy bills, increased safety, and improved indoor air quality. • 53 percent of survey respondents cited a decrease in their energy bills and 57 percent reported improved indoor air quality. • Almost three-quarters of respondents reported an increase in safety following the installation of Lead Locally measures.

Research Topic	Findings/Conclusions
Program Experience	• 22 percent of survey respondents reported learning about the program through the SCP or AEC website and 20 percent through an SCP email. • Satisfaction ratings were high for all program experience categories (average of 4.6 out of 5) and end users were most satisfied with interactions with SCP program staff (4.8 out of 5).

Source: SCP, Frontier Energy, and Det Norske Veritas (DNV)

Knowledge Transfer Next Steps

The AEC has been the focal point for sharing knowledge and lessons learned from Lead Locally activities. This has been accompanied by the website, press releases, and social media. SCP will continue to operate the AEC, host more visitors, classes, trainings, and events. SCP is gearing up to provide even more customer service at the AEC in the coming year and exploring configurations and strategies that invite customers of different demographics to be served. SCP will also continue to deploy technologies and provide incentives where needed.

SCP is actively reaching out to the community to understand the barriers that the low-income and underserved customers faced with participating in Lead Locally. SCP will develop strategies to engage with and assist underserved and low-income customers with a more targeted and intentional approach and will share lessons learned with other utilities, decision makers, program implementers, and statewide and federal programs. Similar efforts will be made for commercial customers.

SCP will continue to engage and recruit contractors to install and advocate for energy efficiency and electrification technologies. SCP hosted 120 events and 29 contractor training courses during the duration of the project. SCP intends to continue the strategy of having staff members focus on contractor engagement and aligning with statewide and regional contractor networks.

SCP and the Lead Locally partners will continue outreach efforts to engage with regional, statewide, and federal programs including more direct outreach to stakeholders through meetings and conference presentations and communicating important lessons learned to a broad range of stakeholders. The outreach efforts will serve to enhance existing energy efficiency and electrification programs around the state, educate the public about cost-effective solutions for their home and business, stimulate Title 24 building code improvements for existing homes, and develop a more knowledgeable workforce that can promote new technologies and install them in accordance with best practices.

CHAPTER 1: Introduction

Scope

The Lead Locally Grant, led by Sonoma Clean Power (SCP) under funding by the California Energy Commission (CEC) through the Electric Program Investment Charge (EPIC) Program, was designed to develop innovative strategies and technologies to help the State of California meet its goal of doubling the efficiency of existing buildings by 2030. The grant focused on research, development, and demonstration projects in existing buildings, including a range of innovative technologies, program features, and market strategies to engage and motivate home and business owners.

The general approach for Lead Locally was to advance technology readiness through applied research and demonstration projects, followed by deployment of proven technologies through innovative channels such as the Advanced Energy Center (AEC). Technology Readiness Level (TRL) is a good indicator of the level of risk associated with a technology or product (see Figure 1). The applied research projects for Lead Locally were considered either TRL 4 (Component and/or system validation in laboratory environment) or TRL 5 (Laboratory scale, similar system validation in relevant environment). The objective was to move the technologies to TRL 9 (Actual system proven through successful mission operations). Lead Locally adopted a gradual risk reduction process that included lab testing, field testing, modeling, and technology demonstration, before proceeding with large-scale deployment.

Figure 1: Risk Reduction Strategy for Lead Locally

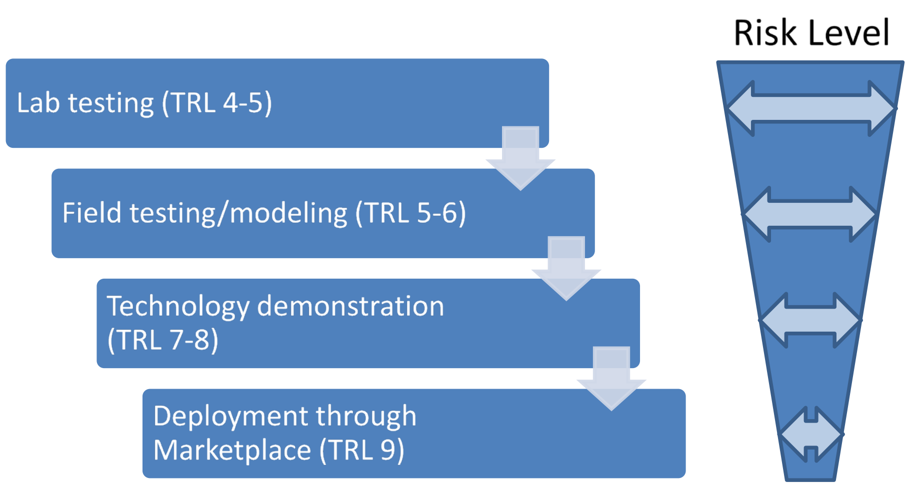


Image Credit: Frontier Energy

Lead Locally originally focused on reducing electricity use in housing and commercial buildings. As the project developed and input was provided by the Technical Advisory Committee (TAC), the priorities expanded to include electrification and greenhouse gas emission (GHG) reductions. This adjustment in scope was made to align program objectives with other important long-term energy goals and policies in California.

Purpose

The purpose of Lead Locally was to accelerate the adoption of emerging and proven technologies in existing residential and commercial buildings, driven through SCP's AEC. The primary objectives included the following:

- Applied research projects to evaluate the market readiness of emerging technologies through a combination of laboratory and field testing with detailed tracking of performance, durability, cost, installation challenges, and occupant satisfaction
- Technology demonstration activities to demonstrate how certain underutilized energy efficiency technologies perform in retrofit applications in the mild northern California climate, and to identify and overcome potential technology and market barriers. These projects included efforts to help home and business owners use and maintain their equipment appropriately, and feedback on possible behavior changes that could enhance energy savings from their retrofits.
- Technology deployment activities to accelerate the adoption of the most viable Lead Locally measures and, in doing so, contribute to meeting and potentially exceeding the project's retrofit performance goals of 10 percent residential and 20 percent commercial site electric savings in a total of 300,000 square feet of existing building space. Special attention was given to ensuring that benefits reach historically underserved populations and disadvantaged communities in Sonoma and Mendocino Counties, through the selection process for technology demonstrations and outreach to these communities at the AEC.
- Knowledge and technology transfer activities to maximize program visibility and extend the benefits of Lead Locally to other local governments, utilities, professional organizations, and other stakeholders throughout California and beyond. These efforts also help ensure that the program continues to have positive impacts long after the grant period ends.
- Inform California policies and regulations, such as future Title 24 code development activities and local reach code programs, by identifying technologies that are cost-effective and documenting best practices for design and installation. The results will also support California's Electronic Technical Reference Manual to enhance the accuracy of deemed savings calculations for the evaluation of utility programs and other initiatives throughout the state.
- An evaluation of project impacts of at least 300,000 square feet of project sites through a comprehensive EM&V Program, assessing energy savings, GHG reductions, customer satisfaction, and achievement of programmatic goals

These Lead Locally activities were well aligned with SCP's primary objectives for serving its customers:

- Provide cost-competitive electric services.
- Stimulate and sustain the local economy by developing local jobs in renewable energy and energy efficiency.
- Reduce GHG emissions related to use of power in Sonoma and Mendocino Counties by implementing energy efficiency and demand reduction programs.
- Develop long-term rate stability and energy reliability for residents through local control.

The Lead Locally Program sought to generate public benefits consistent with these objectives through strategies and solutions that could deliver a substantial decrease in site GHG emissions, stable and competitive electric rate, a broader range of technology options for meeting efficiency goals, and other local/regional economic benefits, especially for historically underserved communities.

Further details about the scope and purpose of Lead Locally are provided in the following documents: the Technology Demonstration Program Implementation Plan (Asay et al., 2019), the Advanced Energy Center Marketing Plan (SCP, 2019b), the Phase 1 and Phase 2 Research, Instrumentation, and Monitoring Plans (Hendron et al., 2018) (Hendron et al., 2019), and the Phase 1 and Phase 2 Evaluation Measurement and Verification Frameworks (Metoyer et al., 2018) (Metoyer et al., 2019).

CHAPTER 2: Applied Research and Technology Demonstration

The applied research and technology demonstration activities for Lead Locally were led by Frontier Energy and focused on gaining performance and energy use data through laboratory testing, field testing, and energy modeling of several emerging technologies that showed high savings potential yet were understudied in terms of cost and performance across a range of applications. Applied research projects generally included a lab test component along with limited field testing in up to five buildings, while technology demonstrations focused on field testing in five to 10 homes or businesses. In addition to energy savings and non-energy performance data, information was gathered regarding costs and simple payback, installation challenges, and market structures and barriers. Further details about the general approach used to evaluate the technologies are included in the Phase 1 Research, Instrumentation, and Monitoring Plan (Hendron et al., 2018), Phase 2 Research, Instrumentation, and Monitoring Plan (Hendron et al., 2019), and the Technology Demonstration Program Implementation Plan (Asay et al., 2019).

Summary of Project Types

Ten categories of retrofit technologies (see Table 1) were evaluated by Lead Locally, some in multiple forms (such as alternate daylighting approaches) or in different building types (residential and commercial phase change materials [PCM]).

Table 1: Overview of Technologies Evaluated by Lead Locally

Technology	Description	Expected Electricity Savings	Other Benefits
Ducted mini-split heat pumps (residential)	Space heating/AC utilizing heat pump technology; a smaller, variable speed version of a ducted split system (separate indoor and outdoor units); includes whole-house supply ventilation	20-30 percent heating and cooling (vs. standard air-source heat pump)	Peak load reduction Reduced cycling Thermal comfort Indoor air quality improvement
Grid-interactive heat pump water heaters (residential and small commercial)	Tank water heaters utilizing heat pump technology with electric resistance “backup;” potential to communicate with electric grid for load shifting and optimal efficiency	60 percent water heating (vs. electric resistance water heater)	Load shifting Hot water availability during peak hours

Technology	Description	Expected Electricity Savings	Other Benefits
Induction cooking (residential and commercial)	Rangetops that use electromagnetism to heat cookware instead of a flame or electric resistive elements	10-40 percent cooking (vs. electric resistance)	Cooking speed Safety Cleanliness Peak load reduction
Heat recovery dishmachines (commercial)	Commercial dishmachines that retrieve heat from the steam exhaust via a heat exchanger and redirect to the water pre-heating compartment	30-50 percent water heating	Gas savings Thermal comfort Lighter humidity load on ventilation system
Aerosol envelope sealing (residential)	Solution sprayed into a space that can plug small gaps due to its aerosol particle size and pressurized application. Different product/application used for building envelope vs. ductwork	20 percent heating and cooling	Gas savings Less drafts
Radiant ceiling panels (residential)	Hydronic heating and cooling system using cross-linked polyethylene pipes mounted to ceiling panels and served by an air-to-water heat pump . Panels replace existing ceiling drywall.	33 percent heating and cooling	Gas savings Thermal comfort
Air-to-water heat pumps with fan coils (residential)	Integrated space heating, cooling, and hot water system with central fan coil for distribution	25 percent heating, ventilation, and air condition (HVAC) and hot water savings	Gas savings Thermal comfort
Daylighting (commercial)	Measures to increase the amount of free natural light available to commercial spaces, and control of electric lighting to maintain visual comfort	40 percent lighting, 5 percent cooling	Better color rendering Reduced glare
Phase change materials (residential and commercial)	Materials that absorb and release heat via melting/freezing. Material can be selected based on	30 percent cooling, 10 percent heating	Load shifting Thermal comfort Gas savings

Technology	Description	Expected Electricity Savings	Other Benefits
	melting point to suit particular space conditioning needs. Flexible mats in attic for residential, rigid panels above drop ceilings for commercial		
Nighttime ventilation (residential)	Addition to ducted space conditioning system that brings in cool outdoor air at night, pre-cooling the house before rising daytime temperatures. Can supplement existing air conditioning (AC) systems or avoid the need for AC	30 percent cooling relative to adding an AC system	Peak load reduction Indoor air quality improvement

Source: Frontier Energy

The technology evaluations involved field testing of these 10 technologies across 48 residential and 13 commercial test sites within Sonoma and Mendocino Counties spanning 2019 to 2022. Conditions monitored before and after the technologies were installed included energy usage, thermal performance, and participant perspectives. Details on the equipment and methodology used for each technology varied depending on the needs of the project, but all technologies used the following general research framework:

Site Selection: SCP customers were recruited through various outreach channels to complete an application. The Lead Locally team evaluated site suitability based on a range of weighted criteria developed for each technology including expected energy savings, installation cost, consistency of equipment usage, installation feasibility, and occupant health and safety. Site visits were used to select the final sites. Test sites were numbered from 1 to 62, with Site #11 being used for two technologies and Site #15 dropping out of the program prior to installation.

Baseline Data Collection: Most sites had instrumentation installed to measure baseline data for three to 12 months depending on seasonality and technology type. For a few sites, baseline data was either not relevant due to major site repurposing or not available due to time constraints, as will be described later in this section.

Retrofit: The new equipment was installed at each site. All but a few simple self-installations (four of the six commercial PCM sites) used contractors that held an active Contractor's State License Board license appropriate for the scope of work, as well as appropriate insurance and bonding. All installers (including self-installers) received mandatory training provided by Lead Locally or the product manufacturer.

Post-Retrofit Data Collection: Each site had instrumentation installed to measure relevant metrics for three to 16 months, except one daylighting site that could only be monitored for one month due to recruitment and installation delays. At the end of the testing period, monitoring equipment was removed, but the installed technologies remained in place, except residential PCM where durability was an issue.

Data Analysis: Technology performance was analyzed through a combination of direct monitoring of the installed equipment, weather-normalized utility bill comparisons, occupant surveys, and cost-effectiveness calculations using simple payback as the most practical and commonly used metric.

Costs, Savings, & Payback: For consistency and relevance, costs and savings associated with applied research and technology demonstration were converted to 2023 monetary values even though they were incurred from 2019 to 2022. To be consistent with statewide energy budgeting protocols, utility savings calculations used recent rate structures applied to specific building prototypes for a time-of-use (TOU) metric of annual energy costs. The following specific utility rate structures were used:

Residential projects- Pacific Gas and Electric (PG&E, 2023) E-TOU-C electricity rate and (PG&E, 2022a) G-1 natural gas rate;

Commercial projects- (PG&E, 2022c) TOU B-1 small general service electricity rate and (PG&E, 2022b) G-NR1 small commercial natural gas rate.

A summary of these utility rates is provided in Table 2.

Table 2: Utility Rate Assumptions for Cost Savings Analysis

Building Type	Fuel	Average TOU or Seasonal Rate	Source
Residential	Natural Gas	\$2.17/therm	Annual average based on the 2023 PG&E G-1 rate applied to the standard 1665 feet squared (ft^2) Title 24 existing home prototype in Climate Zone 2 averaged across the 3 vintages (German et al., 2020)
Residential	Electricity	\$0.36/kilowatt-hour (kWh)	Annual average based on the 2023 PG&E E-TOU-C rate applied to the standard 1665 ft^2 Title 24 existing home prototype in Climate Zone 2 averaged across the 3 vintages (German et al., 2020)
Commercial	Natural gas	\$1.60/therm	Annual average based on the 2022 PG&E small commercial G-NR1 tariff applied to the small office buildings modeled for the Lead Locally

Building Type	Fuel	Average TOU or Seasonal Rate	Source
			Optimized Retrofit Strategies report (German et al., 2023).
Commercial	Electricity	$0.337/kWh	Annual average based on the 2022 PG&E/SCP small general service TOU B-1 tariff applied to the small office buildings modeled for the Lead Locally Optimized Retrofit Strategies report (German et al., 2023).

The following sections provide a summary of the technologies evaluated by Lead Locally and some of the key results and lessons learned. Further details are included in Appendix A and the published final reports for each technology as referenced.

Minisplit Heat Pumps

A "heat pump" is a highly efficient air conditioner that can also work in reverse and provide heat during the winter. A "split" system is one that is split into two components: an "indoor unit" and an "outdoor unit." A mini-split heat pump (MSHP) is just a smaller version that can vary the speed of its components to match the current needs of the home, using less energy in the process. A ducted mini-split typically has one indoor unit and distributes conditioned air throughout the house using compact ductwork inside conditioned space, in contrast to a ductless mini-split, which typically distributes refrigerant to multiple small indoor units, each with its own fan-coil and often with a separate thermostat. Ducted MSHPs were selected because the loads in larger homes generally exceed the capacity of ductless systems, and more uniform temperature distributions can be achieved. The retrofit package that was evaluated for Lead Locally included envelope improvements that reduced the required capacity and cost of the MSHP, and integrated exhaust ventilation to improve indoor air quality. This technology is targeted primarily to the single-family residential market.

To reduce the capacity requirements for the MSHPs, attic insulation levels were improved, and the envelope was tightened significantly to reduce air infiltration. Continuous exhaust ventilation was also added when necessary to ensure proper indoor air quality.

The installed MSHP outdoor unit and indoor unit at Site 39 are shown in Figure 2 and Figure 3, respectively.

Figure 2: MSHP Outdoor Unit at Site 39

Photo credit: EnergyDocs

Figure 3: MSHP Indoor Unit at Site 39

Photo credit: EnergyDocs

The following sections provide an overview of the MSHP demonstration project and key results. Further details can be found in the Lead Locally Technology Demonstration Final Report (Hendron et al., 2022).

Sites

The MSHP system was installed at seven single-family home test sites with square footages varying from 720 ft^2 to 1,828 ft^2 (see Table 3). All homes used natural gas heating pre-retrofit except for Site 37, which used electric resistance. Site 40 was the only site with a photovoltaic

(PV) system. Site 41 required a power vented water heater because the envelope tightening measures made the existing natural combustion water heater hazardous.

Table 3: Overview of MSHP Test Sites

Site #	City	Conditioned Floor Area (ft^2)	Existing Heating Equipment	Existing Cooling Equipment	New Equipment Make/Model
35	Sonoma	1,152	Gas furnace	Central AC	Outdoor Unit: Fujitsu AOU9RLFC Air Handler: Fujitsu ARU9RLF
39	Sonoma	720	Gas furnace	Central AC	Outdoor Unit: Mitsubishi SUZ-KA12NA2 Air Handler: Mitsubishi SVZ-KP12NA
36	Windsor	1,618	Gas furnace	Central AC	Outdoor Unit: Mitsubishi SUZ-KA18NA2 Air Handler: Mitsubishi SVZ-KP18NA
37	Sebastopol	1,100	Packaged heat pump	Central AC	Outdoor Unit: Fujitsu AOU12RLFC Air Handler: Fujitsu ARU12RLF
38	Santa Rosa	1,106	Gas furnace	Central AC	Outdoor Unit: Mitsubishi SUZ-KA12NA2 Air Handler: Mitsubishi SVZ-KP12NA
40	Santa Rosa	1,570	Gas furnace	Central AC	Outdoor Unit: Mitsubishi SUZ-KA18NA2 Air Handler: Mitsubishi SVZ-KP18NA
41	Sonoma	1,828	Gas furnace	Central AC	Outdoor Unit: Mitsubishi SUZ-KA18NA2 Air Handler: Mitsubishi SVZ-KP18NA Power Vent Water Heater: Bradford White RG2PV50H6N

Source: Frontier Energy

Key Results

Table 4 presents estimated energy cost savings and simple payback periods for the seven test sites, including both heating and cooling. The cost savings for natural gas does not compensate for increased cost in electricity for all test sites. Only Sites 39 and 41 realized total cost savings. Total estimated energy costs range from an increase of $476 to a savings of $126 annually. Based on an average installed cost of $31,129, no project would have a payback period that would be viable without incentives, or unless the existing equipment was at the end of its useful life (which was not the case for any of these sites). However, the installation costs were paid by Lead Locally, so the sites only experience the utility bill impacts and any future maintenance costs.

Table 4: Energy & Cost Savings for the Seven Test Sites and Simple Payback (Measured at Meter, Adjusted for Weather and Behavior)

Annual Energy Savings	Site 35	Site 39	Site 36	Site 37	Site 38	Site 40	Site 41
Heating kBtu[a]	908.2	10,801.5	3,680.2	-	4,813.5	4,234.3	580.4
Heating kWh	-910.1	-300.4	-776.0	-604.6	-1,538.1	-1,117.1	-29.3
Cooling kWh	-29.2		546.3	87.7	-73.7	834.2	
Annual Cost Savings	**Site 35**	**Site 39**	**Site36**	**Site 37**	**Site 38**	**Site 40**	**Site 41**
Heating kBtu[a]	$19.71	$234.45	$79.88	$0.00	$104.48	$91.91	$12.60
Heating kWh	($327.6)	($108.14)	($279.36)	($217.66)	($553.72)	($402.16)	($10.55)
Cooling kWh	($10.51)		$196.67	$31.57	($26.53)	$300.31	
Total	**($318)**	**$126**	**($3)**	**($186)**	**($476)**	**($10)**	**$2**
Simple Payback[b] [years]	**-**	**246**	**-**	**-**	**-**	**-**	**15,187**

[a] *1 kBtu= 0.293 kWh*
[b] Average cost estimated at $31,129.
Source: Frontier Energy

Lessons Learned

The MSHP systems installed at the seven test sites resulted in positive feedback from the homeowners based on post-retrofit surveys, where everyone was satisfied with system performance, energy efficiency, and perceived comfort.

The start of the COVID-19 pandemic in early 2020 complicated the cost-effectiveness analysis considerably. The occupants spent more time at home (increasing HVAC run time and internal gains), and thermostat settings changed for many homeowners. These changes in occupant behavior made it challenging to calculate energy savings based on measurements alone.

Despite being viewed favorably by the homeowners of the test sites, the specific MSHP systems designed and installed for this study cannot be considered an overall success because of the lack of cost-effectiveness as a retrofit option due to the cost of labor and converting from natural gas to electricity. For labor, the cost was roughly $22,237, which was more than 70 percent of the total cost. When converting from gas to electricity, a technology must be very energy efficient to overcome the additional cost of electricity, or financial incentives may be necessary. In applications with PV systems in place, the MSHP systems designed for this project may become cost-effective as a retrofit. Applications in new construction and end-of-useful-life replacements could also show more positive results.

Grid Interactive Heat Pump Water Heaters

Heat pump water heaters (HPWHs) utilize a high-efficiency heat pump with electric resistance backup. Modern hybrid HPWHs have Uniform Energy Factor (UEF) ratings of up to 4.0 in ideal conditions, compared to UEFs of 0.90-0.95 for conventional electric resistance water heaters and 0.60-0.65 for natural gas storage water heaters. For homes that replace electric resistance water heaters with HPWHs, it is possible to reduce hot water energy usage by as much as 75 percent.

HPWH operating efficiencies can be lower than the UEF ratings when they operate in less favorable air and water temperature conditions and have high hot water draws that require the use of the electric resistance elements to provide required hot water demand. This can be especially expensive when electric resistance is engaged during TOU rate on-peak hours. Grid interactive HPWHs (GIHPWHs) work to reduce the electric resistance component, both overall and especially during on-peak hours, through load-shifting. Upon receiving a grid signal from a utility or manufacturer, GIHPWHs can pre-condition the tank water temperature before the TOU on-peak hours and shift as much of the load as possible from the resistance element to the heat pump. A thermostatic mixing valve can allow the pre-conditioned tank temperature to be driven higher (for example, 145°F [63°C]) while maintaining a safe mixed outlet temperature (for example 120°F [49°C]), thereby increasing effective capacity (see Figure 4).

Figure 4: Installed GIHPWH with Thermostatic Mixing Valve

Photo credit: Frontier Energy

For Lead Locally, this technology evaluation included both an applied research component and a technology demonstration. The applied research component focused on efficiency optimizing algorithms and machine learning for GIHPWH controls. For the technology demonstration project, GIHPWHs were evaluated at nine single-family homes via a baseline and replacement monitoring in-situ field study.

The following sections provide an overview of the GIHPWH applied research and demonstration projects, along with key results. Further details can be found in Appendix A, the

Lead Locally Technology Demonstration Final Report (Hendron et al., 2022), and Optimization Strategies for Residential Heat Pump Water Heaters (Hendron et al., 2021).

Lab Testing

The GIHPWH applied research evaluation was originally meant to include a lab testing activity at Frontier's Building Science Research Laboratory (BSRL). The primary objective was to develop and test a predictive control algorithm that would optimize efficiency by responding to changing weather and operational conditions, leading to reduced energy costs. Several months after work began, the National Renewable Energy Laboratory (NREL) obtained a patent for a predictive control algorithm with similar functionality, leading to suspension of work to avoid duplication of effort. Although a collaboration with NREL was pursued, NREL was unable to identify a manufacturer willing to include their algorithm in a prototype HPWH that could be tested under Lead Locally within the time frame of the program.

Instead, the CEC asked the Lead Locally team to develop practical information for homeowners seeking to purchase GIHPWHs with advanced controls and operate them in an energy-efficient manner. This information is found in the report titled Optimization Strategies for Residential Heat Pump Water Heaters (Hendron et al., 2021).

Sites

Nine residential sites were used for GIHPWH demonstrations, including a mix of sites with existing gas and electric water heaters. Important criteria included sufficient physical space, good ventilation, and adequate electric panel capacity. The load shifting functions of the GIHPWHs were remotely controlled by Frontier Energy, not through grid signals (See Appendix A for more details). A summary of the demonstration sites is provided in Table 5.

Table 5: GIHPWH Demonstration Sites

Site #	City	Building Type	Conditioned Floor Area (ft^2)	Year Built	Existing Water Heater	GIHPWH Model
17	Petaluma	Residential	1,103	1941	Gas	Rheem PROPH65 T2 RH350 DCB
18	Sonoma	Residential	1,767	1956	Gas	Ruud PROUH80 T2 RU375-30
19	Cazader	Residential	1,950	1955	Gas	Ruud PROUH80 T2 RU375-30
20	Santa Rosa	Residential	1,495	1957	Gas	Ruud PROUH80 T2 RU375-30
21	Guerneville	Residential	750	1969	Electric	Ruud PROUH80 T2 RU375-30
22	Santa Rosa	Residential	1,248	1963	Gas	Rheem XE80T10HS45U0

Site #	City	Building Type	Conditioned Floor Area (ft^2)	Year Built	Existing Water Heater	GIHPWH Model
23	Santa Rosa	Residential	1,431	1956	Gas	Ruud PROUH80 T2 RU375-30
24	Sebastopol	Residential	1,300	1975	Gas	Ruud PROUH80 T2 RU375-30
25	Santa Rosa	Residential	1,008	1951	Gas	Ruud PROUH50 T2 RU375-30

Source: Frontier Energy

The installed retrofit units were Rheem ProTerra and Ruud Ultra hybrid GIHPWHs equipped with the Rheem EcoNet Wi-Fi interface. Seven of the nine sites received 80-gal units. Site 17 received a 65-gal unit, and site 25 received a 50-gal unit (to reduce the cost to the homeowners), as it was determined from the baseline data that these households had relatively low hot water demand.

Key Results

Table 6 shows the gross energy and cost savings at each site.

Table 6: GIHPWH Energy Savings Results (Measured)

Participant	Baseline Water Heater (gas or electric)	Baseline Energy Usage (kWh/y or kBtu/y)[a]	Replacement Energy Usage (kWh/y)	Gross Energy Savings (kBtu/y[a])	Cost Savings ($/y)
Site 17	Gas	23,100 kBtu/y	2,032	16,200	$352
Site 18	Gas	13,900 kBtu/y	1,399	9,100	$198
Site 19	Gas	19,000 kBtu/y	2,404	10,800	$234
Site 20	Gas	16,700 kBtu/y	1,449	12,800	$278
Site 21	Electric	6,518 kWh/y	1,858	15,900	$1,678
Site 22	Gas	10,200 kBtu/y	3,060	-200	($4)
Site 23	Gas	8,600 kBtu/y	1,027	5,100	$111
Site 24	Gas	15,500 kBtu/y	2,929	5,500	$119
Site 25	Gas	9,893 kBtu/y	2,885	49	$1
Average		**15,300 kBtu/y**	**7,200 kBtu/y**	**8,100 kBtu/y**	**$217**

[a] *1 kBtu= 0.293 kWh*
Source: Frontier Energy

GIHPWHs saved an average of 8,100 kBtu per year, or about 53 percent of the baseline water heater energy usage. The highest cost saving was seen at the site with the electric baseline water heater. Overall, the expected value of cost savings was calculated to be $217 per year, but the cost savings given fuel switching from a gas water heater to the electric heat pump were only $161. The electric resistance to hybrid electric heat pump conversion saved the site $1,678/year.

The installed GIHPWHs were in heat pump mode for an average of 77 percent of their total runtime. The most common event that triggered activation of the electric heating element was clothes washer or dishwasher operation shortly after shower use. The GIHPWHs were generally successful at not running during peak hours from 4 p.m. to 9 p.m., with only 34 recorded instances of any unit using electric resistance during peak periods.

The retail cost of an 80-gallon GIHPWH is about $2,953. Given the average yearly project site savings of $217, the simple payback time for these units is 11 years. However, the incremental cost difference between the GIHPWH and a conventional gas or conventional electric water heater is roughly $1,770 and would have a similar installation cost, which would yield a simple payback time of 7 years.

The homeowner satisfaction survey showed that 80 percent of the homeowners were satisfied or very satisfied with their water heaters. The most common problem with the GIHPWH from a satisfaction standpoint was the amount of noise the heat pump made for indoor installations.

Lessons Learned

GIHPWHs were clearly shown to be a viable technology for the residential market because they show positive cost savings even when replacing gas water heaters, and the grid interaction component (simulated in these tests) coupled with demand-pricing-informed occupant hot water usage behavior can successfully minimize the consequences of demand peak pricing. The sites which had the worst paybacks were the sites that ran the largest number of loads of laundry or dishes during on-peak periods, and also tended to be the sites with the highest number of occupants. This suggests that the storage tank size of 80 gallons might be insufficient for households with more than five members.

One issue for this technology is the choice of location for installation. Generally, as a retrofit technology, the location of a water heater is difficult to change. However, placing a HPWH in a cold garage or in an unheated room is known to lessen its coefficient of performance (COP), so new construction contractors and designers need to be aware that placing GIHPWHs in conditioned spaces or in rooms known to get very hot will improve their performance. Alternately, evaporator inlet and/or outlet ducting can be installed to improve temperature conditions.

The most important benefit of GIHPWHs in general is that they are a viable replacement technology for gas water heaters and can be used in a cost-effective way that can offset the higher price associated with using electricity instead of gas. The grid interaction was shown to reduce the operating costs of GIHPWHs significantly.

Induction Cooking

Induction cooking is an emerging replacement technology for gas and electric resistance stovetops and ranges. Induction cooktops work by generating a magnetic field by use of an induction coil. Any ferromagnetic piece of cookware placed on the cooktop will quickly get hot as a result. In addition to better energy efficiency, induction stovetops have thermal response times similar to gas ranges and the added benefit of being cooler to the touch.

The purpose of this study was to document the energy savings associated with replacing existing gas or electric ranges in residential and commercial buildings with induction cooktops (see Figure 5). Another goal was to document user experiences with induction cooktops and introduce induction as a viable electric alternative to gas cooking.

Figure 5: Replacement Residential Induction Range

Photo Credit: Frontier Energy

The following sections provide an overview of the induction cooking technology demonstration project. Further details can be found in Appendix A and the Lead Locally Technology Demonstration Final Report (Hendron et al., 2022).

Sites

A summary of the seven demonstration sites is provided in Table 7.

Table 7: Induction Cooking Demonstration Sites

Site #	City	Building Type	Conditioned Floor Area (ft^2)	Year Built	Induction Cooking Model
28	Santa Rosa	Residential	1,420	1951	KitchenAid KSIB900ESS
29	Santa Rosa	Residential	1,346	1986	KitchenAid KSIB900ESS
30	Sebastopol	Residential	1,705	1973	Electrolux EW30IC50LS
31	Guerneville	Residential	1,817	1936	KitchenAid KFID500ESS
32	Ukiah	Residential	2,200	1977	KitchenAid KFID500ESS
33	Petaluma	Junior College Dining Facility	3,000	1995	CookTek 645100
34	Sonoma	Hotel	10,000	2001	Vollrath 924HIMC

Source: Frontier Energy

Key Results

One commercial site was monitored for this project, a full-service restaurant in a hotel (Site 34), which originally had a gas 6-hob range connected to a convection oven. Delays obtaining approval from the junior college for installation at Site 33 prevented useful monitoring at that site. Table 8 details the energy consumption results from Site 34.

The total energy use was a very small portion of the site's overall energy usage because the range tops were only used for finishing foods (for example, searing a steak) or for warming soups. Most of the bulk cooking was done using convection ovens or other cooking appliances. Overall, this site saved 361 kBtu per day (78 percent relative to original cooktop), partially due to the elimination of pilot usage and partially due to the higher efficiency of the induction stovetop. However, the higher cost of electricity compared to gas resulted in higher estimated energy costs.

Table 8: Energy Results from Induction Cooktop Retrofit at Site 34 (Measured)

	Pilot Usage	Total Energy Use*	Daily Energy Cost ($/d)	Annual Energy Cost ($/y)
Baseline	84 kBtu/day	460 kBtu/day	$7.38	$1,871
Replacement	0	29 kWh/day	$9.77	$2,443
Savings	84 kBtu/day	360 kBtu/day equivalent	($2.40)	($579)

*1 kWh = 3.142 kBtu
Source: Frontier Energy

Measured savings for the residential induction cooking demonstration sites are shown in Table 9. All homes used electric resistance cooking prior to the retrofit. The annual savings averaged 248 kWh/year (846 kBtu/year) and were mainly associated with reduced cook times – 18 percent lower on average – per cooking event. Four of the five sites showed energy and cost savings.

Table 9: Residential Induction Cooking Energy Savings Data (Measured)

	Baseline Energy Use (kWh/y)	Baseline Energy Cost ($/y)	Retrofit Energy Use (kWh/y)	Retrofit Energy Cost ($/y)	Energy Savings (kWh/y)	Cost Savings ($/y)
Site 28	1,377	$496	937	$337	440	$158
Site 29	2,981	$1,073	2,369	$853	612	$220
Site 30	2,313	$833	2,201	$792	112	$40
Site 31	1,345	$484	1,494	$538	-149	($54)
Site 32	2,014	$725	1,787	$643	227	$82
Averages	2,006	$722	1,758	$633	248	$89

Source: Frontier Energy

There were no significant installation costs because the new stoves just needed to be plugged in, so the total cost of replacement was primarily limited to the retail and delivery fees, which averaged $6,186 for the commercial sites and $3,556 for the residential sites. For sites with positive energy cost savings, the simple payback period ranged from 16 to 88 years. With such long payback periods, increased market adoption would be driven by non-financial benefits such as performance, safety, and environmental concerns. The payback would also be greatly improved if existing equipment was at the end of its useful life, which we did not require for this demonstration project. From participant feedback gained via surveys, all sites reported being satisfied with the performance of their induction cooktops. The biggest complaints were about smaller oven capacity, which was unrelated to fuel substitution, and the need for new cookware.

Lessons Learned

There were significant energy savings at the commercial site, but the commercial site was unable to overcome the higher cost of electricity associated with the stovetop after switching from natural gas. For residential sites switching from an electric stovetop to an induction stovetop, positive energy cost savings were achieved. Induction stovetops are a way for people to have a similar cooking experience to gas ranges through an electric technology that presents fewer health concerns related to fossil fuel combustion.

Induction cooktops are often as easy to install as gas ranges, as long as there is space on the existing breaker. The most significant barrier to widespread adoption is public education. The narrative around electric stovetops is still dominated by peoples’ negative experiences with resistance coils, and there is a significant need for programs like induction cooktop lending to help influence public perception.

Heat Recovery Dishmachines

Exhaust heat recovery dishmachines are much more efficient than conventional high-temperature-rinse dishmachines (see Figure 6) because they use a heat exchanger or a heat pump to recycle energy by heating the incoming cold water for the next rinse cycle instead of wasting it through the production of steam in the washing process. Dishmachines are typically fed by the building water heater and usually represent around 75 percent of a full-service restaurant’s hot water load. This technology has the added benefit of reducing ventilation requirements because it produces much less steam.

Figure 6: Existing Undercounter Dishmachines

Photo Credit: Frontier Energy

The goal of this study was to document the energy savings of undercounter and door-type exhaust heat recovery dishmachines in various commercial foodservice facility settings.

The following sections provide an overview of the heat recovery dishmachine technology demonstration project. Further details can be found in Appendix A and the Lead Locally Technology Demonstration Final Report (Hendron et al., 2022).

Sites

A summary of the test sites and retrofit equipment models is provided in Table 10. Both sites were served by electric resistance water heaters. An additional site at a junior college was originally selected and pre-monitored, but the partner withdrew from the program.

Table 10: Heat Recovery Dishmachine Demonstration Sites

Site #	City	Building Type	Conditioned Floor Area (ft^2)	Year Built	Dishmachine Model
14	Rohnert Park	Brewery	8,911	1984	Hobart LXE Advansys Undercounter Dishwasher, LXER +BUILDUP, 3-phase
16	Sonoma	Winery	2,072	1914	Meiko M-iClean UM GIO

Source: Frontier Energy

Key Results

A summary of energy and cost calculations is provided in Table 11.

Table 11: Exhaust Heat Recovery Dishmachine Water and Energy Savings (Measured, Adjusted for Usage)

Site	Racks/ Day	Hot Water Use (gal/d)	Water Heater Energy (kWh/day)	Dishwasher Energy (kWh/day)	Net Annual Energy Savings (kWh/y)	Cost Savings ($/y)	Simple Pay-back (yrs)
Brewery Baseline	47	73	15	38			
Brewery Replacement	47	52	0	45			
Brewery Savings		21	15	-7	2,080	$701	6
Winery Baseline	62	108	21	42			
Winery Replacement	62	74	0	41			
Winery Savings		34	21	1	5,720	$1,928	2

Source: Frontier Energy

The annual cost savings were $701 at the brewery and $1,928 at the winery, based primarily on the reduction in hot water usage assuming that the electric resistance water heaters were 100 percent efficient. The incremental cost difference between a heat recovery dishmachine and a conventional dishmachine is about $4,130, so the sites in this study had simple payback periods ranging from two to six years, assuming the existing dishmachines were nearing the end of their useful life.

Surveys were used to understand the overall satisfaction with the replacement machines. Generally, both sites were happy with the replacement, although the winery site observed that the heat recovery machine had a somewhat longer wash cycle time, requiring some time for staff to adjust. Both sites commented that the heat recovery machine improved the thermal comfort and smell of the space where they were installed.

Lessons Learned

Exhaust heat recovery dishmachines have the potential to save significant amounts of energy in commercial foodservice facilities. For undercounter and door-type models, the barriers to widespread adoption are the significant upfront cost and the additional time per wash cycle. Most dishmachines require increasing the wash cycle time from 60 to 90 seconds to accommodate the heat recovery unit.

Aerosol Envelope Sealing

The AeroBarrier sealant is a water based acrylic compound designed to seal gaps while preventing the trapping of moisture between walls or other interstitial spaces within a home. The AeroBarrier process involves pressurizing a building while injecting an aerosol "fog" (as shown in Figure 7). As air escapes through leaks in the exterior shell of the building, the aerosolized sealant is transported to the leaks, accumulates, and seals the leakage path. Existing blower door equipment is used to facilitate the sealing process and to provide real-time feedback and a permanent record of the sealing that is occurring.

Figure 7: Aerosolized Sealant Released into the Interior of a Building

Photo credit: AeroSeal

The objective of this project was to determine the readiness of Aerobarrier for broad deployment as a retrofit measure. In addition to evaluating energy savings and cost-effectiveness, the project investigated the potential need for supplemental mechanical ventilation, sealant deposition in undesired locations, residue clean-up time, and possible degradation in effectiveness over time. Duct sealing using the similar but more established Aeroseal process was evaluated as well, when possible.

The following sections provide an overview of the Aerobarrier technology demonstration project in residential buildings. Further details can be found in Appendix A and the Lead Locally Technology Demonstration Final Report (Hendron et al., 2022).

Sites

A summary of the characteristics of the ten selected test sites is provided in Table 12. All sites had the Aerobarrier process applied. Only three of the sites had ducts that were compatible with the Aeroseal process. The other sites were either ductless or the leaks were too large.

Table 12: AeroBarrier Demonstration Sites

Site #	City	Building Type	Conditioned Floor Area (ft^2)	Year Built	Aeroseal Duct Sealing	Same Occupants Post-Retrofit
1	Santa Rosa	Single-Family	1,648	1925	NNo	
2	Santa Rosa	Single-Family	1,198	1910	Yes	No
3	Santa Rosa	Single-Family	1,162	1947	NNo	

Site #	City	Building Type	Conditioned Floor Area (ft²)	Year Built	Aeroseal Duct Sealing	Same Occupants Post-Retrofit
4	Santa Rosa	Single-Family	1,346	1986	NNo	
5	Petaluma	Multi-Family	720	1960	Yes	Yes
6	Petaluma	Multi-Family	630	1960	NYes	
7	Petaluma	Multi-Family	630	1960	NYes	
8	Petaluma	Multi-Family	630	1960	NYes	
9	Petaluma	Multi-Family	630	1960	NYes	
10	Petaluma	Multi-Family	590	1960	Yes	Yes

Source: Frontier Energy

Key Results

The electricity and gas savings for each site are reported in Table 13. Sites 5 and 10 saw very little to no savings because they were located on the second floor of a three-story building, and energy losses due to infiltration were small. The average gas and electricity savings found for the ten test sites were 2,214 kBtu/year and 168 kWh/year respectively. The total average energy savings when including both gas and electricity was 27.9 MMBtu/year or 6.0 percent of whole-house energy use per year.

Table 13: Aerosol Sealing Energy Savings (Modeled based on Measured Data)

	Electrical Energy Savings (kWh/year)	Gas Energy Savings (kBtu/year)	Total Savings (kBtu/year)	Total Savings, Percent of Whole-House Annual Energy Use
Site 1	931.4	47	3,225	6.5 percent
Site 2	59.8	10,814	11,018	11.7 percent
Site 3	49.1	8,814	8,982	14.9 percent
Site 4	7.2	2,110	2,135	2.9 percent
Site 5	-0.002	0	0	0.0 percent
Site 6	97.3	66	398	1.4 percent
Site 7	219.7	53	803	2.6 percent
Site 8	209.9	61	777	2.3 percent
Site 9	100.7	55	398	1.3 percent
Site 10	7.1	125	149	0.5 percent

Source: Frontier Energy

The average cost to install AeroBarrier for the ten sites was $2,828.32, and the average cost of Aeroseal for the three applicable sites was $3,823.95. On average, AeroBarrier and Aeroseal (when applicable) offered $135 a year in gas and electric energy savings leading to an average payback period of 38 years (excluding sites 5 and 10). Sites 5 and 10 were excluded from these averages due to seeing negligible savings. Payback ranged from 14 to 121 years, and installation costs for all sites ranged from $1,356 to $8,249. Installation costs shown here include primarily labor; material costs are negligible for this technology, and customer relocation costs were avoided through selection of vacant sites (those being remodeled or between tenancies).

Lessons Learned

The AeroBarrier sealant was highly effective in reducing infiltration, on average reducing the whole home infiltration by 57 percent. However, this improvement did not translate to significant energy savings for every site to be cost-effective. Whether the installation is cost-effective depends on the magnitude of leaks in parts of the home that aren't addressed by AeroBarrier, such as leaky window frames, leaky floors, or a leaky duct system. It was also evident that units in multifamily buildings with minimal external exposure do not benefit much from AeroBarrier. Aeroseal also proved to be very effective when sealing duct systems (see details in Appendix A).

Several occupants noticed that there were sealant particles around the house once they moved in. It is recommended that contractors clean the site thoroughly prior to leaving and are trained on how to protect materials and equipment that can be damaged from the sealant. It is also important for contractors to be well-versed in combustion air ventilation requirements to ensure sealing does not create any combustion safety hazards. It is also important to follow ASHRAE 62.2 minimum fresh air requirements by installing mechanical ventilation if the home is sealed below the minimum guideline. Finally, further research is recommended to take multiple blower door measurements from one month to three years after the retrofit to determine to what extent and how rapidly the sealant degrades.

Because belongings and furnishings must be covered up or removed during sealant installation, the most appealing application is for new construction or retrofit during tenant turnover when rental units or single-family homes are vacant.

Radiant Ceiling Panels

Radiant ceiling panels are heated using either a heated fluid or electric resistance cables but can only be cooled using a chilled fluid, typically water in the 50°F to 60°F (10°C to 16°C) range. Because radiant ceiling panels often cover most of the ceiling area in a home and have a large heat transfer surface, radiant systems deliver comfort at more moderate temperatures than hydronic fan coils, which use water temperatures around 140°F to 160°F (60°C to 71°C) in heating and around 45°F (7°C) in cooling. The moderate temperature translates to improved equipment efficiency. Radiant panels in residential applications have additional challenges compared to more well-studied commercial applications. Because homes typically do not have humidity control beyond water that condenses at the AC evaporator coil, a hydronic system often requires supplemental dehumidification to maintain comfort. In addition, the radiant panels are in direct contact with the ceiling in homes, resulting in greater energy losses through the attic than occur in commercial buildings, where panels are usually suspended as part of drop ceiling and upward heat flows are less consequential.

Though these panel systems are intended to primarily heat or cool through the exchange of radiation with the indoor space and occupants, they also transfer energy to the conditioned space through convection. In this study, a retrofit radiant panel system with cross-linked polyethylene (PEX) pipes served by hot or chilled water from an air-to-water heat pump (AWHP) was evaluated in a residential building. An AWHP transfers energy to a water loop instead of directly to the indoor air stream.

Radiant ceiling panels were tested in Frontier's Building Science Research Laboratory (BSRL) to evaluate distribution losses and sizing methods, and in one residential field test site in combination with an AWHP, enhanced ventilation, and improved insulation.

The following sections provide an overview of the field test component of the radiant ceiling panel applied research project in residential buildings. Further details about laboratory testing and field test methodology can be found in Appendix A and the Residential Hydronic Heating and Cooling Applications by Air-to-Water Heat Pump Systems Final Report (Pallin and Haile, 2022).

Sites

A summary of the test site and pre- and post-retrofit HVAC systems is provided in Table 14.

Table 14: Overview of Radiant Ceiling Panel Test Site

Site #	City	Conditioned Floor Area (ft^2)	Year Built	Existing Heating Equipment	Existing Cooling Equipment	Retrofit Design
62	Windsor	1,897	1989	Gas furnace	Central AC	Warmboard-R radiant panels AWHP (Chiltrix CX34)

Source: Frontier Energy

Key Results

The installation of the radiant panels was disruptive and required the homeowners to leave the house during installation. The panels were mounted on the outside of the existing ceiling drywall (see Figure 8), PEX tubing was installed in the channels, and the panels were then covered with another layer of gypsum board to match the appearance of the original ceiling.

Figure 8: Partially Installed Radiant Panels in Great Room

Image credit: EnergyDocs

Table 15 presents estimated average energy costs and savings using the weather, occupant behavior post-retrofit. These values show the actual post-retrofit costs and calculated costs for energy if the radiant panel retrofit was not conducted. This was done due to COVID impacts on changes to occupancy and thermostat settings post-retrofit that the actual utility bills pre-retrofit did not reflect. The results show significant energy savings for heating and cooling, and cost savings around 40 percent.

Table 15: Energy Use for Radiant Panels Pre- and Post-Retrofit

Weather Period	**No Retrofit (Calculated)**					
	Degree Hours [H°F] (Post-Retrofit Settings) **Cooling**	**Heating**	Cooling (kWh)	Heating (kBtu)	Total Cost	
2021 (Jan. 1-Dec. 31)	28,540	23,729	2,426	10,820	**$1,108**	
Weather Period	**Post-Retrofit**					
	Degree Hours [H°F] (Post-Retrofit Settings) **Cooling**	**Heating**	Cooling (kWh)	Heating (kWh)	Total Cost	Annual Savings
2021 (Jan. 1-Dec. 31)	28,540	23,729	542	1,305	**$665**	**$443**

Source: Frontier Energy

The total cost to install the radiant panel system at the test site was about $136,891. This high upfront cost results in a prohibitive average payback period of 309 years, indicating that substantial innovations in low-cost radiant panel retrofits will be required for this technology to be viable.

The homeowner completed a survey more than a year after the radiant panel system was installed. The homeowner marked satisfied or very satisfied for the comfort questions related to temperature, feeling of drafts, perceived air quality, noise, and general comfort. Likewise, the HVAC system control was perceived as satisfactory, except for the thermal responsiveness of the system. The quality, visual appearance, and ease of maintenance were rated highly. The homeowner indicated that they changed thermostat setpoints pre- and post-retrofit. They noted that the indoor environment is somewhat slow to respond to thermostat and control changes. The homeowners also commented that they love not having air blowing through the vent system and constantly turning on and off.

Lessons Learned

It was determined that despite significant energy and cost savings, the lack of cost-effectiveness would limit the technology's potential for significant market adoption in SCP territory and elsewhere in Northern California. Barriers to cost-effectiveness and/or market adoption include the items noted below:

- Homeowner relocation required during installation

- Installation in existing homes is not cost-effective. The cost of labor was roughly three times higher than the cost of material and equipment. Radiant panels require skilled and experienced installers and various trades, driving up the cost of labor.
- Radiant panels installed in existing buildings may require special attention and design around penetrations through the ceiling plane and complex architectural features.
- Depending on ceiling joist dimensions and spacing, the joist system may require reinforcement to support the additional weight associated with the radiant panels.
- Water pipes running through the building envelope always represent a risk. Leaks may occur in the pipes or in couplings and connections.
- Based on laboratory testing, a very high ceiling R-value is needed to minimize upward energy losses from the radiant panels.

Hydronic Fan Coils with Air-to-Water Heat Pumps

Hydronic fan coil systems are an emerging technology in California, most often seen in heating dominated climates, as they are easily integrated into existing hot water systems. In climates that require air conditioning, they are often paired with AWHPs to provide both heating and cooling. While not expected to provide higher efficiency, AWHPs have lower expected maintenance requirements than air-to-air systems because the refrigerant is factory-installed, and the necessary refrigerant volume in the evaporator is reduced because heat transfer to the water loop is more efficient than to forced air. The hydronic fan coil system evaluated for this project included high efficiency fan coils connected to a low static pressure duct system installed in conditioned space. A three-function AWHP was used to provide space heating, space cooling, and domestic hot water. This integrated system can help avoid costly panel upgrades as an electrification measure compared to a HPWH in combination with an air source heat pump. This system design was evaluated in two houses in Sonoma County.

