California Energy Commission

CONSULTANT REPORT

Technology Demonstration and Deployment Evaluation, Measurement and Verification Framework

Lead Locally, EPIC Grant EPC-17-041

Prepared for: **California Energy Commission**
Prepared by: **Sonoma Clean Power Authority**

California Energy Commission

Gavin Newsom, Governor

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PREFACE

Project Overview

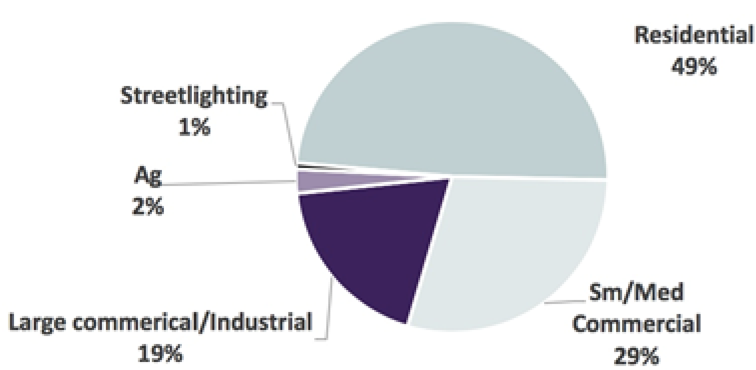
Sonoma Clean Power's (SCP) "Lead Locally" project (Project), funded through the California Energy Commission's (CEC) GFO-17-304, aims to identify strategies and technologies that can assist with the State's goals of doubling the efficiency of existing buildings by 2030. The Project will include applied research and technology deployment activities, each of which will propose innovations that could stimulate the energy efficiency market. With the applied research work, the team will investigate a series of innovative technologies that have the potential to be integrated into existing program models. Lessons learned from the applied research projects will be funneled directly to consumers, contractors, real estate professionals, and building officials through SCP and its local partner organizations. The technology deployment work will be driven in part through the SCP "Advanced Energy Center", a physical storefront where consumers can directly procure energy efficient products and services. The Advanced Energy Center has the potential to increase the deployment speed of energy efficiency products, make energy efficiency programs more accessible to all customers, and increase customer knowledge of energy efficiency and energy code requirements.

About Sonoma Clean Power and its Customers

SCP is a public power provider operating as a Community Choice Aggregator (CCA), and the default electricity provider for Sonoma and Mendocino Counties. SCP exists to provide broad public benefits relating to affordability, reliability, climate change and sustainability, coordination with local agencies, customer programs, and to support the local economy. The default service for SCP customers is CleanStart, which provided customers in 2017 with 45% renewable power and 87% carbon free power. SCP customers also have the option to select EverGreen service, which is 100% renewable power produced entirely within the SCP service area.

SCP serves just over 220,000 accounts, of which 86% are residential accounts. On an annual basis, SCP's load is comprised of about 50% residential energy use as shown in Figure P-1.

Fig P-1. SCP Customer Load for 2017



SCP, its employees, agents, contractors, and affiliates shall maintain the confidentiality of individual customers' names, service addresses, billing addresses, telephone numbers, email addresses, account numbers, and electricity consumption, except where reasonably necessary to conduct SCP's business or to provide services to customers as required by the California Public Utilities Commission (CPUC). SCP shall not, under any circumstance, disclose customer information for third-party telemarketing, e-mail, or direct mail solicitation. Aggregated data that cannot be traced to specific customers may be released at SCP's discretion.

Any questions or concerns regarding the collection, storage, use, or distribution of customer information, or who wish to view, inquire about, or dispute any customer information held by SCP or limit the collection, use, or disclosure of such information, may contact Erica Torgerson, Director of Customer Service, via email at etorgerson@sonomacleanpower.org.

Project Team, Roles and Responsibilities

The technology demonstration team is comprised of the following parties (referenced in this document as the Team), with roles and responsibilities outlined below.