This system serves hydronic fan coils and a water tank, so it requires special controls to prioritize modes. For example, if the heat pump happens to be operating in cooling mode and receives a call for domestic water heating, the heat pump switched to heating mode and the 3-way valve (see Figure 9) was signaled to divert flow to the indirect water heater.

Figure 9: Integrated Domestic Water Heating and Space Conditioning

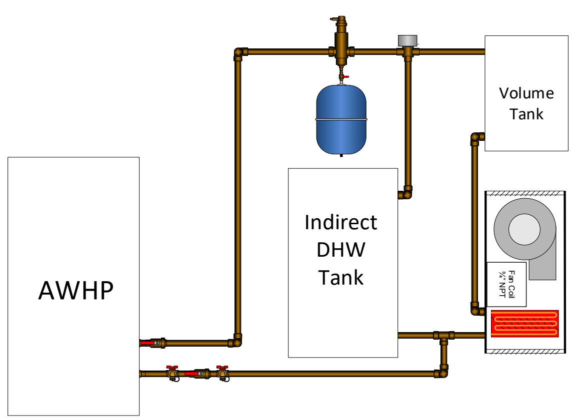


Image credit: Frontier Energy

The following sections provide an overview of the hydronic fan coil applied research project in residential buildings. Further details can be found in Appendix A, the Residential Hydronic Heating and Cooling Applications by Air-to-Water Heat Pump Systems Final Report (Pallin and Haile, 2022), and the Air-to-Water Heat Pump Design and Installation Guide (Frontier Energy, 2021).

Sites

A summary of the two test sites and pre- and post-retrofit is provided in Table 16. Both sites were one-story single-family homes with three bedrooms and crawlspace foundations. Both sites also had natural gas water heaters pre-retrofit.

Table 16: Overview of Hydronic Fan Coil with AWHP Test Sites

Site #	City	Conditioned Floor Area (ft^2)	Year Built	Existing Heating Equipment	Existing Cooling Equipment	Retrofit Design
26	Santa Rosa	1,700	1976	Gas furnace	Central ducted AC	Outdoor Unit: Chiltrix CX-34 Indirect Water Heater: Triangle Tube Smart 60
27	Santa Rosa	1,560	1963	Gas furnace	Central AC	Outdoor Unit: Chiltrix CX-34 Indirect Water Heater: Triangle Tube Smart 60

Source: Frontier Energy

Key Results

Table 17 and Table 18 show space conditioning energy costs for the test sites pre- and post-retrofit. Domestic hot water savings were not quantified because no pre-monitoring was done for the pre-retrofit water heaters. This was because the original plan was to install radiant ceiling panels and the decision to install an integrated water heating system was not made until after the pre-monitoring period was over. The assessment includes actual post-retrofit measured data, as well as pre-retrofit data calculated to adjust for weather and behavioral changes. Results show a small increase in energy costs for Site 26 and small savings for Site 27.

Table 17: Pre-and Post-Retrofit Cost of Space Conditioning Energy for Site 26 (Measured, Adjusted for Weather and Occupant Behavior)

Site 26	Annual Weather Period (Jan. 1-Dec. 31, 2021)				
	Degree Hours [H°F]		Cooling (kWh)	Heating (kBtu)	Total Cost
Pre-retrofit (calculated)	8,561	60,161	137	22,921	**$547**
Post-retrofit (measured)	8,561	60,161	111	1,504	**$582**
Savings			26	21,417	**-$35**

Source: Frontier Energy

Table 18: Pre- and Post-Retrofit Cost of Space Conditioning Energy for Site 27 (Measured, Adjusted for Weather and Occupant Behavior)

Site 27	Annual Weather Period (Jan. 1-Dec. 31, 2021)				
	Degree Hours [H°F]		Cooling (kWh)	Heating (kBtu)	Total Cost
Pre-retrofit (calculated)	23,317	28,068	630	13,894	**$528**
Post-retrofit (measured)	23,317	28,068	303	702	**$362**
Savings			327	13,192	**$166**

Source: Frontier Energy

The cost to install the AWHP system with hydronic fan and indirect water heating was about $83,610 for each test site. It was clear that the total cost of labor, equipment, and material far exceeds any potential savings, even if domestic hot water heater savings were accounted for.

The homeowners completed a survey more than a year after the AWHP systems were installed. For Site 26, the occupants were very satisfied, or satisfied with the comfort questions related to temperature, feeling of drafts, perceived air quality, noise, and general comfort. Likewise, the HVAC system control was perceived as satisfactory, except for "Availability of options (for example, temperature, schedule, fan speed, and so on)." The quality, visual appearance, and ease of maintenance were rated highly. For Site 27, the occupants were very satisfied or satisfied on all comfort topics. The occupants of Site 26 stated that they would like the ability to override the system control priority of space heating versus domestic hot water (DHW) They also would like the ability to adjust fan speed and complained about the outdoor unit being loud and operating a lot during the winter. The occupants used a humidifier during periods of dry air. Site 27 occupants also discussed overriding the DWH priority and provided an example of heating halting in the middle of the night to heat up the water heater tank, which they were not going to use that night. They also mention overriding the DHW system during hot days when cooling should have priority. For both test sites, occupancy and operating conditions were changed after March 2020 due to the COVID-19 pandemic.

Lessons Learned

The total cost of labor, equipment, and material far exceeds estimated savings for the specific design and applications evaluated for Lead Locally.

Other lessons learned include the following:

- Installing a vapor retarder in the crawl space can potentially improve the indoor air quality and reduce the risk of pest problems and/or moisture damage. However, this costly measure was not directly related to the AWHP system and overall energy performance.
- There is likely no need for duct replacement when they are in acceptable condition.
- Removal of existing attic insulation is in most cases unnecessary since it will still contribute to overall thermal resistance if new insulation is added. Caulking and applying spray foam to improve airtightness can still be done by moving existing insulation around.

Daylighting

Daylighting refers to the use of natural light to illuminate interior spaces and has been shown to have numerous benefits, including energy savings, improved occupant health and productivity, and reduced GHG emissions. Studies have shown that daylighting can reduce electricity use for lighting by up to 38 percent in commercial buildings (Papamichael et al., 2018), depending on the design and use of the building. However, traditional daylighting methods, such as skylights and windows, are often limited by the availability of sunlight, the size and orientation of the glazing, and the presence of obstructions, or can result in glare, thermal discomfort, and visual discomfort.

Advanced daylighting technologies, such as tubular daylighting devices (TDDs), fiber optic systems, and automated louvers, aim to overcome some of the limitations of traditional daylighting methods and improve the performance of daylighting systems in existing buildings. They can provide a higher level and more consistent quality of daylight, reduce the need for electric lighting, and improve the indoor environment. Lead Locally evaluated the performance of selected advanced daylighting technologies in the laboratory and at test sites.

The following sections provide an overview of the daylighting applied research project in commercial buildings. Further details about laboratory testing and test methodology can be found in Appendix A and in the Commercial Daylighting Retrofits Report (Harper et al., 2023).

Sites

A summary of the test sites and installed equipment is provided in Table 19. A photo of the daylighting luminaires at Site 11 is shown in Figure 10.

Table 19: Overview of Commercial Daylighting Test Sites

Site #	City	Building/ Area Type	Conditioned Floor Area (ft^2)	Year Built	TDD Design
11	Santa Rosa	Educational/ Classroom	9,460 (~500 affected)	1946	Solatube 290DSC w/ Daylight Dimmer - no lighting integration
12	Santa Rosa	Office	2,700	1906	Solatube 750DSC DA L1 w/ Daylight Dimmer, Dimmable LED Lighting integrated with Tubes
13	Santa Rosa	Performing arts/ Maintenance Shop	1,400	1965	Solatube 750DSC DA L1 w/ Daylight Dimmer, Dimmable LED Lighting integrated with Tubes

Source: Frontier Energy

Figure 10: Demonstration Site 11

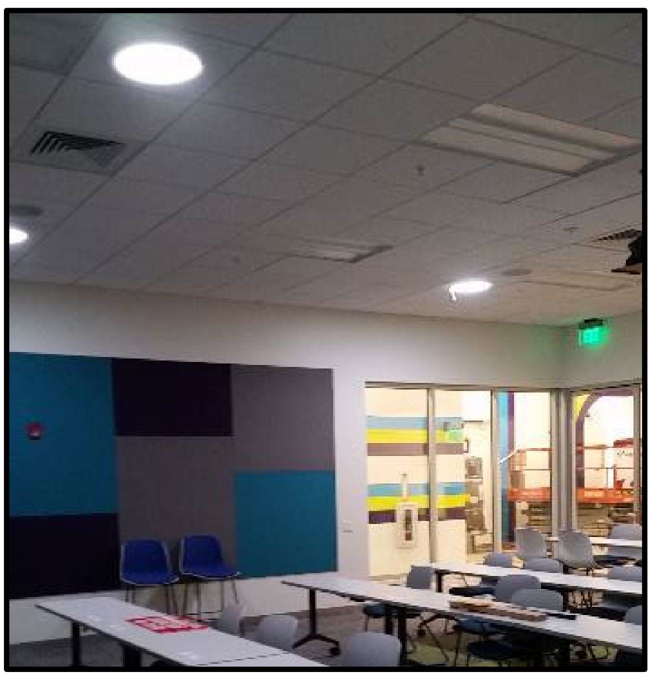


Image credit: California Lighting Technology Center (CLTC)

Key Results

Table 20 shows savings achieved from TDDs at the field demonstration sites. For Site 12, the test results indicated that no savings were achieved because electric lighting use did not decrease significantly. The introduction of TDDs into the spaces incurred solar heat gain in the summer. All or most of this solar heat gain was mitigated by the use of dimmable TDD baffles integrated with the lighting system. While the TDDs with integrated lighting control systems and occupancy sensors reduced the lighting and HVAC load of a building, the cost associated with installation resulted in a very high predicted payback period.

Table 20: Results from the Field Demonstrations (Measured)

Site #	Daily Total Energy Savings (kWh)	Daily Savings	System Cost	Simple Payback (Years)
11	0.9	$0.31	$22,287	201
12	0	$0.00	$15,745	N/A
13	1.53	$0.53	$22,610	120

Table credit: California Lighting Technology Center (CLTC)

Lessons Learned

The laboratory evaluation of advanced daylighting technologies revealed that the fiber optic daylighting system was not suitable for a field demonstration due to its susceptibility to large output fluctuations, particularly on cloudy and overcast days. The automated louvers, while promising for glare mitigation, were found to be unsuitable for further testing or field demonstration due to their inability to accurately determine the current solar position and the significant magnitude of error associated with their positioning. Only TDDs appeared promising for field test applications.

Demonstration Site 11 showed that the control strategy used with the integrated lighting and Solatube TDD system reduced energy consumption and maintained desired light levels. Demonstration Site 12 study highlighted the importance of considering the specific context and user behavior when evaluating the effectiveness of daylighting strategies in buildings. The survey and data analysis revealed that the occupants tended to close the tubes for the majority of the monitoring period, mainly due to hot spots created under the tubes during the summer months. While the occupants preferred the natural daylight provided by the TDDs over electric lighting, they were not inclined to turn off electric lighting even when significant daylight was available in the space. The TDD system in Demonstration Site 13 was able to offset 24.5 percent of the electric lighting load. The larger diameter TDDs installed in Demonstration Site 13 should result in a proportionally larger solar heat gain and loss energy savings. However, the data from the limited monitoring period showed that the net heat gain and loss between heating and cooling season for this site should be about zero.

This study showed that advanced daylighting technologies have the potential to reduce energy consumption, carbon emissions, and improve the indoor environment in commercial buildings. However, the current cost and associated payback period for this system is too high for broad deployment but could be considered in new construction.

Residential Phase Change Materials

PCMs are a promising technology for reducing and shifting building envelope thermal loads by storing and discharging energy over the course of a day, reducing heating and cooling needs. The project team identified a new product called Infinite RTM, at the time distributed by

Insolcorp and manufactured by Active Integration, that could be easily installed between joists above or below attic insulation in existing homes (see Figure 11).

Infinite R consists of a salt-based PCM encapsulated in cells that are sealed in flexible mats. The PCM can be designed to melt and freeze at any temperature in the 66°F to 84°F (19°C to 29°C) range.

Figure 11: Infinite R PCM Product

Image credit: Insolcorp, LLC

The objective of this applied research project was to characterize the energy savings for PCM installed in residential attics and to determine its cost-effectiveness and viability for further deployment efforts. PCM evaluation was performed using a combination of field testing, laboratory testing, and energy modeling.

The following sections provide an overview of the field testing of PCM in residential buildings. Further details about laboratory testing and field test methodology can be found in Appendix A and the Phase Change Materials in Residential Applications Final Report (Hendron and Chally, 2022).

Sites

Five homes were selected as field test sites for detailed monitoring of PCM performance. A summary of the sites, PCM melting point, and installation location is provided in Table 21.

Table 21: Overview of Residential PCM Test Sites

Site #	City	Conditioned Floor Area (ft^2)	Year Built	Existing Heating Equipment	Existing Cooling Equipment	PCM Design
53	Santa Rosa	1,300	2001	Gas furnace	Central AC	Infinite R 77°F (25°C) MP, below R-19 attic insulation
56	Santa Rosa	1,338	1965	Gas furnace	Central AC	Infinite R 77°F (25°C) MP, below

Site #	City	Conditioned Floor Area (ft^2)	Year Built	Existing Heating Equipment	Existing Cooling Equipment	PCM Design
						R-19 attic insulation
52	Sonoma	1,551	1983	Heat pump	Central AC	Infinite R 77°F (25°C) MP, above R-19 attic insulation
54	Santa Rosa	1,505	1954	Gas furnace	Window AC	Infinite R 77°F (25°C) MP, below R-19 attic insulation
55	Petaluma	1,361	1920	Gas furnace	Central AC	Infinite R 77°F (25°C) MP, below R-19 attic insulation

Source: Frontier Energy

Key Results

A summary of the weather normalized utility bill analysis is provided in Table 22. The results show a mix of positive and negative energy savings for both gas and electricity. The impact of occupant behavior is almost certainly much larger than the actual energy savings for the PCM, as suggested by the large variations in savings across different sites.

Table 22: Weather Normalized Utility Billing Data at 5 Test Sites (11 months)

Site	Pre-Retrofit Weather Normalized Electrical Energy (kWh)	Post-Retrofit Weather Normalized Electrical Energy (kWh)	Weather Normalized Electrical Energy Savings (percent)	Pre-Retrofit Weather Normalized Gas Energy (Therms)	Post-Retrofit Weather Normalized Gas Energy (Therms)	Weather Normalized Gas Energy Savings (percent)
52	5,839	4,651	20.3 percent	72	63	11.6 percent
53	7,512	8,039	-7.0 percent	580	580	-0.04 percent
54	3,915	4,873	-24.5 percent	377	234	37.9 percent
55	5,660	4,664	17.6 percent	439	409	6.7 percent
56	5,134	4,739	7.7 percent	487	509	-4.4 percent
Total	28,059	26,966	3.9 percent	1954	1796	8.1 percent

Source: Frontier Energy

EnergyPlus modeling results are summarized in Table 23. Small cooling savings and heating increases resulted in utility bill increases in all cases except with PCM below insulation and a 77°F (25°C) melting point. Similar modeling was done in Sacramento and Truckee, California to determine the effect of climatic conditions, but the results were not significantly better.

Table 23: Modeled Total Utility Cost Savings for PCM

Case	Base Total Utility Bill	PCM Total Utility Bill	Total Utility Bill Savings
PCM above insulation, 73°F (23°C) melting point	$3,218	$3,248	-$31
PCM below insulation, 73°F (23°C) melting point	$3,218	$3,238	-$20
PCM above insulation, 77°F (25°C) melting point	$3,218	$3,249	-$32
PCM below insulation, 77°F (25°C) melting point	$3,218	$3,210	$8

Source: Frontier Energy

The final cost-effectiveness calculation based on the best-case scenario from energy modeling ($8/year) and actual average installed costs of $11,836 resulted in a simple payback of 1,480 years. Even assuming long-term projected costs (without prevailing wage, installer learning curve, and other expenses that would diminish with market maturity) of $7,592 per site, the payback period would be 949 years.

Lessons Learned

Lab testing demonstrated that energy savings may be small or negative for PCMs installed in residential attics. For field tests, homeowners indicated they were already energy conscious when setting their thermostats and turning on their air conditioners. This resulted in limited energy savings from the PCM retrofit, especially in the summer months. In addition, the onset of the COVID-19 pandemic created difficulty for comparing pre- and post-retrofit energy use. Finally, leaking PCM mats in the attics of the test sites caused a great deal of difficulty for the homeowners and project partners. The Lead Locally team removed the PCMs to prevent further damage and provided ceiling repair. Durability concerns for the product that was tested prevented any recommendations for further deployment. Other PCM products with more durable packaging may be viable in certain applications, although the cost-effectiveness must be improved.

Commercial Phase Change Materials

The use of PCMs as a retrofit for commercial buildings is a more proven application involving less risk to building owners because many more commercial PCM installations exist, and there is more field data available to support energy savings predictions.

The macro-encapsulated inorganic PCM product Templok, sold by Insolcorp through Lead Locally partner Winwerks, was the technology evaluated for six of the seven demonstration sites. The one exception was a winery/restaurant that used Infinite R in an attic application comparable to the residential sites discussed in the Summary of Project Types section. Templok is a rigid product with PCM stored in cells contained within a hard plastic package that can be easily placed above ceiling tiles, as shown in Figure 12. Panels can be selected with a melting point anywhere between 65°F and 80°F (18°C and 27°C), depending on the application. Insolcorp predicts 20 to 30 percent reductions in HVAC loads for Templok installed in ceiling applications (Insolcorp, 2022).

Figure 12: Templok PCM Tiles in Drop Ceiling

Image credit: Insolcorp, LLC

To charge and discharge heat from the PCM during the summer in commercial building applications, it is helpful to have significantly lower temperature settings at night either through nighttime ventilation cooling or pre-cooling during off-peak rate hours using the HVAC system. During the winter, PCM works most effectively in applications where there are large internal heat gains during the day, and where the thermostat is set back at night. Performance can also be enhanced by combining PCM with controls set points that maximize energy storage and minimize electricity use during the peak demand period. If ducts are located in the dropped ceiling, the PCM may be exposed to larger temperature excursions during hot or cold weather, which could enhance overall effectiveness.

The following sections provide an overview of the PCM demonstration projects in commercial buildings, along with some of the key findings. Further details can be found in Appendix A and the Lead Locally Technology Demonstration Final Report (Hendron et al., 2022).

Sites

Several commercial building types served as test sites to provide diversity in occupancy patterns, internal gains, and other variables. The test sites had limited instrumentation for measuring PCM performance, instead relying on temperature measurements to verify melting and freezing, utility bills to quantify energy savings, and occupant feedback to determine comfort and other non-energy impacts. A summary of the six test sites is provided in Table 24.

Table 24: Overview of Commercial PCM Test Sites

Site #	City	Building Type	Conditioned Floor Area (ft^2)	Year Built	Existing Heating Equipment	Existing Cooling Equipment	PCM Design
11	Santa Rosa	Classroom	9,460	1946	Heat pump	Central AC	Templok rigid PCM panels (75°F [24°C] melting point) in drop ceilings
57	Cloverdale	Restaurant	2,300	1998	Heat pump	Central AC	Templok rigid PCM panels (72°F [22°C] melting point) in drop ceilings
58	Forestville	Restaurant/ Lobby	4,603	1956	Propane furnace	Central AC	Infinite R PCM mats (77°F [25°C] and 73°F [23°C] melting point) in attic
59	Cloverdale	Restaurant	2,750	1948	Gas furnace	Central AC	Templok rigid PCM panels (75°F [24°C] melting point) in drop ceilings
60	Cloverdale	Restaurant	1,800	1958	Gas furnace	Central AC	Templok rigid PCM panels (78°F [26°C] melting point) in drop ceilings
61	Santa Rosa	Classroom/ Office	4,436	2003	Gas furnace	None	Templok rigid PCM panels (78°F [26°C] melting point) in drop ceilings

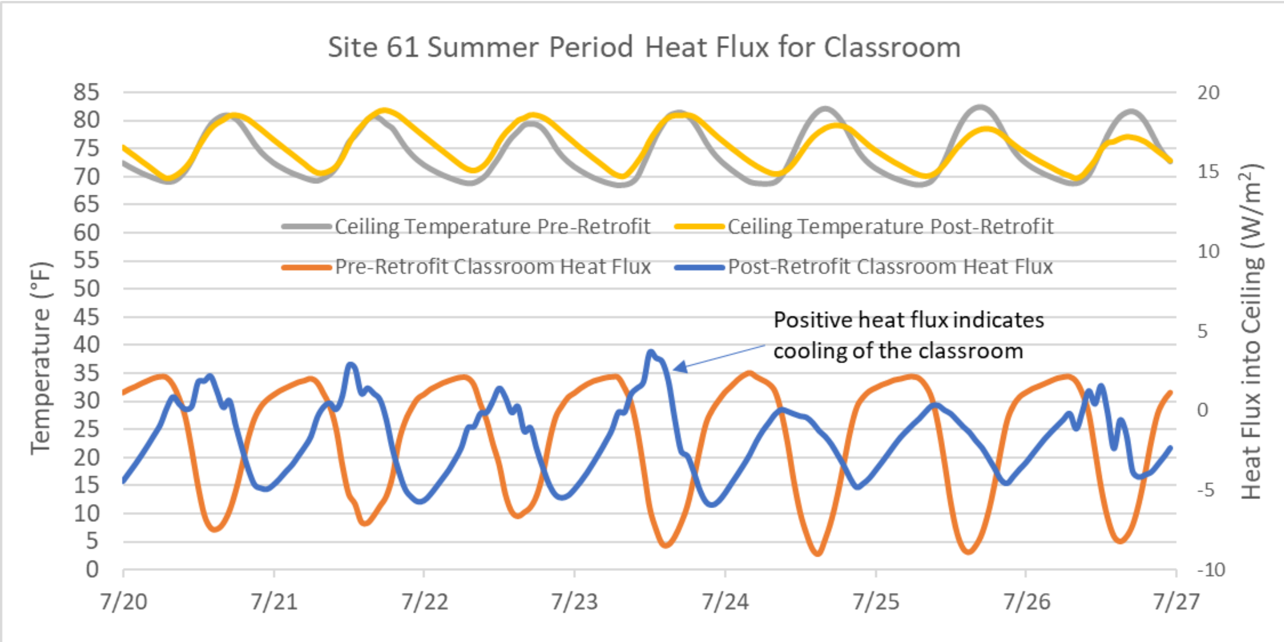
Source: Frontier Energy

Key Results

Example test results for Site 61 are presented here, because it had the most available measured data. However, full case studies for all six sites are provided in the Technology Demonstration Final Report (Hendron et al., 2022).

Heat flux from the classroom at Site 61 for the week of July 20 of the pre- and post-retrofit years are shown in Figure 13. The weather was similar in 2020 and 2021 during that week. The melting of the PCM served to cool the classroom as it warmed up during the day. The stored energy was released back into the classroom at night when there was no need for cooling. The heat flux data provided an explanation for lower peak temperatures that were observed in the classroom during hot summer days.

Figure 13: Summer Heat Flux Before and After Retrofit – Site 61 Classroom (Measured)



Source: Frontier Energy

A summary of the energy savings and cost-effectiveness analysis for the three test sites with meaningful results is provided in Table 25. The results indicate that for sites similar to those selected for this demonstration project, the technology leads to an average of 8.9 percent whole-building energy savings and a simple payback period of four years assuming a mature market.

Table 25: Energy and Cost Savings Summary for PCM in Commercial Buildings (Measured, Adjusted for Weather)

	Site 57	Site 59	Site 60	Average
Actual cost of measure	$6,810	$4,992	$7,062	**$6,288**
Projected long-term cost	$4,365	$3,704	$6,249	**$4,773**
Annual electricity savings (Site kWh)	811	-5,389	1,261	**(1,106)**
Annual gas savings (Site kBtu)	31,500	31,000	45,800	**36,100**
Annual Energy savings (Site MMBtu)	34.3	12.6	50.1	**32**
Percent energy savings (whole building)	9.20 percent	1.50 percent	15.90 percent	**8.87 percent**
Annual TOU utility bill savings ($)	$976	($1,267)	$1,448	**$386**
Simple payback (years) (actual)	7	N/A	5	**16**
Simple payback (years) (projected long-term)	4	N/A	4	**12**

Source: Frontier Energy

Lessons Learned

There appears to be significant energy savings for PCM installed in drop ceilings, especially if the melting point is properly aligned with the temperature of the ceiling during the cooling months. Comfort improved in certain cases based on surveys of the business owners, but it was only quantifiable when there was no air conditioning. The Templok product appeared to be durable based on observations over a year after the retrofit. The weight of the product caused a number of concerns with business owners prior to installation, and in one case it appears that some of the ceiling tiles have deformed due to the weight. Based on the results of this study, the Templok technology seems very promising for further deployment in the right applications. Incentives may be necessary to ensure cost-effectiveness.

Nighttime Ventilation Cooling

Residential Nighttime Ventilation (NTV) cooling has demonstrated benefits for reducing energy used in residential cooling, achieved by flushing the home with cool outdoor air at night, to reduce indoor air temperatures throughout the day and delay the time the air conditioner (AC) starts working. Benefits are realized even for homes that do not have central AC, by providing improved thermal comfort and preventing the installation of new AC systems.

This project adapted NTV technology to provide improved thermal comfort in homes without central AC by adding an outdoor air duct and damper to existing heating ductwork and fans. The overnight NTV cooling may last throughout the day and keep the occupants reasonably comfortable. NTV cooling is well suited to the climate in the Sonoma region, which has some high daytime maximum temperatures but consistently low nighttime temperatures.

The configuration of the economizer box, provided by AirScape, is shown in Figure 14. It includes a damper, actuator, and a control board that controls the operation of the damper and overrides the thermostat's operation of the fan when appropriate.

Figure 14: Configuration of AirScape Economizer Box

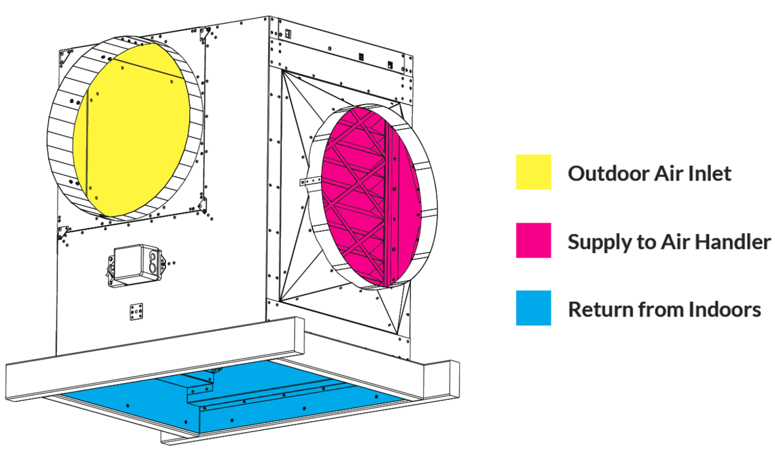


Image credit: AirScape

The following sections provide an overview of the NTV demonstration project, along with some of the key findings. Further details can be found in Appendix A and the Lead Locally Technology Demonstration Final Report (Hendron et al., 2022).

Sites

A summary of the ten test homes selected for this project is provided in Table 26.

Table 26: Overview of Nighttime Ventilation Test Sites

Site #	City	Conditioned Floor Area (ft^2)	House Size	Year Built	Existing Cooling Equipment	Existing Heating Equipment
42	Santa Rosa	1,782	Medium	1964	None	Gas furnace
43	Santa Rosa	1,337	Small	1942	None	Gas furnace
44	Santa Rosa	1,681	Medium	1967	None	Gas furnace
45	Santa Rosa	873	Tiny	1930	None	Gas furnace
46	Petaluma	1,868	Medium	1968	None	Gas furnace
47	Petaluma	2,121	Large	1999	None	Gas furnace
48	Santa Rosa	1,467	Small	1958	None	Gas furnace
49	Santa Rosa	1,495	Small	1991	None	Gas furnace
50	Guerneville	1,160	Small	1980	None	Propane furnace
51	Santa Rosa	1,298	Small	1998	None	Gas furnace

Source: Frontier Energy

Key Results

The overall approach to savings analysis is summarized in Table 27. Savings were estimated based on the difference between the hypothetical consumption with an added central AC and the post-retrofit condition—AC and POST.

Table 27: Scenarios Used in Savings Analysis

Scenario	Cooling Solution	Winter Whole Home	Summer Cooling
PRE (Baseline #1)	Actual pre-retrofit condition: neither AC nor NTV	Utility gas bills before retrofit, normalized to post-retrofit weather.	Cooling energy use = 0.
POST	Actual post-retrofit condition: NTV	Utility gas bills after retrofit.	Regression of measured fan energy against actual temperature, applied to typical year weather.
AC (Baseline #2)	Hypothetical: Central AC Added instead of NTV	Not evaluated.	Modeled AC energy use for a typical home / typical year weather.

Scenario	Cooling Solution	Winter Whole Home	Summer Cooling
Net Savings		Difference between PRE and POST indicates any winter penalty for NTV.	Difference between AC and POST.

Source: Frontier Energy

Table 28 shows the estimated energy savings—comparing modeled POST energy use with simulated AC and baseload energy use. Overall net savings from avoiding installation of AC were 46 percent of cooling energy use and 4 percent of whole home energy use. In the AC scenario, 66 percent of cooling energy use was on-peak, while after the retrofit (with NTV), only 8 percent of cooling energy use was on-peak. Therefore, on-peak cooling energy use was reduced by 93 percent, while off-peak cooling energy use was increased by 44 percent. On-peak whole home energy use was reduced by 15 percent, while off-peak home energy use was increased by 1 percent.

Table 28: Cooling and Whole Home Energy Use (Modeled Based on Measurements)

MONTH	COOLING ENERGY (kWh)					WHOLE HOME ENERGY (kWh)				
	PRE	AC	POST	Savings	Savings percent	PRE	AC	POST	Savings	Savings percent
1	-	-	-	-	0 percent	576	576	576	-	0 percent
2	-	-	-	-	0 percent	520	520	520	-	0 percent
3	-	-	-	-	0 percent	546	546	546	-	0 percent
4	-	-	-	-	0 percent	507	508	507	-	0 percent
5	-	41	41	1	2 percent	510	551	551	1	0 percent
6	-	130	58	72	55 percent	457	587	515	72	12 percent
7	-	122	57	65	53 percent	468	590	525	65	11 percent
8	-	167	76	91	54 percent	474	641	551	91	14 percent
9	-	68	52	16	23 percent	474	542	526	16	3 percent
10	-	-	-	-	0 percent	514	557	514	-	0 percent
11	-	-	-	-	0 percent	513	513	513	-	0 percent
12	-	-	-	-	0 percent	574	574	574	-	0 percent
TOTAL	-	528	284	244	46 percent	6,134	6,706	6,418	244	4 percent
On Peak	-	347	23	324	93 percent	1,924	2,298	1,947	350	15 percent
percent On Peak	0 percent	66 percent	8 percent	0 percent		31 percent	34 percent	30 percent		
Off Peak	-	181	261	(80)	-44 percent	2,298	4,408	4,471	(63)	-1 percent

Source: Frontier Energy

The average system cost over $4,000 to install, which was significantly higher than the originally expected average of about $1,650, due to COVID and general labor cost increases in the region during the time of the installation. Contractors also needed to wire the unit to the existing thermostat, which was provided by the research team in this demonstration.

Table 29 shows the cooling energy savings of installing NTV. For most sites, there is a cost savings of installing NTV instead of AC resulting in an immediate payback period (0 years).

Table 29: Financial Analysis of NTV (Modeled Based on Measurements)

SITE	PRE		POST		AC		NET SAVINGS (POST vs AC)		
	Equip Cost	Annual Cooling Cost	Equip Cost	Annual Cooling Cost	Equip Cost	Annual Cooling Cost	Equip Cost	Energy Cost	Simple Payback (yrs)
42	$ -	$0	$5,386	$102	$6,184	$190	($798)	$88	0
43	$ -	$0	$4,909	$102	$5,183	$190	($274)	$88	0
44	$ -	$0	$4,904	$102	$5,838	$190	($934)	$88	0
45	$ -	$0	$5,144	$102	$4,222	$190	$922	$88	11
46	$ -	$0	$5,529	$102	$6,228	$190	($699)	$88	0
47	$ -	$0	$5,581	$102	$6,758	$190	($1,177)	$88	0
48	$ -	$0	$4,999	$102	$5,494	$190	($495)	$88	0
49	$ -	$0	$5,666	$102	$5,541	$190	$125	$88	1
50	$ -	$0	$5,406	$102	$4,833	$190	$573	$88	7
51*	$ -	$0	$1,856	$102	$5,125	$190	($3,269)	$88	0
AVG*	**$ -**	**$0**	**$5,280**	**$102**	**$5,587**	**$190**	**($306)**	**$88**	**2**

*Site 51 was a custom application and was installed in-house. Site 51 not included in the average.
Source: Frontier Energy

Indoor air temperatures, monitored and logged using Hobo dataloggers, were downloaded at various points throughout the study. The results indicate that in almost all cases, temperatures were lower in the post-retrofit dataset, indicating that NTV had a positive comfort impact.

Occupant surveys completed throughout the monitoring period generally indicated overall satisfaction with the system, along with a few concerns. Wildfires in the region caused very smoky conditions with poor air quality, and most occupants remained uncomfortable because they were unable to use the NTV systems during these periods. Several occupants reported that the sound of the damper modulating was irritating, which was addressed by installing a time-delay relay on the damper. Some occupants reported no improvement in comfort.

Lessons Learned

NTV is a relatively low-cost retrofit that can used in relatively small homes with central heating systems with the air handling unit in the attic, and no AC. This system can be an alternative to installing AC but may not provide comfort at all times or reduce bills. Because it costs less than

AC in most cases and uses less energy than AC, it is automatically cost effective when compared to AC. But on average for this demonstration, the so economics are not likely to drive its adoption. Notably, using NTV instead of AC reduced peak period energy use by 15 percent, which could provide further savings with TOU rates. TOU savings are not accounted for in this analysis because individual calibrated models to capture accurate TOU billing impacts were not developed.

Summary of Field Test Results

An overview of the energy savings, installation cost, and simple payback for all 62 field test sites is provided in Table 30. A few of the test sites did not yield meaningful or reliable results due to lack of a baseline, COVID-19 impacts, or monitoring issues.

Table 30: Overall Results of Field Test Projects (Modeled or Measured as Described in Preceding Sections)

Site #	Technology	Building type	Cost of measure	Annual gas savings (kBtu)	Annual electricity savings (kWh)	Annual TOU utility bill savings ($)	Simple payback (years)
1	Aerosol Envelope Sealing	Residential	$4,607	47	931	$336	14
2	Aerosol Envelope Sealing	Residential	$8,249	10,811	60	$256	32
3	Aerosol Envelope Sealing	Residential	$4,998	8,812	49	$209	24
4	Aerosol Envelope Sealing	Residential	$5,858	2,110	7.2	$48	121
5	Aerosol Envelope Sealing	Residential	$5,047	0	0	$0	N/A
6	Aerosol Envelope Sealing	Residential	$1,412	66	97	$36	39
7	Aerosol Envelope Sealing	Residential	$1,412	53	220	$80	18
8	Aerosol Envelope Sealing	Residential	$1,356	61	210	$77	18
9	Aerosol Envelope Sealing	Residential	$1,356	55	101	$37	36
10	Aerosol Envelope Sealing	Residential	$5,002	125	7.1	$5	950
11a	Phase Change Materials	Commercial	$4,754*	N/A	N/A	N/A	N/A
11b	Daylighting Enhancement	Commercial	$22,287	N/A	329	$111	201

Site #	Technology	Building type	Cost of measure	Annual gas savings (kBtu)	Annual electricity savings (kWh)	Annual TOU utility bill savings ($)	Simple payback (years)
12	Daylighting Enhancement	Commercial	$15,745	N/A	0	$0	N/A
13	Daylighting Enhancement	Commercial	$22,610	N/A	558	$188	120
14	Exhaust Heat Recovery Dishwashers	Commercial	$4,157***	N/A	2,080	$701	6
15	Exhaust Heat Recovery Dishwashers****	Commercial	N/A	N/A	N/A	N/A	N/A
16	Exhaust Heat Recovery Dishwashers	Commercial	$4,103***	N/A	5,720	$1,928	2
17	GIHPWH	Residential	$4,725	23,100	-2,032	$352	13
18	GIHPWH	Residential	$4,705	13,900	-1,399	$198	24
19	GIHPWH	Residential	$4,705	19,000	-2,404	$234	20
20	GIHPWH	Residential	$4,725	16,700	-1,449	$278	17
21	GIHPWH	Residential	$4,705	N/A	4,660	$1,678	3
22	GIHPWH	Residential	$4,729	10,200	-3,060	-$4	N/A
23	GIHPWH	Residential	$4,725	8,600	-1,027	$111	43
24	GIHPWH	Residential	$4,646	15,500	-2,929	$119	39
25	GIHPWH	Residential	$4,725	9,893	-2,885	$1	4,443
26	Hydronic Fan Coil	Residential	$83,486	17,788	26	-$35	N/A
27	Hydronic Fan Coil	Residential	$83,734	11,499	326	$166	503
28	Induction Cooking	Residential	$3,544	N/A	440	$158	22
29	Induction Cooking	Residential	$3,547	N/A	612	$220	16
30	Induction Cooking	Residential	$3,545	N/A	112	$40	88
31	Induction Cooking	Residential	$3,562	N/A	-149	-$54	NA
32	Induction Cooking	Residential	$3,580	N/A	227	$82	44
33	Induction Cooking*****	Commercial	N/A	N/A	N/A	N/A	N/A
34	Induction Cooking	Commercial	$6,186	460	-29	-$579	N/A
35	Ducted Mini-Split Heat Pump	Residential	$31,104	908	-939	-$318	N/A
36	Ducted Mini-Split Heat Pump	Residential	$31,175	3,680	-230	-$3	N/A

Site #	Technology	Building type	Cost of measure	Annual gas savings (kBtu)	Annual electricity savings (kWh)	Annual TOU utility bill savings ($)	Simple payback (years)
37	Ducted Mini-Split Heat Pump	Residential	$31,104	-	-517	-$186	N/A
38	Ducted Mini-Split Heat Pump	Residential	$31,175	4,814	-1,612	-$476	N/A
39	Ducted Mini-Split Heat Pump	Residential	$31,104	10,802	-300	$126	246
40	Ducted Mini-Split Heat Pump	Residential	$31,120	4,234	-283	-$10	N/A
41	Ducted Mini-Split Heat Pump	Residential	$31,120	580	-29	$2	15,187
42	Nighttime Economizer**	Residential	-$798	N/A	244	$88	0
43	Nighttime Economizer**	Residential	-$274	N/A	244	$88	0
44	Nighttime Economizer**	Residential	-$934	N/A	244	$88	0
45	Nighttime Economizer**	Residential	$922	N/A	244	$88	11
46	Nighttime Economizer**	Residential	-$699	N/A	244	$88	0
47	Nighttime Economizer**	Residential	-$1,177	N/A	244	$88	0
48	Nighttime Economizer**	Residential	-$495	N/A	244	$88	0
49	Nighttime Economizer**	Residential	$125	N/A	244	$88	1
50	Nighttime Economizer**	Residential	$573	N/A	244	$88	7
51	Nighttime Economizer**	Residential	-$3,269	N/A	244	$88	0
52	Phase Change Materials	Residential	$12,352	-1,478	1.4	-$32	N/A
53	Phase Change Materials	Residential	$9,596	-1,402	107	$8	1,206
54	Phase Change Materials	Residential	$11,839	-1,402	107	$8	1,488
55	Phase Change Materials	Residential	$11,700	-1,402	107	$8	1,471

Site #	Technology	Building type	Cost of measure	Annual gas savings (kBtu)	Annual electricity savings (kWh)	Annual TOU utility bill savings ($)	Simple payback (years)
56	Phase Change Materials	Residential	$13,693	-1,402	107	$8	1,721
57	Phase Change Materials	Commercial	$6,810	31,500	811	$976	7
58	Phase Change Materials	Commercial	$5,890	N/A	N/A	N/A	N/A
59	Phase Change Materials	Commercial	$4,992	31,000	-5,389	-$1,267	N/A
60	Phase Change Materials	Commercial	$7,062	45,800	1,261	$1,448	5
61	Phase Change Materials	Commercial	$7,623	N/A	N/A	N/A	N/A
62	Radiant Ceiling Panels	Residential	$136,891	6,366	1,884	$443	309

* Material cost only. Labor costs for AEC measures could not easily be separated from other renovation costs.
** All values calculated relative to new AC.
*** First cost is incremental relative to a standard dishmachine.
**** Partner withdrew from Lead Locally prior to the retrofit.
***** Partner did not receive approval for retrofit from college administration until monitoring phase was over.
Source: Frontier Energy

Optimal Retrofit Strategies Analysis

The optimal retrofit strategies analysis used hourly building simulations to identify the most beneficial energy efficiency measures for SCP customers based on existing building type, building characteristics, and climate zone. This work integrated a large-scale modeling exercise with performance and cost data from technology demonstrations to identify those that maximize cost-effectiveness, electricity savings, and GHG savings. The analysis included technologies evaluated in the applied research and technology demonstration phases of Lead Locally as well as common off-the-shelf retrofit measures. Building types covered were single-family residential and small office commercial occupancy.

Full details of the analysis are provided in the Optimized Retrofit Strategies Final Report (German et al., 2023).

CHAPTER 3: Technology Deployment to Community

The technology deployment component of the Lead Locally Program involved efforts to initiate or accelerate the dissemination of select technologies to the local community. The purpose was to stimulate the market for energy saving technologies that otherwise had low market adoption. While the SCP region was the focus of technology deployment, market impacts may very well have spanned beyond that locale or even the state (see Grant Deliverables section in Chapter 4). Technology deployment occurred though technology education at the Advanced Energy Center as well as incentives and financing offered by SCP, as described below.

Advanced Energy Center

The Sonoma Clean Power AEC is a 9,400 square-foot space in downtown Santa Rosa that is open to the public and is staffed by SCP employees. Through the storefront and its associated website (https://scpadvancedenergycenter.org/), the AEC serves to engage, educate, and assist customers and the community in energy efficiency and utility savings. It aims to do so in a number of ways, including:

- Demonstrating multiple advanced energy technologies through technology displays, educational offerings, and performance results from Lead Locally demonstration sites.
- Hastening deployment of energy efficiency and decarbonization technologies to make them more accessible to all customers and increase customer knowledge.
- Providing customer education on electricity rates, how to read their bill, how to save money on their bill, and ways to access income-qualified discounted rates.
- Engaging local contractors and vendors of technologies through trainings, equipment displays, demonstrations, and the Contractor Network (see Contractor Network section).

Deployed technologies were electric only and included heat pump space conditioning, heat pump water heaters, induction cooking, heat recovery dishmachines, and heat recovery ventilators. Most of these technologies were selected based on the results of Applied Research and Technology Demonstration outlined in the previous chapter (see Chapter 2 for more information on these technologies).

The AEC website provided information on technologies, connected customers with contractors and facilitated the public-facing incentive and financing processes.

Incentives

Financial incentives were provided by SCP to customers for deployed technologies in order to accelerate their market adoption. SCP also established a network of contractors that were trained and actively participating in the SCP program. This was intended to ensure adequate customer access to these products, strengthen the local market, and help SCP deepen its relationship with local contractors, which is a critical piece of the clean energy transition. More information on contractor engagement is available in the Contractor Network section

The technology incentive amounts as of August 2023 are shown in Table 31. The incentive amounts and structure have changed throughout the years, and will continue to change over time, based on customer and contractor feedback, market conditions, and completed project trends. The structure for incentives is described below:

- Where applicable, incentives could be stacked with other incentives available through the Bay Area Regional Energy Network (BayREN) Home Plus program and other statewide programs.
- SCP initially provided the incentives to the installing contractor through the AEC Contractor Network. Feedback was that neither the contractors nor the customers liked this approach. While the intent was to provide an immediate discount on the project cost, contractors did not like the complexity of the process and paperwork, while customers felt that the full incentives were not being recognized in the overall cost. Customers also expressed the desire to use their own trusted contractors. As a result of this feedback and initial low project participation, SCP pivoted to provide the incentives directly to the customers after they completed installation and submitted documentation, including proof of permit.
- For many technologies, an additional income-qualified “kicker” discount was available to recipients of CARE (California Alternate Rates for Energy Program) or FERA (Family Electric Rate Assistance Program). These are utility financial assistance programs available to customers meeting certain income requirements. This kicker was intended to address potential equity issues in technology deployment.
    - The incentives for these customers were offered at 50 percent of the total project cost up to $10,000.
- A tiered discount rate based on product efficiencies was initially planned, though it did not get implemented due to complexities and local market confusion. Flat incentives per technology were used.
- SCP required proof of permits where installation permits were required by local building officials.

Table 31: August 2023 Incentives Provided by Lead Locally

CARE/FERA Customers			
Equipment	**Performance Requirements**	**Rebate Amount**	**Documentation Requirements**
Heat Pump Heating and Cooling Heat Pump Water Heaters Induction Cooktop	See performance standards per technology below	50% of total project cost not to exceed **$10,000**	See documentation requirements per technology below

Induction Cooktops*			
Equipment	**Performance Requirements**	**Rebate Amount** (Effective 8/1/23)	**Documentation Requirements**
Induction Cooktop	Proof of Installation	**$500** Plus an induction cookware set	Paid Invoice Photo of Installed Product

Heat Pump Heating & Cooling Systems*			
Equipment	**Performance Requirements**	**Rebate Amount** (Effective 8/1/23)	**Documentation Requirements**
Air-Source Heat Pump	Ducted, central split DX **18 SEER or higher; 17.2 SEER2** or higher**	**$1000**	Final Permit AHRI Certificate Paid Invoice Photo of Nameplate
	Ductless, single zone **20 SEER or higher; 19.1 SEER2 or higher**	**$1000**	
	Multizone **17 SEER or higher; 16.2 SEER2 or higher**	**$1000**	

Hydronics System			
Equipment	**Performance Requirements**	**Rebate Amount** (Effective 8/1/23)	**Documentation Requirements**
Air-to-Water Heat Pumps *for heating and cooling*	Proof of Installation	**$1000**	Final Permit Paid Invoice Photo of Installed Product
Air-to-Water Heat Pumps *for heating, cooling, and water heating*	Proof of Installation System must provide space conditioning and water heating	**$1700**	

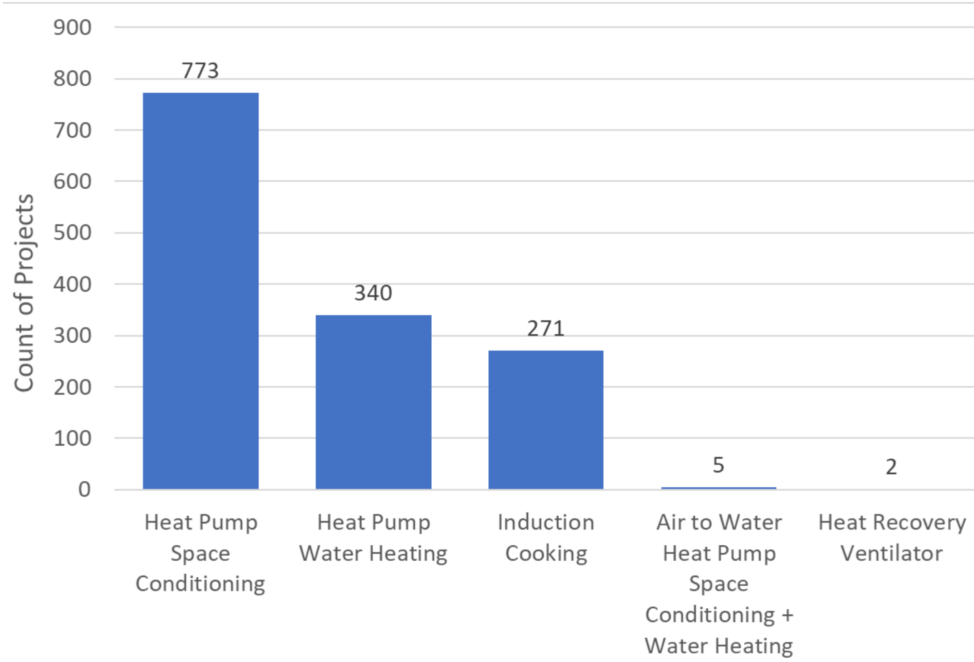
Heat Pump Water Heaters*			
Equipment	**Performance Requirements**	**Rebate Amount** (Effective 8/1/23)	**Documentation Requirements**
Heat Pump Water Heaters *any tank size*	UEF 3.43+ Wi-Fi Capable & Sanco2 models eligible	**$700**	Final Permit Paid Invoice

Heat Recovery Ventilators*			
Equipment	**Performance Requirements**	**Rebate Amount** (Effective 8/1/23)	**Documentation Requirements**
Heat Recovery Ventilators	Proof of Installation	**$1000**	Final Permit Paid Invoice Photo of Installed Product

Source: Sonoma Clean Power

Figure 15 shows the number of projects that were incentivized by SCP. Heat pump space conditioning and water heating were the most popular. As of November 30, 2023, a total of 1,391 projects were completed and $3,165,484 incentives were issued.

Figure 15: Lead Locally Incentives Provided through November 30, 2023



Source: Sonoma Clean Power

Financing

In addition to the technology incentives described in the previous section, SCP began offering zero percent interest on-bill financing (OBF). OBF loans are backed by the utility and repaid by the customer through their energy bills. If the measures are cost-effective and the expected energy savings are achieved, the total energy bill, including loan payments, would still be lower following the retrofit. This financing was designed to go hand-in-hand with incentives.

The process began with an interested customer completing a screening application for the OBF program via the AEC website. SCP verified that the applicant was eligible, and then a bid request form was delivered to the network of OBF-certified contractors that install the requested technology type(s). The OBF-certified contractor(s) would then reach out to the customer with a bid for installing their selected technology type(s). The customer then selected a bid and provided it to SCP for final approval. Once approved, a final agreement was signed by the customer and SCP, and the project work was authorized to begin.

Zero percent interest loans that could be paid back in regular installments over a term of up to 120 months provided an opportunity for low-income customers to acquire energy efficient technologies with a significantly lower up-front cost.

The OBF program financed over $1.35M of work for 174 projects. Table 32 below shows the breakdown of technology types installed with OBF, the number of installations of each, and the total financed amount of each.

Table 32: Count and Value of Lead Locally OBF Loans Provided

Tech Type	Count of Projects	Sum of Loan Amount	Average Loan Amount per project
Heat Pump Space Conditioning	101	$942,886.40	$9,335.51
Heat Pump Water Heating	64	$355,643.27	$5,556.93
Induction Cooking	7	$35,069.34	$5,009.91
Air to Water Heat Pump Space Conditioning + Water Heating	2	$20,000.00	$10,000.00
Grand Total	**174**	**$1,353,599.01**	**$7,779.30**

Source: Sonoma Clean Power

The limit of funds available for SCP to lend was exceeded by May 2023, and SCP is evaluating the opportunity and the ability to reinstate OBF.

Contractor Network

SCP created a Contractor Network as part of the AEC. These contractors were required to be licensed, insured, and bonded and sign participation agreements with SCP. A contractor matching tool connected enrolled contractors by the type(s) of technologies they install with customers who wanted to receive project bids. This connected contractors to numerous customer leads, pre-approved by SCP for incentives or financing, with whom they follow up to provide project cost estimates.

Contractor recruitment began during the earliest stages of Lead Locally, well before the Contractor Network was created. Early participation was limited to a handful of contractors. The growth of the Contractor Network is largely attributable to a dedicated SCP staff member who focused on recruitment and engagement. This involved creating awareness about the program, educating contractors about its benefits, and fostering strong, trustworthy relationships. Achieving such growth demanded commitment, dedication, and persistence. In July 2022, there were a total of 23 installers participating in the Contractor Network. This number grew to 57 by June 2023.

Results

Technology deployment efforts under the Lead Locally Program led to 1,391 project installations of which 174 utilized OBF. Important lessons learned through observations of SCP staff that could be applied to similar programs are described below:

- Initial contractor recruitment and participation was difficult. Initial feedback to SCP from many contractors was that they already had plenty of work, they were skilled in the installation of their existing technologies, did not trust new technologies, and did not want the administrative burden of utility programs.
- SCP put more resources into contractor recruitment, hired a staff member to focus on contractor engagement and encouraged customers to bring their own contractors to the

program. Contractor participation more than doubled over the course of the year after these strategies were employed.

- Technology deployment is most successful when applied to standardized and commonly used household systems such as space conditioning, water heating, and cooking. Equipment types not standardized among homes (such as heat recovery ventilators) are much more difficult to deploy. This is demonstrated by only having two heat recovery ventilators deployed as of November 2023.
- OBF proved popular, as observed by SCP reaching its funding limit more than six months earlier than forecast.
- OBF was used mostly for heat pump space conditioning and heat pump water heating projects.
- OBF aimed at allowing lower income households the ability to complete projects without the need for upfront capital, however only 11 out of the 174 projects financed were to income-qualified recipients. Only 7 percent of the projects financed were for income-qualified households, when approximately 20 percent of SCP's customer base is income-qualified. This indicates that a more targeted and intentional approach should be used to reach low-income customers.
- 62 percent of financed projects were for customers who are on the Net Energy Metering solar rate. This indicates that customers that may already have capital but are financially savvy or are motivated by reducing GHG emissions were more likely to participate.
- Automation wherever possible is useful for data entry, data quality, and streamlining necessary communication channels. As such, future financing programs should prioritize automating population of data fields to ensure consistency and quality of data.
- Incentives are attractive to customers and help raise awareness for technologies.
- SCP gained little traction at first with lower incentives and decided to raise the incentive amounts to attract more customers. In the first year of providing lower incentives, only 120 projects were completed. SCP raised incentives and that resulted in 892 projects being completed in the second year. SCP then reduced incentives back down to original amounts since awareness had been gained and is still on track to complete more projects in the third year than the second.
    - Increasing incentive levels when participation is low can create more attention and interest from customers. Providing increased incentive levels until market movement is achieved can be a very effective tool. Once awareness of these technologies takes off and more projects are installed, reducing incentives and directing money to markets that have not taken off or need much more support may be prudent.
- Higher incentives for income-qualified customers are essential to make these technologies viable for those customers and provide equitable access. However, even

with the higher incentives provided by this program, less than 8 percent of incentivized projects were provided to income-qualified customers.

- Direct incentives to customers, rather than contractors, proved to be a more effective tool as observed by overwhelming feedback from customers and contractors to SCP staff.
- Customers rely on knowledgeable program staff to help them understand their options and the benefits of technologies. When visiting the AEC, customers very rarely did not use staff help.
- Customers appreciate being provided with a list of contractors to use through a vetted contractor network when they do not know where to start as observed by SCP staff.
- Customers appreciate the flexibility to use their own trusted contractor as observed by feedback to SCP staff. This also helps other contractors become familiar with the program and the technologies.

CHAPTER 4: Technology/Knowledge Transfer

A key component of the Lead Locally grant was knowledge transfer to the public, key decision makers, and market actors (including other utilities, contractors, suppliers, and so on). Knowledge transfer is important because by sharing the successes and challenges of a project, other market actors can more effectively design and implement their own related efforts.

Key activities undertaken for technology transfer are summarized in this report and detailed in the Technology and Knowledge Transfer Report (Hendron, et al. 2023). Primary activities included the following:

- Publishing and/or presenting technical findings at relevant conferences.
- Disseminating fact sheets, videos, press releases, and other information through the AEC, websites, social media, and traditional news media.
- Informing future Title 24 code development activities.

Supporting SCP were implementers and partners (see Table 33). Implementers led the development of the plan, defined the messages, delivered the products, and reported and validated the outcomes. Partners represented the team in communicating results and included all members of the TAC, which was organized for the purpose of overseeing the project's development and implementation.

Table 33: Knowledge Transfer Implementers and Partners

Implementers	Partners	
Sonoma Clean Power (SCP)	Bay Area Regional Energy Network (BayREN)	East Bay Community Energy (EBCE)
DNV	Pacific Gas & Electric Company (PG&E)	StopWaste
Frontier Energy	Natural Resources Defense Council (NRDC)	Carbon Free Palo Alto
County of Sonoma – Energy and Sustainability Division (SCESD) now Climate Action and Resiliency Division (CARD)	Bay Area Air Quality Management District (BAAQMD)	Northwest Energy Efficiency Alliance (NEEA)
Design Avenues, LLC	Electric Power Research Institute (EPRI)	Vermont Energy Investment Corporation (VEIC)
Sonoma County Regional Climate Protection Authority (RCPA)	Metropolitan Transportation Commission (MTC)	ConSol

Source: Sonoma Clean Power

Public accessibility to technology transfer activities and publications was central to meaningful knowledge transfer to the community. As the project was funded through a CEC grant, the focus of the project was to maximize the financial benefits to California ratepayers. However, many of the lessons learned could apply more broadly to other market actors, especially in other mild climate zones across the country. Some other market actors targeted include state and local governments, utilities, industry professionals and organizations, program administrators, and academic/research institutions.

Knowledge transfer activities occurred from July 2018 through November 2023, with ongoing activities expected through the AEC, conferences, and other deployment channels long after the conclusion of the grant. Lessons learned from these activities were used to enhance the effectiveness of Lead Locally deployment initiatives, and were also funneled directly to consumers, contractors, real estate professionals, and building officials through SCP and its local partner organizations.

Results from Lead Locally have helped guide the 2025 Title 24 code development process by identifying technologies that are ready for inclusion in the energy code, either as compliance options or mandatory requirements. Frontier Energy is currently developing a statewide Codes and Standards Enhancement (CASE) report addressing advanced heat pump requirements and supporting a CASE report focusing on HPWH installation requirements. Frontier is also working with CEC on a new base case for Title 24 that includes heat pumps for space conditioning and water heating. Cost and performance data from Lead Locally, along with lessons learned from installation, permitting, and customer feedback, are all factored into the recommendations in the CASE reports.

Advanced Energy Center

The AEC and associated website were the primary means of communicating knowledge gained from Lead Locally.

AEC educational and technology displays generally focused on incentivized and financed products but did include other technologies that had been vetted by SCP. Displays included heat pump water heaters, hydronic fan-coils, mini-split heat pumps, heat recovery ventilation, heat recovery dishmachines, induction cooking, and battery storage technologies. More recently, displays have been added for electric bikes, electric vehicle charging stations, and electric fireplaces. Non-technology displays include a lending library and an educational space for children. The displays throughout the AEC's large demonstration area range from videos to live product demonstrations and offer an opportunity for visitors to compare energy efficient products, learn about the benefits of electrification, and sign up for energy upgrades at their home or business. Many of the displays and videos are in both English and Spanish to serve the multilingual community in Northern California.

Since opening to the public on June 15, 2021, through November 2023, the AEC has seen over 10,000 total visitors. SCP has also received hundreds of calls per month to their dedicated customer service line. The COVID-19 pandemic impacted public interaction both directly due to shutdowns and indirectly due to impacts on the home remodeling market. It is expected that public interaction will increase over time as both the economy continues to settle from the pandemic and awareness of the AEC increases throughout the community.

Education, Training, and Events

Education and events have been a leading mechanism of knowledge transfer for the community. Educational offerings took place at the AEC, online, or both. The AEC was designed to flexibly make use of its space. For example, a classroom training and kitchen demonstration may occur simultaneously while keeping the technology display areas open to the general public. Additionally, the classroom's video capabilities allow the class to be broadcast in the AEC lounge area or webcast to those not physically at the AEC.

Since opening on June 15, 2021 through November 2023, the AEC has hosted over 120 events including classes for the public, contractor classes, public tours, meetings, and other events. SCP also provided education through customer service provided to walk-ins. In 2021, SCP focused more on tours of the space and the technologies but over time has shifted more of its focus to events, organized trainings, and classes. A breakdown of visitors for these activities over time is shown in Figure 16. Note that the AEC was closed for large portions of January and February 2022 due to COVID-19.

Figure 16: Number of visitors by AEC Activity Over Time

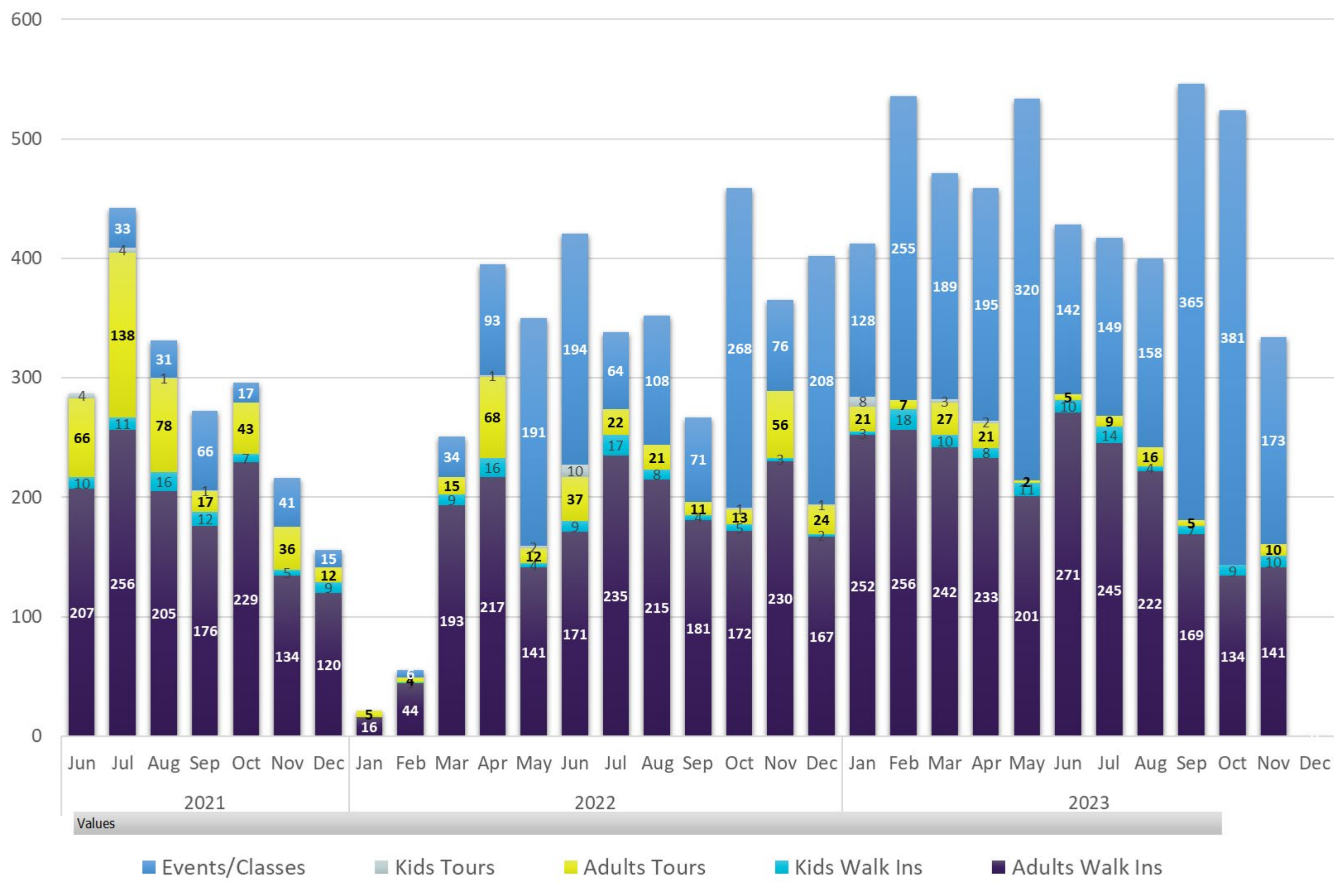


Image Credit: Sonoma Clean Power

Public Classes

In 2021, the majority of classes were held online due to COVID-19 policies. However, as these restrictions were lifted in late 2021, many more customers had the option to attend in person. Class topics were diverse, covering nighttime ventilation, heat pump water heating and HVAC, induction cooking, on-bill financing, fuel switching, battery storage, electric vehicles, wildfire resiliency, and indoor air quality. Many of these classes are available on the AEC website for on-demand viewing, and several were made available in Spanish. Some of the most popular classes included Home Remodeling for Resiliency and Fuel Switching, Introduction to Electric Bikes, Smart and Efficient Electric Water Heating for Homes, and Solar Plus Battery Storage.

Contractor Classes

Contractor classes focused on technical, product, or incentive program information relevant to participating or prospective contractors. These classes covered a number of grant-funded technologies, including grid-interactive heat pump water heaters, nighttime ventilation, and hydronic fan coils.

Through November 2023, 29 contractor training classes were held at the AEC or online. In all, an estimated 174 individuals attended them in person, although some sessions were available simultaneously via live webinar. While open to anyone, these classes were targeted at local contractors that would install the technologies being covered.

Contractor classes were initially envisioned to certify companies and individuals to install Lead Locally technologies. Over time, this approach evolved to one of more direct recruitment and relationship building, along with topic-based training by industry experts.

Meetings

In addition to educational classes, the AEC provided meeting space for external organizations. Organizations included local agencies and governments, energy and environmental organizations, private companies, utilities, and program administrators. Sonoma Clean Power itself also regularly made use of the AEC for internal meetings. Due to the nature of the meeting space and the partners invited, many meetings themselves focused on knowledge transfer.

Knowledge transfer was not limited to the AEC. Highlighted below are just a few examples of SCP's direct engagement with the local building community.

- A meeting between SCP, Sonoma County Energy and Sustainability, Design Avenues LLC, and the Regional Climate Protection Authority in September 2018 focused on educational and public engagement strategies for the AEC.
- Lead Locally, represented by both SCP and Frontier Energy team members, presented information about evaluated technologies to the Redwood Empire Association of Code Officials in 2019. This served to both alert local code officials to potential increases in installation of these technologies and to gain their perspective on jurisdictional requirements for each technology.

- During the summer of 2019, Frontier held discussions with nine Program Administrators related to how their programs could support Lead Locally installations: PG&E Advanced Home Upgrade, PG&E Multifamily Upgrade, BayREN Multifamily Upgrade, Fannie Mae Green Initiative, California First, Ygrene, Renovate America HERO, Federal Housing Administration, Department of Veterans Affairs. The results led to greater leveraging of existing programs to help offset the retrofit cost of, and generally amplified the awareness of, Lead Locally technologies.
- Between 2021 and 2023, SCP attended monthly meetings with PG&E and Northern California community choice aggregators to discuss lessons learned from decarbonization efforts including the Lead Locally Program.

Other engaged organizations included Sonoma County Bicycle Coalition, Toastmasters, The Climate Center, Zero Waste Sonoma, and the Sonoma County chapter of the NAACP. Overall, the Lead Locally Program transferred knowledge and deepened partnerships with various actors within the local private and public community. The impact of direct outreach is having tangible effects around the country. SCP program strategies are being duplicated within California and as far away as Boulder, Colorado, and Vermont.

Other Planned Events

Since the opening of the AEC through November 2023, the AEC has hosted various special events, many open to the general public. The induction demonstration kitchen has provided a unique space for customers to learn about and experience induction cooking technology. To highlight the benefits of induction, SCP has invited renowned local chefs to teach cooking classes and hosted two chocolate-making classes.

The AEC also hosted field trips and tours. School field trips have provided educational opportunities for hundreds of local youths, helping them understand the worsening climate challenge and how electrification and energy-efficiency technologies can help confront it.

One tour in 2023 included Congressman Thompson and members of his staff to provide information on the Lead Locally Program and the impacts of the AEC. Congressman Huffman and staff also visited the AEC in 2023.

SCP also hosted a tour and information session with the Sacramento Municipal Utility District to exchange results and lessons learned.

Photos highlighting some of the special events at the AEC are shown in Figure 17.

Figure 17: Special events held at the AEC

		
Molcajetes Induction Cooking Class	Student Field Trip in the AEC Classroom	Congressman Mike Thompson Press Conference

Image Credit: Sonoma Clean Power

AEC Website/Social Media

The AEC website is a resource for technology and knowledge transfer to educate, engage, and inspire uptake/investment in electrification and energy-efficient technologies. This was accomplished by showcasing technologies, enabling use of incentives and financing to acquire the technologies, and educating through live or recorded trainings.

The initial Lead Locally webpage (https://sonomacleanpower.org/lead-locally) was launched in November 2018. Its purpose then was to provide basic information about the wider Lead Locally Program and to recruit volunteers for research and technology demonstration projects. By February 2019, however, it had grown to include information about the upcoming AEC and provided additional details about Lead Locally Program initiatives. Social media platforms, including Facebook and Twitter, were also used for site recruitment and educational purposes. The Lead Locally website now houses the final reports delivered for this grant.

The AEC website (https://scpadvancedenergycenter.org/) was launched to provide more customer-friendly information. Included in this launch was the Contractor Network described in the Contractor Network section of Chapter 3. In subsequent months, SCP added information on the benefits of grant-funded technologies, upcoming events, available incentives, and on-bill financing.

As of November 2023, the AEC website has received 241,722 page views, with 144,167 unique users. The most popular page was the home page, followed by the Education Hub and products page.

- The AEC website was viewed by users across the globe on every continent (except Antarctica). 6,830 unique users were from outside of the United States. The top countries with the most unique users were as follows (in descending order): Canada, Netherlands, India, China, Germany, Japan, Iran, United Kingdom, and Mexico.

- Website users from within the United States spanned across the continent and reached every state, with 80 percent of the users being in California. 27,569 unique users were from outside of California. The top states with the most unique users were as follows (in descending order): Washington, Oregon, Texas, Virginia, New York, Nevada, Florida, and Colorado.
- Website users from within California spanned from north to south. The top cities in California with the most unique users were as follows (in descending order): Santa Rosa, San Jose, Petaluma, San Francisco, Sebastopol, Windsor, Los Angeles, Rohnert Park, and Cloverdale.

SCP has issued a series of press releases, e-mail blasts, website updates, and social media postings throughout the grant period publicizing the AEC and other activities under the Lead Locally grant. Example social media postings are shown in Figure 18.

Figure 18: Example Social Media Posts

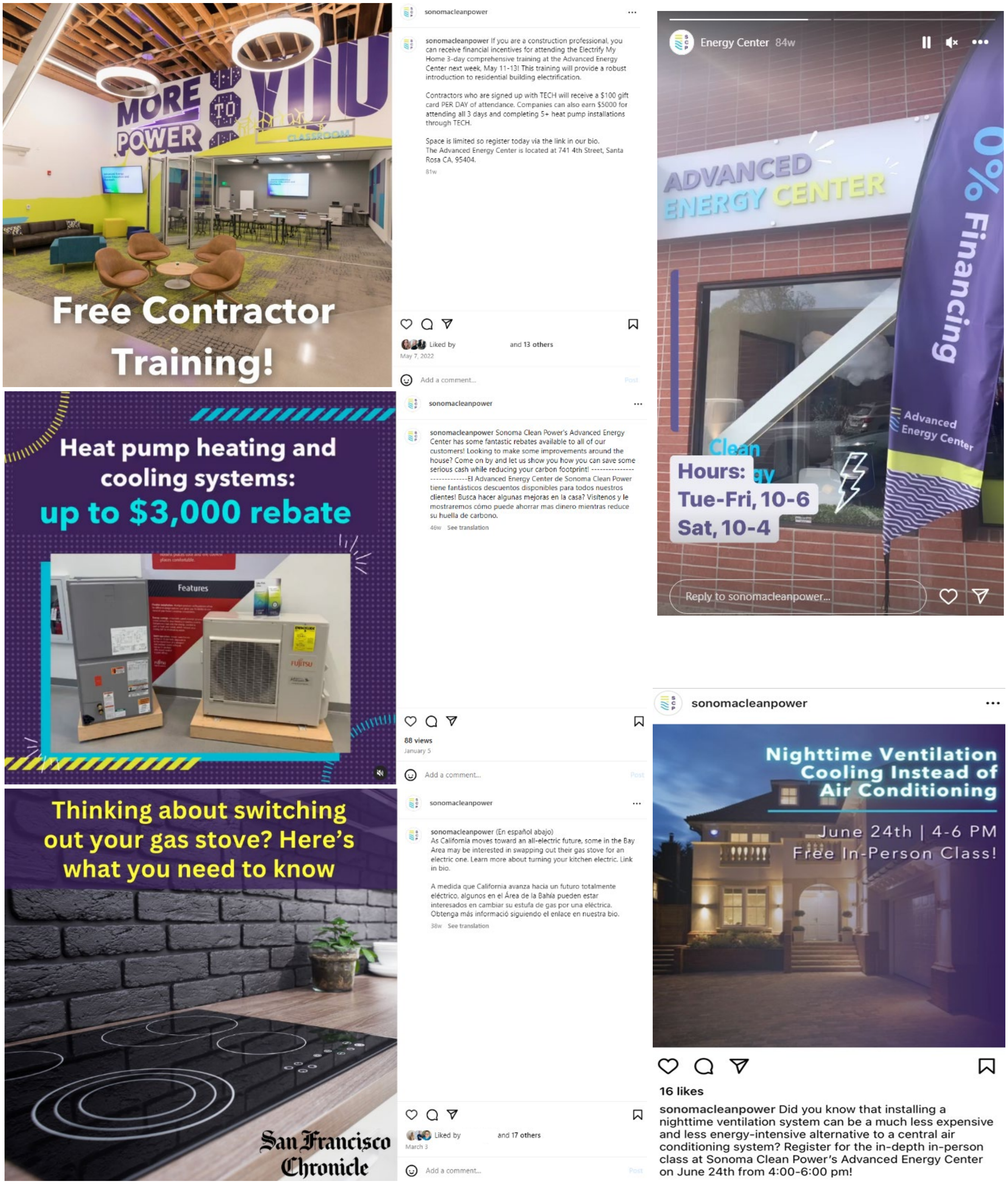


Image Credit: Sonoma Clean Power

Conferences & Papers

The Lead Locally team participated in multiple conferences within California and across the country to share lessons learned from the program. Conference proceedings and publications were generally peer-reviewed, and they will remain available to the public long after the event. Conferences and publications are as follows:

- 2019 American Council for an Energy-Efficient Economy (ACEEE) Hot Water Forum—Frontier described progress on the use of machine learning techniques to predict hot water use in support of the HPWH research project. Researchers and manufacturers in attendance provided ideas for improving this project.
- 2022 ACEEE Summer Study on Buildings—The Lead Locally team wrote two peer-reviewed papers and presented them. The papers included findings from PCM (see Figure 19) and radiant panel research. Findings from Aerobarrier demonstrations were also publicized by the Western Cooling Efficiency Center at this conference.
- 2023 ACEEE Hot Air Forum—Frontier presented results from the ten grant-funded HVAC projects. The presentation discussed the lessons learned from field testing of mini-split heat pumps, radiant ceiling panels, and AWHPs with hydronic fan-coils.
- 2023 Dry Climate Forum—The Frontier team presented the field test results, installation best practices, and challenges for several technologies: ducted MSHP, hydronic fan-coil with air-to-water heat pump, and radiant ceiling panel projects. Exposure at this event helped raise awareness of Lead Locally technologies and lessons learned.
- 2023 Association of Energy Services Professionals national conference held in New Orleans—Frontier presented on the three-function HVAC/water heating technology, and SCP presented on the AEC to an audience of national experts on energy efficiency program design and deployment, including utilities, energy consultants, state and local governments, and industry organizations.
- 2023 California Community Choice Association (CalCCA) Conference—The AEC was presented with an award for Community Impact for First Place in the "Decarbonization Category".

Figure 19: Presentation on PCM at 2022 ACEEE Summer Study

Image Credit: Frontier Energy

Grant Deliverables

In addition to publications for technical conferences and other events, the final CEC-approved deliverable reports for Lead Locally are available on the SCP website https://sonomaclean power.org/lead-locally). All reports that discuss test results had the test sites anonymized, so no personally identifiable information is included.

CHAPTER 5: Evaluation, Measurement, and Verification

Summary of Savings Results

DNV analyzed annual energy savings resulting from the Lead Locally Program for installations that occurred from September 2019 to June 2022 across 166 sites totaling more than 305,000 square feet across residential and commercial building spaces. There were 192 measures installed across these sites, with 141 sites receiving a single measure, 24 sites receiving two measures, and one site receiving three measures. These measures were installed as part of the applied research, technology demonstration, and deployment phases of the Lead Locally project. DNV engineers evaluated site specific savings across all sites and estimated the impact of each technology installed at these sites. Note that the evaluation, measurement, and verification (EM&V) analysis does not include all deployed projects to date (over 1,400 and counting) because the goal of the program was to assess 300,000 square feet of projects and there needed to be an end date to collecting project data, including having an adequate number of post-installation consumption data, for EM&V to be feasibly accomplished.

Overall

Table 34 shows the total summary of annual energy savings across 166 sites. Through June 2022, the program resulted in an annual increase in electric consumption of 40,041 kWh and more than 29,000 therms in gas savings annually.[3] The increase in electric load was expected since most of the installed measures were fuel switching strategies, including HPWHs, heat pumps for space conditioning, and induction cooktops. Considering both the increase in electric consumption and decrease in gas consumption, the program produced more than 2.7 million in site kBtu energy savings annually (more than 814,000 kWh savings).

Table 34: Summary of Annual Site Energy Savings

Sector	# of Sites	kWh	Therms	kBtu	Equivalent kWh
Commercial	11	74,417	2,746	528,518	154,900
Residential	155	-114,458	26,411	2,250,559	659,601
Total	**166**	**-40,041**	**29,157**	**2,779,077**	**814,501**

Source: DNV (Modeled and Measured)

The goal of the Lead Locally Program was to reduce annual energy consumption by 10 percent for participating residential customers and 20 percent for participating commercial customers across 300,000 square feet of building space for both sectors combined. The program exceeded the square footage target in June 2022, with 93 percent of the sites being

[3] Note that throughout this chapter there are tables that summarize annual energy savings and tables that summarize the percent change in annual energy consumption. Table values are reported positive (greater than zero) to illustrate either energy savings or a reduction in energy consumption. Table values are negative (less than zero) to illustrate either energy penalties or an increase in energy consumption.

residential. Table 35 shows that the residential customers reduced their energy consumption by 23 percent, far exceeding the goal of 10 percent. The commercial sites achieved 3 percent energy reduction, falling short of the 20 percent savings goal. Across both sectors, the program achieved an 11 percent reduction in energy consumption.[4]

Table 35: Percent Change in Site Annual Energy Consumption

Sector	# of Sites	Percent Change kWh	Percent Change Therms	Percent Change kBtu
Commercial	11	4 percent	3 percent	3 percent
Residential	155	-12 percent	39 percent	23 percent
Total	**166**	**-1 percent**	**17 percent**	**11 percent**

Source: DNV (Modeled and Measured)

Residential MSHPs and HPWHs proved particularly popular during the deployment phase and drove energy savings for the program overall. The primary reasons for commercial sites not achieving the savings goal were: 1) the COVID-19 pandemic made recruitment of commercial sites particularly challenging and only 11 commercial sites participated compared to the target of 20 sites, 2) The applied research and demonstration phases of the project were limited to the installation of a single energy efficient measure per commercial site to better understand the energy impacts of that measure, 3) Commercial customers had very limited uptake of high-energy savings measures, such as ducted MSHPS and HPWHs, during the deployment phase of the project, and 4) the measures installed for commercial sites represented far less of the total building load for commercial than for residential sites.

Residential

EM&V was performed for 180 measures at over 150 residential sites, with six sites falling within the multifamily sector. Twenty-six residential sites had multiple measures installed. The overwhelming measure combination (20 of the 26 sites) was MSHP and HPWH, which accounted for the vast majority of program savings. Table 36 summarizes the total annual site energy savings for the residential measures. All residential sites that implemented PCM unfortunately had to have the materials removed, mostly due to manufacturing defects. As a result, PCM measure savings were zeroed.

Table 36: Summary of Residential Annual Site Energy Savings[5]

Technology	# of Technologies	kWh	Therms	kBtu	Equivalent kWh
Aerosol Envelope and Duct Sealant	10	1,682	221	27,870	8,168
Heat Pump Water Heater	78	-63,107	11,323	917,026	268,765

[4] The project specified energy savings goals for residential and commercial sectors but not overall.

[5] Estimated peak demand impacts are discussed in the respective technology sections (Summary of Savings Results section in Chapter 5).

Technology	# of Technologies	kWh	Therms	kBtu	Equivalent kWh
Hydronic Fan Coil with DHW	2	-2,337	595	51,535	15,104
Mini-Split Heat Pump	57	-56,903	14,160	1,221,879	358,112
Nighttime Ventilation	10	2,068	0	7,057	2,068
PCM	5	-	-	0	-
Radiant Ceiling Panels	1	1,203	82	12,307	3,607
Residential Induction Cooktop	16	2,936	29	12,886	3,777
Residential Total	**180**	**-114,458**	**26,411**	**2,250,559**	**659,601**

Source: DNV (Modeled and Measured)

Table 37 shows the relative proportion of energy savings that each technology contributed to total savings for the program in the residential sector. As shown, MSHPs and HPWHs combined accounted for 95 percent of savings in the residential sector.

Table 37: Share of Residential Annual Energy Savings by Technology

Technology	# of Technologies	Percent of overall residential kBtu savings
Aerosol Duct Sealant	10	1 percent
HPWH	78	41 percent
Hydronic Fan Coil with DHW	2	2 percent
MSHP	57	54 percent
Nighttime Ventilation/Economizer	10	0 percent
Phase Change Material	5	0 percent
Radiant Ceiling Panels	1	1 percent
Residential Induction Cooktop	16	1 percent
Residential Total	**180**	**100 percent**

Source: DNV

Table 38 summarizes the percent each technology reduced overall residential site annual consumption. Across 78 sites, HPWHs increased electric consumption by 12 percent and reduced gas consumption by 38 percent, yielding energy savings of 19 percent overall. Across the 57 sites MSHPs increased electric consumption by 15 percent and reduced gas consumption by 64 percent, yielding energy savings of 34 percent overall. DNV capped energy savings by comparing measure savings to the predicted (and weather normalized) pre-retrofit electric and gas consumption.[6]

Table 38: Percent Change in Residential Annual Energy Consumption

Technology	# of Technologies	Percent Change kWh	Percent Change Therms	Percent Change kBtu
Aerosol Envelope and Duct Sealant	10	6 percent	1 percent	2 percent
HPWH	78	-12 percent	38 percent	19 percent
Hydronic Fan Coil with DHW	2	-24 percent	84 percent	49 percent
MSHP	57	-15 percent	64 percent	34 percent
Nighttime Ventilation	10	4 percent	0 percent	1 percent
Phase Change Material	5	-	-	-
Radiant Ceiling Panels	1	22 percent	13 percent	15 percent
Residential Induction Cooktop	16	2 percent	1 percent	1 percent
Residential Total	**180**	**-12 percent**	**39 percent**	**23 percent**

Source: DNV

Commercial

EM&V was performed for 12 measures at 11 commercial sites. Eleven measures were installed during the demonstration phase. Six sites implemented PCMs which accounted for over 280,000 kBtu of the total 528,518 kBtu combined energy savings. Table 39 shows the total technology-level savings for the commercial sites. The induction cooktop was the sole measure that increased electricity consumption; however, it was the largest gas savings measure, accounting for 1,658 therms of the total 2,746 therms savings for the commercial sector.

Table 39: Summary of Commercial Annual Site Energy Savings

Technology	# of Technologies	kWh	Therms	kBtu	Equivalent kWh
Commercial Dishwasher	2	11,748	0	40,084	11,748
Commercial Induction Cooktop	1	-10,727	1,658	129,243	37,879
Daylighting Enhancement	2	365	0	1,245	365

[6] In other words, DNV made sure that fuel savings did not exceed the predicted pre-implementation annual consumption of that fuel. Fuel substitution measure electric penalties were also capped depending on the ratio of estimated gas savings and gas consumption.

Technology	# of Technologies	kWh	Therms	kBtu	Equivalent kWh
MSHP	1	1,600	691	74,571	21,856
PCM	6	71,431	397	283,375	83,052
Commercial Total	**12**	**74,417**	**2,746**	**528,518**	**154,900**

Source: DNV (Modeled and Measured)

Table 40 shows the relative proportion of energy savings that each technology contributed to total commercial sector savings. As shown, PCMs and induction cooktops combined accounted for 78 percent of total commercial sector savings.

Table 40: Share of Commercial Annual Energy Savings by Technology

Technology	# of Technologies	Percent of Overall Commercial kbtu Savings
Commercial Dishwasher	2	8 percent
Commercial Induction Cooktop	1	24 percent
Daylighting Enhancement	2	0 percent
MSHP	1	14 percent
PCM	6	54 percent
Commercial Total	**12**	**100 percent**

Source: DNV

Table 41 summarizes the percent each technology reduced overall commercial site annual consumption. Overall, the program measures reduced site annual electric consumption by 4 percent and gas consumption by 3 percent.

Table 41: Percent Change in Commercial Annual Energy Consumption

Technology	# of Technologies	Percent Change kWh	Percent Change Therms	Percent Change kBtu
Commercial Dishwasher	2	10 percent	0 percent	5 percent
Commercial Induction Cooktop	1	-1 percent	2 percent	1 percent
Daylighting Enhancement	2	2 percent	0 percent	1 percent
MSHP	1	13 percent	92 percent	64 percent
PCM	6	39 percent	4 percent	17 percent
Commercial Total	**12**	**4 percent**	**3 percent**	**3 percent**

Source: DNV

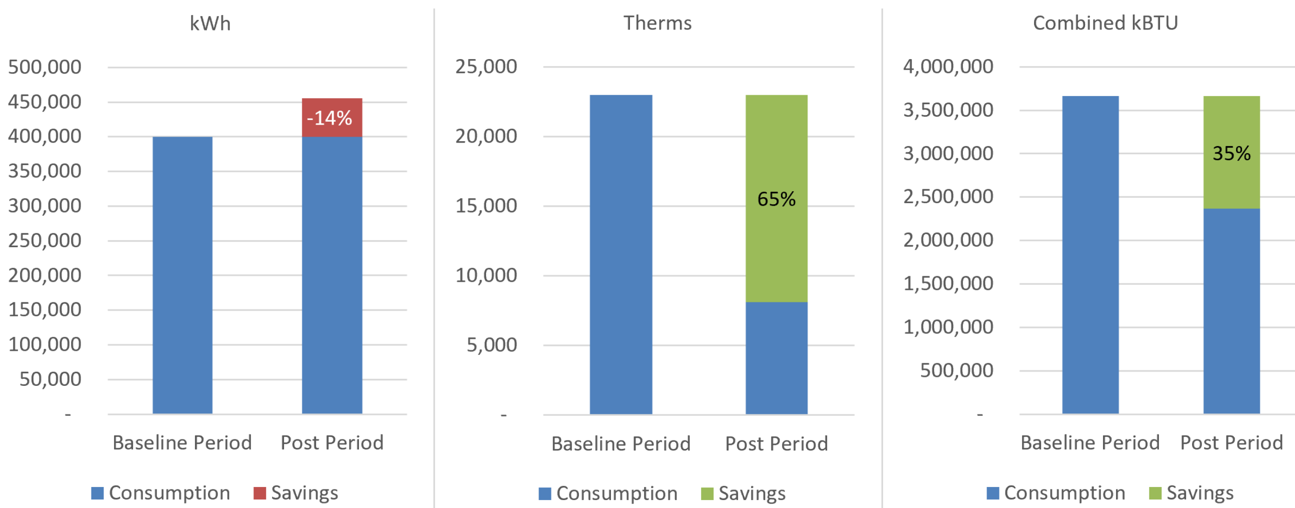
Savings Results by Technology

Energy savings results by technology are provided in the sections below. For further details on methodologies used to calculate savings at the technology level and additional site-level details, please see EM&V Detailed Methods and Results in Appendix D.

Mini-Split Heat Pumps

A total of 58 sites installed MSHPs and site-specific inputs were used to evaluate the savings of this technology. Figure 20 shows the total baseline and post-period annual consumption by fuel type and overall for MSHPs. As shown, baseline electric consumption increased by 14 percent, but gas consumption decreased by nearly two-thirds, and total energy consumption decreased by more than one-third.

Figure 20: Total and Percent Savings for MSHPs

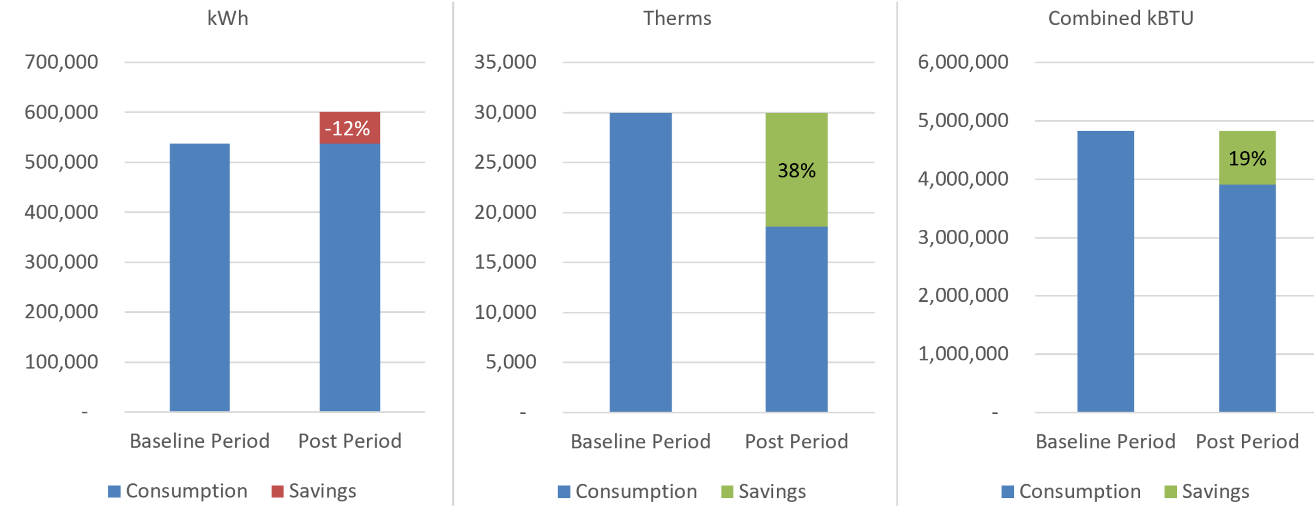


Source: DNV (Modeled)

Heat Pump Water Heaters

There were 78 residential sites with HPWH installations. Figure 21 shows the total baseline and post-period annual consumption by fuel type and overall for HPWHs. While electric consumption increased by 12 percent, gas consumption decreased by 38 percent and overall energy consumption was reduced by 19 percent.

Figure 21: Total and Percent Savings for HPWHs



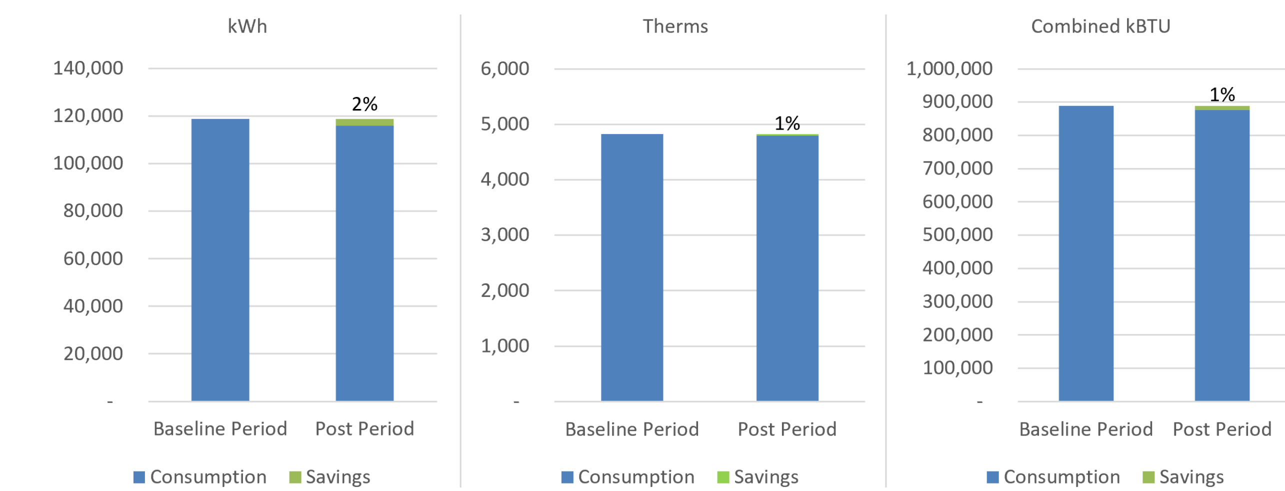
Source: DNV (Modeled)

Induction Cooking

Residential

There were 16 sites that installed residential induction cooktops. Figure 22 shows the total baseline and post-period annual consumption by fuel type and overall for residential induction cooktops. Electric consumption decreased by 2 percent, gas consumption decreased by 1 percent, and overall energy consumption was reduced by 1 percent.

Figure 22: Total and Percent Savings for Residential Induction Cooktops

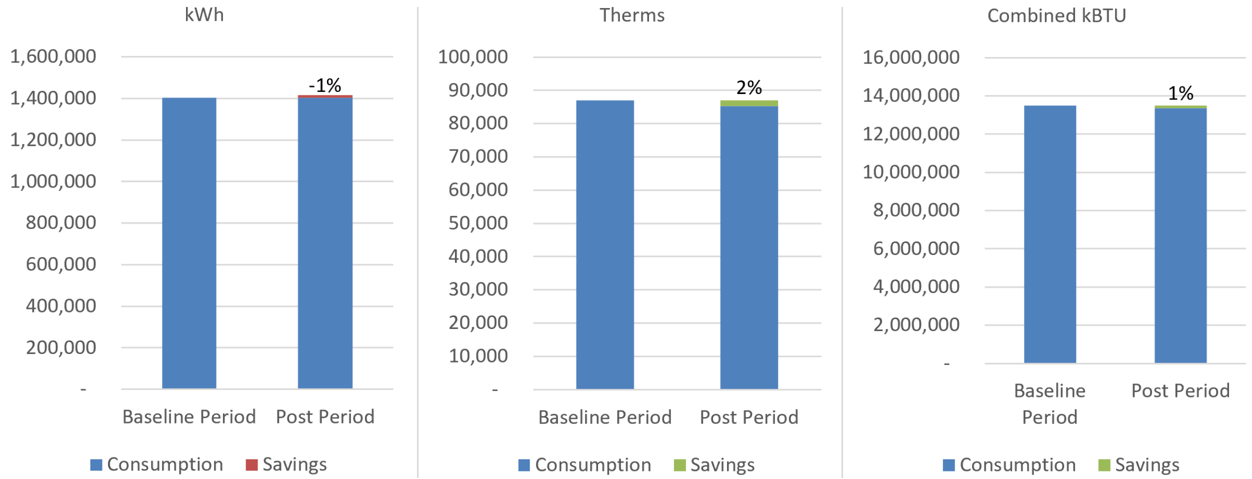


Source: DNV (Modeled and Measured)

Commercial

The Lead Locally Program implemented induction cooktops at two commercial sites. However, one site was dropped from the sample due to lack of a verified installation date. Figure 23 shows the total baseline and post-period annual consumption by fuel type and overall for commercial cooktops. While electric consumption increased by 1 percent, gas consumption decreased by 2 percent, and overall energy consumption was reduced by 1 percent.

Figure 23: Total and Percent Savings for Commercial Induction Cooktops

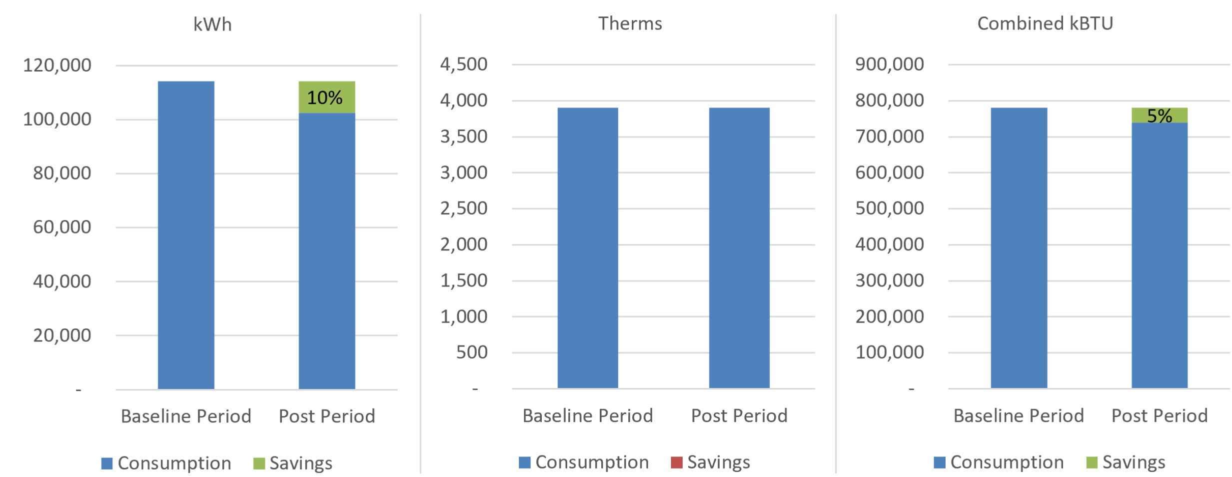


Source: DNV (Modeled and Measured)

Heat Recovery Dishmachines

The Lead Locally Program implemented two commercial heat recovery dishmachine projects that replaced conventional undercounter dishmachines with electric water heaters. Figure 24 shows the total baseline and post-period annual consumption by fuel type and overall for heat recovery dishmachines. As shown, electric consumption decreased by 10 percent and overall energy consumption was reduced by 5 percent. There are no therms savings associated with this project since the systems are electric in both the baseline and post-install cases.

Figure 24: Total and Percent Savings for Heat Recovery Dishmachines



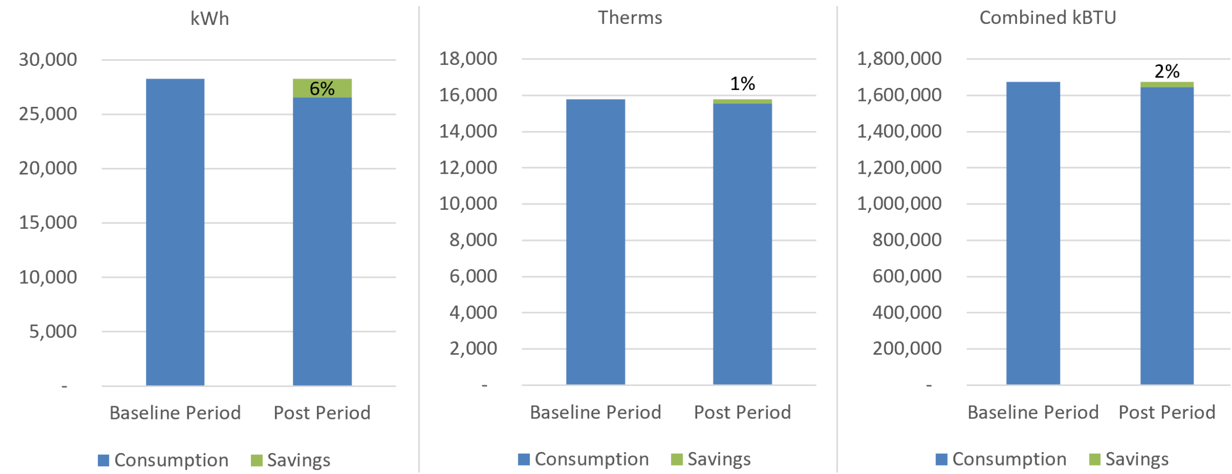
Source: DNV (Measured)

Aerobarrier Envelope Sealing

Aerobarrier sealing was installed at 10 residential sites (six multi-family and four single-family homes). Three of the 10 sites received Aerosol duct sealing in addition to Aerobarrier. Figure

25 shows the total baseline and post-period annual consumption by fuel type and overall for Aerobarrier envelope sealing. Electric consumption decreased by 6 percent, gas consumption decreased by 1 percent, and overall energy consumption was reduced by 2 percent.