Sonoma Clean Power serves as the prime coordinator with the CEC, and will be responsible for identifying project sites, initial outreach to customers, operation of the Advanced Energy Center, customer records, and reporting Project progress to the CEC.

Frontier Energy's lead roles are management of the applied research and technology demonstration activities and associated subcontractors, execution of laboratory testing, installation of instrumentation at test sites, analysis of monitored data, energy modeling, and technical reporting. Frontier also provides technical and program support to SCP for Lead Locally and Advanced Energy Center customer engagement and project performance.

DNV-GL will provide independent Evaluation, Measurement, and Verification (EM&V) for the Project, specify required measurement points and accuracy levels for the instrumentation package, and evaluate performance relative to the metrics for success.

California Lighting Technology Center (CLTC) will manage the commercial daylighting applied research project, select and evaluate daylighting technologies in both laboratory and field test settings, and assist in extrapolating field performance to estimate energy savings and peak electricity demand reduction for other space types and locations across California. CLTC will advise the Team during the technology demonstration and deployment phases.

Energy Docs and **Rick Chitwood** will design and install the ducted mini-split heat pumps and load reduction retrofits, and advise the Team during the radiant panel and mini-split technology demonstration and deployment phases.

PLT Multipoint and **Huvco** will serve as vendors for daylight harvesting sensors and daylight enhancement technologies, respectively, and provide informal design guidance and field test support throughout the project. Additional product vendors may join the Team and provide support as the Project proceeds.

Winwerks will serve as the vendor for phase change materials for commercial applications and will provide informal design guidance and field test support throughout the project. Insolcorp will provide additional advice and peer review technical plans and reports.

Aeroseal will participate in the planning of the aerosol sealing demonstration project and will provide peer reviews of all key reports.

Airscape will be consulted during the planning of the NightBreeze project and may serve as the vendor for key components of the selected system.

Mitsubishi will provide minisplit heat pumps at a discounted rate, and provide technical support to test activities and contractor training.

Chiltrix will provide air-to-water heat pumps at a discounted rate and assist with field test planning.

AO Smith and Rheem will provide heat pump water heaters at a discounted rate.

Warmboard will serve as the vendor for radiant panels and provide technical advice.

Ecodrain will provide discounted drainwater heat recovery devices and provide technical advice on lab and field test planning.

Olivine will support the enablement of the demand response component for grid-interactive heat pump water heaters through SCP's GridSavvy Community.

Sonoma County Regional Climate Protection Agency and BayREN will assist with training and staffing of the Advanced Energy Center.

Sonoma County Office of Energy and Sustainability will assist with training and staffing of the Advanced Energy Center.

Design Avenues LLC will assist with training and staffing of the Advanced Energy Center.

ABSTRACT

The purpose of this Technology Demonstration and Deployment Evaluation Measurement and Verification (EM&V) Framework is to document the methodology that will be used by the Lead Locally project team to evaluate specific retrofit measures involving innovative, emerging building technologies that are part of the technology demonstration and deployment phases of the Lead Locally project. This Framework addresses the technology demonstration technologies: phase change materials for commercial applications, ducted mini-split heat pumps, induction cooking, waste heat recovery for commercial dishwashers, aerosol duct and envelope sealing, and residential nighttime ventilation.

This Framework presents general strategies for conducting the EM&V for the technology demonstration and deployment phases for Lead Locally, which is also relevant for both Phase 1 applied research technologies (radiant panels with air-to-water heat pumps and commercial daylighting retrofits) as well as the Phase 2 applied research technologies (phase change materials in residential applications and optimized grid-interactive heat pump water heaters). We will also discuss proposed steps tailored to the specific technology and retrofit application to be used if the applied research determines the technology is a suitable candidate for large-scale deployment in Sonoma and Mendocino Counties, or elsewhere in California. The EM&V Framework sets up approaches to quantify and extrapolate energy savings and other benefits to determine future statewide impacts and cost-effectiveness.