Figure 25: Total and Percent Savings for Aerobarrier

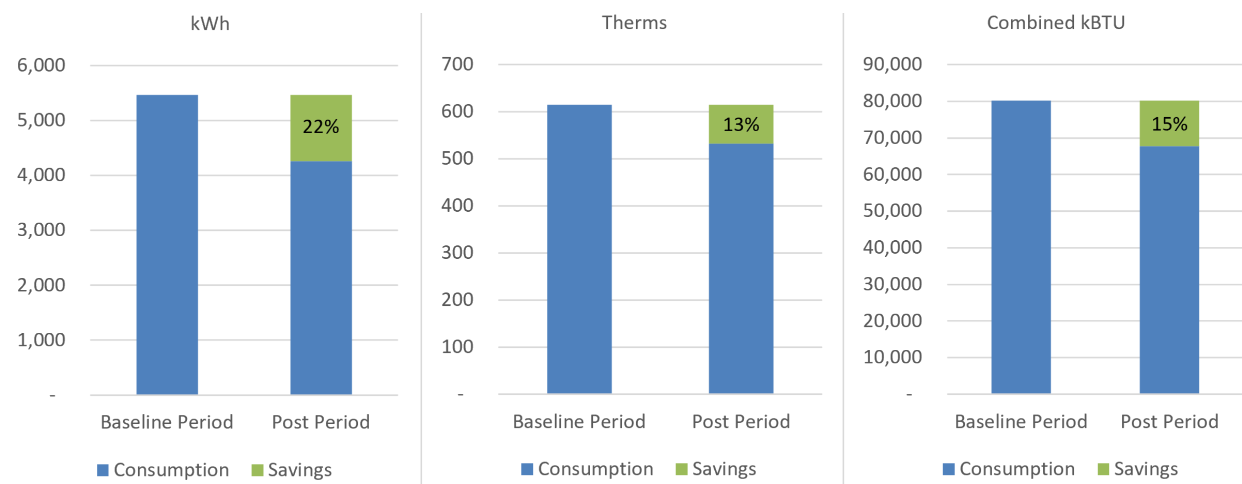


Source: DNV (Modeled)

Radiant Ceiling Panels

The program installed one radiant ceiling panel (RCP) measure, but due to higher than projected installation costs, the program re-allocated funds initially intended for RCP installations. Figure 26 shows the total baseline and post-period annual consumption by fuel type and overall for RCPs. Electric consumption decreased by 22 percent, gas consumption decreased by 13 percent, and overall energy consumption was reduced by 15 percent.

Figure 26: Total and Percent Savings for Radiant Ceiling Panels

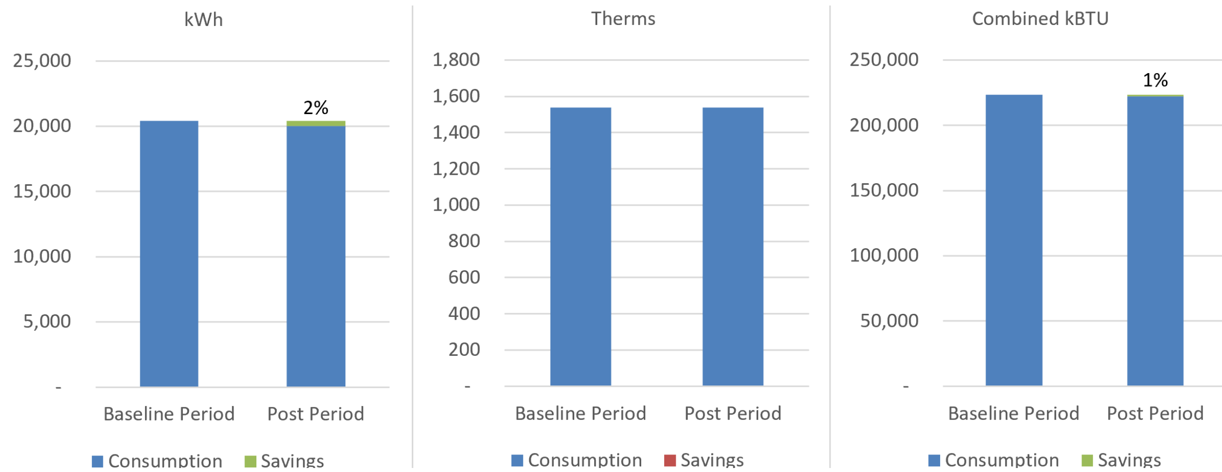


Source: DNV (Measured)

Daylighting

The program implemented tubular daylighting devices (TDD), as well as a lighting control system at two demonstration sites. Figure 27 shows the total baseline and post-period annual consumption by fuel type and overall for daylighting. Electric consumption decreased by 2 percent, and overall energy consumption was reduced by 1 percent. There are no therms savings associated with this project since the systems are electric in both the baseline and post-install cases.

Figure 27: Total and Percent Savings for Daylighting



Source: DNV (Measured)

Phase Change Materials

Residential

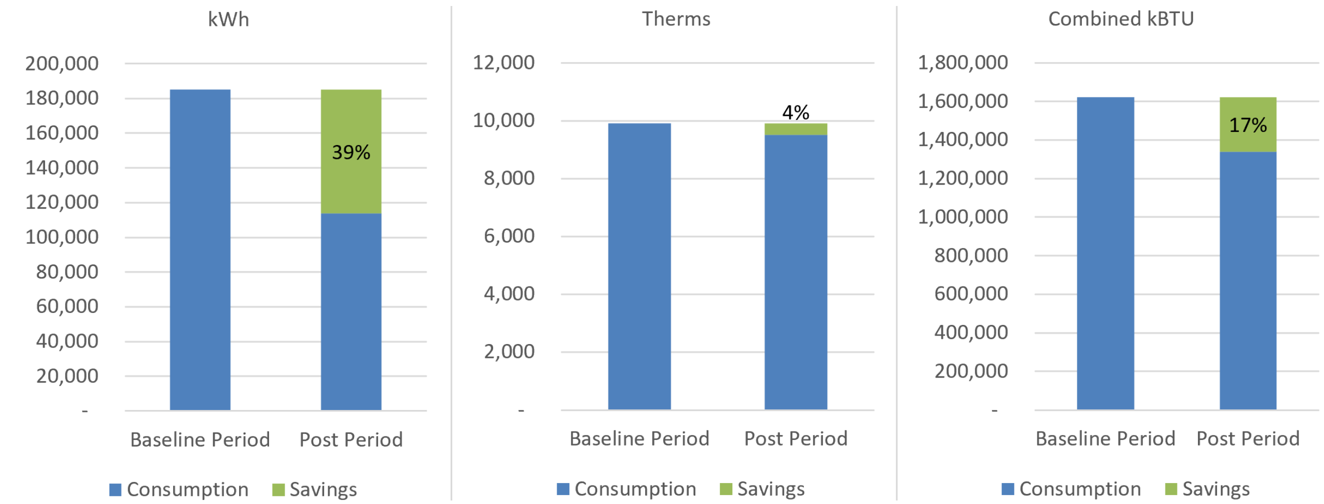
PCMs were installed at five residential sites. However, the PCMs needed to be removed prior to this evaluation due to defective materials (one site did not have PCM removed but had a change in ownership). DNV interviewed two participants and determined how the PCMs performed while they were installed:

- One site indicated that the material started leaking and damaged their ceiling. The whole PCM assembly was removed and the ceiling repaired by Frontier. Frontier has confirmed that all of the residential sites had the PCM removed. The participant noted that there was not any significant change in heating/cooling for the year after the measure was installed.
- The other site confirmed that the PCM was removed about a year after its installation due to its defects. They indicated that prior to removal, their house had better capabilities of retaining its heating and cooling comfort. However, they did not explicitly change their thermostat usage habits.

Commercial

PCMs were installed at six commercial sites. The evaluation analysis was done for three sampled sites and average savings of these three sampled sites were used for three non-sampled sites. Figure 28 shows the total baseline and post-period annual consumption by fuel type and overall for commercial PCMs. Electric consumption decreased by over a third (39 percent), gas consumption decreased by 4 percent, and overall energy consumption was reduced by 17 percent.

Figure 28: Total and Percent Savings for Commercial PCM

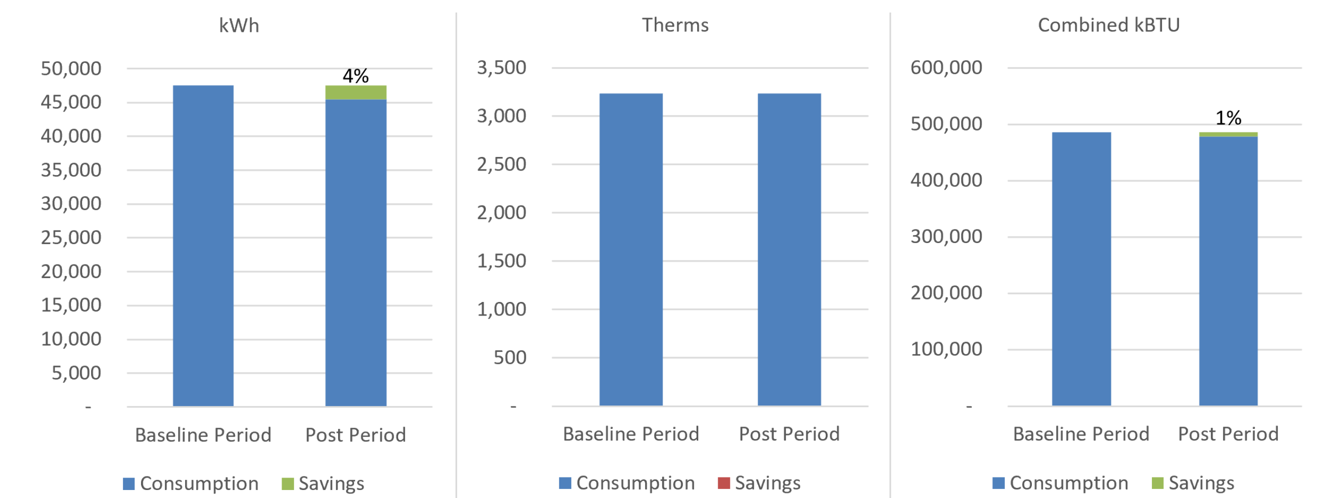


Source: DNV (Measured)

Nighttime Ventilation

Nighttime ventilation (NTV) was installed at 10 customer sites. Figure 29 shows the total baseline and post-period annual consumption by fuel type and overall for NTV. Electric consumption decreased by 4 percent, and overall energy consumption was reduced by 1 percent. There are no therms savings associated with this electric measure.

Figure 29: Total and Percent Savings for NTV

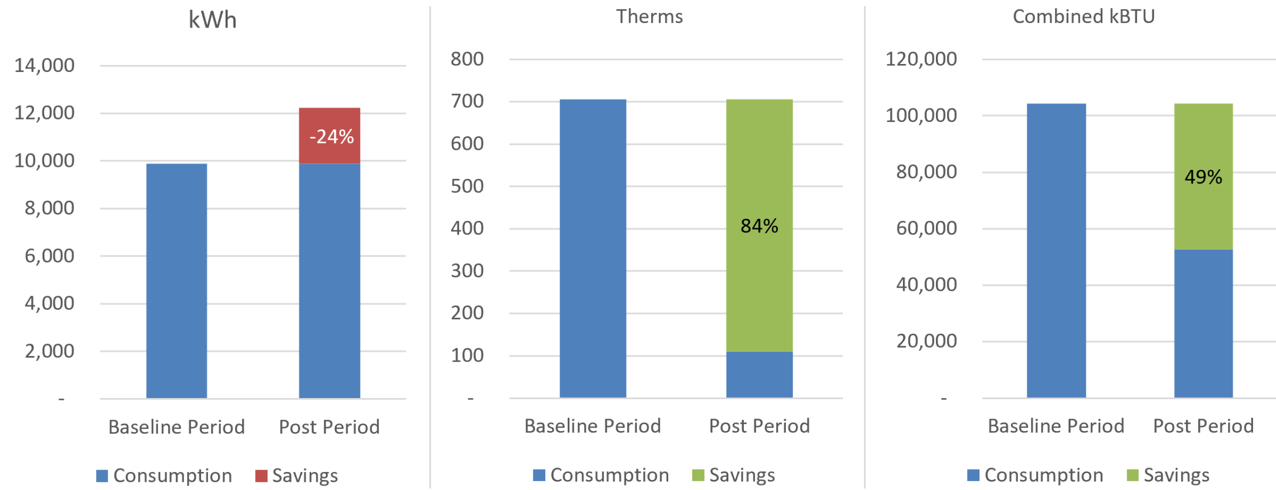


Source: DNV (Modeled)

Hydronic Fan Coil

Two hydronic fan coil and air-to-water heat pump (AWHP) measures were installed for space condition and water heating along with R-49 insulation in the attic and caulking and spray foam interfaces between ceiling joists and drywalls to reduce air leakage. Figure 30 below shows the total baseline and post-period annual consumption by fuel type and overall for hydronic fan coils. While electric consumption increased by almost a quarter, gas consumption decreased by 84 percent, and overall energy consumption was reduced by almost 50 percent.

Figure 30: Total and Percent Savings for Hydronic Fan Coil



Source: DNV (Modeled and Measured)

Greenhouse Gas (GHG) Impacts

DNV estimated GHG impacts associated with Lead Locally Program savings using the "Fuel Substitution Calculator,"[7] an Excel-based tool maintained by the California Public Utilities Commission (CPUC). The output from the calculator provides lifecycle emissions impacts for each technology broken down by electricity, natural gas, and refrigerant. The calculator accounts for refrigerants' equivalent carbon dioxide (CO_2) emissions by assuming its global warming potential (GWP),[8] the amount and type of refrigerant typically contained within common technologies, and the refrigerant leakage rates.

Table 42 shows lifecycle CO_2 emissions reductions for residential technologies in metric tons of carbon dioxide (tCO_2). The largest CO_2 emission reductions come from MSHPs and HPWHs and account for the increase in emissions from refrigerants. Refrigerants inevitably leak over the lifetime of the equipment and contribute to global warming, but do not outweigh the reductions from removing the pre-existing natural gas-consuming equipment.

Table 42: Summary of Residential GHG Emissions Reductions

Technology	# of Tech-nologies	Measure life (years)	Electric lifecycle emissions tCO_2	Natural gas lifecycle emissions tCO_2	Refrigerant lifecycle emissions tCO_2	Total lifecycle emissions tCO_2
Aerosol Envelope and Duct Sealant	10	18	4.8	23.1	0.0	27.9
Heat Pump Water Heater	78	10	-116.5	657.1	-116.6	424.1

[7] https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency

[8] GWP is a measure of a greenhouse gas' time-elapsed impact for global warming relative to CO_2. The GWP of CO_2 is 1. Residential heat pump water heaters implemented in the program use R-134a (GWP of 1,430). MSHPs use R-401A (GWP of 1,182).

Technology	# of Tech-nologies	Measure life (years)	Electric lifecycle emissions tCO_2	Natural gas lifecycle emissions tCO_2	Refrigerant lifecycle emissions tCO_2	Total lifecycle emissions tCO_2
Hydronic Fan Coil with DHW	2	15	-5.9	51.8	-2.5	43.4
Mini-Split Heat Pump	57	15	-143.0	1,232.6	-70.8	1,018.8
Nighttime Ventilation	10	20	6.2	0.0	119.3	125.5
Phase Change Material	5	15	0.0	0.0	0.0	0.0
Radiant Ceiling Panels	1	15	3.0	7.1	0.0	10.2
Residential Induction Cooktop	16	16	7.7	2.7	0.0	10.4
Residential Total	**180**	**N/A**	**-243.7**	**1,974.4**	**-70.6**	**1,660.3**

Source: DNV (Modeled)

Table 43 summarizes the CO_2 emissions savings for the commercial technologies. PCMs account for 70 percent of total emissions savings due to their overall savings magnitude relative to other measure savings and its energy efficiency focus (it is not a fuel substitution measure and does not add refrigerants). The sole commercial induction cooktop installation accounted for 28 percent of reduction in commercial natural gas emissions, highlighting the substantial cooking loads that commercial kitchens serve. This single natural gas cooktop emissions savings of 89 tCO_2 has an estimated lifetime emissions equivalent of 10,000 gallons of gasoline consumed.

Table 43: Summary of Commercial GHG Emissions Reductions

Technology	# of Tech-nologies	Measure life (years)	Electric lifecycle emissions tCO_2	Natural gas lifecycle emissions tCO_2	Refrigerant lifecycle emissions tCO_2	Total lifecycle emissions tCO_2
Commercial Dishwasher	2	12	25.0	0.0	0.0	25.0
Commercial Induction Cooktop	1	12	-22.8	111.5	0.0	88.6
Daylighting Enhancement	2	15	0.9	0.0	0.0	0.9
MSHP	1	15	4.0	58.1	-0.7	61.4
PCM	6	15	179.6	230.8	0.0	410.3
Commercial Total	**12**	**N/A**	**186.7**	**400.4**	**-0.7**	**586.2**

Source: DNV (Modeled)

Non-Energy Impacts

Non-energy impacts (NEIs) include any positive (benefit) or negative (cost) impacts that result from installed program equipment. NEIs were determined by surveying program participants in accordance with the Midterm Questionnaire for Benefits Analysis of EPIC Projects, which includes an evaluation of the impacts related to costs (that is, changes in utility energy bill amounts), increased safety, and public health (for example, indoor air quality).

This section provides a summary of the overall NEIs as well as a breakout of the NEIs for the following three deployment technologies:

- MSHPs
- HPWHs
- Residential Induction Cooking

Summary of Overall Non-Energy Impacts

Program participants were surveyed on the following NEIs:

- Energy bill amount—the total change in energy costs resulting from installed measures
- Indoor air quality—the quality of the air related to indoor air pollutants
- Operations and maintenance costs—the expenses associated with running and maintaining measures over their lifetime
- Safety—the condition of the environment that impacts the well-being of the occupants, such as removing combustion gas equipment
- Thermal Comfort—comfort (for example, building temperatures or hot water availability). This NEI is specific to MSHPs, HPWHs, AeroBarrier envelope sealing, PCM, NTV, and hydronic fan coil equipment
- Noise—the amount of noise that can be heard. This NEI is specific to MSHP, HPWH, NTV, and hydronic fan coil equipment.
- Ability to control temperature—the ability to adjust the temperature of the cooktop when cooking. This NEI is specific to induction cooking equipment.
- Time for stove to heat up—the duration it takes for a cooktop to reach a specific temperature. This NEI is specific to induction cooking equipment.

The number of survey respondents for each technology are shown below:

- Mini-split heat pump (n=16)
- Heat pump water heater (n=22)
- Residential induction cooking (n=9)
- Commercial induction cooking (n=1)
- Aerobarrier envelope sealing (n=2)
- Daylighting (n=1)
- Phase change material (n=2)

- Nighttime ventilation (n=6)
- Hydronic fan coil (n=2)

Figure 31 summarizes the overall NEI survey results:

Figure 31: Cross-Technology Non-Energy Impacts

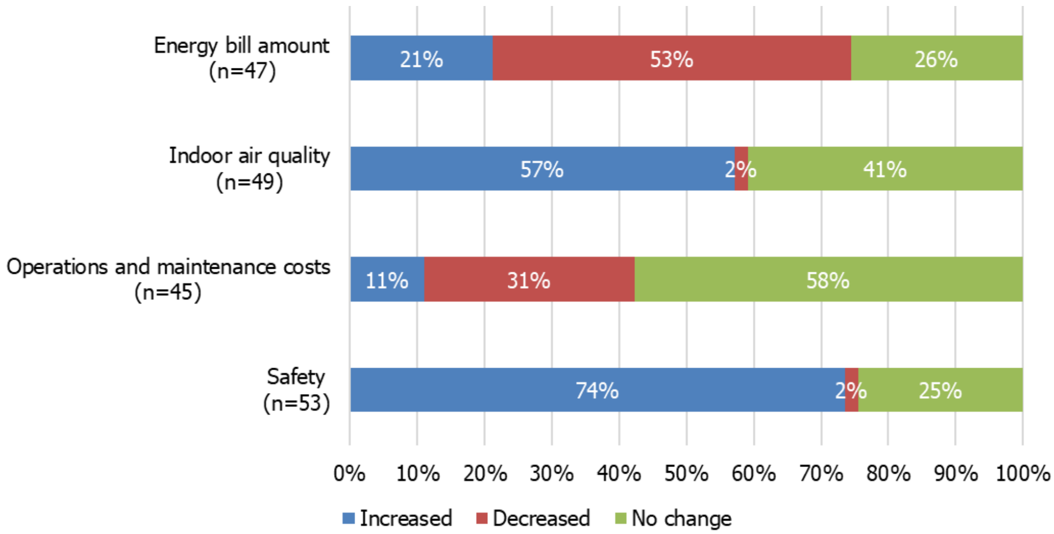


Image Credit: DNV

Energy bill amount

Fifty-three percent of respondents observed a decreased energy bill, 26 percent observed no change, and 21 percent observed an increase to their bill. The participants citing an increased energy bill consisted of 5 HPWH sites, 3 NTV sites, and 2 MSHP sites. NTV sites had increased electricity consumption because they did not previously have air conditioning. HPWHs and MSHPs installed should have noticed an increase in electric consumption and costs, but a decrease in gas consumption and costs. Electricity rates increased by more than 10 percent from 2021 to 2023, while natural gas rates have increased by 70 percent during the same period. Thus, both electricity and gas rates increased, but natural gas rates increased more rapidly during this period.

Indoor air quality

Fifty-seven percent of respondents indicated that indoor air quality increased, and 41 percent reported that they did not experience any changes. Only one respondent who installed a HPWH cited a decrease in indoor air quality but did not provide an explanation.

Operations and maintenance (O&M) costs

Thirty-one percent of respondents indicated decreased O&M costs, 11 percent reported increased O&M costs, and 58 percent cited no change. The respondents citing increases in O&M costs consisted of 2 HPWHs, 2 MSHPs, and 1 NTV site.

Safety

Seventy-four percent of respondents observed safety-related benefits, 25 percent observed no change, and only one respondent cited decreased safety. The single respondent who reported a decrease in safety had installed a MSHP but did not provide an explanation.

Non-Energy Impacts by Technology

Mini-Split Heat Pumps

The NEI survey results for MSHPs are summarized below in Figure 32.

Figure 32: Non-Energy Impacts Associated with Mini-Split Heat Pumps

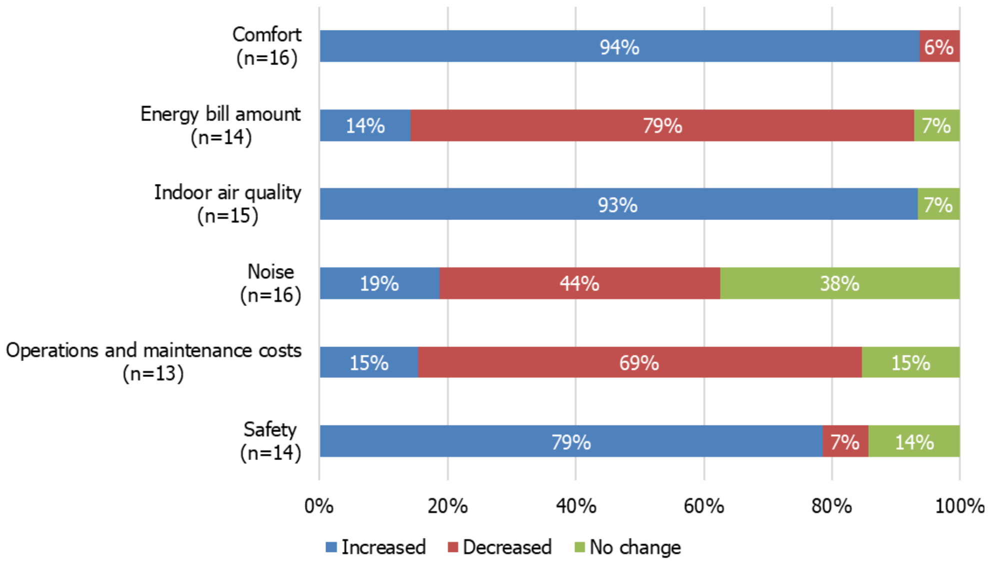


Image Credit: DNV

Comfort

Ninety-four percent of MSHP respondents reported increased comfort, and only one respondent reported decreased comfort. Explanations for how their comfort increased are as follows:

- "I now have cooling, which is amazing. I also run the heat at whatever temp keeps us comfortable rather than skimping."
- "The heat pump provides a much more comfortable temperature versus our old gas furnace. We heat or cool only the rooms we are in, so we save energy costs."
- "Able to heat the house to comfortable temperature before lighting the wood stove."
- "Better temperature management and consistency."

The one respondent who reported their comfort decreased explained that they "should have installed one more mini-split in my living room. Skipped that room and that was a mistake."

Energy bill amount

Seventy-nine percent of respondents stated their energy bill decreased, two participants reported an increase, and one participant reported no change. No explanations were provided for bill increases. Explanations for bill decreases include:

- "Decreased significantly and did not spike during recent increases in costs of fossil gas."
- "[I] can turn off the gas system when in bathroom addition/bedroom."
- "Cut bills by more than half."
- "Marked decline in electric bills when used in combo with solar."

Indoor air quality

Thirteen out of 14 respondents reported an increase in indoor air quality, and one respondent reported no change. Explanations for how indoor air quality increased include:

- "Both reduced emissions from old gas heaters, and from delay in lighting the wood stove."
- "No furnace / hot metal smells."
- "With cooling, I can close the house on smoky days."
- "Not as dry. Gas system creates drafts and dry air."
- "No noxious fumes."

Noise

Forty-four percent of respondents stated the noise in their house decreased, 38 percent reported no change, and three respondents reported an increase in noise. Explanations include:

- Decreased noise
    - "The system is virtually silent...love it!"
    - "Much quieter than forced air."
    - "Noise level decreased because the mini-split heat pump is very quiet."
- Increased noise
    - "Have to say the mini-split system is a bit noisy."

Operations and maintenance costs

Sixty-nine percent of respondents reported a decrease in O&M costs, 15 percent reported increased O&M costs, and 15 percent respondents reported no change. Explanations include:

- Decreased O&M costs
    - "No methane gas costs. Filter can be cleaned without having to replace it."
    - "Heat pump costs less to run than space heaters!!"
    - "The heat pump is efficient. [I] only have to run central system during winter days; evenings we use the remodeled part of the house."

- Increased O&M costs
    - "Ongoing costs increased slightly with higher quality air filters, but that is a trade I happily make for the air quality my family experienced."

Safety

Seventy-nine percent of respondents indicated significant safety benefits, two respondents reported no change to safety, and one indicated a decrease in safety. No explanation was provided by the single respondent who reported a decrease in safety. Explanations for increased safety include:

- "Turning off methane gas service means better air quality and no gas issues."
- "Fire risk is minimized due to removal of gas from home."
- "No more concerns about gas leaks."

Heat Pump Water Heaters

The NEI survey results for HPWHs are summarized in Figure 33.

Figure 33: Non-Energy Impacts Associated with Heat Pump Water Heaters

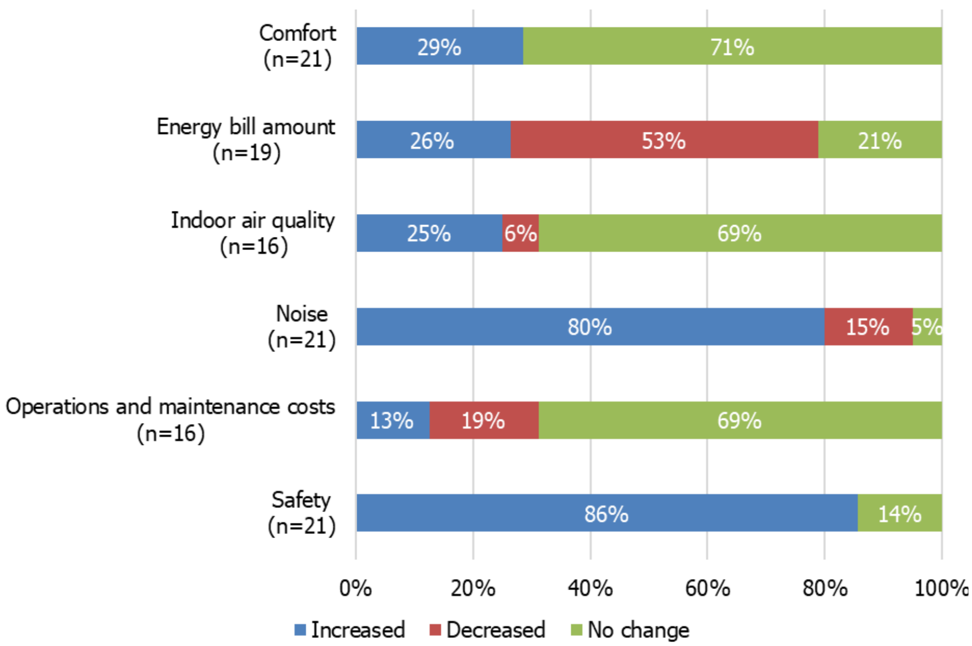


Image Credit: DNV

Comfort

Seventy-one percent of respondents stated that their comfort had not changed, and 29 percent indicated their comfort increased. Explanations for how their comfort increased include:

- "Hot water doesn't run out - and garage is cooler!"
- "More hot water overall."
- "Water is hotter."

Energy bill amount

Fifty-three percent of respondents stated their energy bill decreased, 26 percent indicated an energy bill increase, and 21 percent saw no change. Explanations include:

- Decreased energy bill amount -
  - "Decreased $45 per month."
  - "Gas bill has decreased to almost $0."
  - "[My Energy bill] decreased by $20."
  - "Hard to say, but it went down slightly."
- Increased energy bill amount -
  - "Huge increase in electricity use. No way to shift this to cheapest times—eventually installed solar to compensate."
  - "[My Energy bill] increased by $5." (n=2)
  - "More expensive than using gas."

<u>Indoor air quality</u>

Sixty-nine percent of respondents stated that there was no change related to indoor air quality, 25 percent observed an increase in indoor air quality, and one respondent reported a decrease in indoor air quality. No explanation was provided by the respondent who reported a decrease in indoor air quality. Explanations for improved indoor air quality include:

- "Less burning gas smell in general."
- "Reduced gas combustion"
- "Not burning gas indoors is supposedly better for health."

<u>Noise</u>

Eighty percent of respondents stated that the noise in their house increased, 15 percent of respondents reported it decreased, and one reported no change. Explanations include:

- Decreased noise
  - "[The heat pump water heater was] quieter than I imagined."
  - "Nearly zero noise with new system."
- Increased noise
  - "The heat pump water heater is noisier than the gas water heater it replaced, but we relocated it to the garage, so the noise increase is minimal."
  - "Heat pump water heater is noisier, but only in the garage."
  - "Noise level increased from HP Water Heater. After time I don't notice it."
  - "That heat pump water heater is pretty dang noisy."
  - "It is noisy, even with mitigations. It's [a] model everyone complains about being noisy."

Operations and maintenance (O&M) costs

Sixty-nine percent of respondents reported no change to their O&M costs, 19 percent reported a decrease in O&M costs, and two reported an increase. Explanations include:

- Decreased O&M costs:
  - "Lower power usage."
  - "New unit, so less to worry about."
- Increased O&M costs
  - "It will cost more to have water heater serviced professionally, since I cannot do it DIY."

Safety

Eight-six percent of respondents reported an increase in safety, and 14 percent reported no change to safety. Explanations include:

- "After replacing the gas water heater and gas furnace with electric appliances, we removed our gas meter. Our risk of fire from natural gas is basically zero now."
- "Fewer access points of gas coming into house."
- "Reduced gas combustion."

Residential Induction Cooking

The NEI survey results for induction cooking are summarized in Figure 34.

Figure 34: Non-Energy Impacts Associated with Residential Cooking Equipment

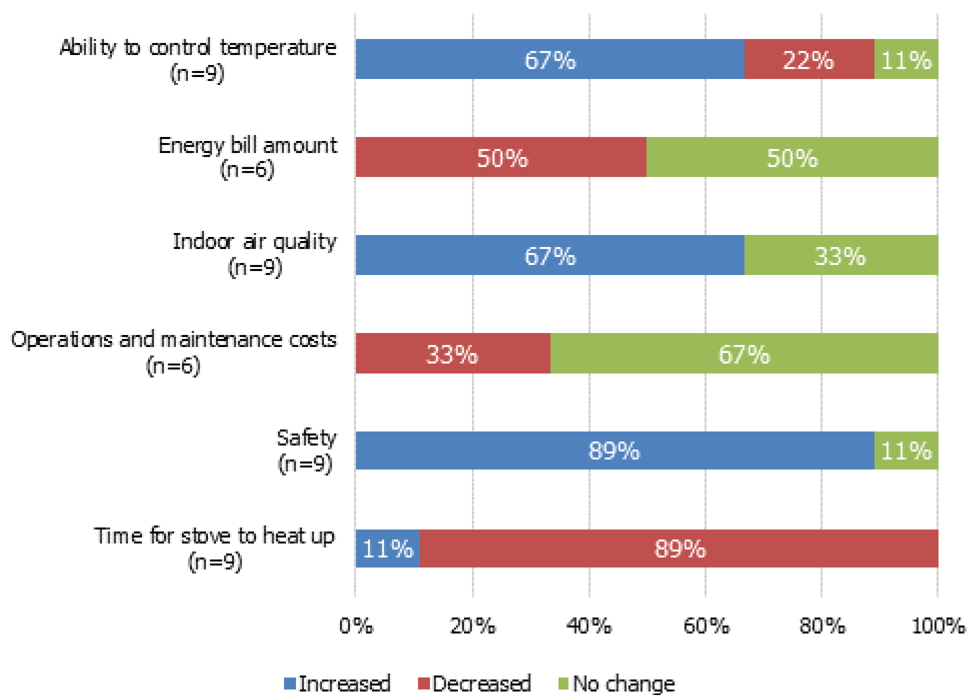


Image Credit: DNV

Ability to control temperature

Sixty-seven percent of respondents reported that their ability to control the temperature has increased, 22 percent of respondents cited a decreased ability to control temperature, and one respondent reported no change. Explanations include:

- Increased ability to control temperature
  - "Exceptional incremental temperature control using induction cooking technology."
  - "I have learned how to precisely control temp with induction."
  - "Induction cooktop is easier to control temperature."
  - "We have much better temperature control."
- Decreased ability to control temperature
  - "Despite selecting a fairly high-end appliance, the digital controls do not give the precise temperature control that the gas knobs did."
  - "Temperature control is a little inconsistent."

Energy bill amount

Fifty percent of the respondents stated that their energy bill decreased, and the other 50 percent reported no change to their energy bill amount. Explanations include:

- "Switched from gas to electric, which uses solar power from our panels and batteries, so cost to operate became negligible."
- "Less on gas bill."

Indoor air quality

Sixty-seven percent of respondents reported increased indoor air quality, and the remaining 33 percent of respondents reported no change to indoor air quality. Explanations include:

- "No more burning gas inside house."
- "We do not burn foods nor overcook them as much as before."
- "We eliminated gas from inside our house."

Operations and maintenance (O&M) costs

Thirty-three percent of respondents cited a decrease in O&M costs, and 67 percent reported no change to their O&M costs thus far. Explanations include:

- "Old stove was at end of its life and requiring maintenance."
- "The equipment to-date has been 100 percent completely reliable with no issues or downtime."

Safety

Eighty-nine percent of respondents reported an increase in safety, and one respondent indicated there was no change to safety. Explanations include:

- "The cabinet under our gas cooktop always smelled like gas, and a few burners would not light without help from a lighter. We feel MUCH safer with the induction cooktop now."
- "Gas stove fumes have been eliminated."
- "No more pilot light constantly running."
- "No radiant heat."

Time for cooktop to heat up

Eight-nine percent of respondents reported a decrease in the time for their cooktop to heat up, and one respondent reported an increase in time. Explanations include:

- Decreased time for cooktop to heat up
    - "Water boils in just a minute or two, which has to be at least a 5x improvement."
    - "Vastly improved heat-up and overall cooking experience. Induction cooking technology (once we upgraded to new stainless-steel cookware) is absolutely a joy to use."
    - "Induction cooktop is very quick."
- Increased time for cooktop to heat up
    - "Gas is instant, induction cooktop is not."

Program Experience

Contractors and participants were surveyed on their experience with the program regarding awareness of their participation in the program, motivations to participate, program satisfaction, barriers to participation, and suggestions for program improvements.

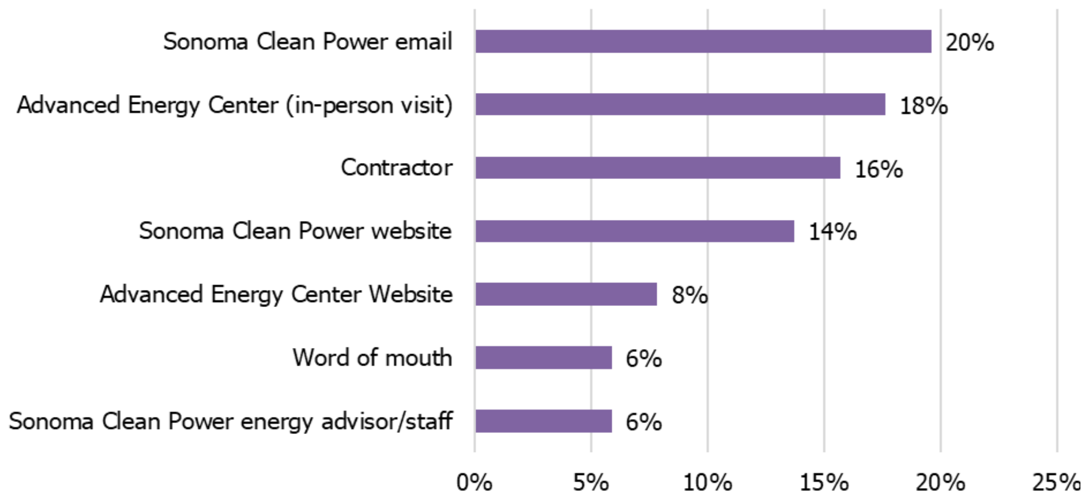
Awareness

Ninety-five percent of respondents still had an active residential account with SCP, and 97 percent recalled that they had equipment installed through the program. Two residential customers did not recall having equipment installed and were subsequently dropped from the survey.

Figure 35 shows how 51 survey respondents learned about the Lead Locally Program. Twenty-two percent learned about the program through the SCP or AEC website, 20 percent through an SCP email, 18 percent through an in-person visit to the AEC, and 16 percent through a contractor.

Figure 35: How Participants Heard About the Lead Locally Program

(n=51 respondents)



Additional responses included: Sonoma Clean Power direct mail / outreach (2 percent), Sonoma Clean Power bill insert (2 percent), Lead Locally marketing collateral / signage (2 percent), and 'other' reasons (8 percent).

Image Credit: DNV

Motivation To Participate

Figure 36 shows the survey respondents' primary motivations to participate. Thirty-nine percent of respondents reported reducing carbon emissions as the primary reason for participating in the program, and 36 percent of respondents reported saving energy/money as their primary motivation.

Figure 36: Primary Motivations to Participate

(n=59 respondents)

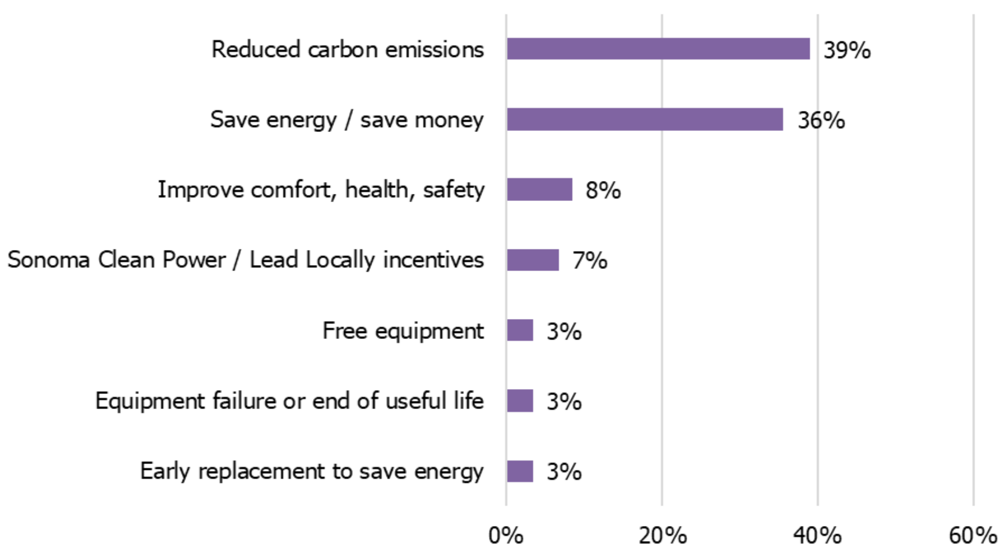
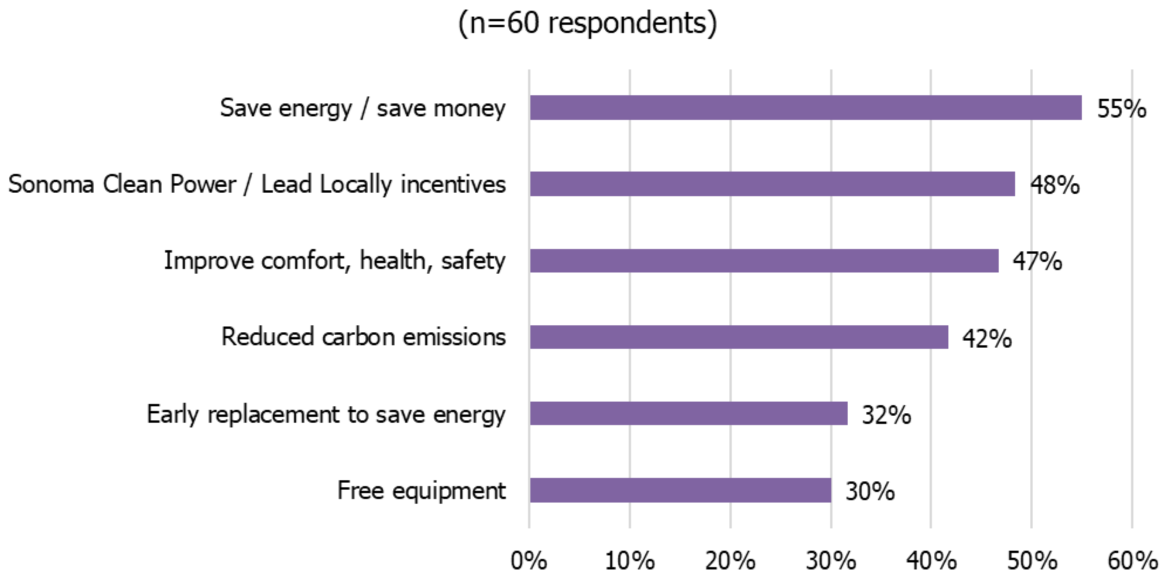


Image Credit: DNV

Figure 37 shows respondents' other motivations to participate. Fifty-five percent cited saving energy/money, 48 percent cited incentives, 47 percent mentioned comfort/health/safety, and 42 percent cited reducing carbon emissions.

Figure 37: Additional Motivations to Participate



Totals exceed 100 percent because multiple responses were accepted. Additional responses included: equipment failure or end of useful life (13 percent), renovation or remodel (8 percent), and recommendation from a contractor (7 percent).

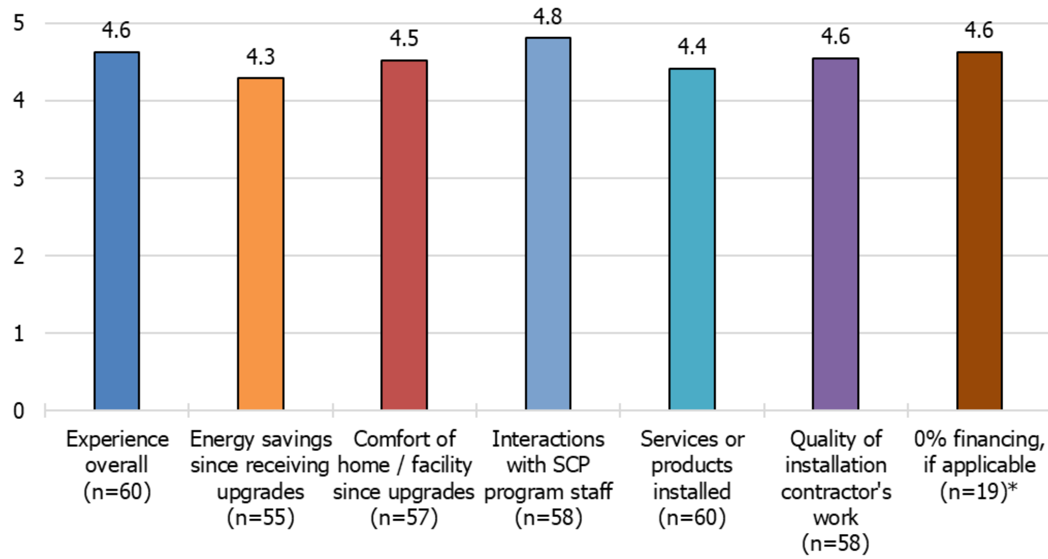
Image Credit: DNV

Program Satisfaction

Figure 38 highlights key satisfaction results of the respondents' program experiences, with the remaining results detailed in Appendix D. Program satisfaction survey questions used a five-point Likert scale, where 5 meant "very satisfied" and 1 meant "very dissatisfied."

Respondents reported an average satisfaction score of 4.6 out of 5. Respondents were most satisfied with interactions with SCP program staff (4.8). Energy savings related to the program received the lowest satisfaction rating (4.3). While this is a relatively high average satisfaction rating, customers may have been negatively impacted by increases in the cost of electricity.

Figure 38: Customer Satisfaction



Only residential program participants were asked to rate their satisfaction of 0 percent financing, where applicable.

Image Credit: DNV

Despite the high average satisfaction scores, 26 percent of residential respondents and 33 percent of commercial respondents rated at least one of the distinct program aspects below 3 on the Likert scale. Reasons for their dissatisfaction included:

- "The nighttime ventilation system is not very effective in general. It's a little bit quicker than opening windows, but not by much. I had hoped it would be a way to cool the house during fire season without opening windows, but it pulls smoky air into the house, so cannot be used that way."
- "Few contractors approved and little or no coordination with other incentive programs and their approved contractor lists…[the] water heater [was] not well engineered, controls are a "black box" and customer service was poor. Water heater schedule is lost if internet connection fails – [the] schedule is in the cloud."
- "Not satisfied with the work performed. Contractor was supposed to seal the house but left a large area unsealed." (Aerobarrier envelope sealing)
- "Material was defective. Ruined my ceilings. Needs extensive repair." (PCM)
- "Very unhappy with the heat pump hot water system itself… The Wi-Fi interface is nonfunctional because of my rural hotspot driven internet connection, a feature the manufacturer only revealed after the heater was installed and we spent almost 6 hours waiting for tech support on the phone."
- "The installation of the electric heat pump water heater has not resulted in a reduction in our energy bill. Our gas bill is lower, but the electric bill is higher."

- "The overall process was clunky, a little mismanaged by both the contractor and SCP. I had a lot of different estimates, and the pricing on some was absurd – this was a fairly straight forward job overall." (HPWH)

Figure 39 summarizes the most frequent open-ended responses to what aspects of the program went well. Thirty-one percent of respondents indicated that everything went well, 21 percent reported that their experience with the contractor/technician went well, and 21 percent reported that their experience with the program staff went well. Responses in the "Other" category included getting more contractors in the program and linking contractors with installers.

Figure 39: What Aspects of the Program Went Well According to End Users

(n=42 respondents)

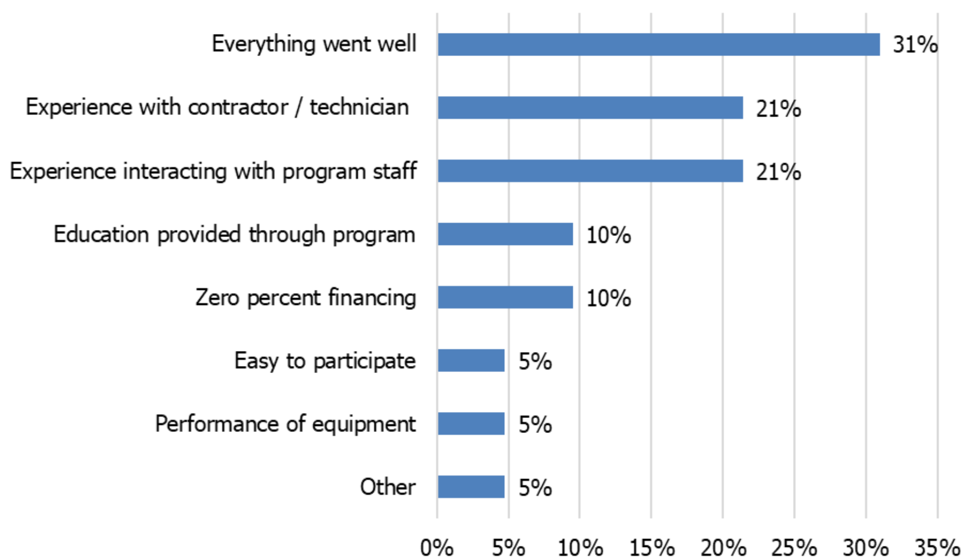


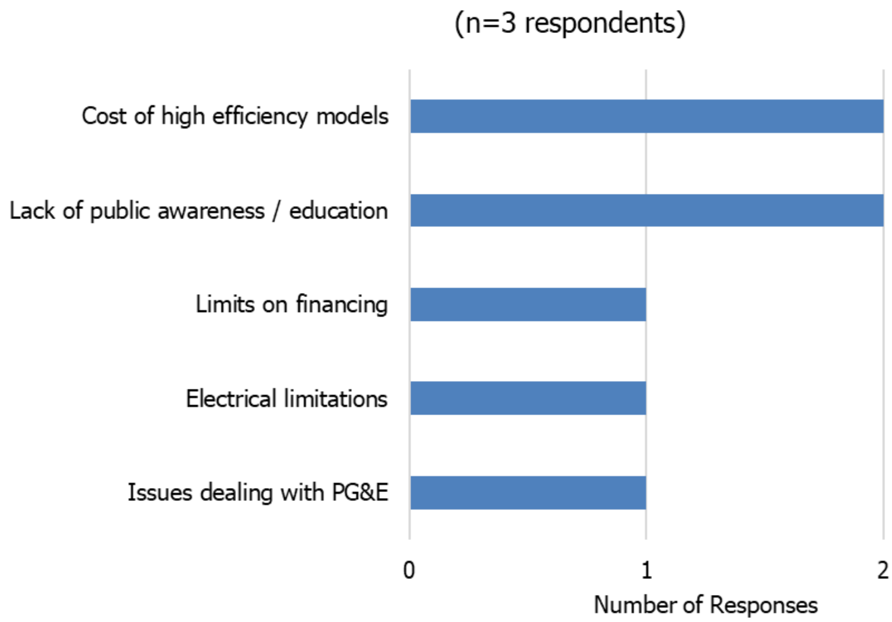
Image Credit: DNV

Barriers

Participating contractors were surveyed regarding barriers to selling high-efficiency equipment. Figure 40 shows the results. Two of the three respondents stated that the higher cost of high-efficiency models was a barrier, although one of these contractors noted that the incentives and financing help overcome the higher costs. Two contractors cited lack of public awareness and education as a barrier. Less commonly reported barriers included the $10,000 limit on financing,[9] electrical limitations, and issues dealing with PG&E.

[9] The respondent who stated the $10,000 limit on financing was a barrier to selling high-efficiency equipment further explained that the limit should be raised to $20,000 to $30,000.

Figure 40: Contractor-Reported Barriers to Selling High Efficiency Equipment



Multiple responses were accepted from each contractor respondent.

Image Credit: DNV

Opportunities for Improvement

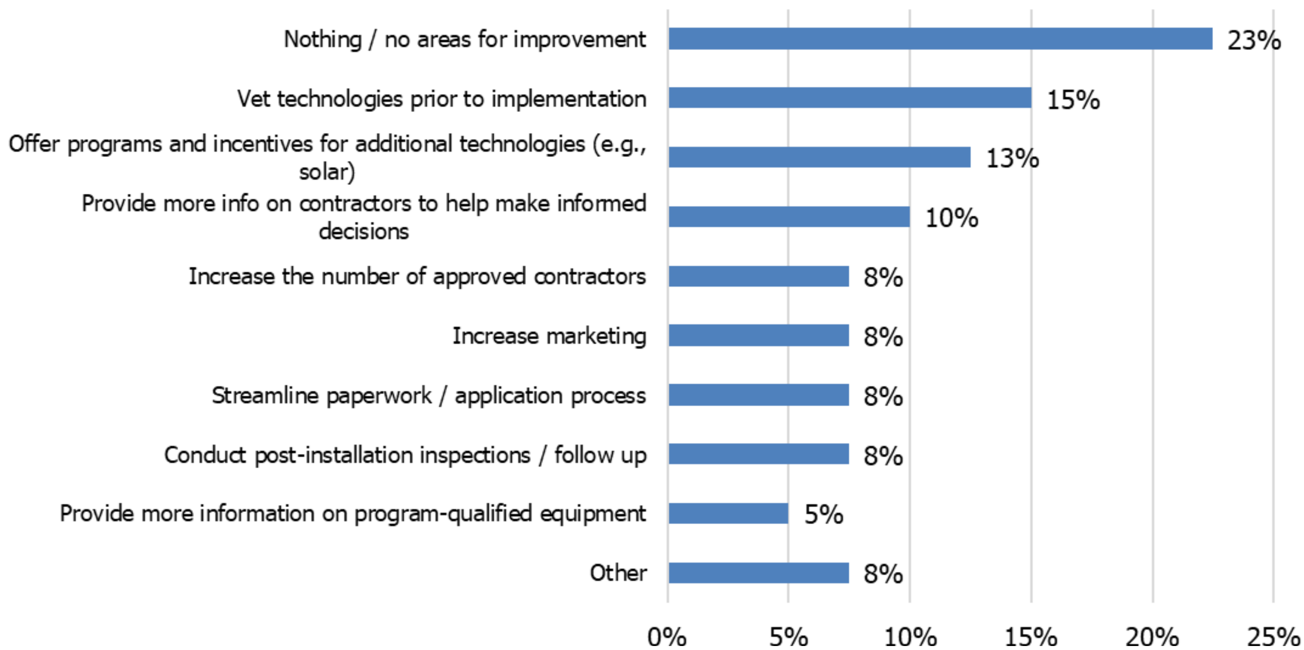
Contractors provided the following responses to opportunities for improvement:

- "SCP should get involved in new construction. Build everything using an advanced framing technique (that is, two-foot center on two header detail, windows no king stud/trimmer). There are no pre-approved plans for it."
- "Expand [the Lead Locally] program to include incentivizing flooring contractors to caulk and seal leak as another energy saving measure; the gap in between sheet rock and framing is not airtight when assembled."
- "Not really [any areas for improvement]. Overall, it seems to be run really well."

Residential and commercial customers were also surveyed for suggestions for improvement as shown in Figure 41. Twenty-three percent of respondents stated that they did not have any suggestions for program improvements. The three most frequently cited areas for improvements were to vet technologies prior to implementation (15 percent), offer programs and incentives for additional technologies such as solar (13 percent), and provide more information on contractors to help end users make informed decisions (10 percent).

Figure 41: End User Reported Opportunities for Program Improvements

(n=40 respondents)



'Other' suggestions for program improvements included: a) allowing customers to make partial lump sum payments on the 0 percent interest loans, b) restructuring the incentives program design to ensure incentives result in real world savings for customers as opposed to incentives for local businesses, and c) ensuring there is advice on how to use/manage the new high-efficiency equipment.

Image Credit: DNV

CHAPTER 6: Conclusion

Lead Locally has successfully achieved its main purpose to accelerate the adoption of energy efficiency and decarbonization technologies in existing residential and commercial buildings, driven through SCP's Advanced Energy Center (AEC). The most important conclusions and lessons learned from the program are the following:

- Lead Locally met its primary goal of retrofitting over 300,000 square feet of existing building space and met the efficiency goal of 10 percent savings in residential buildings while falling short on the 20 percent savings goal for commercial sites.
- Rebates and on-bill financing, combined with outreach and education through the AEC, were effective tools for expanding the number of retrofit projects in SCP service territory.
- Mini-split heat pumps and heat pump water heaters drove overall program savings and accounted for 95 percent of energy savings among residential customers.
- Among the emerging technologies evaluated through applied research efforts, aerosol sealing, nighttime ventilation, mini-split heat pumps, air-to-water heat pumps, and heat pump water heaters show the greatest potential in the near-term, especially if combined with financial incentives to increase their cost-effectiveness for building owners.
- Contractor availability and training remain a barrier for reducing the cost of installing many new energy-efficient and all-electric technologies.
- Persuading commercial building owners to take action, even when retrofits were offered free of charge, was extremely challenging. Further investment in creative methods for generating action in this sector will be required in the future.

Key Results

We provide a summary of energy savings, peak demand reduction, and GHG lifecycle emissions reductions for the residential sector in Table 44. A summary for the commercial sector is provided in Table 45.

Table 44: Residential Savings, Peak Demand, and GHG Emissions Reductions

Technology	Number Installed	Percent Change kWh	Percent Change Therms	Percent Change kBtu	Peak Demand Reduction (kW)	Total Lifecycle Emissions tCO_2
Aerosol Envelope and Duct Sealant	10	6%	1%	2%	-	28
Heat Pump Water Heater	78	-12%	38%	19%	-6.2	424

Technology	Number Installed	Percent Change kWh	Percent Change Therms	Percent Change kBtu	Peak Demand Reduction (kW)	Total Lifecycle Emissions tCO_2
Hydronic Fan Coil with DHW	2	-24%	84%	49%	-	43
Mini-Split Heat Pump	57	-15%	64%	34%	-24.5	1,019
Nighttime Ventilation	10	4%	0%	1%	-	126
Phase Change Material (PCM)	5	-	-	-	-	0
Radiant Ceiling Panels	1	22%	13%	15%	-	10
Residential Induction Cooktop	16	2%	1%	1%	-	10
Residential Total	**180**	**-12%**	**39%**	**23%**	**-**	**1,660**

Table 45: Commercial Savings, Peak Demand, and GHG Emissions Reductions

Technology	Number Installed	Percent Change kWh	Percent Change Therms	Percent Change kBtu	Peak Demand Reduction (kW)	Total Lifecycle Emissions tCO_2
Commercial Dishwasher	2	10%	0%	5%	2.2	25
Commercial Induction Cooktop	1	-1%	2%	1%	-3.4	89
Daylighting Enhancement	2	2%	0%	1%	-	1
Mini-Split Heat Pump	1	13%	92%	64%	2.4	61
Phase Change Material	6	39%	4%	17%	-	410
Commercial Total	**12**	**4%**	**3%**	**3%**		**586**

A summary of additional key findings and conclusions is provided in Table 46.

Table 46: Additional Key Findings and Conclusions

Research Topic	Findings/Conclusions
Summary of Energy Savings	The 166 sites over 305,000 square feet that were evaluated for energy savings achieved the following results: • Annual energy savings > 2.7 million kBtu (814,000 kWh equivalent). • 11% reduction in annual site-level energy consumption overall. • 23% reduction in residential site annual energy consumption, which far exceeded the grant goal of 10%. • 3% reduction in commercial site annual energy consumption, which fell short of the grant goal of 20%. • Phase change materials accounted for 54% of energy savings among commercial sites.

Research Topic	Findings/Conclusions
Greenhouse Gas Impacts	The 166 sites over 305,000 square feet that were evaluated for energy savings achieved the following results: • 2,250 tCO_2 reduction in lifecycle carbon emissions (equivalent to 500 gasoline passenger cars driven for one year or 284 homes' energy use for one year). • Mini-split heat pumps and heat pump water heaters contributed to 67% of the total lifecycle GHG reduction.
Technology Evaluations	• More than 20 emerging retrofit technologies were evaluated in the laboratory or in field applications, which included 62 field test sites. • Three technologies were eliminated from further evaluation during the lab testing stage. Efficiency optimizing controls for HPWHs were not yet available in a commercial product; automated louvers for window blinds did not perform with enough reliability; and fiber optic daylighting was deemed too expensive and had issues with lighting quality. • Energy cost savings per technology ranged from -3% to 64% with paybacks ranging from immediate to 1,000 years (or no payback at all). • Several technologies showed great promise for future deployment, including aerosol sealing, nighttime ventilation, mini-split heat pumps, air-to-water heat pumps, and heat pump water heaters. Others require further technology development or lower installation costs. • Energy savings for emerging technologies were highly application dependent, depending on initial conditions of the building and mechanical equipment and the comfort preferences of the occupants. • Fuel substitution technologies were cost-effective if the improvement in efficiency overcame the cost of electricity, or if a PV system was present.
Deployment	• Over \$3.1 million in incentives and over \$1.35 million in on-bill financing were provided to SCP customers to stimulate deployment. • More than 1,390 incentives were issued and 174 projects were on-bill financed. • Strategic incentives and on-bill financing helped increase customer access to energy efficiency and decarbonization technologies. • The AEC and website provided awareness and education as well as connected customers with contractors who could install deployment technologies.

Research Topic	Findings/Conclusions
Knowledge Transfer	• The AEC hosted over 10,000 visitors and hosted over 120 events. • The AEC website received 241,722 page views as of November 2023. • Lead Locally partners have made presentations at technical conferences and conducted direct meetings with numerous stakeholders to discuss the project. • Technologies and program strategies provided valuable strategies to help local governments, residents, and businesses in other California climate zones deliver on the state's energy efficiency and renewable energy goals. • Field trips and tours of the AEC provided opportunities to reach out to students from historically underserved populations and get them excited about working in the energy efficiency field.
Non-Energy Impacts	• Non-energy benefits resulting from Lead Locally included lower energy bills, increased safety, and improved indoor air quality. • 53% of survey respondents cited a decrease in their energy bills, and 57% reported increased indoor air quality. • Almost three-quarters of respondents reported an increase in safety following the installation of Lead Locally measures.
Program Experience	• 22% of survey respondents reported learning about the program through the SCP or AEC website, and 20% learned about the program through an SCP email. • Satisfaction ratings were high for all program experience categories (average of 4.6 out of 5), and end users were most satisfied with interactions with SCP program staff (4.8 out of 5).

Source: Frontier Energy and DNV

Lessons Learned

The project team encountered a range of challenges that had to be overcome for successful implementation of Lead Locally and learned valuable information that can be used for future research, demonstration, and deployment programs sponsored by CEC. Those lessons learned are summarized in the following sections.

Test Site Recruitment

Recruiting residential sites was straightforward, and an adequate number of sites was secured early in the program, but recruiting commercial sites proved more challenging. Despite providing full financial support, a lead time of at least 6 to 12 months was necessary to recruit commercial sites to participate due to the time it takes a commercial business to plan for a large-scale construction project with minimal disruption. Business shutdowns during the COVID-19 pandemic also interfered with the ability to perform site visits and meet with business owners. Recruitment of commercial and public sites was easier when the project champion for the company was also the building owner.

Because it was difficult to recruit test sites based on required building attributes, there were few opportunities to target underserved communities specifically. However, a local junior college with a minority enrollment of 56 percent was a key partner in the program. In addition, several of the subcontractors were minority-owned or included skilled workers from minority populations.

Technology Installation

Field demonstrations of new technologies and technology applications are critical to identifying barriers to larger scale deployment, such as site design challenges impacting standardized installation, and needs for contractor and workforce training to increase adoption of best installation practices. Close collaboration between SCP, Frontier, manufacturers, and installers was essential for selecting quality field test sites, along with finding supportive building owners. This collaboration ensured the retrofits were installed and monitored effectively, and addressed issues immediately once they were identified. The permitting process, including Title 24 compliance, was sometimes difficult for unfamiliar technologies where building codes and equipment standards were ambiguous. For example, compliance inspections for home retrofits using nighttime ventilation were treated differently by different inspectors, in one case adding time and cost to address issues that may not have in fact been necessary. This is indicative of a lack of clear and/or consistent compliance guidelines. Early engagement with local code officials helped identify and resolve potential barriers to code compliance and enforcement. An example is residential PCM, where the building department in Santa Rosa informed the project team that PCM was considered insulation, and a permit was not required. In Sonoma, a permit would have been required if the PCM was under the insulation but not if installed above the insulation.

Trained contractors were readily available for some technologies (such as induction cooking and HPWHs), but others required further infrastructure development to reduce installation costs (PCM, Aerobarrier, nighttime ventilation, ducted mini-splits). It was also difficult to find contractors interested in learning about new technologies, because they generally had a backlog of customers interested in their existing line of product and service offerings. Incorporating budget flexibility to accommodate additional, often unforeseeable costs—such as prevailing wage requirements, time allotted to subcontractors to learn unfamiliar technologies, and federal tariffs on product and materials imports—is important for programs that aim for deployment of innovative technologies.

Monitoring and Analysis

Unexpected challenges related to monitoring and evaluating technology performance arose for several sites that were difficult to predict and overcome. For example, COVID-19 impacts on residential occupancy schedules and business operations made reliable calculation of pre-retrofit energy usage extremely difficult. Building simulations or use of utility data from two years earlier were sometimes necessary to establish a meaningful baseline. In addition, leaking PCM mats in residential attics caused damage to the ceiling and attic insulation, requiring removal of PCM from all residential sites and significant remediation efforts.

Deployment and Outreach Initiatives

Technology deployment is most successful when applied to standardized and commonly used household systems such as space conditioning, water heating, and cooking. Equipment types not standardized among homes (such as heat recovery ventilators) are much more difficult to deploy.

Incentives and on-bill financing help increase customer access to energy-efficiency technologies. Bundling with other rebate programs and higher incentives for income-qualified customers are essential to make these technologies viable for those customers and provide equitable access. Downstream rebates directly to customers proved more reliable than providing rebates to contractors, who often had difficulties complying with administrative requirements and required advance payments. Increasing incentive levels when participation is low can create more attention and interest from customers. Providing increased incentive levels until market movement is achieved can be a very effective tool. Once awareness of these technologies takes off and more projects are installed, reducing incentives and directing money to markets that have not taken off or need much more support may be prudent.

On-bill financing proved popular, as observed by SCP reaching its funding limit more than six months earlier than forecast. On-bill financing was used mostly for heat pump space conditioning and heat pump water heating projects. On-bill financing aimed at allowing lower income households the ability to complete projects without the need for upfront capital, however only 7 percent of the projects financed were for income-qualified households, when approximately 20 percent of SCP's customer base is income-qualified.

The AEC and website provide awareness, education, and support to enable customers to install technologies that are suitable to their energy needs. Customers rely on knowledgeable program staff to help them understand their options and the benefits of technologies. Customers appreciate being provided with a list of contractors to use through a vetted contractor network when they do not know where to start as observed by SCP staff. Customers also appreciate the flexibility to use their own trusted contractor as observed by feedback to SCP staff. This also helps other contractors become familiar with the program and the technologies. Initial contractor recruitment and participation were difficult. SCP put more resources into contractor recruitment, hired a staff member to focus on contractor engagement, and encouraged customers to bring their own contractors to the program. Contractor participation more than doubled over the course of the year after these strategies were employed.

Recommendations for Future Studies

Although generally cost-effective for new construction, electrification measures were not often cost-effective as a retrofit without financial incentives. However, for buildings with PV systems that can provide free electricity at the same time energy is needed, the cost-effectiveness would be greatly improved. This grant did not focus on buildings with PV, but it would be valuable to further evaluate electrification retrofits when PV systems, battery storage, and EV charging are available. Similarly, additional studies of energy efficiency technologies with load-shifting capabilities (such as grid-interactive HPWHs [GIHPWHs], smart thermostats, and home automation) can help quantify potential reductions in peak demand, assist customers to minimize electricity costs under time of use rate schedules, and facilitate increased grid reliability. Such insights would help the building community as well as the public in understanding the financial picture associated with technologies like those studied under this grant.

Specific further research priorities for each technology evaluated by Lead Locally are summarized in Table 47.

Table 47: Technology-Specific Recommendations for Future Study

Technology	Research Priorities
Ducted mini-split heat pumps (residential)	• Installation cost reduction methods • Control strategies to minimize use during peak hours • Room-to-room temperature uniformity • Techniques for separating energy savings for load reduction measures from equipment performance • Cost-effectiveness when bundled with PV • New construction applications
Grid-interactive heat pump water heaters (residential and small commercial)	• Optimal control strategies to minimize operation during peak hours and minimize use of electric resistance backup • Noise reduction • Ways to minimize clothes washer operation during peak hours • Impact of cold temperatures where HPWH is installed • Methods for ducting warmer air to evaporator • Avoidance of need for circuit panel upgrades • Benefits as thermal storage for excess PV generation
Induction cooking (residential and commercial)	• Improving cost-effectiveness when replacing gas stovetops • Overcoming negative user perceptions of cooking with electricity • Avoiding need for electrical upgrades • Combining induction cooking with internal battery for peak period avoidance
Heat recovery dishmachines (commercial)	• Effect on cost-effectiveness when installed in combination with more efficient HPWH • Installation challenges with under-counter machines

Technology	Research Priorities
	• Benefits for larger dishmachines with greater savings potential • Reducing cycle time increases for heat recovery machines • Potential for water heater downsizing • Feasibility of all-electric commercial kitchens
Aerosol envelope sealing (residential)	• Understanding and reducing degradation of sealing over time • Minimizing residual sealant material after installation • Targeting applications in multi-family settings • Reducing cost of covering or moving furnishings • Methods for maintaining ventilation in areas with natural combustion appliances
Radiant ceiling panels (residential)	• Labor cost reduction • Dehumidification requirements and methods • Minimization of heat losses to attic • Disaggregation of necessary load reduction measures from energy savings calculations
Air-to-water heat pumps with fan coils (residential)	• Labor cost reduction • Best practices for integration with water heating • Disaggregation of necessary load reduction measures from energy savings calculations
Daylighting (commercial)	• Integration of TDDs with daylight harvesting to optimize savings • Indirect benefits for space heating load reduction • Mitigating hot spots from TDDs that lead to disabling of system by occupants • Emerging daylighting technologies, including automated louvers and electronically tinted windows
Phase change materials (residential and commercial)	• Lower cost PCM panels • Detailed study of possible time-of-use benefits and associated thermostat control strategies to maximize benefits • Methods for accurately measuring heat flux into and through PCM panels • Best practices for managing weight issues in commercial drop ceiling applications

Technology	Research Priorities
	• Guidance for selecting optimal melting points in commercial applications • Techniques for minimizing damage potential for leaking panels • Possible benefits of additional layers of PCM to increase load shifting potential
Nighttime ventilation (residential)	• Cost reduction through screening criteria and installation best practices • Contractor training requirements • Triggering of additional upgrade requirements to meet Title 24 • Optimal control logic for homes with and without AC • Noise from damper modulation • Response time improvements • Modifications to allow use during smoky conditions due to wildfires

Source: Frontier Energy

Outside of technology-specific research, public perception and market forces related to energy efficiency and decarbonization are valuable components. Possible ways to enhance such research include:

- Offer larger incentives or otherwise increase commercial involvement, perhaps through creative approaches such as offering free publicity or a discount on city-based fees, and so on.
- Incorporate systematic data collection throughout the study on non-participating customers and contractors regarding their own awareness and motivations around energy efficiency and decarbonization efforts.
- Focus more on collecting data and feedback from low-income customers to examine their low participation rates despite financial incentives resulting in zero out-of-pocket expenses.
- To gain a more nuanced understanding of customer motivations and reasons for participating in the Lead Locally Program and visiting the AEC, focus groups of participants would provide more in-depth qualitative information on how and why they use they participate in the program and visit the AEC. This could be a research activity in a future study conducted by SCP.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
ACEEE	American Council for an Energy-Efficient Economy
AEC	Advanced Energy Center - Sonoma Clean Power's customer center located in downtown Santa Rosa, which makes the latest clean energy technologies accessible all under one roof, with 0-percent financing, deep discounts, and a network of qualified contractors.
AMI	Advanced Metering Infrastructure - A two-way communication system to collect detailed metering information throughout a utility's service industry.
Aerosol Sealing	The process of using an aerosol spray and pressure to seal a building and/or ventilation system, reducing air leakage.
ACH50	Air Changes Per Hour at 50 Pascals - How many times per hour the entire volume of air in the building is replaced when the building envelope is subjected to a 50 Pascal pressure.
AC	Air Conditioning - A system that regulates indoor temperature by removing heat and humidity from the air, providing comfortable internal environments during warm weather.
AHU	Air Handling Unit - A mechanical device that circulates air within a building, typically containing components such as fans, filters, coils, and dampers to control temperature, humidity, and air quality.
AWHP	Air-To-Water Heat Pump - A heating device powered by electricity that extracts heat from the outdoor air and transfers it to water, typically used for conditioning indoor spaces and providing hot water.
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers - An American professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction.
AFUE	Annual Fuel Utilization Efficiency - A measure of the efficiency of gas-fired furnaces, indicating the percentage of fuel that is converted into usable heat over the course of a year, with higher ratings representing greater efficiency.
BayREN	Bay Area Regional Energy Network - A coalition of the Bay Area's nine counties — a network of local governments partnering to promote resource efficiency at the regional level, focusing on energy, water and greenhouse gas reduction.
BAAQMD	Bay Area Air Quality Management District - A regional air pollution control agency tasked with regulating stationary sources of air pollution in the nine counties that surround San Francisco Bay:

Term	Definition
	Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, southwestern Solano, and southern Sonoma counties.
BSRL	Building Sciences Research Laboratory - Frontier Energy's Building Science Research Laboratory, a 2200 ft^2 test facility in Davis, California.
BEopt	Building Energy Optimization Tool - A tool that produces detailed simulation-based analysis and design optimization based on specific house characteristics, such as size, architecture, occupancy, vintage, location, and utility rates.
CARD	Climate Action and Resiliency Division - A division the County Administrator's Office that leads projects, programs, and initiatives that advance climate action work across Sonoma County, helping the County and the community to address the climate crisis and achieve climate-related goals and objectives.
CASE	Codes and Standards Enhancement - An initiative that presents recommendations to support the California Energy Commission's efforts to update the California Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies.
CalCCA	California Community Choice Association - An association that represents the interests of California's community choice electricity providers in the legislature and at state regulatory agencies, including the CPUC, CEC and the California Air Resources Board.
CEC	California Energy Commission - The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are: 1. Forecasting future statewide energy needs, 2. Licensing power plants sufficient to meet those needs, 3. Promoting energy conservation and efficiency measures, 4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels, and 5. Planning for and directing state response to energy emergencies.
CLTC	California Lighting Technology Center - A research center affiliated with the University of California, Davis, focusing on advancing energy-efficient lighting technologies and practices.

Term	Definition
CO_2	Carbon Dioxide - A greenhouse gas contributing to climate change when present in excessive amounts.
°C	Celsius - The Celsius scale of temperature.
Commercial Dishmachines	Automated machines that can clean and sanitize a large quantity of kitchenware in a short amount of time by using energy, hot water, soap, and rinse chemicals.
COP	Coefficient Of Performance - A measure of the efficiency of a heating or cooling system, calculated as the ratio of useful heat output or cooling provided to the amount of energy input, with higher COP indicating greater efficiency.
CPUC	California Public Utilities Commission - An agency that regulates privately owned electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies, in addition to authorizing video franchises.
CDD	Cooling Degree Days - Degree days are the difference between the daily temperature mean, (high temperature plus low temperature divided by two) and 65°F. If the temperature mean is above 65°F, we subtract 65 from the mean and the result is CDD.
SCESD	County of Sonoma Energy and Sustainability Division - Part of the General Services Department of the County of Sonoma, SCESD is responsible for planning, evaluating and administering the County-wide Energy Management and Sustainability Program.
PEX	Cross Linked Polyethylene - A type of plastic formed by linking individual polymer chains together, creating a strong and durable structure; commonly used in plumbing, insulation, and wire and cable applications.
CFM25	Cubic Feet Per Minute at 25 Pascals - The air flow (in cubic feet per minute) needed to create a 25 Pascal pressure change in the ductwork.
DEER	Database For Energy-Efficient Resources - A database used by utilities, researchers, and policymakers to assess the energy-saving potential of various technologies and measures.
DHW	Domestic Hot Water - Water that has been heated for use in buildings.
Drop Ceiling	A ceiling suspended from the floor or roof construction above.
Ducted Mini-Split Heat Pump	A term used to refer to variable capacity air-source heat pumps that are small (generally less than 1.5 tons of cooling) and paired to one or more ducted air handlers.

Term	Definition
EBCE	East Bay Community Energy - A not-for-profit public agency that governs the Community Choice Energy Service to provide renewable energy to the County of Alameda.
Economizer (Air)	A ducting arrangement and automatic control system that allows a heating, ventilation, and air conditioning (HVAC) system to supply up to 100 percent outside air to satisfy cooling demands, even if additional mechanical cooling is required.
EPIC	Electric Program Investment Charge - In 2012, the Electric Program Investment Charge 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.
EM&V	Evaluation, Measurement, And Verification - A process used to assess the effectiveness and performance of programs and measures, involving the collection, analysis, and interpretation of data to verify compliance with program goals and objectives.
°F	Fahrenheit - The Fahrenheit scale of temperature.
GWP	Global Warming Potential - A measure of the relative ability of a greenhouse gas to trap heat in the atmosphere over a specified time period compared to carbon dioxide.
GHG	Greenhouse Gas - A gas that traps heat in the atmosphere by absorbing and emitting radiant energy within the thermal infrared range. These gases' ability to trap heat causes the greenhouse effect.
Grid Interactive	Systems that are designed to operate in response to signals from utilities or third-party aggregators to control operation.
GIHPWH	Grid-Interactive Heat Pump Water Heaters - HPWHs that are designed to operate in response to signals from utilities or third-party aggregators to control operation while still providing consistent and reliable hot water to the occupants.
HDD	Heating Degree Days - Degree days are the difference between the daily temperature mean, (high temperature plus low temperature divided by two) and 65°F. If the temperature mean is below 65°F, we subtract the mean from 65 and the result is HDD.
HVAC	Heating, Ventilation, And Air Conditioning - A system that controls and maintains indoor temperature, humidity, and air quality in buildings.
Heat Flux	The amount of heat transfer per unit area per unit time.

Term	Definition
Heat Pump (HP)	An electrically powered system commonly used for heating or cooling indoor spaces by extracting heat from outdoor air, water, or the ground, and transferring it indoors during colder seasons, and vice versa during warmer seasons.
HPWH	Heat Pump Water Heater - Systems that heat and usually store water as for domestic use. They do this by using electricity to move heat from one place to another instead of generating heat directly.
Induction Cooking	The use of an electromagnetic coil to create heat in compatible cookware.
kBtu	Kilobritish Thermal Unit - A unit of energy commonly used to measure energy, equivalent to 1,000 British thermal units (btu). One btu is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.
kWh	Kilowatt-Hour - A unit of energy commonly used to measure electricity consumption. One kilowatt-hour is equal to the energy consumed by a one-kilowatt appliance operating for one hour.
Lead Locally	A grant program managed by Sonoma Clean Power, primarily funded through the California Energy Commission. The program aims to develop strategies to double energy efficiency in existing buildings and measure the results of the prospective technologies prior to launching future customer programs.
LED	Light Emitting Diode - A semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons.
tCO_2	Metric Tons of CO_2 - A unit of measurement used to quantify carbon dioxide emissions, where one metric ton is equivalent to 1,000 kilograms or approximately 2,204.62 pounds of CO_2.
MSHP	Minisplit Heat Pump - An encased, factory-made assembly or assemblies designed to be used as permanently installed equipment to provide conditioned air to an enclosed space(s). It normally includes multiple evaporators, compressor(s), and condenser(s).
MTC	Metropolitan Transportation Commission - The transportation planning, financing and coordinating agency for the nine-county San Francisco Bay Area.
NREL	National Renewable Energy Laboratory - A federally funded national lab that specializes in the research and development of renewable energy, energy efficiency, energy systems integration, and sustainable transportation.

Term	Definition
NRDC	Natural Resources Defense Council - A group of more than 3 million members and online activists with the expertise of some 700 scientists, lawyers, and other environmental specialists that confront the climate crisis, protect the planet's wildlife and wild places, and ensure the rights of all people to clean air, clean water, and healthy communities.
NTV	Nighttime Ventilation - An automated system to move fresh air throughout a building at night to reduce the temperature of its interior thermal mass, reducing daytime cooling usage.
NCGF	Non-condensing gas furnace - A type of gas furnace with a single heat exchanger.
NEI	Non-Energy Impacts - Any positive (benefit) or negative (cost) impacts that result from installed program equipment not related to energy use.
NEEA	Northwest Energy Efficiency Alliance - An alliance of more than 140 utilities and energy efficiency organizations working on behalf of more than 13 million energy consumers to increase the adoption of energy-efficient products, services and practices.
OBF	On-Bill Financing - A financing option that allows consumers to fund energy efficiency upgrades and renewable energy installations by using their utility bills. It is a loan made to a utility customer, such as a homeowner or a commercial building owner, the proceeds of which would pay for energy efficiency improvements. Regular monthly loan payments are collected by the utility on the utility bill until the loan is repaid.
O&M	Operations And Maintenance - The ongoing activities involved in operating and preserving systems, facilities, or equipment, typically aimed at managing their reliability, efficiency, and safety.
PRISM	Parameter-elevation Regressions on Independent Slopes Model - A unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters.
Peak Load Reduction	Changes to the operation of building end uses to minimize the consumption of electricity during utility peak periods.
PCMS	Phase Change Materials - Materials that absorb thermal energy as they melt, releasing the absorbed energy when ambient temperatures fall below the material's melting point. By accumulating energy during the day and releasing energy overnight, PCMs reduce building cooling costs and improve energy efficiency.

Term	Definition
PV	Photovoltaic - A technology that converts sunlight directly into electricity using semiconductor materials.
RCP	Radiant Ceiling Panel - A system installed in a ceiling that uses radiant heat transfer to warm indoor spaces through heating elements embedded in panels.
Retrofit Measures	An action that is taken to reduce the energy or electricity use of a home or commercial building.
SEER	Seasonal Energy Efficiency Ratio - An efficiency rating determined by taking the cooling output of a system divided by its overall power consumption during the cooling season (i.e., the warm part of the year)
Site Energy	The energy consumed at a building location or other end-use site.
SCP	Sonoma Clean Power - A community choice aggregator that serves the residents and businesses in Sonoma and Mendocino Counties, providing clean energy from more renewable resources, such as geothermal, wind, and solar.
TAC	Technical Advisory Committee - An advisory committee composed of diverse professionals to help provide guidance on project direction.
TRL	Technology Readiness Level - A type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. There are nine technology readiness levels. TRL 1 is the lowest and TRL 9 is the highest.
T/RH sensor	Temperature and relative humidity sensor - A sensor that measures the temperature and relative humidity of a three-dimension space.
TOU	Time-Of-Use - An electric rate structure that uses different rates for electricity consumption based on the time of day, typically with higher rates during peak demand periods and lower rates during off-peak hours.
tCO_2	Tons of carbon dioxide
TDD	Tubular Daylighting Device - A system that brings natural sunlight into interior spaces using reflective tubes and a diffuser.
TMY	Typical Meteorological Year - A standardized set of meteorological data representing typical weather conditions over a one-year period for a specific location.
UEF	Uniform Energy Factor - A measure of water heater overall efficiency. The higher the UEF value is, the more efficient the

Term	Definition
	water heater. UEF is determined by the Department of Energy’s test method outlined in 10 CFR Part 430, Subpart B, Appendix E.
Variable Speed	An air conditioning system can use a variable speed compressor (variable capacity system) and/or variable speed blower fan.
VEIC	Vermont Energy Investment Corporation - An investment corporation with services in energy efficiency, building decarbonization, transportation electrification, and clean and flexible grid energy.
Whr/day	Watt-hour per day
Weather Normalization	A method to account for variations in weather conditions when analyzing energy consumption or performance.
WCEC	Western Cooling Efficiency Center - An authoritative and objective research center at the UC Davis Energy and Efficiency Institute that accelerates the development and commercialization of efficient heating, cooling, and energy distribution solutions.

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ENERGY RESEARCH AND DEVELOPMENT DIVISION

APPENDIX A: Applied Research and Technology Demonstration Methodology

October 2024 | CEC-500-2024-100

APPENDIX A: Applied Research and Technology Demonstration Methodology

The following sections provide an overview of the technology evaluation methodologies used for the applied research and technology demonstration activities for Lead Locally, along with intermediate energy savings calculations where needed. Further details can be found in the final reports for the specific technologies, as referenced in the relevant sections below.

Mini-Split Heat Pumps

The pre-retrofit data acquisition system was installed between March and April of 2019, recording information about energy usage, indoor and outdoor ambient temperatures, thermostat set points, and so on. Six months later, the MSHP system was installed, and the data acquisition system kept collecting the same information until the end of 2020. This allowed for an evaluation of the MSHP system and the impact on overall house energy efficiency.

Table A-1 presents energy usage ratios for heating and cooling demand. The ratios are defined as normalized indicators of heating or cooling use per degree hour (using estimated balance points of 60°F for heating and 65°F for cooling) and are applied to evaluate reduction in use by comparing energy usage ratios before and after the MSHP system was installed. The reduction in use is defined as Usage Savings Ratio (kBtu/°F·h or kWh/°F·h) and is multiplied by the degree hours of 2020 to calculate the normalized annual savings associated with the retrofit measure.

Table A-1: Energy Usage, Degree Hours, Energy Usage Ratios, and Annual Energy Savings for the Seven Test Sites

Actual Degree Hours [°F·h]			Site 35	Site 39	Site36	Site 37	Site 38	Site 40	Site 41	AVG
Heating	Pre-Retrofit		15,294	16,402	12,077	13,877	12,194	17,686	5,716	13,321
	Post-Retrofit[a]		46,771	46,772	53,230	51,077	54,049	51,293	43,652	49,549
Cooling	Pre-Retrofit		18,479	-	21,263	15,277	14,325	21,498	32,648	20,582
	Post-Retrofit[a]		32,414	32,415	33,332	20,208	24,816	26,054	-	28,207
Energy Use										
Heating	Pre-Retrofit	*kBtu*	297.0	3,788.0	835.0	-	1,086	1,460.0	76.0	1,257
		kWh	-	-	-	446.3	-	-	-	446
	Post-Retrofit[a]	*kWh*	910.1	300.4	776.0	2,247.4	1,538.1	1,117.1	29.3	988
Cooling	Pre-Retrofit	*kWh*	0.2	-	1,454.2	73.5	273.5	1,213.6	32.3	508
	Post-Retrofit[a]	*kWh*	29.6	137.7	1,733.3	9.5	547.5	636.6	-	516

Actual Degree Hours [°F·h]			Site 35	Site 39	Site36	Site 37	Site 38	Site 40	Site 41	AVG
Usage Ratio [Energy/(°F·h)]										
Heating	Pre-Retrofit	*kBtu*	0.019	0.231	0.069	-	0.089	0.083	0.013	0.084
		kWh	-	-	-	0.032	-	-	-	0.032
	Post-Retrofit[a]	*kWh*	0.019	0.006	0.015	0.044	0.028	0.022	0.001	0.019
Cooling	Pre-Retrofit	*kWh*	0.000	-	0.068	0.005	0.019	0.056	0.001	0.025
	Post-Retrofit[a]	*kWh*	0.001	0.004	0.052	0.000	0.022	0.024	-	0.017
Annual Energy Use Savings										
Heating	Pre- vs. Post-Retrofit	*kBtu*	908	10,801	3,680	-	4,813	4,234	580	4,170
		kWh	-910	-300	-776	-605	-1,538	-1,117	-29	-754
Cooling		*kWh*	-29	-	546	88	-74	834	-	273

a Post-retrofit represents data collected during 2020.
b kBtu is gas savings, kWh is electricity savings
Source: Frontier Energy

All sites show savings in natural gas usage since using electricity for heating post-retrofit, except Site 37, which used electricity for heating pre-retrofit. For electricity usage, all sites showed negative savings post-retrofit. These increases in energy use may have been caused by different thermostat set point temperatures pre-retrofit and changed behavior because of the COVID-19 pandemic. Some of the values in Table A-1 are marked as gray, which means that data is missing or insufficient to complete the energy savings assessment as presented.

Further details can be found in the Lead Locally Technology Demonstration Final Report (R. Hendron, S. Chally, et al. 2022).

Grid Interactive Heat Pump Water Heaters

GIHPWHs were installed in the nine test homes between November 2020 and March 2021. Thermostatic mixing valves were required on all the GIHPWH retrofits, which allowed the storage tanks to be held at a higher temperature during the pre-conditioning load-up time. This facilitated a higher effective storage capacity before and during peak demand operation time. Although it was originally planned to use SCP's GridSavvy program implementor to send daily load shifting signals to these heaters, this plan could not be accommodated, though fortunately Frontier engineers were able to collaborate with Rheem to access the Application Programming Interface and program a script to send the daily control signal directly. This precluded using GIHPWH model offerings from other manufacturers besides Rheem/Ruud.

The baseline water heater at each site was monitored for a minimum of two months, recording data such as water flow rate, GIHPWH inlet and outlet temperatures, electricity energy consumption, and either gas energy use or and gas on/off status via flue temperature. The baseline monitoring was used to determine the average daily and annual energy use of the existing water heaters and the hot water load profiles. The profiles were to determine the required capacity of the replacement heater to accommodate a load-shifting schedule and to estimate the annual utility cost of water heaters, including electrical peak pricing (in one case).

The post-retrofit monitoring included a similar measurement plan but was extended to one-year data sets, which were compared to the baseline to determine energy and cost savings per replacement. Also, focus was placed on whether the electric heating element or only the heat pump was active to determine the effectiveness of dual-mode control (shifting the load from the resistive element to the heat pump when possible), and the effectiveness of the control to divert electricity consumption during peak demand periods to cheaper time-of-use periods.

The analysis was performed without weather normalization, but the data was normalized to the hot water consumption. This was generally done because of the relative, though not complete, independence of residential water heaters to weather conditions. Energy use for water heaters depends on the average temperature of the incoming cold-water supply, which varies slightly based on average weather, but is generally seasonally consistent within a few degrees. Heat pump effectiveness is also dependent on the temperature of the surrounding air since the surrounding air is the source of heat, but the dependence on outdoor weather conditions depends on where the heat pump's evaporator is installed. If the evaporator is installed in a conditioned space, the heat pump is much less dependent on weather conditions than if the evaporator is installed outdoors. It was confirmed by comparing summer and winter data from the same site during the same study phase that the overall energy usage as well as total hot water demand was not largely seasonally dependent, although there was significantly higher hot water demand (~15 percent) during the weekends.

Further details can be found in the Lead Locally Technology Demonstration Final Report (R. Hendron, S. Chally, et al. 2022).

Induction Cooking

To accurately assess the field readiness of this technology, two commercial sites and five residential sites were identified for retrofits. Residential sites needed to fulfill three main criteria: existence of an electric stovetop, at least two people living in the home year-round, and customers with eating habits that rely on cooking using their oven and stovetop (at least five meals per week). Commercial sites just needed to have a single range/oven that the business owners were willing to change out for an induction cooker, and the chefs and line cooks needed to be excited about the project and ready to make a change.

Installations were performed at monitored sites between June 2020 and August 2021. When necessary, cookware was replaced with magnetic options designed for use on induction range tops. Due to approval delays with the building owner at Site 33, the installation occurred in January 2023, well after the demonstration project and final report were written. As a result, no monitoring was performed at that site.

The energy consumption of the existing range was directly measured for at least three months to determine a baseline, followed by continued monitoring for at least three months after replacement. Energy savings were calculated at the residential and commercial sites by directly comparing the energy consumption in the pre- and post-retrofit monitoring periods.

Further details can be found in the Lead Locally Technology Demonstration Final Report (R. Hendron, S. Chally, et al. 2022).

Heat Recovery Dishmachines

Three test sites were targeted for this technology, but one site at a junior college dropped out very late in the process due to difficulties securing approval from college administration. The two sites where installations occurred were a brewery (Site 14) and a winery (Site 16), both of which were open five days per week for in-house service. The baseline dishwashers were fed by electric resistance water heaters, which significantly increased the cost savings when switching to the more efficient heat recovery models. The winery had a 120-gallon tank-type water heater rated at 95 percent thermal efficiency, and the brewery had a tankless water heater rated at 96 percent thermal efficiency. Both sites had undercounter dishwashers and ran between 40 and 60 racks of dishes per day.

Installations of the exhaust heat recovery dishmachines were performed between July and October 2021. The models chosen were cold-feed-only, meaning they could be removed from the hot water system entirely.

The evaluation of the technology was performed by monitoring water and energy usage of the commercial dishmachines for at least one month each, then retrofitting with exhaust heat recovery models and continuing monitoring. The hot water delivery efficiency was assumed to be 70 percent. Energy consumption was normalized to a per-rack-washed basis because of significant COVID-19 impacts on operations, and energy savings were reported consistent with the average number of dishes washed per day.

Further details can be found in the Lead Locally Technology Demonstration Final Report (R. Hendron, S. Chally, et al. 2022).

Aerosol Envelope Sealing

Ten homes were targeted for demonstration of the Aerobarrier technology, as well as Aeroseal duct sealing where appropriate. The primary site selection criteria were whether the site was occupied and if the site had little to no carpeting. Unoccupied sites were given precedence because the houses had to be empty except for large mechanical equipment to avoid the risk of damaging furnishings and other belongings. Sealing an occupied home would have required hiring a mover to transfer all belongings to an offsite location and putting the occupants up in a hotel for one to two nights, which is costly and inconvenient.

Four of the sites were single-family homes, the six remaining were multi-family apartment units that underwent major upgrades (including electrification) at the same time aerosol envelope sealing was performed. All sites were unoccupied during the sealing process. The single-family homes all had new occupants post-retrofit, while the multi-family homes had the same occupants following temporary relocation of people and furnishings. Aeroseal duct sealing was used at three of the sites, but most did not have duct systems or had ducts in such poor condition that Aeroseal was not applicable.

The AeroBarrier process was applied at the test sites between July 2020 and June 2021. The total average time it took to use AeroBarrier on a home was 9.2 hours, ranging between 8.4 hours and 10.7 hours. Project costs were shared between Lead Locally and the Western Cooling Efficiency Center (WCEC), which was funded by the DOE to conduct similar technology demonstrations. In addition to the AeroBarrier and Aeroseal upgrades, two of the sites received new water heaters because of ventilation concerns near existing open combustion gas water heaters.

Prioritizing homes that were unoccupied during the AeroBarrier sealing led to the selection of sites undergoing a tenant changeover or renovation. This made any utility bill or pre- and post-retrofit monitoring approach unfruitful. Therefore, the primary method for determining the effectiveness of Aerobarrier and Aeroseal was a comparison of the initial and final envelope and duct leakages. These tests provided a reduction in air infiltration that was then used in the Building Energy Optimization Tool (BEopt) models approximating each of the sites to estimate annual energy savings. Floor area, pre- and post-retrofit building leakage, pre- and post-retrofit duct leakage (when applicable), vintage, and HVAC system type were used as inputs.

The AeroBarrier process was highly effective when tightening the envelope. On average for all ten sites, 57 percent of the envelope leakage was sealed. The results for these improvements in terms of air changes per hour at 50 pascals (ACH50) are provided in Table A-2.

Table A-2: AeroBarrier Improvements to the Homes

	Baseline Total Leakage (ACH50)	Total Leakage after Sealing (ACH50)	Percent Envelope Sealed
Site 1	15.38	5.09	66.9 percent
Site 2	12.62	4.89	61.2 percent
Site 3	15.24	8.05	47.4 percent
Site 4	9.30	7.44	20.4 percent
Site 5	8.82	2.53	71.3 percent
Site 6	7.65	2.56	66.5 percent
Site 7	9.66	2.92	69.8 percent
Site 8	10.53	4.06	61.4 percent
Site 9	9.44	4.60	51.3 percent
Site 10	6.35	2.93	53.9 percent

Source: Frontier Energy

The results from the Aeroseal improvements for the three applicable sites is presented in Table A-3 where the technology was able to seal 70 percent of the duct leakage on average. The results are presented in CFM25 (cubic feet per minute at 25 Pa).

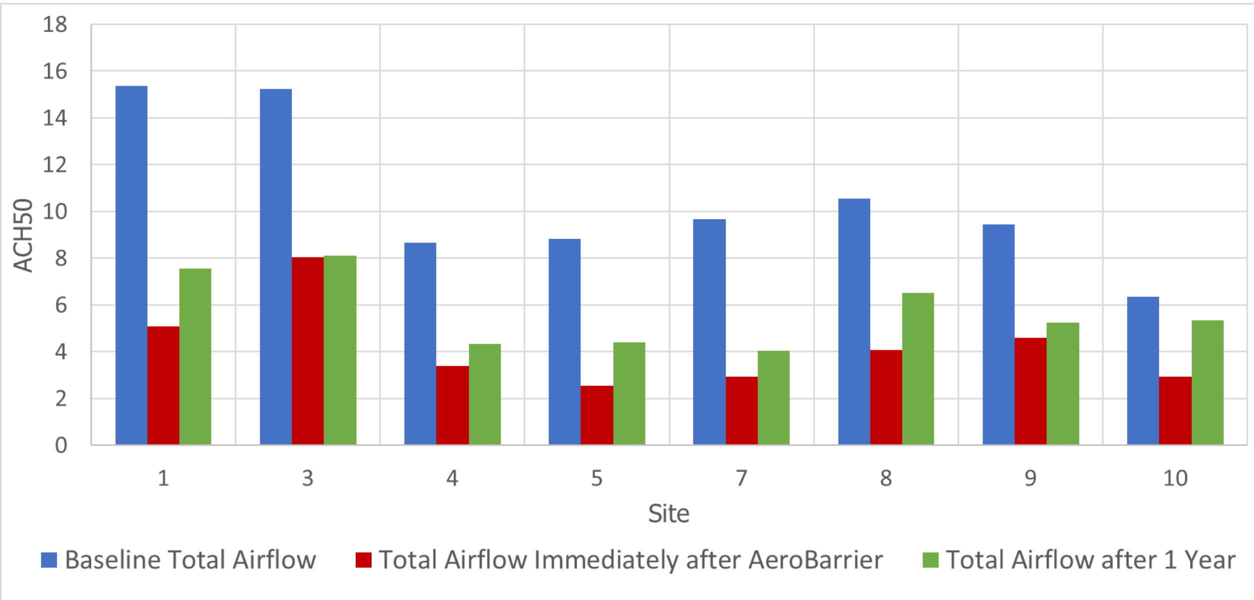
Table A-3: Aeroseal Improvements

	Baseline Duct Leakage (CFM25)	Duct Leakage after Sealing (CFM25)	Percent Improvement
Site 2	23.9	19.1	20 percent
Site 5	39.4	9.3	76 percent
Site 10	38.8	2.7	93 percent

Source: Frontier Energy

To assess if the sealant degrades over time, eight of the ten sites were visited 11–19 months after the initial sealing to perform an additional post-retrofit blower door test. The results from the initial testing compared to the results after roughly a year are presented in Figure A-1. The total degradation in the initial sealing improvement averaged 27 percent. However, since only one post-retrofit measurement was taken, it is unclear if this degradation happened slowly over time or abruptly within the first month or two after the sealing.

Figure A-1: AeroBarrier Degradation



Source: Frontier Energy

An initial post-retrofit survey was sent to Sites 1-4, and an additional survey was sent approximately a year after the retrofit to all ten sites. Since all ten test sites either had an occupant changeover or a complete renovation, no baseline comparison could be made to quantify comfort due to the AeroBarrier upgrade specifically.

Using BEopt models, annual energy use was estimated for each of the sites using the baseline leakage and using the improved envelope and duct leakages measured immediately after the retrofit. Post-retrofit HVAC systems were used in the models to remove the fuel substitution effects.

Further details can be found in the Lead Locally Technology Demonstration Final Report (R. Hendron, S. Chally, et al. 2022).

Radiant Ceiling Panels

The delivery effectiveness of the radiant panels was evaluated in the Frontier Energy's Building Science Research Laboratory (BSRL), a 2200 ft^2 test facility in Davis, California.

Figure A-2 provides an illustration of how the radiant panel system was installed in the climate chamber, along with expected heat transfer flow directions. Q_{down} is the energy given to or taken from the interior space, and Q_{up} is the energy given to or taken from the attic.