Keywords: California Energy Commission, energy, phase change materials, buildings, research, measurement, verification, EM&V, heat pump water heaters, energy efficiency, lighting, daylighting, mini-split heat pumps, induction cooking, waste heat recovery, aerosol duct and envelope sealing, nighttime ventilation.

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EXECUTIVE SUMMARY

The purpose of the Technology Demonstration and Deployment Evaluation, Measurement and Verification (EM&V) Framework is to document the methodology that will be used by the Lead Locally project team to evaluate the energy savings potential for the technologies that are included in the technology demonstration and deployment phases of the project, and to supplement the Technology Demonstration Program Implementation Plan.

The EM&V team anticipates that the research projects will include International Performance Measurement and Verification Protocol (IPMVP) Options B where direct end use metering isolates the measure impacts. In the technology demonstration and deployment, IPMVP Option A may be applicable as some input parameters can be assumed and measurement limited. For envelope measures, the HVAC system(s) are monitored through data loggers or direct data from the installed equipment (may go through the manufacturer). The analyses will include whole building analysis under IPMVP Option C to determine, at a minimum, if the end-use effects can be detected in whole building advanced metering infrastructure (AMI) metering. Calibrated simulation under IPMVP Option D may be used for multi-measure retrofit savings analysis and in secondary analyses to extrapolate measured equipment performance to other situations.

Specific approaches to EM&V of technology demonstration measures, including baselines, timelines, and methods for quantifying energy savings, are detailed in Chapters 3 through 8. We detail EM&V approaches to established measures that may be bundled together with technology demonstration measures in Chapters 9 through 12.

CHAPTER 1: Introduction

The Lead Locally Grant is an innovative programmatic approach to existing buildings research, development and demonstration that includes a range of innovative technologies, program features, and market strategies to engage new customers in energy efficiency upgrades and deliver benefits to California's electric ratepayers. The Grant is led by Sonoma Clean Power (SCP) under funding by the California Energy Commission (CEC) through the Electric Program Investment Charge (EPIC) program. SCP is a community choice energy program providing electricity to 189,000 residential and 31,000 commercial customers in Sonoma and Mendocino Counties. This robust existing building initiative will also serve to complement current fire recovery efforts in Sonoma and Mendocino Counties, enabling SCP programs to have impact far and beyond the scope of this project.

The technology demonstration and deployment phase of Lead Locally focuses on accelerating the adoption of proven technologies in existing residential and commercial buildings through demonstration sites and innovative program strategies and channels driven through the Sonoma Clean Power Advanced Energy Center. This includes:

- Technology Demonstration activities to demonstrate how proven energy efficiency technologies can be installed, optimized, bundled, and promoted to effectively overcome known (and newly discovered) market barriers.
- 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% residential and 20% commercial site electric savings in a total of 300,000 square feet of existing building space.

The *Technology Demonstration Program Implementation Plan* documents the activities and approaches that will be used by the project team to demonstrate how underutilized energy efficiency technologies perform in targeted applications, and how they might be effectively deployed to maximize energy savings in California. Technology demonstration activities will examine various drivers and barriers in the energy efficiency market in Sonoma and Mendocino counties and will establish how that data and results from the applied research and technology demonstration sites will be used in the Advanced Energy Center to accelerate technology deployment.

Purpose

The purpose of this Technology Demonstration and Deployment Evaluation Measurement and Verification (EM&V) Framework is to document the methodology that the project team will use to evaluate specific retrofit measures involving innovative, emerging building technologies for both the technology demonstration and deployment phases of the project. The EM&V

Framework sets up approaches to quantify and extrapolate energy savings and other benefits to determine future statewide impacts and cost-effectiveness.[1]

Scope

This Framework addresses the nine technologies that are included in the technology demonstration phase of the project and outlines potential EM&V strategies the evaluation team may use during the deployment phase of the project, should these technologies prove to be successful:

1. Radiant panels with air-to-water heat pumps
2. Grid-interactive heat pump water heaters
3. Phase change materials for commercial applications
4. Commercial daylighting retrofits
5. Ducted mini-split heat pumps
6. Induction cooking
7. Waste heat recovery for commercial dishwashers
8. Aerosol duct and envelope sealing
9. Residential nighttime ventilation

We provide a detailed description of the EM&V approach to radiant panels with air-to-water heat pumps retrofits in Chapter 3 of the *Phase 1 Evaluation, Measurement and Verification Framework* and commercial daylighting retrofits in Chapter 4 of the *Phase 1 Framework*. Our EM&V approach to grid-interactive heat pump water heaters is detailed in Chapter 3 of the *Phase 2 Evaluation, Measurement and Verification Framework*. We describe our EM&V approach to phase change materials in commercial applications in Chapter 3 below.[2]

This Framework also describes our EM&V approach to four measures that are included in existing SCP programs and may provide additional savings when bundled together with one or more of the technologies (discussed in chapters 3 through 8) during the technology deployment phase of the project:

1. Heat pump water heaters
2. ENERGY STAR® products

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[1] Cost-effectiveness will be calculated using the available standard calculators approved by the California Public Utilities Commission (CPUC) for investor-owned utilities (IOUs) and community choice aggregation (CCAs) and the CEC for publicly owned utilities, which will be updated between 2019 and final reporting in 2022. Specially, the study will explore avoided costs and greenhouse gas emissions (GHG) relative to technology impact on time of day load shapes that create load shifts in addition to annual energy savings.

[2] A detailed description of the EM&V approach to phase change materials in residential applications can also be found in Chapter 4 of the *Phase 2 Framework*.

3. U.S. Environmental Protection Agency Water Sense® products
4. Electric vehicles

These measures are examples among a larger group of technologies that may be installed during the deployment phase of the project.

Report Organization

In the chapters that follow, we present general strategies for conducting the EM&V for the technology demonstration and deployment phases of the project. We also discuss proposed steps tailored to the specific technology and retrofit application to be used, if the applied research determines the technology is a suitable candidate for large-scale deployment in Sonoma and Mendocino Counties, or elsewhere in California.

The remainder of this report is organized as follows:

- Chapter 2: Lead Locally EM&V Approach
- Chapter 3: Phase change materials for residential and commercial applications
- Chapter 4: Ducted mini-split heat pumps
- Chapter 5: Induction cooking
- Chapter 6: Waste heat recovery for commercial dishwashers
- Chapter 7: Aerosol duct and envelope sealing
- Chapter 8: Residential nighttime ventilation
- Chapter 9: Heat pump water heaters
- Chapter 10: ENERGY STAR® products
- Chapter 11: U.S. Environmental Protection Agency Water Sense® products
- Chapter 12: Electric vehicles
- Chapter 13: Reporting

CHAPTER 2: Lead Locally EM&V Approach

Evaluation, Measurement and Verification (EM&V) is the collection of methods and processes used to assess the performance of energy efficiency activities so that planned results can be achieved with greater certainty and future activities can be more effective.

The main objectives of an EM&V process are to assess the performance of an energy efficiency program or project, measure the energy or demand savings, and verify if the program is generating the expected level of savings. EM&V data can inform recommendations for improvements in program performance. Having a clear understanding and description of how the program is expected to deliver results is critical to an effective EM&V process.

The EM&V process is analogous to the evaluation of business or employee performance. For example, did the company meet its profit or growth objective? What can be done to improve performance? In the energy efficiency market, the EM&V process answers the question of whether the investments in energy efficiency achieved the expected or required objectives.