Figure A-2: Diagram of the BSRL Indoor Environment Chamber

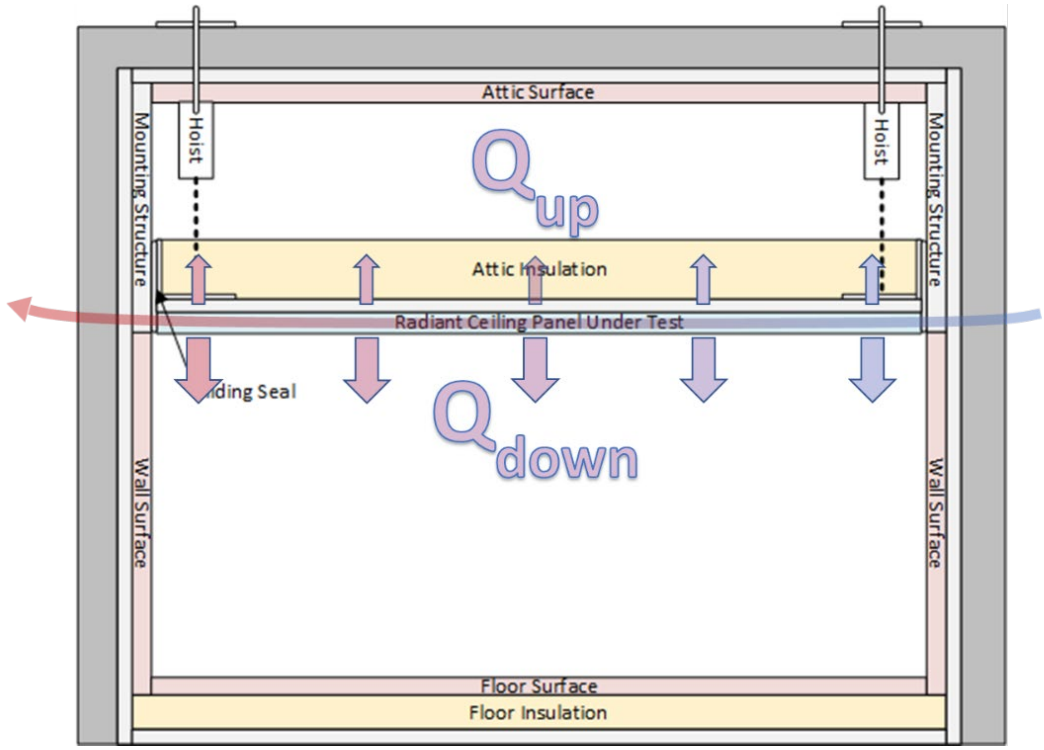


Image credit: Frontier Energy

Radiant systems experience conductive thermal losses, typically upwards to the attic space. For this reason, it was important to reduce these losses for the sake of energy use and indoor comfort. The impact of these losses was evaluated by calculating the delivery effectiveness, which is the ratio of the quantity of heating or cooling energy delivered to the conditioned space over the total energy provided to the system. Evaluating the thermal delivery effectiveness for a range of attic insulation levels and operating conditions in a laboratory setting allowed determination of a minimum recommended attic insulation level for use with radiant ceiling systems.

Table A-4 presents the result of these 16 laboratory tests, indicating that delivery effectiveness (δ) varied between 48 to 77 percent for cooling mode and 54 to 66 percent during heating conditions. The average δ across all cases in cooling mode was 62 percent, and for heating it was 60 percent. For both heating and cooling, it was found that the level of attic insulation had the highest impact on δ which varied between R-19 and R-49.

Table A-4: Laboratory Results from the Radiant Panel System

Insulation R-value ($ft^2 \cdot °F \cdot h/BTU$)	Indoor Temperature (°F)	Attic Temperature (°F)	Water Flow Rate (gpm)	Panel Supply Temperature (°F)	Return/Supply Temperature Difference (°F)	Delivery Effectiveness, δ (-)
19	76	140.0	0.50	50.0	-7.3	**53.1 percent**
49	76	140.0	0.50	50.0	-5.5	**76.7 percent**
19	76	140.0	0.50	55.0	-5.8	**47.8 percent**

Insulation R-value ($ft^2 \cdot °F \cdot h/BTU$)	Indoor Temperature (°F)	Attic Temperature (°F)	Water Flow Rate (gpm)	Panel Supply Temperature (°F)	Return/Supply Temperature Difference (°F)	Delivery Effectiveness, δ (-)
49	76	140.0	0.50	55.0	-4.9	**66.0 percent**
19	76	140.0	0.75	50.0	-4.7	**56.7 percent**
49	76	140.0	0.75	50.0	-4.1	**75.8 percent**
19	76	140.0	0.75	55.0	-4.1	**49.3 percent**
49	76	140.0	0.75	55.0	-3.5	**66.9 percent**
19	68	55.0	0.50	95.0	5.2	**53.6 percent**
49	68	55.0	0.50	95.0	4.9	**61.2 percent**
19	68	55.0	0.50	105.0	7.0	**56.4 percent**
49	68	55.0	0.50	105.0	6.6	**64.7 percent**
19	68	55.0	0.75	95.0	3.5	**54.8 percent**
49	68	55.0	0.75	95.0	3.3	**63.2 percent**
19	68	55.0	0.75	105.0	4.8	**57.8 percent**
49	68	55.0	0.75	105.0	4.5	**66.2 percent**

Source: Frontier Energy

Although field tests were planned and sites were identified for five single-family homes, ultimately only one home was studied because the installation cost was higher than anticipated (>$100,000). SCP and Frontier Energy recommended investing the remaining funds into two hydronic fan-coil systems and two additional MSHP field tests.

Candidates for the installation were selected based on home, system, and occupant characteristics. For the residential sites, selection criteria required that all test sites be single family one-story homes, at least ten years old, with less than 2,000 ft^2 of conditioned space, and containing no asbestos. For the existing HVAC, targeted homes must have existing central heating and cooling, ducts located in an unconditioned attic space, and be at least 10 years old. Finally, the current owners had to be full-time occupants that did not expect to move within two years.

The home that received radiant ceiling panels was an 1,812 square foot single story house, built in 1989 with three bedrooms and two baths. Prior to the retrofit, the heating and cooling system consisted of a traditional central ducted system with gas furnace and electrical air conditioning.

Six months of monitored baseline data were collected prior to the retrofit, followed by one year of monitored data collection post-retrofit. Data collected was focused on system performance, as well as occupant comfort and behavior. The homeowner was asked to complete a quarterly survey, provide access to their utility data, and allow technicians to enter the residence for data collection or repairs with reasonable notice.

The data logger recorded data from sensors at a 15-second interval. Temperature and occupancy in every room, as well as setpoint and equipment operation time were recorded every five minutes through an Ecobee thermostat. In addition, the thermostat recorded relative humidity and controlled a whole house dehumidifier to provide emergency dehumidification to avoid condensation on the radiant panel surfaces during the cooling season. Weather conditions were retrieved from a nearby weather station.

The impact of variation in outdoor climate pre- and post-retrofit was accounted for using a method based on heating and cooling degree hours. Degree hours are applied to normalize the weather data and allow for a comparison between the baseline and post-retrofit performance data. For cooling degree hours, ASHRAE 169 suggests summarizing all hours during a year when the outdoor temperature exceeds specific balance points, which makes sense when estimating building heating and cooling energy demand in the abstract. However, the drawback is that this approach assumes that heating and cooling always occur at the same outdoor air temperature regardless of thermostat setpoints and building envelope and HVAC system characteristics, all of which changed before and after the retrofits. Instead of using pre-defined base temperatures for heating and cooling degree hours, this study used a method to calculate actual degree hours from site specific data. Using available information on thermostat setpoints, occupancy presence and energy demand, these baseline temperatures were then defined for the test site for the purpose of weather and occupant behavior normalization.

Further details can be found in the Residential Hydronic Heating and Cooling Applications by Air-to-Water Heat Pump Systems Final Report (Pallin and Haile 2022).

Hydronic Fan Coils with Air-to-Water Heat Pumps

Site selection criteria for the two hydronic fan coil test sites were the same as for the radiant panel field test described in Chapter 2 Both test sites were single family one-story homes, at least ten years old, with less than 2,000 ft^2 of conditioned space, and containing no asbestos. Both homes had existing central heating and cooling, ducts located in an unconditioned attic space, and the HVAC system was at least 10 years old. The current owners were full-time occupants that did not expect to move within two years.

Installation of the AWHP systems at the two test sites occurred between November 6, 2019, and January 24, 2020. During this time, the outdoor condensing units were replaced with the AWHP, see Figure A-3. The location of the new water tanks and air handling units (AHUs) remained the same post retrofit, and the hydronic fan coils were installed with the AHUs as depicted in Figure A-4, with some minor installation differences between Sites 26 and 27. Building envelope improvements were also implemented. The attic insulation was removed and replaced with R-49 blown-in insulation, caulk and spray foam were applied to seal gaps in the ceiling plane around penetrations and joist/drywall interfaces. In addition, the crawlspace at Site 27 was cleaned and installed with a ground surface vapor retarder.

Figure A-3: AWHP Outside Unit at Site 26

Image credit: EnergyDocs

Figure A-4: AWHP Indoor Unit and Water Tanks at Site 26

Image credit: EnergyDocs

The hydronic coil used in Site 26 was an "A" coil (referring to its shape) while the coil used in Site 27 was a "slab" coil. For Site 27, this required mounting the coil horizontally and the AHU vertically in order to fit both in the closet. Additionally, even though the furnace closet was deep enough to accommodate both the fan coil and the DHW tank, one would have had to be installed behind the other, preventing access in the event of maintenance. Instead, the DHW tank and fan coil had to be installed in separate closets, as the baseline system was. This added complexity and required installing most of the other hydronic system components in the much smaller DHW closet.

Various information was collected from the test sites. Data loggers collected data from sensors reading inputs such as temperature and relative humidity. Heating, cooling and ventilation energy usage was recorded together operational modes of AWHP, AHU, and valves. The installed data loggers and acquisition system collected information on energy performance from the start of the baseline period in March 2019 for Site 26 and May 2019 for Site 27, until the end of December 2021.

The same weather normalization methodology described in Chapter 2 was used for the energy savings analysis of the hydronic fan coil test sites.

Further details can be found in the Residential Hydronic Heating and Cooling Applications by Air-to-Water Heat Pump Systems Final Report (Pallin and Haile 2022).

Daylighting

The California Lighting Technology Center (CLTC) conducted a market assessment and identified 34 manufacturers offering emerging or underutilized advanced daylighting technologies. From these offerings, CLTC selected three technologies for laboratory evaluation. The selection criteria for these products included the market readiness of the product, its potential for integration with existing lighting systems, cost-effectiveness, and availability.

This first technology evaluated by CLTC was the Automated Louver system (Figure A-5). This system consisted of an aluminum frame containing nine aluminum slats connected to a lever arm such that the slats open and close in unison. This side-lighting technology is designed to be retrofitted onto either the interior or exterior of existing fenestration. The primary potential benefit of this technology was glare mitigation.

Figure A-5: Automated Louver System

Image credit: CLTC

To determine if the automated louver system could be used as a glare mitigation strategy, CLTC constructed a mock office space with the automated louver system mounted externally to a single pane window. The results of this testing showed that for each target position, the error associated with the angular positioning of the louvers was as high as 29 percent, resulting in poor performance. Due to the magnitude of error associated with the positioning of the louvers, and the fact that CLTC had to modify to louvers to provide angular position feedback to the controller, it was determined that they would not be suitable for further testing or a field demonstration.

The next technology evaluated by CLTC was the Fiber Optic Solar Tracking device (see Figure A-6). This system consisted of three sets of 16 solar collectors, a motorized base, and an electronic control system. The electronic control system used geographical positioning and time data to enable the device to follow the sun as it moves across the sky throughout the year. The 48 solar collectors used optics to focus the incident solar radiation onto a fiber optic cable bundle. Each group of four fibers was then combined into a single fiber bundle resulting in 12 discrete light sources. The fiber optic bundles were flexible, allowing installation around barriers and through conduits to reach the desired interior location with minimal losses.

Figure A-6: Fiber Optic Solar Tracker with 48 Solar Collectors to Concentrate Sunlight onto Fiber Optic Cables

Image credit: Parans

In evaluating the performance of the fiber optic daylighting system, CLTC conducted three experiments. First, CLTC evaluated how much light the system delivers throughout a day, in different seasons, and under different weather conditions. Second, the effect on the spectral content of the light passing through the collectors and fibers was evaluated. Finally, CLTC metered the system to quantify the overall power consumption.

Over the duration of the data collection period, the daily maximum luminous flux varied between 650 lumens and 1,500 lumens. All of the fiber bundles experienced an overall depreciation in luminous flux over the course of the four-month data collection period. On one cloudy day there were over 900 instances where the total luminous flux of the fiber optic system varied by 10 percent over the span of two seconds across all fiber bundles. Fluctuations of this magnitude over such a short time interval were considered to be perceivable and undesirable. Additionally, there were 21 instances where the luminous flux varied by more than 90 percent over 2 seconds, the equivalent of turning a light on and off. On clear days, the system delivered much more consistent light outputs.

CLTC measured the spectral power distribution for each of the 12 bundles using a 2-meter integrating sphere equipped with a CDS-3020 Spectrometer. The results indicated a noticeably green shift in output light as compared to natural daylight. Fiber curvature did not have a measurable effect on the color quality of the delivered light.

CLTC metered each electrical system and recorded power usage from May 14th to June 26th, 2020. The solar tracking fiber optic daylighting system had two operating states: tracking and stand-by. When the system is in tracking mode, the power consumption for the system was around 12.3 Watts. When in stand-by mode, the system used a total of 8 Watts. Over the course of a day, the entire system used an average of 252.5 Whr/day. Using the average luminous flux for each day, an efficacy of 620 lumens per watt (lm/W) was calculated for the duration of the testing period. For comparison, a high efficiency LED luminaire will have an efficacy around 120 lm/W.

The overall result of the laboratory evaluation was that the fiber optic daylighting system was not suitable for a field demonstration. Although the luminous efficacy of the system was nearly five times that of a typical LED luminaire, the system was very expensive (~$50,000) and was susceptible to large fluctuations in output over short time periods.

The final advanced daylighting technology evaluated by CLTC was a Tubular Daylighting Device (TDD) with a motorized daylight dimmer (see Figure A-7). The TDD system consists of a collector dome, reflective tube, motorized baffle, and a diffuser. It uses optics and lensing to redirect light from any sun angle down the reflective tube. The reflective tubing extends through the building envelope and into the building, where it is terminated at the desired ceiling location. The reflective tubing can incorporate bends to enable installation around interior obstructions, but there are efficiency losses associated with each bend.

Figure A-7: Tubular Daylighting Device (Left) with Motorized Daylighting Dimming Baffle (Right) That Can Reject Daylight When Closed

Image credit: Solatube

The research team devised an experiment to quantify the luminous flux through the TDD system for different solar angles. To do this, CLTC constructed a large tunnel using metal framing and wiring covered with a black-out curtain. At one end of the tunnel, the TDD system was mounted to the side of a three-meter integrating sphere. At the other end, exactly 30 feet from the flat surface of the sphere, a 1,000-Watt metal halide lamp was mounted to a stand such that the center of the lamp was along the same axis as the center of the TDD dome (Figure A-8).

Figure A-8: Schematic of TDD Setup to Quantify Luminous Flux at Different Solar Angles

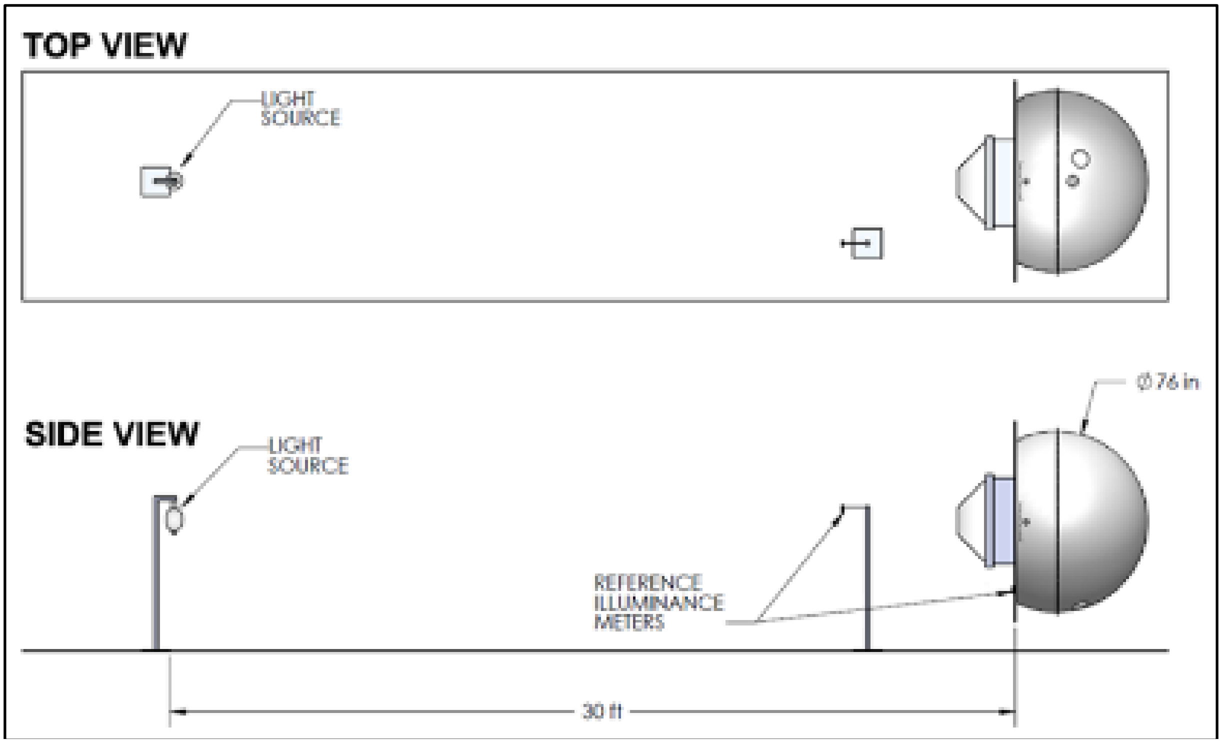


Image credit: CLTC

The data collected from these three trials showed that the luminous flux through the TDD was relatively consistent for elevation angles between 45 and 75 degrees. However, the luminous flux did tend to slightly increase with increasing elevation angle, while it showed a nearly linear relationship with baffle angle. Overall, the TDD system was found to be effective in delivering daylight to interior spaces while providing the ability to reject any excess light and solar heat gain using the motorized baffle (daylight dimmer). Therefore, it was decided that the technology should be field tested in commercial buildings.

Three sites were selected for installation and monitoring of TDDs. CLTC considered various factors in selecting sites, including building construction, location, interior design, building use, and occupancy patterns. In addition to these factors, the CLTC team also considered the availability of suitable test rooms and the willingness of building owners to participate in the study. Finally, the team looked for opportunities to demonstrate energy savings and improve occupant benefits with advanced daylighting technologies. TDD installations at the selected sites were performed between November 2020 and April 2023.

Further details can be found in the Commercial Daylighting Retrofits Report (Harper, Graeber and Hendron 2023).

Residential Phase Change Materials

During the lab testing phase of the project, the PCM mats were installed in an environmental chamber at Frontier's BSRL that had a simulated attic controlled separately from the interior space. Lab testing provided an opportunity to remove unpredictable weather and occupant behavior from the evaluation through strict control over the temperature profiles. Tests were conducted using typical summer and winter attic temperature profiles from one of the field test sites, and interior thermostat settings based on Title 24 modeling guidelines. A variety of PCM installation configurations, attic insulation levels, and simulated melting points were tested. A graphical depiction of the test chamber and instrumentation is shown in Figure A-9.

Figure A-9: Instrumentation Used for PCM testing in the BSRL Environmental Chamber

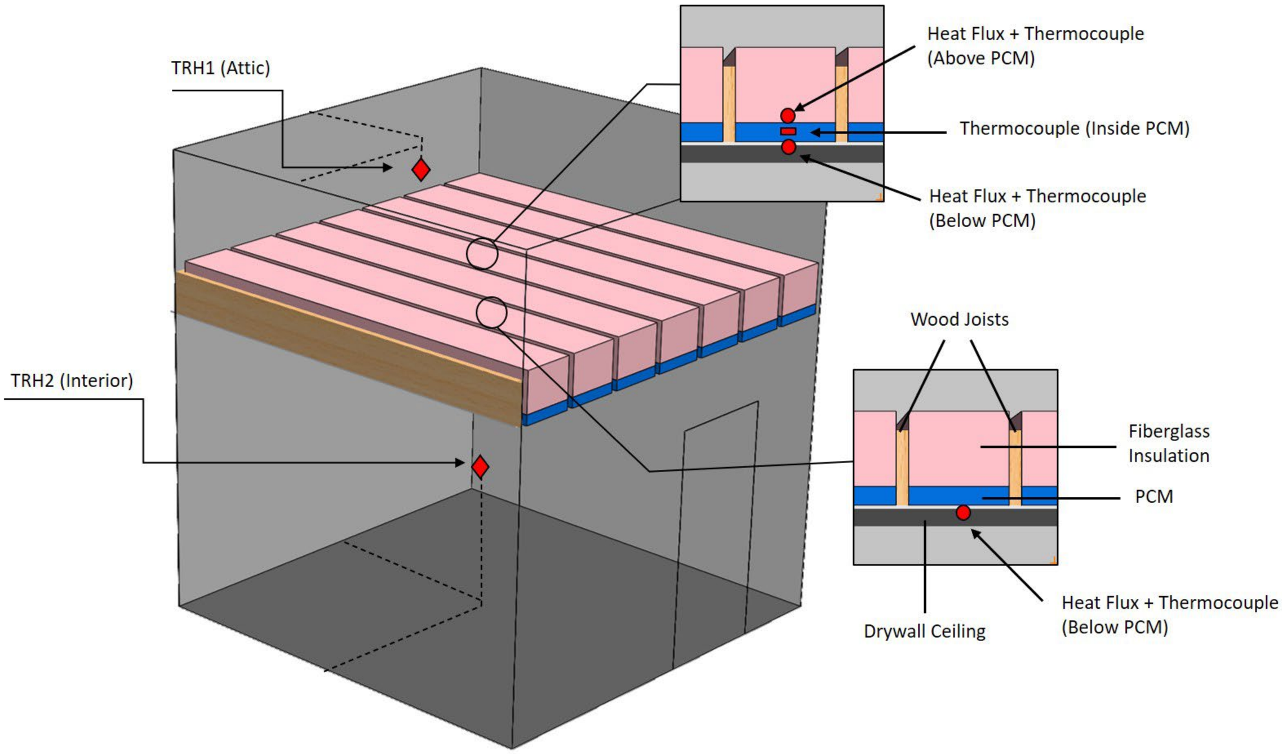
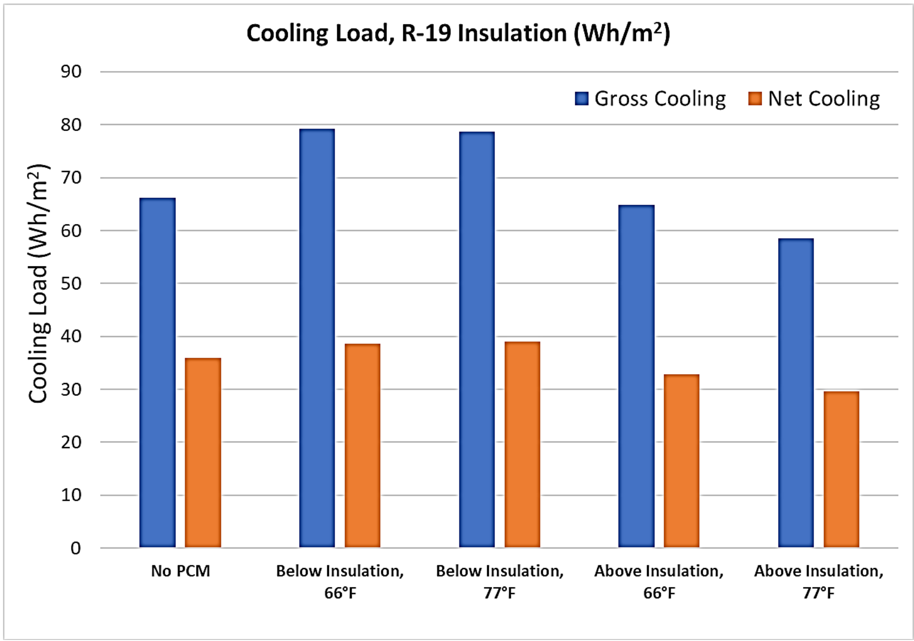


Image credit: Kate Rivera, Frontier Energy

The results of the lab testing show modest cooling savings potential of 10 to 15 percent compared to the case with no PCM (see Figure A-10), with the best-case scenario being 77°F melting point PCM installed above the insulation. PCM installed below the insulation resulted in negative cooling savings. Gross cooling is the total daily cooling load using only the hours when a cooling load is present. Net cooling includes the effects of both the cooling load (heat transfer from the attic to the interior) and free cooling (heat transfer from the interior to the attic).

Figure A-10: Cooling Load Reduction by Melting Point and Configuration



Source: Frontier Energy

Heating energy savings for the same lab test scenarios indicated that PCM above the insulation provides a small reduction in gross heating, but all PCM configurations result in negative impacts on net heating load. In fact, the sunny winter weather in Sonoma County may result in no net heating load from the attic to the interior even without PCM, because the attic heats up so much during the day.

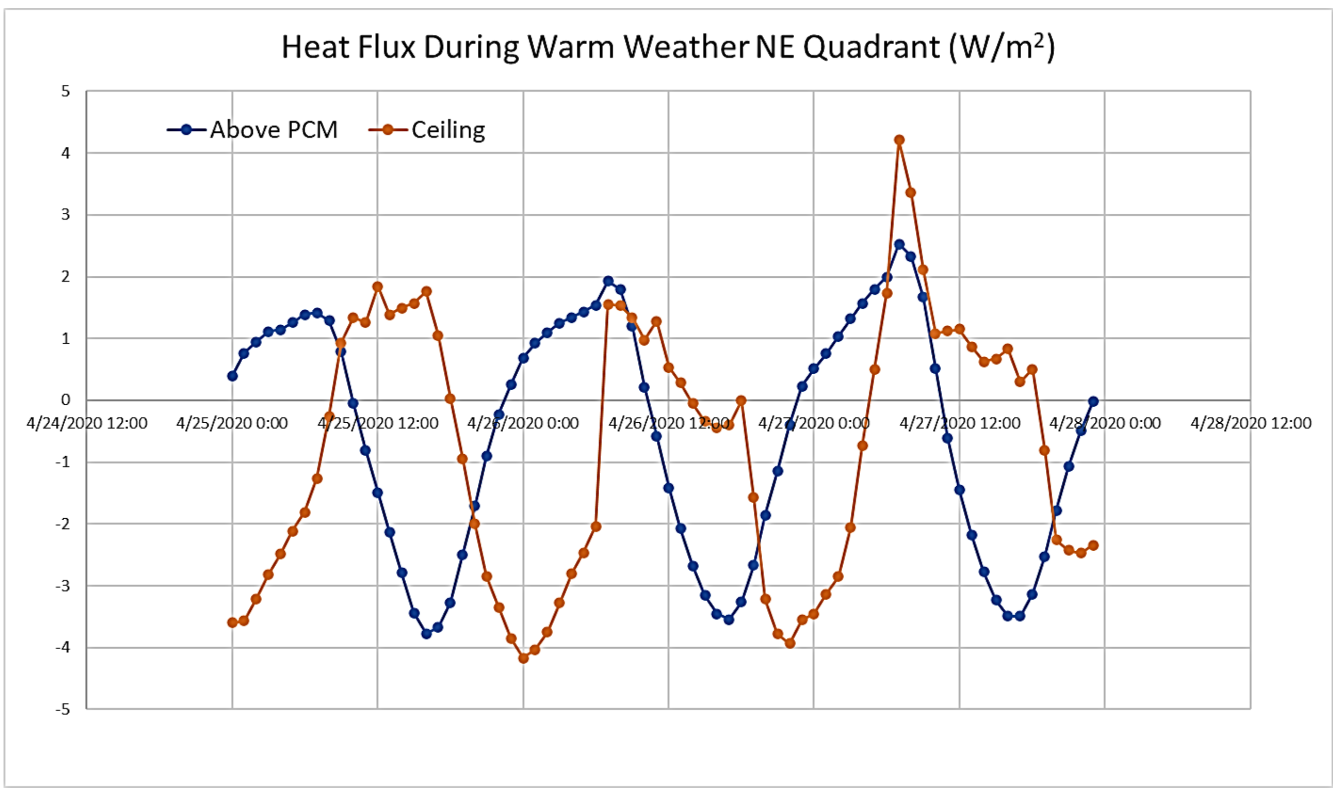
PCM was tested in five residential buildings for this project. A screening matrix was used to identify and score candidate field test sites based on desired characteristics. The criteria were driven primarily by technology performance considerations, cost limitations, and practical issues. Relatively small homes were targeted, with vented attics and central HVAC systems. Additional considerations included potential health and safety issues for both homeowners and installers.

The baseline, or pre-retrofit, test period lasted approximately nine months, during which the homes were monitored using multiple sensors and a data logging system to capture the conditions of the attic and conditioned space before the PCM was installed. Four heat flux sensors were installed in various quadrants of the attic to measure heat flow through the ceiling prior to PCM installation. Following the retrofit, two of the heat flux sensors were moved above the PCM, aligned vertically with the other two heat flux sensors, to monitor the amount of heat entering and leaving the PCM. Total heating and cooling energy were measured directly using gas meters at the furnace and power meters on the heat pump and air conditioners.

The daytime and nighttime heating and cooling set points for several sites changed following the PCM installation in December 2019. Heating set points changed significantly before and after the retrofit, sometimes higher and sometimes lower. The COVID 19 pandemic may be a partial explanation, along with take-back effects where some energy savings are lost in order to improve comfort for occupants. All heating set points were consistently below 68°F, possibly because homeowners were energy conscious. However, low heating set points can also reduce the energy savings and cost-effectiveness of the measure. Three sites used significant thermostat setbacks at night during the heating season. Two sites did not use setbacks. Cooling set points were significantly lower for three of the sites following the retrofit, with no change for the others. Use of air conditioning was likely affected by COVID 19 stay-at-home guidance during the post-retrofit period.

In general, the test data indicated that PCM installed under the insulation rarely reached its melting point except during certain times of year. To illustrate operation of the PCM under ideal conditions, we can examine data during the April swing season for Site 56. The heat flux is clearly reversed above and below the PCM, as shown in Figure A-11. This indicates that the PCM is freezing and melting nearly continuously, as the PCM temperature exceeds the low end of the melting point range (75 to 79°F). The result is cooling of the interior space during hot afternoons and heating of the interior space during cool nights, which is the intended effect of PCM during warmer weather. The magnitudes of the overall heating and cooling loads appear comparable, but they may occur at more beneficial times during the day.

Figure A-11: Site 56 Heat Flux In and Out of PCM from Apr 25-27, 2020



Source: Frontier Energy

The energy use of the gas furnaces, air conditioners, and heat pumps were measured directly before and after the PCM retrofit. Because weather conditions were different before and after the retrofit, and data were collected for less than a full year, weather normalization was necessary to convert the HVAC energy into a form that could be compared on an equal basis. Nonlinear regression was used for this project because the relationship between energy storage in the PCM and the surrounding temperature is complex, and the project team did not expect energy savings to have a linear correlation with outside temperature. In the final analysis, two independent regression variables were used: degree hours (heating or cooling) and global horizontal solar radiation. Weather normalized energy use for an entire year was calculated by taking the regression equations developed for each site and applying typical meteorological year (TMY3) weather data for Santa Rosa. The heating and cooling energy for each site was then adjusted based on EnergyPlus simulation of the effects of changes to thermostat settings and occupancy levels before and after the retrofit.

Stains began appearing at the ceiling at one test site about 12 to 18 months after PCM installation. Frontier Energy made a decision in consultation with SCP to remove all of the Infinite R material from the test sites, even though the other homeowners did not see any evidence of leaks. PCM was removed at four sites from late 2021 to early 2022, and leaks were discovered at all sites, although only two sites had stains at the ceiling. The homeowner at the fifth site would not allow access to Lead Locally staff. Regardless of energy savings, the potential for leaks and water damage prevented the team from pursuing further deployment of the Infinite-R product.

As a final step, Frontier created an EnergyPlus model representing a typical existing home in Sonoma County. Because there are many possible house designs, we selected the attributes most common in the existing housing stock in Sonoma County, supported by the modeling efforts performed for the Optimal Retrofit Strategy activities (see Chapter 2). To improve the accuracy of the model, we used data collected from Site 53 (not including measured PCM performance data) to help guide the model calibration process.

Further details about the residential PCM applied research project can be found in the Phase Change Materials in Residential Applications Final Report (Hendron and Chally 2022).

Commercial Phase Change Materials

The project team targeted 10 commercial buildings with the following characteristics:

1. Dropped tile ceilings
2. Year-round building occupancy
3. Significant day and evening occupancy at least five days per week, with minimal operation at night
4. Large internal heat gains
5. Wintertime thermostat setback and summertime set up at night, or willingness to include HVAC scheduling following the retrofit

Despite significant recruitment challenges stemming from COVID-19 business shutdowns and practical difficulties securing landlord support, six business owners eventually volunteered for PCM installation and monitoring for the entire building or certain critical spaces, like kitchen areas. All sites had central cooling except Site 61, which did not have a cooling system. Two sites had heat pumps, one had a propane furnace (making utility bill analysis problematic), and the remainder had gas furnaces. Sites 11 and 61 underwent significant repurposing prior to the test period, which made before and after comparisons of utility bills meaningless. All sites had Templok panels installed above drop ceilings, generally in office, classroom, or kitchen areas, except Site 58 which had Infinite R above the insulation in the attic and Site 60, which had some of the panels installed on the floor of a second story unconditioned storage area.

For many of the sites, the temperature in the drop ceiling or attic was monitored prior to purchase of the PCM, which allowed the project team to select melting points that best fit the application. For a couple of the restaurants, there was significant overheating in the kitchen and dining areas. A higher melting point (77°F) material was selected for those areas. Site 61 was a school with no air conditioning, making it another good candidate for high melting point PCM. The other sites generally had more well controlled summer temperatures, and a lower PCM melting point of 72°F or 75°F was selected.

All sites were self-installations performed in March 2021, except Site 61 for which an insulation contractor was hired, and Site 58, which had PCM installed in December 2021. Most of the sites only used about 50-75 percent of the material provided, because of weight concerns, installation challenges, or overestimates of available ceiling area.

The instrumentation packages installed at the six demonstration sites are summarized in Table A-5. Site 61 included heat flux sensors, while the others had only temperature and relative humidity measurements to analyze melting/freezing conditions and comfort. Utility bills were collected for all sites.

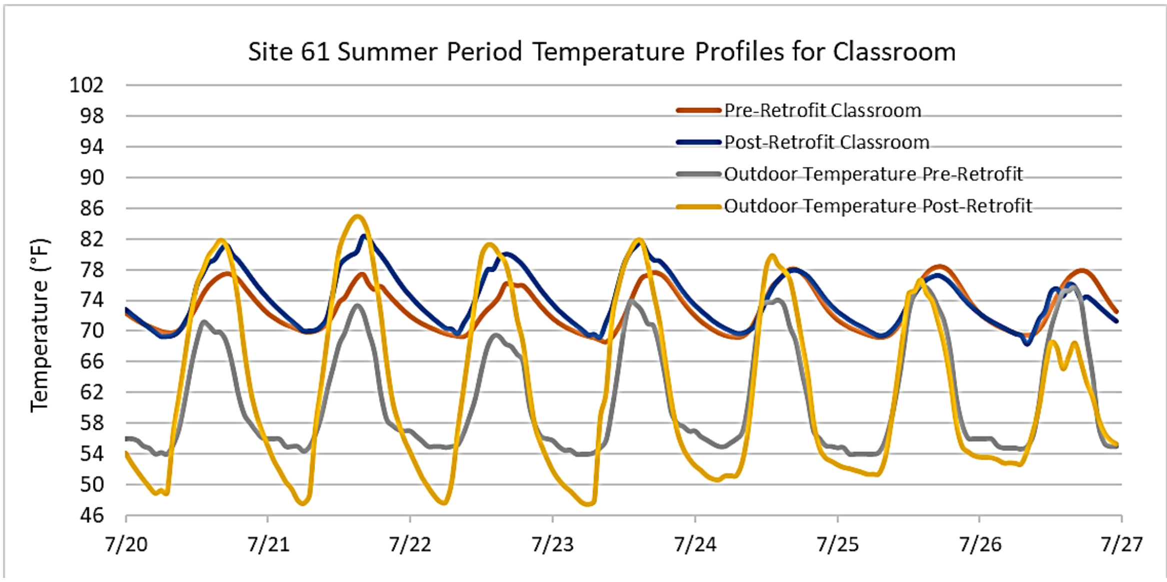
Table A-5: Instrumentation Used at PCM Commercial Demonstration Sites

Site #	Measured Data	Locations	Sensor Type
11	Temperature	Interior space; ceiling plenum (area between structural ceiling and dropped ceiling)	Temperature and relative humidity (T/RH) sensor
57	Temperature	Dining area; ceiling plenum	T/RH sensor
58	Temperature	Kitchen and lobby; attic above kitchen and lobby	Thermocouples, T/RH sensor, and gateway
59	Temperature	Dining area; ceiling plenum between dining area and kitchen	T/RH sensor
60	Temperature	Dining area; office hallway	Thermocouples, T/RH sensor
61	Heat Flux/ Temperature	Classroom and office, plenum above classroom and office	Heat flux sensors, thermocouples

Source: Frontier Energy

A comparison of pre- and post-retrofit temperatures in the classroom for Site 61 during the week of July 20th (of 2020 and 2021, respectively) are shown in Figure A-12. Site 61 did not have a cooling system, so the PCM was expected to keep the classroom from getting too warm during the day. The comparison is difficult because the weather conditions were different in 2020 versus 2021, but for days with similar temperatures it appears that the classroom remained a bit cooler, perhaps by 1 to 2°F. It is likely this is attributable to the PCM, but there could have been differences in internal gains as well. There is also some evidence of delayed temperature response or flattening of the curve at the warmer temperatures in the post-retrofit case, which may be caused by the PCM freezing and melting. Similar results were evident in the office area.

Figure A-12: Summer Temperature Profiles Before and After Retrofit – Site 61 Classroom



Source: Frontier Energy

Further details about this project can be found in the Lead Locally Technology Demonstration Final Report (R. Hendron, S. Chally, et al. 2022).

Nighttime Ventilation Cooling

Ten sites were recruited for field testing of the NTV technology. Essential criteria included no air conditioner, central heating system, safe working conditions, and space availability. Site visits were conducted to assess the ability to install a roof or gable vent, the presence of only a single return duct, the availability of power in the attic, the lack of expected need to do drywall alterations, and the absence of any other complications.

Prior to installation in homes, one of the economizer boxes was installed in the laboratory and connected to a fan, in order to ensure that the system behaved as expected during all operating modes. It worked as expected with a range of filtration ratings, total external static pressures, and airflow rates.

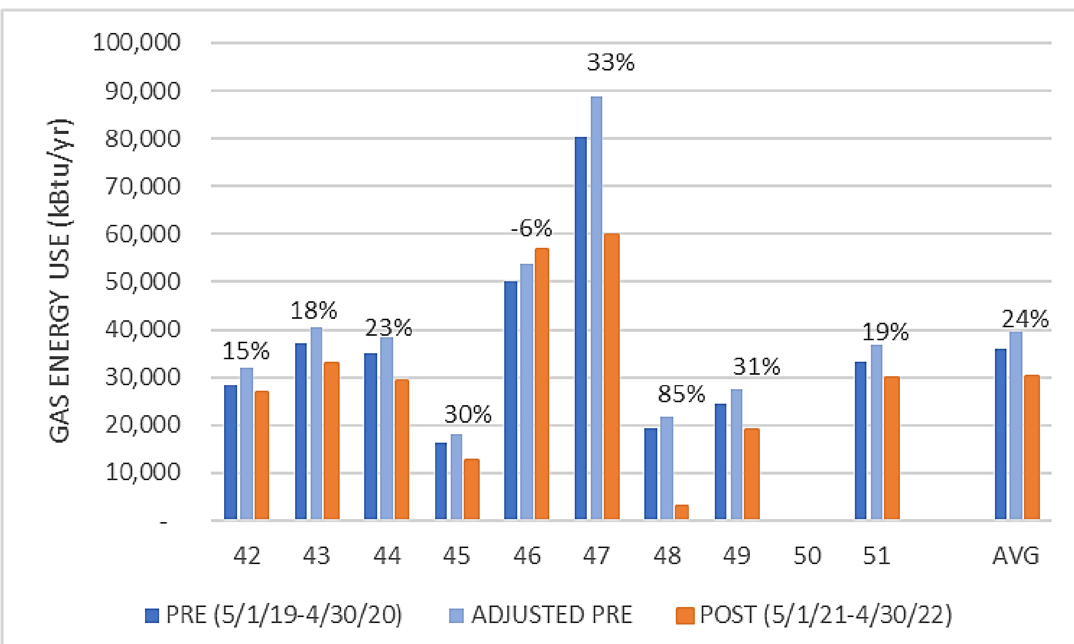
NTV was installed at the ten test sites between July 2020 and April 2021. A single HVAC contractor was hired to install all the NTV systems. Instructions were provided on how to do the installation, and a Frontier Energy technician worked with the installer on the first few sites to help in the training and address any confusion or concerns. The contractor was uncomfortable with the custom-wiring required to add the relays to adapt the economizer controller for homes without AC, so the research team technician carried out this part of the installation at the time of instrumentation. At most sites, the installation was completed in about one day, while at some sites it took longer.

The primary data used for analysis was site-monitored furnace air-handler unit fan power using current transformers and voltage measurements.

Analysis of utility bills was done to detect any increases in winter consumption due to the presence of the NTV system and the increase in energy use due to the addition of fan operation during the summer. (Since the AC scenario was hypothetical, there were no corresponding utility bills to analyze). Since the PRE condition had no electricity use for HVAC, it was not necessary to weather normalize the summer electrical use. Gas use was normalized by determining the heating degree difference each hour during the PRE and POST periods and summing them over the year. This was done using a base-temperature selected for each home based on regression analysis.

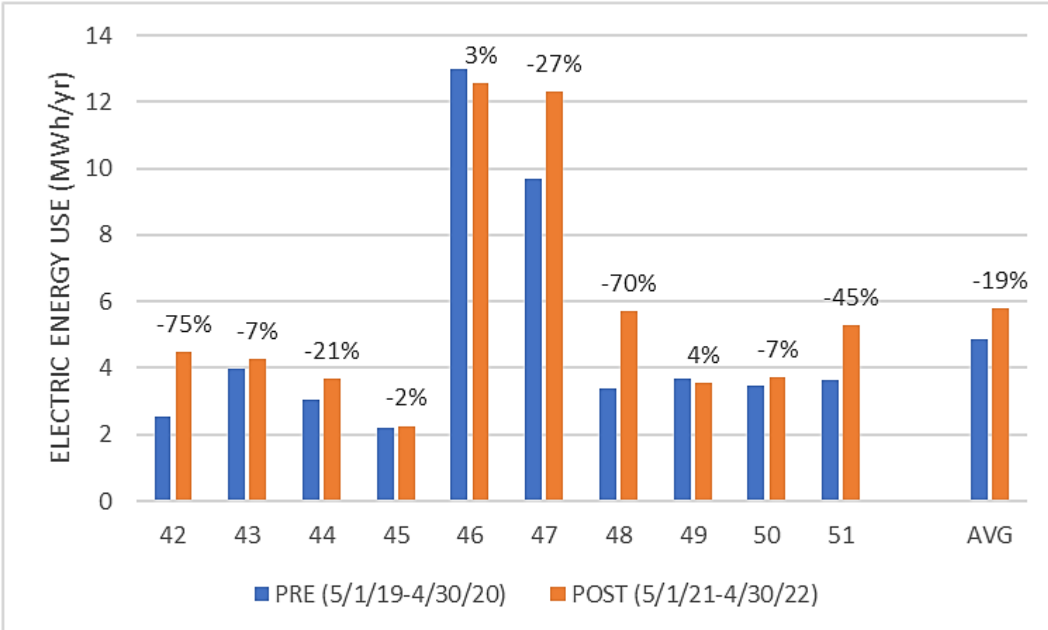
The utility bill analysis confirmed that natural gas use did not increase between pre- and post-retrofit, suggesting that there was no heating penalty due to the presence of the economizer box and outdoor air duct, as shown in Figure A-13. In fact, weather normalized energy actually went down on average by 9,600 kBtu per year, or 24 percent. Of course, there could be many other changes that happened between the PRE and POST periods—most notably the emergence of the COVID pandemic. As shown in Figure A-14, electric bills did increase, as expected. On average, annual whole-home electric energy use went up by about 915 kWh, or 19 percent. This was likely due to a combination of the extra energy used for the NTV fan and other factors such as COVID. This was also caused by two homes (42 and 48), which did install air conditioning. Without the electricity consumption of these two homes, the average electric bill increase was only 610 kWh or 11 percent.

Figure A-13: Utility Whole Home Gas Use



Source: Frontier Energy

Figure A-14: Utility Whole Home Electricity Use



Source: Frontier Energy

To estimate the energy saved by using NTV instead of central AC, a typical small home was modeled in EnergyPlus. It had a central heating system with gas furnace, and the AC unit had a Seasonal Energy Efficiency Ratio (SEER) of 13. The heating setpoint was 65°F and the cooling setpoint was based on Title 24 modeling software, varying from 78°F to 83°F. The house was simulated using TMY3 weather data from Santa Rosa. Regression coefficients derived from field monitoring were applied to the TMY3 dataset used for the simulation. A rates calculator was used to estimate bill impacts for the different scenarios, under flat and TOU rates.

Further details about this project can be found in the Lead Locally Technology Demonstration Final Report (R. Hendron, S. Chally, et al. 2022).

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APPENDIX B: EM&V Methods

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APPENDIX B: EM&V Methods

Data Preparation

Estimates of technology and program savings evaluated by DNV were evaluated against normalized baseline consumption for each site for both gas and electric consumption. Daily gas data and sub-hourly electric AMI data for each participating site was provided by Sonoma Clean Power staff for this purpose. To determine an appropriate baseline for each site, DNV assigned a consumption data “blackout period” to each site based on their earliest and latest technology installation dates, filtered the data based on this blackout period, and then performed weather normalization to remove variability in site-level consumption due to weather.

Blackout Period

Blackout periods were defined on a site-by-site basis. For a given site, a blackout period is defined as the entire month in which a technology installation takes place. For example, if a site had an installation on March 5, 2021, the site blackout period would be March 1, 2021 – March 31, 2021. If a site had multiple installations, the blackout period would span the entire time period between the installation-specific blackout periods. This methodology was chosen to avoid working with consumption data that is in flux due to the installation of a new technology.

After creating blackout periods, each site was assigned a pre-installation and post-installation period. The pre-installation period was defined as the year preceding the beginning of the blackout period, while the post-installation period is defined as the year following the end of the blackout period. A site was considered to have a complete pre- or post-period if the specified time period had at least 328 days of data. The normalized pre-installation period for each site was used as the annual baseline consumption. This ensured each site had the most recent, representative patterns of consumption to compare the evaluated technologies against.

Weather Normalization

DNV performed weather normalization using the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Consumption data for both fuel types was aggregated to the daily level and labelled as either pre-installation period or post-installation period. Daily average temperature was gathered for the closest weather station to each site. Using PRISM, site-level models were fit for each time period on the daily-level data to determine a given site’s heating and cooling energy use patterns. Model results were then used to place site-usage patterns in the context of a Typical Meteorological Year (TMY), removing variable energy consumption due to extreme weather. The resulting TMY consumption, or Normalized Annual Consumption, was used as the baseline consumption for each site when available.

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APPENDIX C: EM&V Sample Design

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APPENDIX C:
EM&V Sample Design

EM&V Sample Design

This section presents the residential and commercial sample designs including methodology, population summary statistics, and sample design summary information. The first step in the sample design was to define the population. For this evaluation, the population is defined as 166 sites. The population was divided into the residential and commercial sectors. Next, the population was further broken down by 13 unique measures across the two sectors. The program was dominated by residential measures, which account for 94 percent of the measures installed and 88 percent of the annual (kBtu) savings. Table C-1 presents the population summary statistics.

Table C-1: Program Population Summary

Sector	Measure Type	Accounts	Annual Combined Savings (kBtu)	Mean	Minimum	Maximum
Commercial	Commercial Dishwasher	3	34,686	11,562	11,562	11,562
	Commercial Induction Cooktop	2	132,399	66,200	999	131,400
	Daylighting Enhancement	1	999	999	999	999
	Mini-Split Heat Pump	1	22,558	22,558	22,558	22,558
	Phase Change Material	4	97,999	24,500	999	50,100
Residential	Aerosol Duct Sealant	10	16,766	1,677	1,677	1,677
	Heat Pump Water Heater	77	864,380	11,226	829	14,810
	Heat recovery ventilation	7	18,085	2,584	(1,764)	9,777
	Hydronic Fan Coil with DHW	2	1,998	999	999	999
	Mini-Split Heat Pump	46	1,301,206	28,287	106	88,057
	Nighttime Ventilation/ Economizer	10	8,325	833	833	833
	Phase Change Material	5	4,995	999	999	999
	Radiant Ceiling Panels	1	999	999	999	999
	Residential Induction Cooktop	16	3,145	197	41	267
	Smart Thermostat	1	1,153	1,153	1,153	1,153

Source: DNV

Having established the population frame the next step was to design the sample. Due to the small number of commercial measures, DNV decided that a census of commercial measures would be included in the evaluation.

For the residential sector, HPWHs and MSHP measures account for 98 percent of the savings. These two measures were allocated sample sizes in proportion to the savings represented by the measure groups. For the MSHP measures, three strata were defined based on the amount annual kBtu savings. Due to the uniformity of savings within the HPWH measure, no additional savings stratification was used. For all other measures except for smart thermostats, a sample of two sites was selected to provide insight into each technology type. The smart thermostat measure was not evaluated because there was just a single measure in the population and also because the measure was not part of the Lead Locally Program.

Table C-2 presents the sample design summary including number of accounts in the population, number of accounts proposed for the sample, strata cut-points, annual savings, and inclusion probability.

Table C-2: Sample Design Summary

Sector	Measure	Stratum	Maximum Savings (kBtu)	Accounts	Combined Annual Savings (kBtu)	Sample	Inclusion Probability
Commercial	Commercial Dishwasher	1	11,562	3	34,686	3	1.00
	Commercial Induction Cooktop	1	131,400	2	132,399	2	1.00
	Daylighting Enhancement	1	999	1	999	1	1.00
	Mini-Split Heat Pump	1	22,558	1	22,558	1	1.00
	Phase Change Material	1	50,100	4	97,999	4	1.00
Residential	Aerosol Duct Sealant	1	1,677	10	16,766	2	0.20
	Heat Pump Water Heater	1	14,810	77	864,380	7	0.09
	Heat recovery ventilation	1	9,777	7	18,085	2	0.29
	Hydronic Fan Coil with DHW	1	999	2	1,998	2	1.00
	Mini-Split Heat Pump	1	28,601	22	379,559	5	0.23
	Mini-Split Heat Pump	2	35,978	13	429,287	4	0.31
	Mini-Split Heat Pump	3	88,057	11	492,361	4	0.36
	Nighttime Ventilation/Economizer	1	833	10	8,325	2	0.20
	Phase Change Material	1	999	5	4,995	2	0.40
	Radiant Ceiling Panels	1	999	1	999	1	1.00
	Residential Induction Cooktop	1	267	16	3,145	2	0.13

Source: DNV

ENERGY RESEARCH AND DEVELOPMENT DIVISION

APPENDIX D: EM&V Detailed Methods and Results

October 2024 | CEC-500-2024-100

APPENDIX D: EM&V Detailed Methods and Results

EM&V Detailed Methods and Results

We provide further details on EM&V methods by technology and additional information about variation between specific sites below.

Mini-Split Heat Pumps

Table D-1 shows a summary of total electric savings, gas savings, total energy savings, and peak demand for MSHPs. Table D-2 shows the percent change in electric, gas, and total energy consumption for MSHPs.

Table D-1: Total Savings and Peak Demand Summary for MSHPs

# of Sites	kWh Savings	Therms Savings	kBtu Savings	Equivalent kWh Savings	Peak Demand Reduction (kW)
58	-55,303	14,851	1,296,450	379,968	-22.0

Source: DNV (Modeled)

Table D-2: Percent Savings Summary for MSHPs

# of Sites	percent Change kWh	percent Change Therms	percent Change kBtu
58	-14 percent	65 percent	35 percent

Source: DNV (Modeled)

We provide further details on the MSHP analysis below:

- The engineering phone verification survey and web-survey for selected sample sites probed whether participant performed any additional upgrades and major renovations after the measure install date. Almost all sites (16 sites out of 17; the 17th site was a commercial site) from sample reported they completed some type of additional upgrades or renovations to their homes. Notable upgrades include:
    - Additional insulation for attic and floor
    - HPWH
    - Added Solar Panels and/or battery storage with net meter installs
    - Electric-Vehicle (with or without home charger)

The sites that received additional upgrades were included in the site savings estimate along with mini-split savings. In cases of non-routine events, DNV's savings calculation accounted for them and isolated them from the site savings by using the Database for Energy Efficient Resources (DEER) deemed model savings where appropriate. Since for some sites, the deemed savings estimates were higher than the normalized building consumptions derived from the billing data, a separate savings analysis approach was adopted. This is further explained below in the methodology section.

A few of the sites used propane as their heating fuel prior to heat pump installation. In this case, the savings calculation assumed a gas baseline that is equivalent to a replacement of a natural gas furnace with a mini-split system.

- Most sites had gas furnace as pre-retrofit heating, some sites had room AC for cooling in addition to gas heating, and some had no cooling in their baseline condition. A few sites had electric baseboard heating instead of gas. These characteristics were considered in the DEER baseline model selection, further described below.
- Also, the evaluation found seven sites with significantly higher percentage gas savings, that is, above 90 percent of site baseline gas usage. The evaluation verified the billing usage of the sites and found that the evaluated savings are consistent with the billing usage. This high percentage savings was the result of fuel substitution.

Site-specific savings varied for several reasons that are listed below:

- **Use of site-specific area.** The modeled savings results were normalized based on the prototype model area and were applied to other sites using their respective conditioned floor space area. Thus, site-specific savings varied based on their area.
- **Different baseline system type.** The existing HVAC system type was one of the reasons for variation in savings estimates. Based on online survey and engineering phone survey responses, DNV estimated savings using DEER prototype models and utilized different baseline system types. The baseline model variation based on system type is shown in Table D-3 below.
- **Billing savings substitutions cases.** For each site in the population, DNV estimated savings using both DEER models and a site-level billing analysis. There are cases where the deemed savings were higher compared to billing level savings. In those cases, the savings from the billing analysis was used for that site.
- **Heating/Cooling setpoints.** In the DEER model analysis, setpoint dead band is estimated to be 68 to 72 °F. Based on the engineering interviews, DNV determined that 68 to 72 °F is the best estimate that describes the whole sample population. All deemed model estimates used this setpoint. This setpoint is different than the ones used in Frontier's analysis, described in the next bullet.
- **Frontier methodology.** Seven sites in the population had analysis performed by Frontier Energy, which were research study sites instead of deployment sites. These sites utilized hourly logger data on site with setpoints and consumption, and a savings per degree hours approach with base temperature 65° F for cooling and 60° F for heating. This method is appropriate since it may have reflected site-level energy usage. DNV decided to retain these savings numbers in the population. The difference in methodology and setpoint temperature (60 to 65° F vs. 68 to 72° F) contribute to the variance in savings.

- **Hypothetical baselines for sites with insufficient pre-billing data.** There are five propane sites and most propane sites do not have pre-retrofit gas billing data. For these sites where pre-retrofit gas data was lacking, DNV created an assumed equivalent gas baseline consumption based on a similar home (in square-footage, using per square-footage rate to scale) to estimate the percent savings with respect to the baseline. Two sites were also lacking in pre-retrofit kWh data. A similar approach was used.
- **Non-sampled sites approximation.** Savings estimates are largely based only on the key input parameter (non-routine events, set points) adjustments for the 17 sampled sites in addition to billing and program data. For the remaining 41 sites that were not sampled, savings estimates were approximated using the sampled sites savings, billing, and program data, with adjustments where necessary (that is, square footage, similar baseline systems). The aforementioned variation drivers apply for these sites also, in addition to this variation driver itself.

DNV estimated mini-split heat pump savings by using a combination of DEER deemed model estimates and site-specific weather-normalized billing analysis (degree-days optimization model with most of the site-specific billing data). The DEER deemed model has key input modifications based on site surveys (setpoints, different baseline systems, average heat pump SEER). After calculating both a hypothetical deemed savings from DEER models and a site-specific normalized billing savings for each fuel type (kWh or therms), DNV examined available online survey data, engineering phone survey data, and Lead Locally Program data to determine whether a site had pre-existing gas or electric equipment to verify the actual fuel-type of site (fuel-switch or electric-only site). With the aforementioned information, plus the availability of the appropriate pre-retrofit billing data (gas or electric), DNV engineers made informed decisions based on availability and completeness of site-level data when determining whether deemed estimated savings or site-level billing analysis methods should be applied for estimating kWh and therm savings at given site.

The deemed model estimate utilized EnergyPlus prototype models from the DEER2024 Residential models.[1] From engineering phone verification surveys and Lead Locally Program data, DNV determined that surveyed sites had different pre-existing system types (see Table D-3 for details), such as gas furnace or electric baseboard for heating with no cooling, room AC, or central AC for cooling and determined the modeled savings and then calculated savings per conditioned area (ft^2). These unit savings were subsequently applied to non-sampled sites with the appropriate site area. DNV made the following assumptions in choosing which deemed prototypes to use:

- Baseline-case model choices
    - Gas Furnace Heat + No Cooling
    - Gas Furnace Heat + Room AC
    - Gas Furnace Heat + Central AC (Commercial model)
    - Electric Baseboard + Room AC
    - Electric baseboard + No AC

[1] https://github.com/sound-data/DEER-Prototypes-EnergyPlus

- Measure-case model choices
  Ductless HP, efficiency is approx. Seasonal energy efficiency ratio (SEER)=20 based on program data (Make/Model of MSHP) of population
- Heating setpoint 68° F, Cooling setpoint 72° F
  Population level approximation based on engineering survey data

Under these assumptions, the following prototypes models were selected as models for deemed savings analysis:

- Non-condensing gas furnace (NCGF) pre-existing baseline model (Annual Fuel Utilization Efficiency (AFUE) 80)
- Room AC pre-existing baseline model from DEER Ductless HP measure
- SEER-20 Ductless HP measure case model from DEER Ductless HP measure
- Building vintage of the prototype is 1975.

Table D-3: Mini-Split Analysis, Deemed Model Baseline Type Used

Existing System Type	Number of Sites	Pre-retrofit model type	Post-retrofit model type
Residential			
Gas Furnace + No AC	42	Gas Furnace 80 percent AFUE	Ductless HP, 20 SEER (Cooling COP 4.22, Heating COP 3.02
Gas Furnace + Room AC	12	Gas Furnace 80 percent AFUE + Room AC (cooling COP 2.64, Heating COP 2.26)	Ductless HP, 20 SEER (Cooling COP 4.22, Heating COP 3.02
Electric Baseboard + Room AC	1	Room AC (cooling COP 2.64, Heating COP 2.26) + Electric Resistance Heating	Ductless HP, 20 SEER (Cooling COP 4.22, Heating COP 3.02
Electric Baseboard + No AC	1	Electric Resistance Heating	Ductless HP, 20 SEER (Cooling COP 4.22, Heating COP 3.02
Commercial			
Gas Furnace + Evaporative Cooler	1	Gas Furnace + Central AC	HP, 18 SEER

Source: DNV

The peak demand reduction per square-foot was estimated using hourly results from corresponding models, with the current California peak definition for Climate Zone 1 and 2, where peak period is 4 p.m. to 9 p.m. for August 26th, 27th, and 28th (days 238, 239, and 240). The peak demand reduction estimation is calculated by applying site-specific square-footage.

Knowing there are non-routine upgrades or renovations for almost all sites prevented DNV from fully relying on site-specific billing analysis to estimate technology-level savings, as billing consumptions reflect the combination of upgrades and renovations. Depending on billing data availability, billing normalized savings validity, and deemed savings validity, savings were approximated using deemed or billing, where appropriate.

Eight out of 17 sampled sites were verified to have a net meter (solar panels) installed during the pre-retrofit or post-retrofit period of the mini-split heat pump measure. This means that energy consumption for the examined billing periods included the effects of solar. Site-specific billing consumption was less than what they could have been without solar, thus energy savings will appear inflated without a solar correction.

- For these eight sampled net-meter sites, DNV approximated a solar correction to the billing consumption before calculating site-specific billing savings.
- The solar correction procedure estimated total solar power generation using NREL's PV calculator,[2] with the estimated solar panel area (using Google Maps) and assumed power rating (250W per panel, 17.5 square-ft per panel) as inputs to the PV calculator. The difference between this estimated solar total generation and net meter generation data (amount kWh delivered back to grid) is the amount of solar power consumed by the site. This amount of solar power consumed by the site is then added back to the billing data on the appropriate date intervals based on the first day of the net meter installation.

Heat Pump Water Heaters

Table D-4 shows a summary of total electric savings, gas savings, total energy savings, and peak demand for HPWHs. Table D-5 shows the percent change in electric, gas, and total energy consumption for HPWHs.

Table D-4: Total Savings and Peak Demand Summary for HPWHs

# of Sites	kWh Savings	Therms Savings	kBtu Savings	Equivalent kWh Savings	Peak Demand Reduction (kW)
78	-63,107	11,323	917,026	268,765	-6.2

Source: DNV (Modeled)

Table D-5: Percent Savings Summary for HPWHs

# of Sites	percent Change kWh	percent Change Therms	percent Change kBtu
78	-12 percent	38 percent	19 percent

Source: DNV (Modeled)

[2] https://pvwatts.nrel.gov/pvwatts.php

Savings across the sites with heat pump water heaters varied due to a few reasons:

1. Site-specific inputs. For sites that were interviewed, DNV entered site-specific information, including pre-existing tank temperature and tank volume (if applicable), HPWH tank temperature, tank location, and number of occupants.
2. Number of occupants. Whether determined via phone interviews or web surveys, site savings are different based on the reported number of occupants. For sites where number of occupants is unknown, an assumed average of 3.3 occupants was used.
3. HPWH tank volume. Tank volume is correlated with utilization of heat pump heating. The larger the tank volume, the more buffer there is to changes in tank temperature. HPWHs tend to use more electric resistance heating when there are large drops (> 10 to 20 °F) in tank temperature.
4. Pre-existing water heater type. Tankless water heaters generally consume less energy than tank water heaters. DNV used available tracking information to determine the pre-existing water heater type. When no information on water heater type was available, DNV assumed a tank water heater.

Some specific findings discovered through the participant interviews include:

- Five of the seven sites had their HPWH located in their garage. One site had the HPWH located in the crawlspace, and one site had the HPWH located in the (conditioned) laundry room.
- Only one site (HPWH located in the laundry room) had alternative venting for the HPWH. The HPWH had inlet and outlet ducting into the attic. All other HPWHs had no ducting.
- Six of the seven sites appeared to have their HPWHs in the "Energy saver" mode, which is usually one of two "hybrid" modes that uses either heat pump and/or electric resistance element for heating. The water heater's control software monitors the lower tank thermistor to determine if turning on the electric resistance element is necessary. The "Energy saver" mode has a lower tank temperature threshold than the "high demand" mode, which is the other, less efficient, hybrid operating mode.
- Two sites were confirmed to have their pre-existing water heaters fueled by propane. Ten other sites were, based on tracking and billing information, assumed to have pre-existing water heaters fueled by propane. In all propane cases, site savings assumed natural gas equivalent water heaters and gas savings were not capped.
- One site was verified to have retained their pre-existing (propane) water heater. The participant explained that their community experiences several power outages every year, and they retained their old water heater for backup purposes when they lose grid electricity. They plumbed the existing propane water heater and HPWH using valves such that only one water heater may be used at any time.

Breakdowns of variance across sites in pre-existing water heaters and HPWH tank sizes are shown in Table D-6 and Table D-7 below. Note that sites either verified or assumed to have propane-fueled water heaters were assigned "gas tank water heater" or "gas tankless water heater."

Table D-6: Pre-Existing Water Heater Type

Pre-existing water heater type	Count	Percent of Total
Gas Tank Water Heater[3]	64	82 percent
Electric Tank Water Heater	11	14 percent
Gas Tankless Water Heater	3	4 percent

Source: DNV

Table D-7: HPWH Tank Size

HPWH Tank Size (gallons)	Count	Percent of Total
50	11	14 percent
65	34	44 percent
80	33	42 percent

Source: DNV

DNV estimated HPWH technology savings using a modified version of the California Database of Energy Efficiency Resources (DEER) Water Heater Calculator (DWHC).[4] The calculator uses pre-defined hourly hot water load profiles, ambient weather (by California climate zone), cold water inlet temperature (by California climate zone), and water heater performance metrics to calculate hourly and annual water heater energy consumption.

The DWHC was designed to estimate deemed savings for water heating measures implemented through energy efficiency programs managed by California utilities. The inputs (for example, water heater characteristics, hot water profiles) are meant to be representative of typical California-state participants and performance-tiered water heating technologies. The DWHC was modified for this evaluation to accept site-specific inputs, including:

- HPWH and pre-existing tank set point temperature
- Number of occupants, which directly influences the hourly hot water profile
- HPWH nominal efficiency and tank volume

For traditional gas and electric tank water heaters, the DWHC hourly hot water load profiles reasonably estimate water heater energy usage. The traditional water heaters have simple controls (for example, burner is on or off, upper/lower electric element is on or off) and only one "mode" of operation.

HPWHs are often controlled using a slightly more complex sequence of operation. Further, the proprietary algorithm that manufacturers design and program into their HPWHs affects how the HPWH responds to water heating demands. Because they have two heating options (the heat pump or the electric heating element), and those heating options have drastically

[3] Four of these did not have water heater type in tracking. They were assigned a gas tank by DNV.

[4] https://cedars.sound-data.com/deer-resources/tools/water-heaters/

different heating efficiencies, modeling when and how often the HPWH uses each heating mode is critical to accurately estimate energy consumption.

The DWHC uses a simple mixed tank temperature model, assumed heat pump and electric resistance heating recovery rates, and 1-minute interval hot water profiles (to more accurately model hot water draws that could trigger electric resistance heating) to estimate utilization factors for heat pump heating and electric resistance element heating. Generally, number of occupants, tank volume, and tank set point temperature have strong influences on how often the HPWH uses backup electric resistance elements to heat the water. The model also assumes a compressor cut-off ambient air temperature (the HPWH disables the heat pump and uses electric resistance elements to heat water) of 45 °F.

Induction Cooktop: Residential

Table D-8 shows a summary of total electric savings, gas savings, and total energy savings for residential induction cooktops. Table D-9 shows the percent change in electric, gas, and total energy consumption for residential induction cooktops.

Table D-8: Total Savings Summary for Residential Induction Cooktops

# of Sites	kWh Savings	Therms Savings	kBtu Savings	Equivalent kWh Savings
16	2,936	29	12,883	3,777

Source: DNV (Modeled and Measured)

Table D-9: Percent Savings Summary for Residential Induction Cooktops

# of Sites	Percent Change kWh	Percent Change Therms	Percent Change kBtu
16	2 percent	0.6 percent	1.5 percent

Source: DNV (Modeled and Measured)

DNV grouped residential sites with induction cooktops varied in three categories:

1. Frontier Research Project sites with direct measurements data for three months pre- and post- installation. There were five sites, all of which were electric cooktop to induction cooktop conversions.
2. Electric cooktops converted to induction cooktops (six sites)
3. Gas cooktops replaced by induction cooktops (five sites)

The team used different methods for each category to estimate energy savings:

- For sites with direct measurements, the project team calculated the savings based on metered data and verified with the participants that cooking behaviors remain reasonably similar to the metering period.

- For non-metered sites with electric to induction cooktop replacements, the team calculated savings using site-specific equipment capacities and the average kWh savings from the five sites with direct measurements.
- For the sites with gas cooktops replaced by induction cooktops (fuel substitution), none of these sites were metered, so DNV used deemed savings from DEER based on each site's climate zone.

For the single site within the commercial sector, DNV concluded that the induction cooktop was a load addition because the participant was expanding their kitchen and decided to install an induction cooktop rather than a new gas cooktop. Their existing cooktop is gas (which Frontier metered to establish baseline gas usage) and is still in operation. The tables above show the induction cooktop allowed a substantial avoidance in what would have been an additional 1,658 Therms or 19 percent in annual gas usage under typical operating conditions.

It was verified by the participant that the use of both gas and induction cooktops are very similar, and both share equivalent loads over the typical kitchen schedule. It was also verified that the participant does not expect significant changes from these operating conditions.

DNV used pre- and post-installation meter data collected by Frontier to estimate daily energy impacts. The daily energy impacts were applied to annual schedules that were collected from the phone survey and an internet search. Frontier metered the existing gas cooktop and induction cooktop each for 90 days. During the phone survey, the participant suggested that both metering periods (one for gas and one for induction) are representative of the typical cooking load that the induction cooktop currently experiences (and what the hypothetical gas cooktop would have experienced).

Peak demand was estimated by spreading the daily electric usage (41.3 kWh/day) evenly over the kitchen's typical operating schedule (9 a.m. to 9 p.m.) and taking the average demand over the Climate Zone 2 peak hours (4 p.m. to 9 p.m.). The induction cooktop increased peak demand by 3.44 kW, a relatively significant factor considering maximum outputs for commercial cooktops can range up to 11.6 kW.

Induction Cooktop: Commercial

The Lead Locally Program implemented two commercial induction cooktops at two commercial sites. DNV verified the installation and other key savings parameters via a phone survey at one of the sites. The other site was dropped from the sample due to lack of a verified installation date and knowledge of the baseline cooktop. Table D-10 shows a summary of total electric savings, gas savings, total energy savings for commercial induction cooktops. Table D-11 shows the percent change in electric, gas, and total energy consumption for commercial induction cooktops.

Table D-10: Total Savings and Peak Demand Summary for Commercial Induction Cooktops

# of Sites	kWh Savings	Therms Savings	kBtu Savings	Equivalent kWh Savings	Peak Demand Reduction (kW)
1	-10,727	1,658	129,243	37,879	-3.44

Source: DNV (Modeled and Measured)

Table D-11: Percent Savings Summary for Commercial Induction Cooktops

# of Sites	Percent Change kWh	Percent Change Therms	Percent Change kBtu
1	-0.8 percent	2 percent	1 percent

Source: DNV (Modeled and Measured)

Heat Recovery Dishmachines

Table D-12 shows a summary of total electric savings, gas savings, total energy savings, and peak demand for heat recovery dishmachines. Table D-13 shows the percent change in electric, gas, and total energy consumption for heat recovery dishmachines.

Table D-12: Total Savings and Peak Demand Summary for Heat Recovery Dishmachines

Sector	# of Sites[5]	kWh	Therms	kBtu	Equivalent kWh	Peak Demand Reduction (kW)
Commercial	2	11,748	0	40,084	11,748	2.2

Source: DNV (Measured)

Table D-13: Percent Savings Summary for Heat Recovery Dishmachines

Sector	# of Sites	Percent kWh	Percent Therms	Percent kBtu
Commercial	2	10 percent	-	5 percent

Source: DNV (Measured)

Sites with heat recovery dishmachines reduced their overall dishwashing energy per rinse event by 13 percent and 38 percent and reduced water use per rinse event by 27 percent and 35 percent.

The electric impacts for these projects are comprised of two components—the electric water heater energy displaced by the heat recovery system (the heat recovery dishmachines do not have a hot water feed) and the change in dishwasher heating element energy between the conventional and heat recovery dishmachines.

[5] One site was dropped because DNV was unable to conduct survey and no install date was provided to perform billing analysis. The site was also not monitored by Frontier.

DNV conducted a phone survey with one of the two sites and verified that their average daily rinse events were within reasonable range of the number of events experienced during the monitored period. DNV also verified that the existing electric water heater was no longer connected to the heat recovery dishmachine.

For both sites, DNV utilized interval data collected by Frontier. They monitored the water heaters and conventional dishmachines for six months prior to the retrofit to capture the baseline period. Monitoring continued for another six months after installation of the heat recovery dishmachine to compare total dishmachine energy use between periods. Additionally, the number of rinsing events per day and gallons of water consumed per day were monitored.

DNV divided the total dishwashing energy (composed of water heater energy and dishmachine energy in the pre-period, and only dishmachine energy in the post-period) over each monitoring period (approximately 180 days in the pre-period and 180 days in the post-period) by the number of total rinse events to calculate a dishwashing energy per rinse event. This allowed DNV to normalize dishmachine energy usage by number of rinse events. DNV then determined an average number of annual rinse events for each site. Table D-14 summarizes the key parameters used to calculate energy savings.

Table D-14: Daily Averages of Key Parameters, Heat Recovery Dishmachines

Site/Case		Total Dishwashing kWh per event	Rinse water gallons per event	Operating Schedule (rinse events/year)	Annual Energy (kWh/year)
DNV_15	Baseline	1.13	1.55	17,568	19,903
	Replacement	0.99	1.13		17,394
	Savings	0.14	0.41		2,509
DNV_113	Baseline	1.01	1.72	23,864	24,141
	Replacement	0.62	1.13		14,902
	Savings	0.39	0.60		9,239

Source: DNV

Peak demand reduction values were calculated for both sites by assuming dishwashing events (and thus energy usage) occurred evenly through business hours.

Aerobarrier Envelope Sealing

DNV reviewed BEopt™ building energy models used by Frontier to estimate site-level savings for the Aerobarrier Envelope Sealing measure. Table D-15 shows a summary of total electric savings, gas savings, total energy savings for aerobarrier envelope sealing. Table D-16 shows the percent change in electric, gas, and total energy consumption for aerobarrier envelope sealing.

Table D-15: Total Savings Summary for Aerobarrier Envelope Sealing

Sector	# of Sites	kWh	Therms	kBtu	Equivalent kWh
Residential	10	1,682	221	27,870	8,168

Source: DNV (Modeled)

Table D-16: Percent Savings Summary for Aerobarrier Envelope Sealing

Sector	# of Sites	Percent Change, kWh	Percent Change, Therms	Percent Change, kBtu
Residential	10	6 percent	1.4 percent	1.7 percent

Source: DNV (Modeled)

Because air infiltration and duct leakage rates (and other characteristics of each home) were entered into the BEopt™ simulation tool to estimate associated HVAC energy savings over a full year, DNV deemed the Frontier savings values reasonable and appropriate to use. Utility billing analysis was not used since some measures were implemented during periods when the homes changed occupants or were installed with other retrofit measures.

Radiant Ceiling Panels

DNV's radiant ceiling panel savings calculations were based on Frontier's analysis using usage ratios (kWh/hr-°F and kBtu/hr-°F) for the pre-retrofit period and the 2021 post-retrofit period, and TMY3 degree hours for Santa Rosa, California. Table D-17 shows a summary of total electric savings, gas savings, and total energy savings for radiant ceiling panels (RCPs). Table D-18 shows the percent change in electric, gas, and total energy consumption for radiant ceiling panels.

Table D-17: Total Savings Summary for Radiant Ceiling Panels

Measure	kWh	Therms	kBtu, Combined	Equivalent kWh
Radiant ceiling panels	1,203	82	12,307	3,607

Source: DNV (Measured)

Table D-18: Percent Savings Summary for Radiant Ceiling Panels

Measure	Percent kWh	Percent Therms	Percent kBtu, Combined
Radiant ceiling panels	22 percent	13 percent	15 percent

Source: DNV (Measured)

The savings values include impacts from other energy conservation measures that were installed with the RCPs. They include R-49 attic insulation, caulking and spray-in for the ceiling and drywall, two ASHRAE 62.2-compliant bathroom fans, and an ENERGY STAR® whole house dehumidifier. Whole house infiltration dropped from a pre-implementation leakage rate of 8.8 ACH50 to a post-implementation leakage rate of 6.1 ACH50.

DNV believes that the RCP site analysis performed by Frontier provides the most realistic and accurate savings relative to what a non-metering savings approach (for example, deemed or building energy modeled savings) would provide. Frontier installed a comprehensive metering suite that was in place for nearly seven months during the pre-retrofit period to capture reasonable cooling and heating season energy consumption for the pre-existing equipment—a ducted forced-air furnace with traditional air conditioning (AC). The metering suite collected an additional two years of post-retrofit data and covered a distinct period where the occupant adjusted to and learned new behaviors for operating the new HVAC system.

During the phone interview, DNV learned that the participant (and main occupant and controller of the new HVAC system) initially struggled learning a comfortable and consistent operating schedule for the RCPs. The radiant delivery method of heating/cooling and response time for "comfort" was drastically different and the participant noted that they needed to unlearn behavior typical with conventional forced-air ducted heating and cooling systems. For example, the participant was used to operating their forced-air furnace with AC very manually, typically turning off at nights and heating and cooling in the mornings for short but heavy-load spurts. They were accustomed to quickly heating up or cooling down their home. That behavior changed with the RCPs in part because the response time was much slower than their pre-existing system. The participant learned that they must keep the system on and at a relatively stable schedule and set point for the house to reach setpoint and to "feel" that their comfort was satisfied.

The participant also noted that they "got a hang" of their new system during the winter of 2020, when they experienced some colder-than-typical days. They had been controlling the system (relatively) manually like their pre-existing system and expecting quick response times. When they tried to quickly heat up the house with the RCP system, it appeared that the cold snap had shut out the compressor or significantly reduced heating output, leaving them with a very cold house.

Lastly, the participant suggested that 2021 could reasonably represent the year they learned the system, and that they have been operating it consistently since then.

Daylighting

There were two daylighting sites in the population data set (DNV_6 and DNV_7). However, DNV's analysis shows savings for only one site that had an adequately long monitoring period to capture both cooling and heating seasons (the site referred to as DNV_6 for the remainder of the report). The other site (DNV_7) installed the TDD system in early 2023 and was monitored for only 15 days. It was not evaluated since the short monitoring period was not long enough to provide an accurate estimate of savings across cooling and heating seasons.

The participating sites could not be contacted for surveys, so DNV used the savings estimates provided by Frontier to evaluate the overall savings for the technology. Table D-19 shows a summary of total electric savings, gas savings, total energy savings for daylighting. Table D-20 shows the percent change in electric, gas, and total energy consumption for daylighting.

Table D-19: Total Savings Summary for Daylighting

Sector	# of Sites	kWh	Therms	kBtu	Equivalent kWh
Commercial	2	365	0	1,246	365

Source: DNV (Measured)

Table D-20: Percent Savings Summary for Daylighting

Sector	# of Sites	Percent Change, kWh	Percent Change, Therms	Percent Change, kBtu
Commercial	2	2 percent	-	0.6 percent

Source: DNV (Measured)

The baseline for these sites is the original lighting fixtures without the TDD and without any dimming and daylighting control systems. It is important to note that DNV_6 is the Advanced Energy Center, and that a hypothetical baseline was used since the site underwent major renovation during the pandemic. Pre-installation consumption was not available for the analysis.

Site specific savings varied because of the following reasons:

- **Revised Fixture Wattage**—The evaluation team used the standard lighting fixture wattage for 2'x4' panel LED which revised the fixture wattage from 40W to 45.7W.
- **Updated Occupied Hours**—The reported savings utilized 4,848 occupied hours, which was based on 676 days of monitoring period. The evaluated savings were based on one whole year and thus revised the occupied hours to 2,618 hours per year to annualize the savings.
- **Interactive Baseline Lighting Load**—The evaluated savings analysis for the baseline period also included the additional HVAC load from the baseline electric lighting fixtures that were not considered in the reported savings analysis.
- **Interactive Post-case Lighting Load**—The evaluated savings analysis for the post period also included the additional HVAC load from the electric lighting fixtures that were operating with dimming controls and were not considered in the reported savings analysis.

DNV estimated the evaluated savings using Frontier's analysis since it used metered lighting system data and revised some of the inputs, as discussed above. The monitoring period for DNV_6 was 676 days, which was sufficient to adequately capture the effects during cooling and heating seasons. The monitoring period was for 676 days that was equivalent to 8,978 working hours and 4,848 occupied hours, which is 54 percent of the total working hours.

The evaluated savings analysis adopted the following approach:

First, the occupied hours over the monitored period were converted to an annualized figure by multiplying 4,848 hours by the ratio (365/676), thus revising the occupied period to 2,618 hours per year that was subsequently used for all lighting power and interactive electric load components.

The baseline lighting system consisted of nine luminaires with assumed fixture wattages of 45.7W each that collectively consume 1,077 kWh/year. To calculate lighting energy consumption in the post-install period, the baseline lighting load was multiplied by the average lighting dimming percentage, which represents the percentage in which the lights were shut off, resulting in 700 kWh. Because lighting fixtures contribute toward heat gain into the space, it was necessary to consider cooling load savings due to these lighting interactive effects. Assuming a cooling efficiency of 12 SEER or 3.20 COP for the HVAC system serving the space, an additional 168 kWh of cooling energy is required to remove the heat generated by the baseline lighting during the summer period and an additional 128 kWh free heating energy available during the winter period. A similar approach was used to determine the post-install case cooling load from the electric lighting fixtures that were working with dimming controls along with the TDDs. Additional cooling load added by the TDDs in the post-install case was calculated using the average daily solar heat gain resulting in 63 kWh of cooling load. The reduced heating load in winter due to the TDDs was also calculated using daily solar heat gain during the heating season resulting in 37 kWh of reduced heating load. The total savings between the pre- and post-install periods considering all savings strategies is 365 kWh per year. The energy components from lighting, TDDs, and their interactions with building cooling and heating energy consumptions are summarized in Table D-21 below.

Table D-21: Summary of Annual Energy Savings by Strategy

Savings Strategy	Baseline	Post-Installation	Savings
Lighting fixtures	1,077	700	377
Summer cooling load - fixtures	168	109	59
Summer cooling load - TDD	-	63	(63)
Winter heating load - fixtures	(128)	(83)	(45)
Winter heating load - TDD	-	(37)	37
Total	1,117	752	365

Source: DNV

Peak demand savings were not calculated since the associated room where the TDDs were installed is a conference/office space that is not occupied during typical DEER peak demand hours, which occur between 4 p.m. through 9 p.m. during the weekdays.

Installing TDD systems with lighting controls in spaces with interior lighting fixtures realizes energy savings. By allowing natural light to enter the space through the TDD, the control system dims the interior lighting by a percentage based on setpoints, thus cutting down on lighting fixture energy. Interior lighting adds heat energy into the spaces as an interactive effect. However, the summer season cooling loads required to offset this lighting heat energy are reduced due to the dimming. Lastly, the solar heat gain through the TDD during the winter season provides some heat to the space, thus reducing the HVAC heating load.

Phase Change Materials: Residential

As discussed in Chapter 5, there were no savings associated with residential phase change materials due to all measures being removed prior to the evaluation.

Phase Change Materials: Commercial

Table D-22 shows a summary of total electric savings, gas savings, and total energy savings for commercial phase change materials (PCM). Table D-23 shows the percent change in electric, gas, and total energy consumption for PCM.

Table D-22: Total Savings Summary for Commercial Phase Change Materials

Sector	# of Sites	kWh, total	Therms, total	kBtu, Combined, total	Equivalent kWh, total
Commercial	6	71,431	397	283,375	83,052

Source: DNV (Measured)

Table D-23: Percent Savings Summary for Commercial Phase Change Materials

Sector	# of Sites	kWh, total	Therms, total	kBtu, Combined, total
Commercial	6	39 percent	4 percent	17 percent

Source: DNV (Measured)

Site-specific findings for the commercial phase change material technology are as follows:

- DNV was able to speak to three commercial sites. One participant stated that he no longer has to pre-condition a room after the PCM install. Another participant stated that there was not any notable difference after the PCM install.
- Some of the commercial sites evaluated may have undergone operational and load changes in the post-COVID period that have impacts on their facility energy consumption. Since the evaluation did not have access to obtain this information, the evaluated savings analysis used the outside air temperature as the sole parameter driving the facility energy consumption.

Site savings varied due to the following reasons:

1. **Site-Specific Cooling and Heating Setpoints**—The reported savings were estimated based on the cooling and heating setpoints of 65 °F. This implies that the cooling was initiated for space temperatures higher than 65 °F, and heating was initiated for space temperatures lower than 65 °F. Based on the survey this evaluation conducted, site-specific heating and cooling setpoints were used. For site(s) that did not have survey information on setpoints, the average cooling setpoint 72 °F was used as the cooling setpoint, and 68 °F was used as the heating setpoint.
2. **Modified Baseline and Post-retrofit Periods**—Frontier savings estimates used baseline and post-retrofit periods that included some durations impacted by COVID. Since COVID-affected durations do not represent the normal facility operations and

energy consumption, DNV excluded COVID-affected periods in both baseline and post-retrofit model development. The evaluation baseline period was from 1/1/2019 through 12/31/2019. The evaluation post-retrofit period was from 1/1/2022 through 4/30/2023.

Three sampled commercial PCM sites were also analyzed by Frontier Energy, using heating degree days and cooling degree days (HDD/CDD) regression analysis. Separate regression models were developed for baseline (pre-retrofit) and post-retrofit period. The regression models used CDD and HDD as the independent parameters and energy usage (kWh or therms) as the dependent parameter.

DNV applied this methodology with updated heating and cooling baseline temperatures based on engineering survey verification data. The regression equations were applied on the TMY3 weekly CDD/HDD to determine the normalized pre- and post-retrofit consumption and the annual savings.

Each of the three sample sites used a different cooling and heating setpoint based on site-specific survey responses. Variation of savings between the three sites that were sampled can largely be explained by variation in cooling and heating setpoints:

- DNV_49 used heating setpoint 67 °F, cooling setpoint 76 °F.
- DNV_50 used heating setpoint 65 °F, cooling setpoint 78 °F.
- DNV_51 used heating setpoint 68 °F, cooling setpoint 72 °F. There was no survey response on thermostats for this site and the evaluation used the typical cooling and heating setpoints found in the commercial spaces. Also, this site has no AC systems (no cooling), therefore only therms savings are realized in the calculation.

A few of the regression models exhibited poor regression correlation (low R^2). DNV suspects that the facilities with poor model correlation may have gone through operational changes in the post-COVID period. Furthermore, while the evaluation team utilized outdoor air temperature (OAT) as the independent parameter for modeling energy consumption, other variables (like occupancy or "production" intensity/scheduling) that were unavailable for the evaluation may have improved regression model fit.

Nighttime Ventilation

Table D-24 shows a summary of total electric savings, gas savings, total energy savings for nighttime ventilation. Table D-25 shows the percent change in electric, gas, and total energy consumption for nighttime ventilation.

Table D-24: Total Savings Summary for Nighttime Ventilation

Sector	No. of Sites	kWh	Therms	Combined kBtu	kWh Equivalent
Residential	10	2,068	0	7,057	2,068

Source: DNV (Modeled)

Table D-25: Percent Savings Summary for Nighttime Ventilation

Sector	No. of sites	Percent kWh	Percent Therms	Percent Combined kBtu
Residential	10	4 percent	0 percent	1.5 percent

Source: DNV (Modeled)

DNV conducted two phone surveys in support of the nighttime ventilation analysis and discovered the following:

- One of the customers reported normal usage and good measure performance during the first year of operation, but poor performance thereafter. This led them to stop utilizing the NTV (they turned it off). They felt that the performance issues were most likely due to a limitation in the size of their existing furnace and ductwork. According to Frontier, the framing of the attic did not allow for installation of the full economizer box. This, in turn, led them to install an improvised solution that may have compromised the effectiveness of the NTV and contributed to the eventual performance and persistence issues. DNV followed up with the participant to verify whether they had any plans to address the sizing and installation challenges at the site. However, no response was received, and savings were credited on the basis of first year measure performance and the assumption that they will address the installation issues and subsequently operate the NTV according to its normal schedule.
- One of the customers opted to install a central AC a year after the NTV install. They commented that while the NTV was a mostly effective cooling solution, it still could not meet the cooling load of the more extreme summer days, and they felt more secure having the central AC as a backup cooling system. DNV felt that no savings adjustments were required since the NTV is being used according to its original design intent and schedule, and the AC is used very rarely during the cooling months, if at all.

The site savings varied because of the following:

- Site square footage. DNV utilized deemed savings normalized by conditioned square footage. DNV used verified floor area for each site to estimate site-specific savings.
- Equipment installation and commissioning issues: The energy impacts for one of the 10 sites were zeroed because the NTV fan did not run for the entirety of the metering period. DNV was unable to interview this site to identify the reason for this.

DNV utilized an EnergyPlus simulation (DEER single family residential model) to determine both the baseline and measure case consumptions. This approach was chosen because:

- The baseline for this measure is a hypothetical AC. No real billing data exists for the pre-implementation period.
- Some sites had load additions (for example, purchased EVs) and building envelope retrofits. The presence of these additional loads lowered confidence in a billing analysis approach.

The DNV baseline is a prototypical two-story 1975 home with a Code Central AC (SEER 15) and central gas furnace. The heating setpoint is 65 °F, and the cooling setpoint is 75 °F. The cooling period is assumed to be May 1 through September 30. DNV believes that these conditions are representative of typical AC usage in California Climate Zone 2.

The measure case uses the same two-story home prototype but replaces the AC with a whole house fan measure package[6] (sized to be the same flow rate and efficiency as the furnace fan) to simulate scheduled mechanical ventilation between 10 p.m. and 6 a.m. during the same cooling months that were used to characterize the baseline AC operation.

TMY3 weather data for Climate Zone 2 was used as the weather file for both baseline and measure case models.[7] Electric savings values, normalized by the modeled square footage, were calculated using the modeled outputs. Site savings were estimated using the modeled normalized savings (kWh/ft^2) and scaled using the verified site square footage. The electric savings is the difference between the baseline AC cooling energy and the measure case ventilation fan energy.

The modelled results predicted very small (1 to 4 therms annually) positive gas savings due to the measure. However, this result is inconsistent with the measure theory, which predicts a slight gas penalty due to potential increase in infiltration load associated with building shell modifications. Since the gas impact attributable to the measure itself was so small, DNV felt it was appropriate to treat this measure as gas neutral for all the sampled sites.

Hydronic Fan Coil

DNV's phone interview with the participant with the hydronic fan coil determined that while the participant had changed heating and cooling set point temperatures slightly from what they were set to during the monitored post-retrofit period, the participant could not comment on whether those set point temperatures would remain constant. The interview suggested heating/cooling behavior consistent with what was observed and surveyed during the pre- and post-retrofit period. That is, the occupants used their central system for primary heating and cooling and would open windows during swing seasons.

DNV reviewed the Frontier savings methodology and determined that it represents the most realistic and accurate savings approach relative to a non-metering savings approach. However, the savings approach was only applicable to the space conditioning equipment. Frontier conducted on-site metering but did not meter the pre-retrofit gas water heaters because these sites were originally planned as radiant ceiling panel test sites. Because the pre-retrofit water heating usage was not measured, DNV chose to use Frontier metering data to estimate savings associated with space conditioning and a deemed savings approach to estimate savings associated with water heating. They measured actual degree hours (indoor and outdoor air temperature was monitored) and collected energy usage associated with indoor and outdoor equipment while the equipment was in space-conditioning mode. Pre-retrofit data was collected for roughly the last six months of 2019, and post-retrofit data was collected for

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[6] In reality, this measure uses the existing furnace fan to ventilate and pull in cooler outside air at night.

[7] All NTV sites in the sample are in climate zone 2 and were simulated using TMY3 data for that region accordingly.

nearly two years (early 2020 to the end of 2021). Table D-26 shows a summary of total electric savings, gas savings, total energy savings for hydronic fan coil. Table D-27 shows the percent change in electric, gas, and total energy consumption for hydronic fan coil.

Table D-26: Total Savings Summary for Hydronic Fan Coil

Sector	# Sites	kWh	Therms	kBtu	Equivalent kWh
Residential	2	-2,337	595	51,535	15,104

Source: DNV (Modeled and Measured)

Table D-27: Percent Savings Summary for Hydronic Fan Coil

Sector	# Sites	Percent Change, kWh	Percent Change, Therms	Percent Change, kBtu
Residential	2	-24 percent	84 percent	49 percent

Source: DNV (Modeled and Measured)

Pre- and post-retrofit energy usage ratios for heating and cooling demand (kWh/hr-°F and kBtu/hr-°F) were calculated and normalized to actual degree-hour measurements. Annual energy savings were estimated using the normalized energy savings ratios (pre-usage ratio minus post-usage ratio) and TMY3 temperature for Santa Rosa, California.

Water heating usage and savings were estimated using a modified version of the DWHC. Details on the DWHC tool and the savings approach are outlined in the HPWH technology section (Chapter 5). DNV used this approach because the hydronic fan coil heat pump heats domestic water using refrigeration cycle and heat exchange principles similar to traditional HPWHs. The DWHC can also readily estimate pre-retrofit gas water heater usage. The following assumptions were made to estimate water heating savings:

- 3.3-person house occupancy (drives hot water usage; the calculator default occupancy)
- HPWH (both tank and compressor/evaporator coil) located in unconditioned space 50-gallon gas tank as pre-retrofit and 65-gallon tank for post-retrofit.

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APPENDIX E: Survey Methods and Disposition

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APPENDIX E: Survey Methods and Disposition

This section of the report summarizes the survey methodology and final dispositions of the contractor and participant surveys.

Contractor Survey

In May 2023, DNV implemented telephone-based surveys with contractors who participated in the Sonoma Clean Power Lead Locally Program. The primary objective of the survey was to investigate what the primary drivers were for customers installing high efficiency equipment and what barriers or process improvements have been observed. It also sought to gain a better understanding of contractor's satisfaction with various aspects of the program.

Sonoma Clean Power and Frontier Energy provided DNV with a list of 9 contractors[1] who were eligible to be contacted and recruited for this survey effort. Responses to the surveys were captured via a data collection tool designed and deployed by highly trained, in-depth interviewers. DNV adopted proven best practices in fielding these telephone-based surveys, including:

- Using a unique traceable ID with custom information for each contractor including the anonymized IDs and key measures of interest
- Providing contractors with a Sonoma Clean Power staff member who could validate the legitimacy of the survey effort
- Contacting non-respondents up to five times via email and phone asking them to complete the survey
- Providing all respondents with the option to opt-out of the survey

The disposition for the contractor survey is summarized in Table E-1 below. Results from the contractor surveys are summarized in Chapter 5 (Program Experience). Appendix G provides the survey instrument used to collect information for this survey.

Table E-1: Disposition for Contractor Telephone Surveys

Contractors	Total
Attempted interviews	9
Completes	3
Response rate	33 percent

Source: DNV

[1] Sonoma Clean Power excluded contractors from the eligible contractor survey population if they had been interviewed recently for other program-related surveys. This was done to reduce the response burden on participating contractors.

End User Survey

From May 2023 to June 2023, DNV implemented web-based surveys with residential and commercial end users who participated in Sonoma Clean Power's Lead Locally Program. The primary objectives of the survey were to evaluate the potential non-energy benefits resulting from program participation and to assess various other aspects of the participant's program experience, such as: awareness, motivations to participate, program satisfaction, barriers, and recommendations for program improvements. The survey also aimed to gather insight regarding potential household changes or improvements that were conducted by end users during or after their program participation.

DNV attempted a census of residential and commercial Lead Locally Program end users for the online survey. Responses to the surveys were captured via a data collection tool designed and deployed through Form.com. DNV adopted proven best practices in fielding these web surveys, including:

- Using a unique traceable hyperlink with custom information for each participant including the anonymized IDs and key measures of interest
- Conducting a soft launch of the survey to assess the quality of data being captured, patterns of non-response and bias, and opportunities for improved question clarity
- Sending out an advanced notification email from Sonoma Clean Power to inform participants that DNV will be reaching out regarding this effort
- Providing participants with a Sonoma Clean Power staff member who could validate the legitimacy of the survey effort
- Cobranding web surveys with the Sonoma Clean Power logo
- Contacting non-respondents up to three times via email asking them to complete the survey
- Providing all respondents with the option to opt-out of the survey

The disposition for the customer online survey is summarized in Table E-2 below. Results from the customer surveys are summarized in Chapter 5 (Program Experience). Appendix G provides the survey instrument used to collect information for this survey.

Table E-2: Disposition for Participant Web Surveys Sector[2]

Invites & Completes	Residential	Commercial	Overall
Invites sent	151	11	162
Completes	58	4	62
Response rate	38 percent	36 percent	38 percent

Source: DNV.

[2] The original Lead Locally Program population for installations that occurred from September 2019 to June 2022 was 168 sites. Two commercial sites were removed from the participant web survey due to not having the install date associated with the equipment they installed through the program, and two residential sites were removed due to having missing or invalid contact info. Furthermore, the Advanced Energy Center site and the site associated with a Sonoma Clean Power employee were both removed to prevent any potential bias.

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APPENDIX F: Supplemental Survey Results

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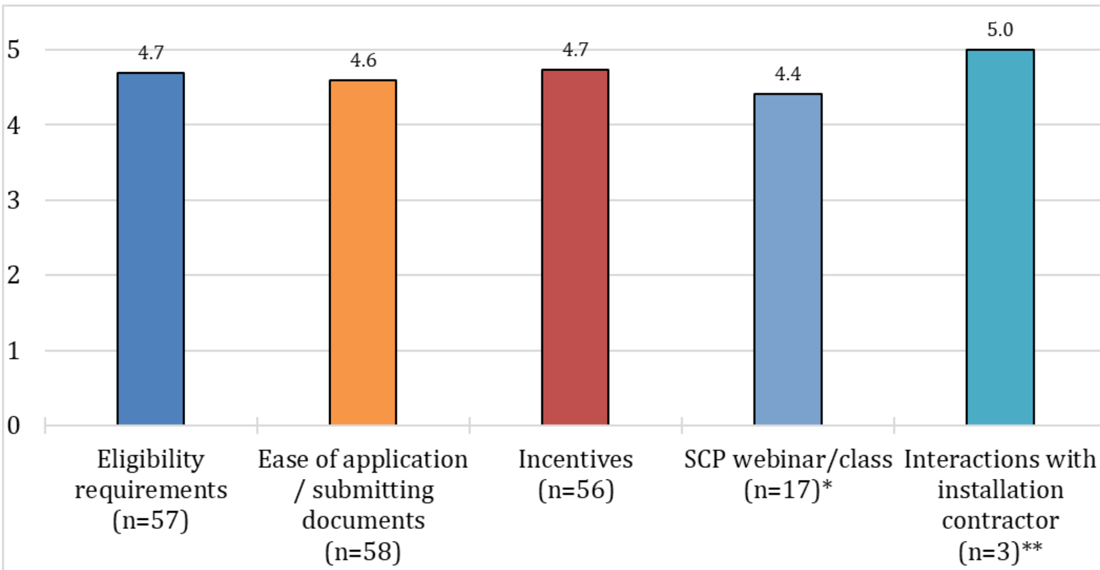
APPENDIX F: Supplemental Survey Results

Supplemental Survey Results

Figure F-1: Additional End User Satisfaction Results – Average Ratings



*Only residential end users were asked to rate their satisfaction with the SCP webinar and/or class.
**Only commercial end users were asked to rate their satisfaction with their interactions with installation contractor(s).
Image Credit: DNV

Residential End User Demographics

The following figures present data on residential customer demographics.[1]

Figure F-2: Highest Degree or Level of School Completed

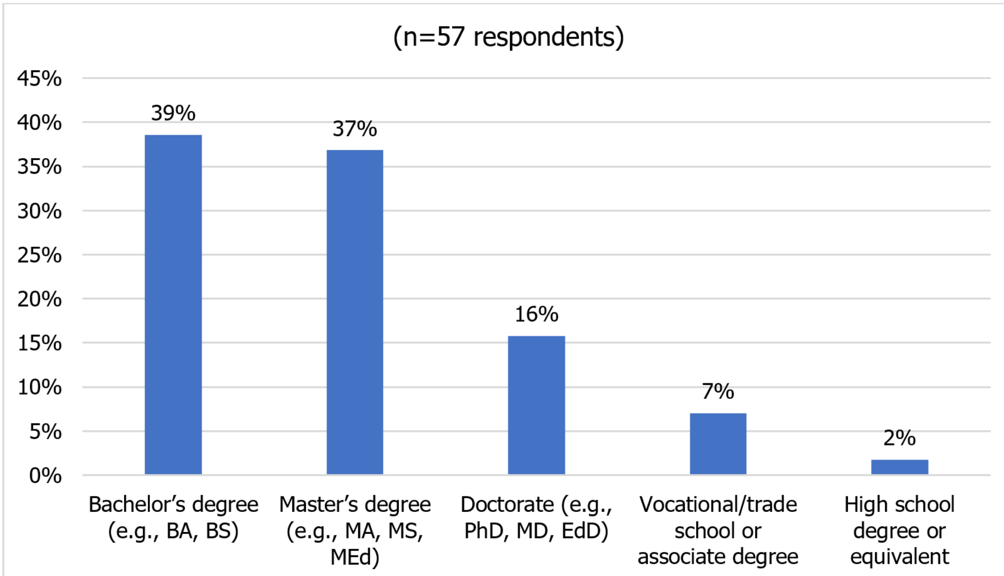


Image Credit: DNV

Figure F-3: Building Type Description

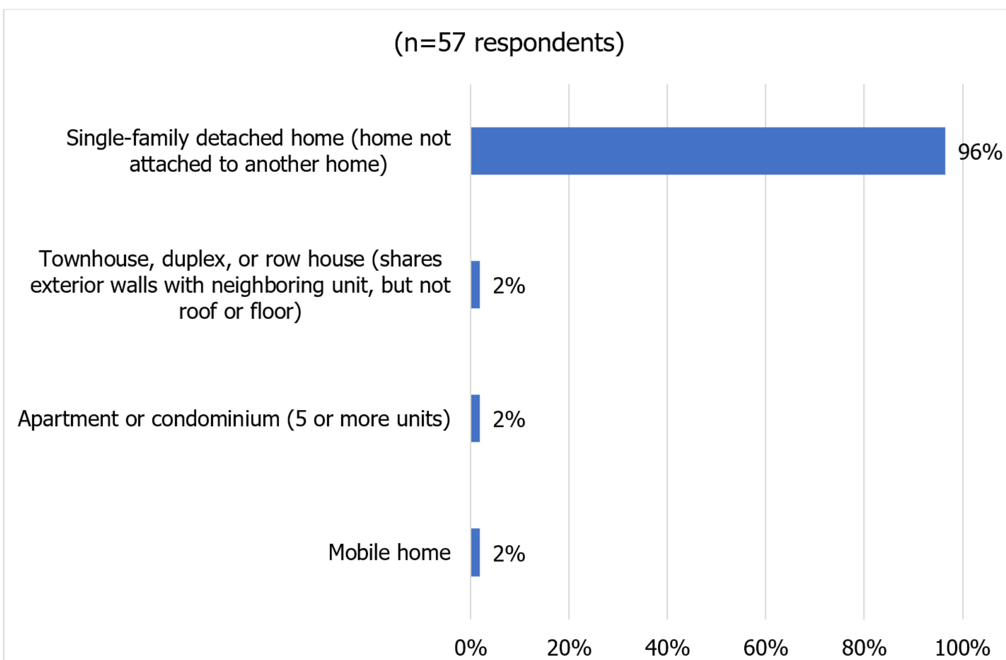


Image Credit: DNV

[1] All (n=57) residential survey respondents reported that English was their primary household language and that they owned their property.

Figure F-4: Household Annual Income (2021)

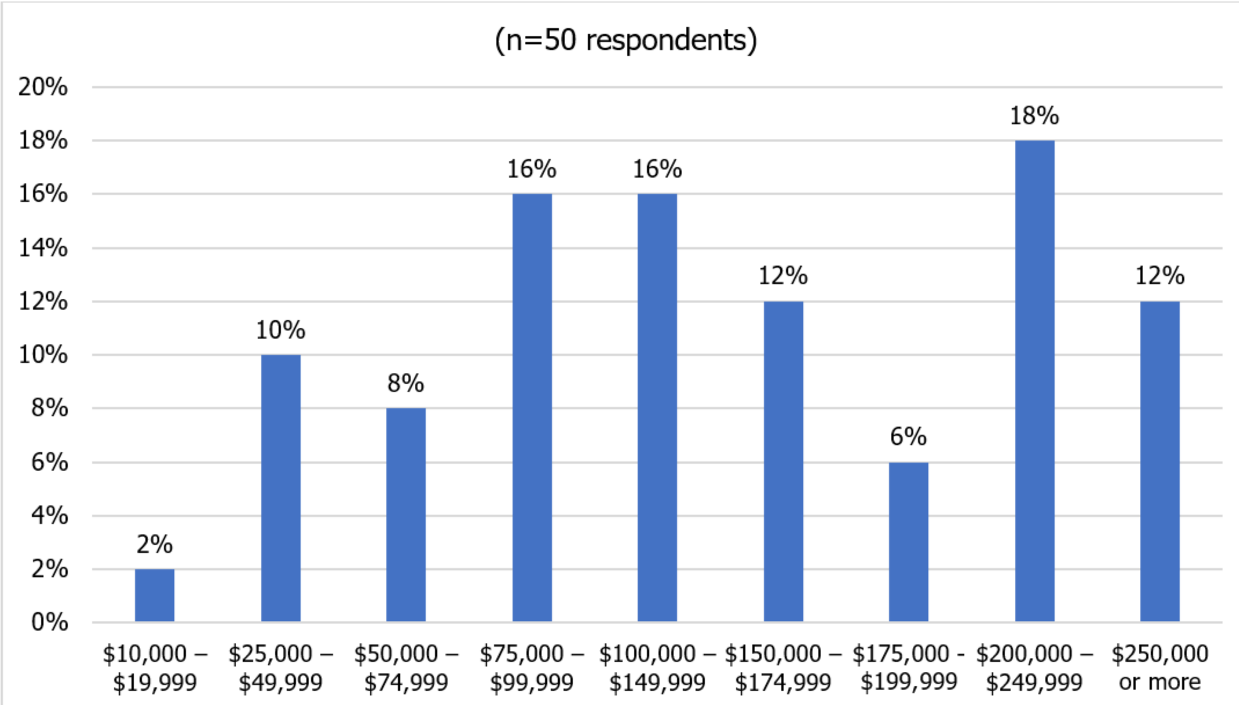


Image Credit: DNV

Commercial End User Firmographics

The following figures present data on commercial customer demographics.[2]

Figure F-5: Number of Employees at Company

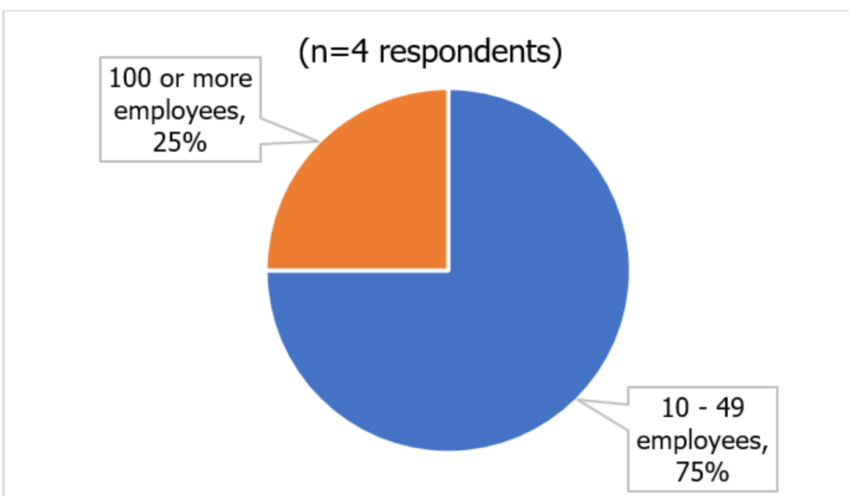


Image Credit: DNV

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[2] Among the commercial survey respondents, three stated English was the primary language spoken by the majority of their employees, with one respondent saying they preferred not to say.

Figure F-6: Does the Company Lease or Own the Space it Occupies?

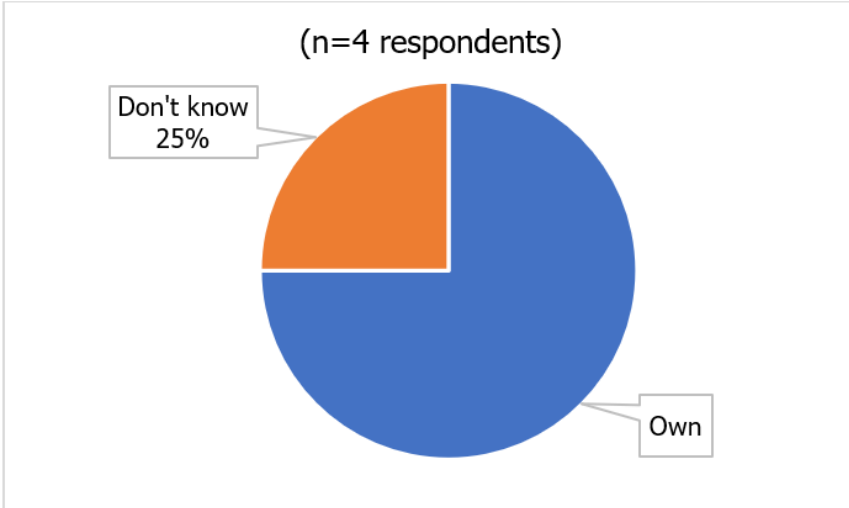

Image Credit: DNV.

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APPENDIX G: Survey Instruments

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SONOMA CLEAN POWER LEAD LOCALLY: RESIDENTIAL PARTICIPANT SURVEY

Research Questions Addressed

- Have participants made any additional upgrades to your home or installed any new equipment during or after their participation in this program?
- Has the Lead Locally program accelerated the adoption of market-ready and advanced technologies?
- Have participations experienced any non-energy benefits (e.g., increase comfort) due to participating in the program?
- To what extent are participating customers satisfied with the Lead Locally program?
- What, if any, barriers have participants experienced during their participation in the program?
- What, if any, general process improvements for the program could be recommended?

Question or Section	Instrument Goal
Screener questions	To verify that the program participation still has an active account and remembers participating in the Lead Locally program.
Verification, Awareness, and Reasons for Participation	A series of questions to verify that the equipment was installed/replaced, understand if the equipment is still operational, assess if they made any additional energy using improvements, and investigate primary drivers for participation in the Lead Locally program.
Heating, Cooling, and Energy Use	To understand which natural gas appliances and heating / AC systems are used in their home. Additional questions to understand if / how they use a thermostat to control their heating and cooling equipment.
Satisfaction and Process	Questions to determine whether program participants are satisfied with various aspects of the program, what aspects of the program they think went well, and discover areas for improvements.
Non-energy impacts	Questions to understand potential non-energy impacts (e.g., increased comfort / indoor air quality) resulting from participating in the program.
About Your Home	Questions characterize customers including demographics (e.g., household occupancy, primary language spoken, education, income, % of participants that rent vs own).

Customer Notification Email

Email: From [evaluation.sonomacleanpower@impact.dnv.com]

Subject: Sonoma Clean Power Requests your feedback with the Lead Locally program

Dear {Customer Name},

We would like to hear about your experience with the Sonoma Clean Power Lead Locally rebate program services performed back in {Install Date}. As a participant in the Lead Locally program, your opinions are important. Sonoma Clean Power would like your input and perspectives to understand how to best structure future energy efficiency programs designed for customers like you.

Your participation is requested in a brief 15 minute survey about the home at: {Address}. The information gathered will be used solely for research purposes and your individual responses will be kept completely confidential.

To get started click on this link: [ST]

DNV is the research provider retained by Sonoma Clean Power to help administer this survey. Please contact me if you have any questions about this survey. Any question about the legitimacy of this request can be directed to the Lead Locally program manager, Scott Salyer, at: evaluations@sonomacleanpower.org.

Thank you for helping to improve energy efficiency programs in California.

David Avenick
Energy Efficiency Evaluation
www.dnv.com

If you would like to be removed from this survey, please click on this link: [remove]

Screener

1. Do you still have an active account with Sonoma Clean Power (SCP) at this address: {Address}? Sonoma Clean Power's electric charges likely show up on your Pacific Gas and Electric (PG&E) energy bill.

   a1. Yes a2. No

2. According to Sonoma Clean Power's records, your household installed the following energy efficiency products through the Lead Locally program and the Advanced Energy Center:

Equipment	Installation Date
[Measure 1]	
[Measure 2]	
[Measure 3]	

   For qualifying customers, Sonoma Clean Power may have offered a 0% loan (formerly known as on-bill financing) and/or incentives for these energy efficiency projects. Do you remember participating in the Lead Locally program?

   a1. Yes
   a2. No
   a3. Don't know

SURVEY

Verification, Awareness, and Reasons for Participation

3. According to our records, you had the following energy efficient products installed on these dates. Please confirm if you are aware of these installations by selecting the appropriate response(s). If the equipment type(s) or installation date(s) are incorrect, please note the corrections in the comments field below. [Populate up to 3 measures based on tracking data]

Equipment	Installation Date	Aware (Yes/No/Don't know/Don't recall having any equipment installed)
[Measure 1]		
[Measure 2]		
[Measure 3]		

a. [Comment field]

[T&T if respondent is not aware of all equipment in Q3]

4. Are you still using the energy efficient products installed through the program or have you removed/replaced them? [Populate based equipment respondent reports being aware of in Q3]

Equipment	[Still using]	[Removed/replaced]
[Measure 1]		
[Measure 2]		
[Measure 3]		

5. [SHOW FOR: Induction Cooktops, Minisplit Heat Pumps, and Heat Pump Water Heaters] What type of fuel did your original equipment use? [Populate based on tracking data]

Equipment	[Gas/Electric/Propane]
Equipment replaced by [Measure 1]	
Equipment replaced by [Measure 2]	
Equipment replaced by [Measure 3]	

6. [SHOW FOR: Mini split Heat Pump] What was the condition of the <u>old space heating or cooling</u> equipment when it was removed? Was it…

   a1. Working but inefficient
   a2. Working but in need of minor repair
   a3. Working but in need of significant repair
   a4. Failed was no longer working
   a5. N/A new installation
   a6. Don't recall

7. [SHOW FOR: Heat Pump Water Heater] What was the condition of the <u>old water heating</u> equipment when it was removed? Was it…

   a1. Working but inefficient
   a2. Working but in need of minor repair

a3. Working but in need of significant repair
a4. Failed was no longer working
a5. N/A new installation
a6. Don't recall

8. Have you completed any major renovations to your home since [install date]? This could include but is not limited to: adding a new addition to your home, finishing/remodelling a basement.
   a. Yes, completed major renovations
   b. No major renovations

9. [IF Q8 = Yes] Please describe what major renovations you completed at {Address} since {install date}:
   a. [Record response]

10. Have you made any additional upgrades to your home or installed any new equipment since [install date]? This could include but is not limited to: installing new space heating or air conditioning equipment, adding a new refrigerator or freezer, adding insulation.
    a1. Yes, completed additional upgrades
    a2. No additional upgrades

11. [IF Q10 = Yes] What other improvement did you make since [install date]? Please select all that apply.
    a1. Space heating and air conditioning
    a2. Water heating
    a3. Added refrigerator or freezer
    a4. Added clothes washer / dryer
    a5. Added insulation
    a6. Windows
    a7. Appliances (microwaves, humidifiers, fans)
    a8. Lighting
    a9. Added spa/hot tub/pool
    a10. Added electric vehicle and/or charger
    a11. Added battery storage
    a12. Added solar electricity
    a13. Other, please specify:

12. How did you <u>first</u> learn about the Sonoma Clean Power Lead Locally program? [Select one]
    a1. Advanced Energy Center (in-person visit)
    a2. Advanced Energy Center Website
    a3. Contractor
    a4. Sonoma Clean Power energy advisor
    a5. Sonoma Clean Power bill insert
    a6. Sonoma Clean Power website
    a7. Sonoma Clean Power email
    a8. Sonoma Clean Power direct mail / outreach
    a9. Lead Locally marketing collateral / signage
    a10. Radio advertisement
    a11. Newspaper ads
    a12. Word of mouth
    a13. Other: specify
    a14. Don't recall

13. Thinking back to the time when you were making the decision to participate in this program, what was the <u>primary</u> reason you choose to participate?
    a1. Save energy / save money
    a2. Sonoma Clean Power / Lead Locally incentives
    a3. Free equipment
    a4. Recommendation from a contractor
    a5. Equipment failure or end of useful life
    a6. Early replacement to save energy
    a7. Improve comfort, health, safety
    a8. Reduced carbon emissions/climate change/good for the environment
    a9. Renovation or remodel
    a10. Other: specify

a11. Don't know

14. Were there any other factors that influenced you to participate in this program? Please select all that apply.

a1. Save energy / save money
a2. Sonoma Clean Power / Lead Locally incentives
a3. Free equipment
a4. Recommendation from a contractor
a5. Equipment failure or end of useful life
a6. Early replacement to save energy
a7. Improve comfort, health, safety
a8. Reduced carbon emissions/climate change/good for the environment
a9. Renovation or remodel
a10. Other: specify
a11. Don't know [Exclusive]

15. Did you enroll in the 0% financing offered through the Lead Locally program?

a1. Yes
a2. No
a3. Don't know
a4. Not applicable

16. [IF Q15 = Yes] Without the 0% financing offered through the Lead Locally program, how likely would you have been to complete this {Measure 1} project?

a5. Very likely
a6. Somewhat likely
a7. Somewhat unlikely
a8. Very unlikely
a9. Don't know

17. Without the Lead Locally program and incentives, when would you have considered installing the {Measure 1} equipment?

a1. Same time or sooner
a2. 1 year later
a3. 2 years later
a4. More than 2 years later
a5. Never
a6. Other [SPECIFY]
a7. Don't know

Heating, Cooling, and Energy Use

18. Which of the following natural gas appliances do you use? Please select all that apply.

a1. Gas cook-top/range
a2. Gas clothes dryer
a3. Gas water heating
a4. Gas heater
a5. None of these [Exclusive]
a6. Don't know [Exclusive]

19. What is the main heating system you use to heat this home? [Select one]

a1. Floor or wall heater
a2. Central gas furnace
a3. Ducted heat pump
a4. Ductless heat pump

a5. Hot water radiator
a6. Electric baseboard
a7. Fireplace (gas)
a8. Fireplace (wood)
a9. Plug-in portable space heater
a10. Ductless heat pump
a11. Other [SPECIFY]
a12. Don't know

20. What other sources, if any, do you use to supplement your heat? Please select all that apply.

a1. No other sources [Exclusive]
a2. Floor or wall heater
a3. Central gas furnace
a4. Ducted heat pump
a5. Ductless heat pump
a6. Hot water radiator
a7. Electric baseboard
a8. Fireplace (gas)
a9. Fireplace (wood)
a10. Plug-in portable space heater
a11. Ductless heat pump
a12. Other [SPECIFY]
a13. Don't know [Exclusive]

21. What is the main cooling system type used to cool this home?

a1. Central AC
a2. Window or portable unit
a3. Ducted Heat Pump AC
a4. Ductless Heat Pump AC
a5. Other [SPECIFY]
a6. Do not use AC
a7. Don't know

22. What type of thermostat is installed in your home?

a1. Non-programmable/manual thermostat
a2. Programmable thermostat that can be set to different temperatures for different times
a3. Smart thermostat, e.g., Nest, Lyric, Sensi or Ecobee
a4. Don't know

23. [SKIP IF Q22 = q1 or a4] How do you use your programmable thermostat?

a1. Set a temperature and leave it alone [Exclusive]
a2. Manually adjust temperature to meet my comfort
a3. Use a programmed schedule and rarely override
a4. Thermostat is off for most months of the year
a5. Smart thermostat automatically responds to my heating/cooling needs
a6. Other [SPECIFY]
a7. Don't recall

Next, I would like to know, since participating in the Lead Locally program, what changes, if any, have you made to the way you heat or cool your home.

24. Since installing the program-rebated equipment, would you say you're using the heating system more, less or about the same?

a1. More
a2. Less
a3. About the same
a4. Not applicable (e.g., use Wood heat)

25. Since installing the program-rebated equipment, would you say you're using the cooling system more, less or about the same?

a1. More
a2. Less
a3. About the same
a4. Not applicable

Satisfaction and Process

Thinking about your experience with the program, I'd like to ask about various aspects of satisfaction with program delivery.

26. Using a scale of 1 to 5 where 1 means very dissatisfied, 2 is somewhat dissatisfied, 3 is neither satisfied nor dissatisfied, 4 is somewhat satisfied, and 5 is very satisfied, how satisfied are you with the following program components?

Program Components	Rating	For any component of the program you are less than satisfied with (<4), please indicate why you are less than satisfied
a1. Eligibility requirements	1 2 3 4 5	
a2. Ease of application / submitting documentation	1 2 3 4 5	
a3. Incentives	1 2 3 4 5	
a4. 0% financing (if applicable)	1 2 3 4 5	
a5. Quality or work done by the installation contractor	1 2 3 4 5	
a6. The services or products installed	1 2 3 4 5	
a7. The comfort of your home since receiving these upgrades	1 2 3 4 5	
a8. Energy savings since receiving these upgrades	1 2 3 4 5	
a9. Interactions with Sonoma Clean Power program staff	1 2 3 4 5	
a10. Sonoma Clean Power webinar / class	1 2 3 4 5	
a11. Your experience overall	1 2 3 4 5	

27. Thinking about this program and your overall experience, what aspects of the program went well?
    a. [Record response]

28. What aspects of the program could be improved?
    b. [Record response]

Non-energy impacts

Next, we would like to understand if you experienced any non-energy impacts associated with the installation of the {Measure 1} equipment. Non-energy impacts are costs or benefits other than savings on your energy bills that you experienced due to installing this equipment.

29. Please go through the following categories and let us know if your household has noticed any costs or benefits in each one after installing the {Measure 1} equipment.

    Did your household experience any changes – positive or negative – to:

Non-energy Impact	Increased – No change – Decreased – Don't know	[If Increased or Decreased] Please explain these changes
a1. [Hide for Induction Cooktop measures] Comfort		

a2. Energy bill amount ($)		
a3. Safety (e.g., risk of fire / gas leak)		
a4. Indoor air quality		
a5. Noise		
a6. Operations and maintenance costs		
a7. [Show for Induction Cooktops] Time for stove to heat up		
a8. [Show for Induction Cooktops] Ability to control temperature		

30. [ASK IF Q29.a1 = Increased] What are some of the sources of discomfort that you experienced before installing {Measure 1}? Please select all that apply.

    a1. Often too hot or too cold
    a2. Occasionally too hot or too cold
    a3. Large temperature swings
    a4. Drafts from leaky windows/doors/vents
    a5. Poor air circulation
    a6. Thermostat not responsive enough
    a7. Water heater is not responsive enough
    a8. None [Exclusive]
    a9. Other, specify:
    a10. Don't recall [Exclusive]

31. [ASK IF Q29.a1 = Decreased] What are some of the sources of discomforts that you are currently experiencing? Please select all that apply.

    a1. Often too hot or too cold
    a2. Occasionally too hot or too cold
    a3. Large temperature swings
    a4. Drafts from leaky windows/doors/vents
    a5. Poor air circulation
    a6. Thermostat not responsive enough
    a7. Water heater is not responsive enough
    a8. None [Exclusive]
    a9. Other, specify:
    a10. Don't recall [Exclusive]

32. Are there any other impacts (positive or negative) that you've experienced after installing the {Measure 1} equipment?

    c. [Record response]

About Your Home

These last questions help better understand customers who utilize these programs. This information is collected for internal purposes only and remains confidential.

33. For each of the following age groups, how many people, including yourself, live in this home at least 6-months a year? Please select one response for each age category.

Age Category:

a1. Under 5
a2. 6 to 18
a3. 19 to 65
a4. 65 and older

34. Has the number of household residents changed since {Install Date}?

a1. Increased
a2. Decreased
a1. Unchanged
a2. Prefer not to say

35. [If Q34= a1 or a2 then ask otherwise skip]: How many more/fewer people live in your home?

a1. Increased by qty:
a2. Decreased by qty:

36. What is the primary household language?

a1. English
a2. Spanish
a3. Chinese (including Mandarin and Cantonese)
a4. Tagalog
a5. Vietnamese
a6. Korean
a7. Prefer not to say
a8. Other (please specify)

37. What is the highest degree or level of school you have completed? If you're currently enrolled in school, please indicate the highest degree you have received.

a1. Less than a high school diploma
a2. High school degree or equivalent
a3. Vocational/trade school or associate degree
a4. Bachelor's degree (e.g., BA, BS)
a5. Master's degree (e.g., MA, MS, MEd)
a6. Doctorate (e.g., PhD, MD, EdD)
a7. Prefer not to say
a8. Other (please specify)

38. Do you own or rent?

a1. Own
a2. Rent

39. Which of the following building types best describes your home?

a1. Single-family detached home (home not attached to another home)
a2. Townhouse, duplex, or row house (shares exterior walls with neighboring unit, but not roof or floor)
a3. Apartment or condominium (2–4 units)
a4. Apartment or condominium (5 or more units)
a5. Mobile home
a6. Other

40. Please check the range that best describes your household's total annual income.

a1. Less than $10,000
a2. $10,000 – $19,999
a3. $20,000 – $24,999
a4. $25,000 – $49,999
a5. $50,000 – $74,999
a6. $75,000 – $99,999
a7. $100,000 – $149,999
a8. $150,000 – $174,999
a9. $175,000 – $199,999
a10. $200,000 – $249,999

a11. $250,000 or more a12. Prefer not to say

41. Thank you for your time for completing our survey. Your feedback matter to us and will help Sonoma Clean Power understand how to best structure future energy efficiency programs. If you have any follow up questions, please contact us at: evaluation.sonomacleanpower@impact.dnv.com

[Survey Close Out]

SONOMA CLEAN POWER LEAD LOCALLY:
NON-RESIDENTIAL PARTICIPANT SURVEY

Research Questions Addressed

- Have participants made any additional upgrades at their facility or installed any new equipment during or after their participation in this program?
- Has the Lead Locally program accelerated the adoption of market-ready and advanced technologies?
- Have participations experienced any non-energy benefits (e.g., increase comfort) due to participating in the program?
- To what extent are participating customers satisfied with the Lead Locally program?
- What, if any, barriers have participants experienced during their participation in the program?
- What, if any, general process improvements for the program could be recommended?

Question or Section	Instrument Goal
Screener questions	To verify that the program participation still has an active account and remembers participating in the Lead Locally program.
Verification, Awareness, and Reasons for Participation	A series of questions to verify that the equipment was installed/replaced, understand if the equipment is still operational, assess if they made any additional energy using improvements, and investigate primary drivers for participation in the Lead Locally program.
Heating, Cooling, and Energy Use	To understand which natural gas appliances and heating / AC systems are used in their facility. Additional questions to understand if / how they use a thermostat to control their heating and cooling equipment.
Satisfaction and Process	Questions to determine whether program participants are satisfied with various aspects of the program, what aspects of the program they think went well, and discover areas for improvements.
Non-energy impacts	Questions to understand potential non-energy impacts (e.g., increased comfort / indoor air quality) resulting from participating in the program.
Firmographics	Questions characterize customers including demographics (e.g., size of company, primary language spoken by employees, rent vs own facility).

Customer Notification Email

Email: From [evaulations@sonomacleanpower.org]

Subject: Sonoma Clean Power Requests your feedback with the Lead Locally program

Dear {Customer Name},

We would like to hear about your experience with the Sonoma Clean Power Lead Locally program services performed back on {Install Date}. As a participant in the Lead Locally program, your opinions are important. Sonoma Clean Power would like your input and perspectives to understand how to best structure future energy efficiency programs designed for customers like you.

Your participation is requested in a brief 15 minute survey about the energy efficient products installed at: {Address}. The information gathered will be used solely for research purposes and your individual responses will be kept completely confidential.

To get started click on this link: [ST]

DNV is the research provider retained by Sonoma Clean Power to help administer this survey. Please contact me if you have any questions about this survey. Any question about the legitimacy of this request can be directed to the Lead Locally program manager, Scott Salyer, at: evaluations@sonomacleanpower.org.

Thank you for helping to improve energy efficiency programs in California.

David Avenick
Energy Efficiency Evaluation
www.dnv.com

If you would like to be removed from this survey, please click on this link: [remove]

Screener

1. Do you still have an active account with Sonoma Clean Power at this address: {Address}? Sonoma Clean Power's electric charges likely show up on your Pacific Gas and Electric (PG&E) energy bill.

   a1. Yes
   a2. No

2. According to Sonoma Clean Power's records, your company / organization installed the following energy efficient products through the Lead Locally program and the Advanced Energy Center:

Equipment	Installation Date
[Measure 1]	
[Measure 2]	
[Measure 3]	

For qualifying customers, Sonoma Clean Power may have offered a 0% loan (formerly known as on-bill financing) and/or incentives for these energy efficiency projects. Do you remember participating in the Lead Locally program?

   a1. Yes
   a2. No
   a3. Don't know

SONOMA CLEAN POWER LEAD LOCALLY: NON-RESIDENTIAL PARTICIPANT SURVEY

SURVEY

Verification, Awareness, and Reasons for Participation

3. According to our records, you had the following energy efficient products installed on these dates. Please confirm if you are aware of these installations by selecting the appropriate response(s). If the equipment type(s) or installation date(s) are incorrect, please note the corrections in the comments field below. [Populate up to 3 measures based on tracking data]

Equipment	Installation Date	Aware (Yes/No/Don't know/Don't recall having any equipment installed)
[Measure 1]		
[Measure 2]		
[Measure 3]		

   a. [Comment field]

[T&T if respondent is not aware of all equipment in Q3]

4. Are you still using the upgrades associated with this program or have you removed/replaced them? [Populate based equipment respondent reports being aware of in Q3]

Equipment	[Using Energy Saving Upgrades]	[Not Using Energy Saving Upgrades]
[Measure 1]		
[Measure 2]		
[Measure 3]		

5. [SHOW FOR: Induction Cooktops, Minisplit Heat Pumps, and Heat Pump Water Heaters] What type of fuel did your original equipment use? [Populate based on tracking data]

Equipment	[Gas/Electric/Propane]
Equipment replaced by [Measure 1]	
Equipment replaced by [Measure 2]	
Equipment replaced by [Measure 3]	

6. [SHOW FOR: Mini split Heat Pump] What was the condition of the old space heating or cooling equipment when it was removed? Was it…

   a1. Working but inefficient
   a2. Working but in need of minor repair
   a3. Working but in need of significant repair
   a4. Failed was no longer working

a5. N/A new installation
a6. Don't recall

7. [SHOW FOR: Heat Pump Water Heater] What was the condition of the old water heating equipment when it was removed? Was it…

   a1. Working but inefficient
   a2. Working but in need of minor repair
   a3. Working but in need of significant repair
   a4. Failed was no longer working
   a5. N/A new installation
   a6. Don't recall

8. Have you completed any major renovations at this facility since {install date}? This could include but is not limited to: adding a new addition to your facility, finishing/remodelling a garage/storage area.

   a. Yes, completed major renovations
   b. No major renovations

9. [IF Q8 = Yes] Please describe what major renovations you completed at {Address} since {install date}:

   c. [Record response]

10. Have you made any additional upgrades at this facility or installed any new equipment since [install date]? This could include but is not limited to: installing new space heating or air conditioning equipment, adding a new refrigerator or freezer, adding insulation.

    a1. Yes, completed additional upgrades
    a2. No additional upgrades

11. [IF Q10 = Yes] What other improvement did you make since [install date]? Please select all that apply.

    a1. Space heating and air conditioning
    a2. Water heating – gas
    a3. Water heating – electric
    a4. Cooking equipment (oven, steamer, fryer, griddle)
    a5. Added additional refrigerator or freezer
    a6. Added additional dishwasher
    a7. Added commercial clothes washer / dryer
    a8. Added insulation
    a9. Add walk in cooler
    a10. Windows
    a11. Appliances (microwaves, fans)
    a12. Major lighting retrofit
    a13. Added electric vehicle and/or charger
    a14. Added battery storage
    a15. Added solar electricity
    a16. Other, specify:

12. How did you first learn about the Sonoma Clean Power Lead Locally program? [Select one]

    a1. Advanced Energy Center (in-person visit)
    a2. Advanced Energy Center Website
    a3. Contractor
    a4. Sonoma Clean Power staff
    a5. Sonoma Clean Power bill insert
    a6. Sonoma Clean Power website
    a7. Sonoma Clean Power email
    a8. Sonoma Clean Power direct mail / outreach
    a9. Lead Locally marketing collateral / signage
    a10. Radio advertisement
    a11. Newspaper ads
    a12. Word of mouth (e.g., from a colleague)
    a13. Other, specify:
    a14. Don't recall

13. Thinking back to the time when you were making the decision to participate in this program, what was the primary reason your company chose to participate?

a1. Save energy / save money
a2. Sonoma Clean Power / Lead Locally incentives
a3. Free equipment
a4. Recommendation from a contractor
a5. Equipment failure or end of useful life
a6. Early replacement to save energy
a7. Improve comfort, health, safety
a8. Reduced carbon emissions / climate change/good for the environment
a9. Renovation or remodel of facility
a10. Corporate policy
a11. LEED or other design certification
a12. Other, specify:
a13. Don't know

14. Were there any other factors that influenced you to participate in this program? Please select all that apply.

a1. Save energy / save money
a2. Sonoma Clean Power / Lead Locally incentives
a3. Free equipment
a4. Recommendation from a contractor
a5. Equipment failure or end of useful life
a6. Early replacement to save energy
a7. Improve comfort, health, safety
a8. Reduced carbon emissions/climate change/good for the environment
a9. Renovation or remodel of facility
a10. Corporate policy
a11. LEED or other design certification
a12. Other, specify:
a13. Don't know

15. Did you enroll in the 0% financing offered through the Lead Locally program?

a1. Yes
a2. No
a3. Don't know
a4. Not applicable

16. [IF Q15 = Yes] Without the 0% financing offered through the Lead Locally program, how likely would you have been to complete this {Measure 1} project?

a5. Very likely
a6. Somewhat likely
a7. Somewhat unlikely
a8. Very unlikely
a9. Don't know

17. Without the Lead Locally program and incentives, when would you have considered installing the {Measure 1} equipment?

a1. Same time or sooner
a2. 1 year later
a3. 2 years later
a4. More than 2 years later
a5. Never
a6. Other [SPECIFY]
a7. Don't know

Heating, Cooling, and Energy Use

18. Which of the following natural gas appliances do you use? Please select all that apply.

    a1. Gas cook-top/range/griddle
    a2. Gas clothes dryer
    a3. Gas water heating
    a4. Gas space heater
    a5. None of these
    a6. Other, specify:
    a7. Don't know

19. What is the main heating system you use to heat your facility? [Select one]

    a1. Floor or wall heater
    a2. Central gas furnace
    a3. Ducted heat pump
    a4. Ductless heat pump
    a5. Boiler
    a6. Hot water radiator
    a7. Electric baseboard
    a8. Fireplace (gas)
    a9. Fireplace (stove)
    a10. Plug-in portable space heater
    a11. Other, specify:
    a12. Don't know

20. What other sources, if any, do you use to supplement your heat? Select all that apply.

    a1. No other sources
    a2. Floor or wall heater
    a3. Central gas furnace
    a4. Ducted heat pump
    a5. Ductless heat pump
    a6. Boiler
    a7. Hot water radiator
    a8. Electric baseboard
    a9. Fireplace (gas)
    a10. Fireplace (stove)
    a11. Plug-in portable space heater
    a12. Infrared / outdoor space heater
    a13. Other, specify:
    a14. Don't know

21. What is the main cooling system type used to cool your facility?

    a1. Central air conditioner
    a2. Window or portable unit
    a3. Ducted Heat Pump AC
    a4. Ductless Heat Pump AC
    a5. Chiller
    a6. Other, specify:
    a7. Don't know

22. What type of thermostat is installed in your facility?

    a1. Non-programmable/manual thermostat
    a2. Programmable thermostat that can be set to different temperatures for different times
    a3. Smart thermostat, e.g., Nest, Lyric, Sensi or Ecobee
    a4. Energy Management System (EMS)
    a5. Don't know

23. [SKIP if Q22 = a1 or a5] How do you use your [programmable thermostat / EMS]?

    a1. Set a temperature and leave it alone
    a2. Manually adjust temperature to meet my comfort
    a3. Use a programmed schedule and rarely override
    a4. Thermostat is off for most months of the year
    a5. Smart thermostat/EMS automatically responds to my heating/cooling needs
    a6. None of these [Exclusive]
    a7. Don't recall

Next, I would like to know, since participating in the Lead Locally program, what changes, if any, have you made to the way you heat or cool your facility.

24. Since installing the program-rebated equipment, would you say you're using the heating system more, less or about the same?

    a1. More
    a2. Less
    a3. About the same
    a4. Not applicable (e.g., use Wood heat)

25. Since installing the program-rebated equipment, would you say you're using the cooling system more, less or about the same?

    a1. More
    a2. Less
    a3. About the same
    a4. Not applicable

Satisfaction and Process

Thinking about your experience with the program, I'd like to ask about various aspects of satisfaction with program delivery.

26. Using a scale of 1 to 5 where 1 means very dissatisfied, 2 is somewhat dissatisfied, 3 is neither satisfied nor dissatisfied, 4 is somewhat satisfied, and 5 is very satisfied, how satisfied are you with the following program components?

Program Components	Rating	For any component of the program you are less than satisfied with (<4), please indicate why you are less than satisfied and what needs to be done to correct it
a1. Eligibility requirements	1 2 3 4 5	
a2. Ease of application / submitting documentation	1 2 3 4 5	
a3. [If applicable] Incentives	1 2 3 4 5	
a4. Quality or work done by the installation contractor	1 2 3 4 5	
a5. The services or products installed	1 2 3 4 5	
a6. The comfort of your facility since receiving these upgrades	1 2 3 4 5	
a7. Energy savings since receiving these upgrades	1 2 3 4 5	
a8. Interactions with Sonoma Clean Power program staff	1 2 3 4 5	
a9. Interactions with installation contractor	1 2 3 4 5	
a10. Your experience overall	1 2 3 4 5	

27. Thinking about this program and your overall experience, what aspects of the program went well?

    a. [Record response]

28. What aspect of the program could be improved?

    b. [Record response]

Non-energy impacts

Next, we would like to understand if you experienced any non-energy impacts associated with the installation of the {Measure 1} equipment. Non-energy impacts are costs or benefits other than savings on your energy bills that you experienced due to installing this equipment.

29. Please go through the following categories and let us know if your organization has noticed any costs or benefits in each one after installing the {Measure 1} equipment.

    Did your organization experience any changes – positive or negative – to:

Non-energy Impact	Increased – No change – Decreased – Don't know	[If Increased or Decreased] Please explain how this changed?
a1. [Show for Phase Change, Mini-split HPs] Comfort		
a2. Energy bill amount ($)		
a3. Safety (e.g., risk of fire / gas leak)		
a4. Indoor air quality		
a5. Noise		
a6. Operations and maintenance costs		
a7. [Show for Dishwashers] Water savings		
a8. [Show for Induction Cooktops] Time for stove to heat up		
a9. [Show for Induction Cooktops] Ability to control temperature		

30. [If Q29.a1 = Increased] What are some of the sources of discomfort that you experienced before installing {Measure 1}? Select all that apply.
    - a1. Often too hot or too cold
    - a2. Occasionally too hot or too cold
    - a3. Large temperature swings
    - a4. Drafts from leaky windows/doors/vents
    - a5. Poor air circulation
    - a6. Thermostat not responsive enough
    - a7. None
    - a8. Other, specify:
    - a9. Don't recall

31. If [Q29.a1 = Decreased] What are some of the sources of discomforts that you are currently experiencing? Select all that apply.
    - a1. Often too hot or too cold
    - a2. Occasionally too hot or too cold
    - a3. Large temperature swings
    - a4. Drafts from leaky windows/doors/vents
    - a5. Poor air circulation
    - a6. Thermostat not responsive enough
    - a7. None
    - a8. Other, specify:
    - a9. Don't recall

32. Are there any other impacts (positive or negative) that you've experienced after installing the {Measure 1} equipment?
    - a. [Record response]

Firmographics

These last questions help better understand customers who utilize these programs. This information is collected for internal purposes only and remains confidential.

33. Approximately how many people are employed at your company?
    - a1. 1 - 9 employees
    - a2. 10 - 49 employees
    - a3. 50 – 99 employees
    - a4. 100 or more employees
    - a5. Don't know
    - a6. Prefer not to say

34. Has the number of employees at {Address} changed since {Install Date}? Select all that apply.
    - a7. Increased
    - a8. Decreased
    - a9. Unchanged
    - a10. Don't know
    - a11. Prefer not to say

35. [If Q31= a1 or a2 then ask otherwise skip]: How many more/fewer people work at this location?
    - a1. Increased by qty:
    - a2. Decreased by qty:

36. What is the primary language spoken by the majority of the employees at your company?
    - a1. English
    - a2. Spanish
    - a3. Chinese (including Mandarin and Cantonese)
    - a4. Tagalog
    - a5. Vietnamese
    - a6. Korean
    - a7. Prefer not to say
    - a8. Other (please specify)

37. Does your company lease or own the space it occupies?
    - a1. Own
    - a2. Rent / lease
    - a3. Don't know
    - a4. Prefer not to answer

38. Thank you for your time for completing our survey. Your feedback matter to us and will help Sonoma Clean Power understand how to best structure future energy efficiency programs. If you have any follow up questions, please contact us at: evaluation.sonomacleanpower@impact.dnv.com

[Survey Close Out]

Contractor Interview Guide

Sonoma Clean Power Lead Locally Program Evaluation

Research Questions Addressed:

- What are the primary drivers for customers installing high efficiency equipment?
- How influential is the Lead Locally program (i.e., incentives, financing, training) on the final installation choices of end users?
- Have participants experienced any non-energy benefits (e.g., increase comfort) due to participating in the program?
- To what extent are participating customers satisfied with the Lead Locally program?
- What, if any, barriers have participants experienced during their participation in the program?
- What, if any, general process improvements for the program could be recommended?

Question or Section	Instrument Goal
Screener questions	To verify that the contractor is aware of their participation in the Lead Locally program.
Intro / Verification	A series of questions to better understand the size of the contractor/company and verify a.) the tracked number of installs, b.) when they participated in the program, and c.) verify if they offer zero percent loans to customers.
Equipment Choices	Questions to understand what the primary drivers are to installing high efficiency equipment, what selling points are used, and who is making the final decisions.
Program Influences	Questions to how influential the incentives and financing are on the final installation choices. How has the program impact the contractor sales?
Benefits	Questions to what benefits the contractors and end users experienced from participating in the program, and if the program has had any impact on job creation, increased leads, increased sales.
Barriers	Questions to better understand contractor and end user barriers to participating in the program, as well as general barriers to selling high efficiency, program-rebated equipment.
Satisfaction and Process	Questions characterize contractor satisfaction with various aspects of the program. Additionally, question to evaluate various processes of the program such as confusion among multiple programs, what is working well, and areas for improvement.

Introduction

Hello. I'm [INTERVIEWER NAME] calling on behalf of the Sonoma Clean Power. We've been hired by the Sonoma Clean Power to get a better understanding of the Lead Locally program.

Sonoma Clean Power would like your input and perspectives to understand how to best structure future energy efficiency programs. The information gathered will be used solely for research purposes and your individual responses will be kept confidential.

1 SCREENER QUESTIONS

1. The Lead Locally program and the Advanced Energy Center delivers incentives and 0% loans, for qualifying customers, for various energy efficiency projects. The program referred to as "Lead Locally" buys down the cost of high efficiency equipment and has offered training to participating contractors. Are you familiar with your company's participation in this program?
    a. [IF NO] Is there anyone else from your company who is familiar with your participation in the Lead Locally program offered through Sonoma Clean Power and the Advanced Energy Center?
        i. [IF YES] Please provide their contact information:
            1. Name
            2. Phone Number
            3. Email
        ii. [IF NO] Continue with interview, but skip questions that are dependent on program awareness

2 INTRO / VERIFICATION

2. Approximately how many employees work for your company?
3. Approximately how long have you participated in the Lead Locally program? [PROBE TO SEE IF PARTICIPATED BEFORE / AFTER JULY 22]
    a. To confirm, you participated in the program when [the contractor / end user] received the incentive?
4. How did you first learn about the Lead Locally program?

1	Radio
2	Newspaper Adds
3	Direct Mailer
4	Local trade shows
5	Sonoma Clean Power marketing
6	Lead Locally marketing
7	From a distributor
8	From Frontier
9	Sonoma Clean Power / AEC website
10	Social Media

11	Phone outreach from SCP
12	Email outreach from SCP
13	Other [specify]:
98	Don't know

5. According to our records, your company installed the following equipment through the Lead Locally program. Does this look correct? [POPULATE WITH TOP 3 MEASURE TYPES]

Equipment Type	# of Projects	3a. (Yes/No/Don't know)	3b. [IF NO] Please record correct quantity
[Measure 1]			
[Measure 2]			
[Measure 3]			

6. Did any of the customers you work with participate in Sonoma Clean Power's zero percent loan program?

    a. [IF YES] Did you participate in any training, or go through a certification process for the zero percent loan program?"

3 EQUIPMENT CHOICES

Next, I'd like to ask some questions about the [Measure 1, Measure 2, Measure 3] rebated equipment.

7. What is the strongest driver when it comes to selling this high efficiency equipment?

1	Sales engineers upselling practices
2	Available stock / delivery time
3	ROI or payback calculations
4	Engineer / Architect preferences
5	Manufacturer rebates / promotions
6	Sonoma Clean Power rebates
7	Financing
8	Non-rebate activities (e.g., quarterly sales meeting, letter of commitment, market reports)
9	Reduced operations and maintenance (O&M) costs
50	Other (Record)
98	Don't know
99	Refused

8. Are there any other drivers you can think of when it comes to selling high efficiency equipment? Please select all that apply.

1	Sales engineers upselling practices
2	Available stock / delivery time
3	ROI or payback calculations
4	Engineer / Architect preferences
5	Manufacturer rebates / promotions
6	Sonoma Clean Power rebates
7	Financing
8	Non-rebate activities (e.g., quarterly sales meeting, letter of commitment, market reports)
9	Reduced operations and maintenance (O&M) costs
50	Other (Record)
98	Don't know
99	Refused

9. Do you have any specific selling points you use when selling the program-rebated equipment?

4 PROGRAM INFLUENCES

10. Using a scale of 1 to 5 where 1 is “not at all influential” and 5 is “extremely influential,” rate how influential the **incentives** offered by the Lead Locally program are on final installation choices?
    a. [ASK IF < 4] Why do you say that?
11. [IF Q6 = YES] Using a scale of 1 to 5 where 1 is “not at all influential” and 5 is “extremely influential,” rate how influential the program’s **zero percent financing** is on final installation choices?
    b. [ASK IF < 4] Why do you say that?
12. In your opinion, has the Lead Locally program affected your overall sales? [PROBE FOR NOT ONLY PROGRAM-REBATE EQUIPMENT TYPES]?
    a. [IF YES] How has the program impacted your sales? [PROBE FOR INCREASE/DECREASE, % CHANGE, AND IMPACTS ON SPECIFIC EQUIPMENT TYPES]

5 BENEFITS

13. Overall, what benefits has your company experienced from participating in the Lead Locally program?
14. Has your company had to hire or subcontract any additional positions due to your participation in the Lead Locally program?
    a. [IF YES] Approximately how many?
15. Does your company ever direct your customers to the Advanced Energy Center?
16. [IF NOT DISCUSSED IN Q15] Has your company experienced any increase in leads or sales directly from the Advanced Energy Center? [PROBE FOR % INCREASE / DECREASE]
    b. How about from the Lead Locally program overall? [PROBE FOR % INCREASE / DECREASE]
17. [IF Q6 = YES] Do you think being qualified to offer zero percent loans helps get you any additional leads or sales?

6 BARRIERS

18. Do you experience any barriers when it comes to selling high efficiency equipment?

Higher cost of high efficiency models	1
Increased size / weight of high efficiency models	2
Increased delivery time of high efficiency models	3
Market demand	4
Availability	5
Sales marketing / educating buyers	5
Unwillingness to get rid of existing equipment	6
Electrical grid reliability	7
Cost of electric panel upgrades	8
Other (Record)	50

Don't know	98
Refused	99

19. [IF NOT MENTIONED IN Q18] Have you experienced any issues with availability of program-rebated equipment since participating in the program?

    c. [IF YES] What was the issue? (e.g., supply chain issues, limited supplies)

    d. [IF YES] Was it a recurring issue?

    e. [IF YES] Were there any delays or cancellations of projects as a result?

    f. [IF YES] Do you still experience issues with availability?

20. Does your company experience any pain points or barriers when participating in the Lead Locally program? (e.g., long time for incentive reimbursement)

21. Any suggestions for improvements that would help the Lead Locally program address these barriers or challenges?

7 SATISFACTION AND PROCESS

22. Please rate your level of satisfaction with each of the following items related to the program using a scale of 1 to 5, where 1 is 'very dissatisfied' and 5 is 'very satisfied.

Topic	**Level of Satisfaction**	**[IF <4] Why?**
Your experience overall		
The incentive amounts		
Program training		
Program marketing and outreach		
On-bill financing certification process		
Interaction with program staff		
Interaction with Advanced Energy Center staff (if applicable)		

23. What do your staff typically tell buyers about the Lead Locally program?

    a. [IF NOT MENTIONED] What do your normally tell them about the financing?

24. When you sell high efficiency equipment, are you or your customers able to claim incentives for the same equipment through other programs (e.g., BayREN's TECH Clean CA Initiative) offered in California in addition to this program?

    b. [IF YES] What other programs also provide incentives for the same equipment?

BayREN's TECH Clean CA Initiative	1
Statewide Third Party New Construction Program(s)	2
Other (specify)	3
Don't know	98
Refused	99

    c. [IF YES] Has there been any confusion around equipment being eligible an incentive through one program but not another?

   d. [IF YES] Has the Advanced Energy Center or Lead Locally program help contractors or customers understand what equipment being eligible an incentive through one program but not another?

25. Are there any additional technologies you would like the program to offer incentives for?
26. What aspects of the program are working well, in your opinion?
27. Based on your experience, which aspects of the program, if any, would you change?

Thank you for taking the time to speak with me today. Those are all the questions I have.