DNV GL's EM&V Framework is designed to align with California Protocols and the International Performance Measurement and Verification Protocol (IPMVP). The energy savings calculations will include both end-use measurement and whole building approaches to ensure state goals and ratepayer-funded program requirements are met. The projects range across residential and commercial building types and primarily impact the heating, cooling, ventilation, water heating, lighting, and cooking end uses. We anticipate most applied research projects will include IPMVP Options B where direct end use metering isolates the measure impacts. In the technology demonstration and deployment phases, IPMVP Option A may be applicable as some input parameters can be assumed and measurement limited. For envelope measures, the HVAC system(s) are monitored through data loggers or direct data from the installed equipment (may go through the manufacturer). The analyses will include whole building analysis under IPMVP Option C to determine, at a minimum, if the end-use effects can be detected in whole building advanced metering infrastructure (AMI) metering. Calibrated simulation under IPMVP Option D may be used for multi-measure retrofit savings analysis and in secondary analyses to extrapolate measured equipment performance to other situations.

Table 1 below summarizes the four IPMVP M&V options along with how savings are calculated for these options as well as the typical applications of these options.

Table 1: IPMVP M&V Options.

IPMVP M&V Option	Descriptions	How Savings are Quantified	Typical Applications
A. Partial Retrofit Isolation	Savings are determined by partial field measurement of energy use of the affected system. Engineering estimation using short-term/ continuous post measurements and stipulations.	Engineering calculation of baseline and reporting period energy from: 1. short-term or continuous measurements of key operating parameter(s); and 2. estimated values. Routine and nonroutine adjustments as required.	A lighting retrofit where power draw is the key performance parameter that is measured periodically. Estimate operating hours of the lights based on facility schedules and occupant behavior.
B. Retrofit Isolation	Savings are determined by field measurement of the energy use of the ECM-affected system. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the savings and the length of the reporting period.	Short-term or continuous measurements of baseline and reporting period energy, and/or engineering computations using measurements of proxies of energy use.	Application of a variable speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute.
C. Whole Facility	Savings are determined by measuring energy use at the whole facility or sub-facility level.	Analysis of whole facility baseline and reporting period (utility) meter data.	Multifaceted energy management program affecting many systems in a facility.
D. Calibrated Simulation	Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility.	Energy use simulation calibrated with hourly or monthly utility billing data. (Energy end use metering may be used to help refine input data.	Multifaceted energy management program affecting many systems in a facility but where no meter existed in the baseline period.

EM&V Process

There are seven (7) major steps in implementing EM&V for the Lead Locally project:

1. **Define evaluation objectives.** The first step of an EM&V project is to establish evaluation objectives. The objectives of the evaluation include assessing energy savings, risk management, and program improvement. The other benefits will include calculation of co-benefits, such as greenhouse gas (GHG) emission and other non-energy benefits.
2. **Developing the sample design.** Sample design development is one of the core steps of the EM&V process. A well-designed sample plan selects a representative number of projects, measures their energy impacts, and then extrapolates results to the population to determine the impact of the program. Setting up accurate and sufficiently robust program tracking data is a critical part of the EM&V process. Complete and accurate program tracking data not only help support implementing successful energy efficiency programs, but also help evaluators make informed decisions on sample design.
3. **Select an evaluation savings determination approach and define baseline.** Determining the appropriate methodology for savings estimations is a key step in the M&V process. The selection of M&V method depends on the following:
    - Complexities of measure
    - Number of interrelated measures at a facility
    - Uncertainty of the savings
    - Project cost and expected savings
    - Availability of M&V data

    Simpler project may require simple methods, whereas more complex projects may require more complex methods to determine savings. For example, it is easier to assess the energy savings of a one-to-one lighting replacement project where T8 fixtures are simply replaced by LED fixtures and operating hours of the lighting system remain unchanged from the baseline conditions to the retrofit conditions. In this case, IPMVP A could be used to quantify the savings where the key performance parameters are known, such as lighting base and post-retrofit installed wattage, and the operating hours based on the facility-wide schedule need to be measured. On the other hand, a complicated chiller measure may not be especially difficult to assess, if there are energy sub-meters and monitoring systems dedicated to the chiller system. Thus, when defining the appropriate M&V requirements for a given project, it is important to consider the following categories of the measures to assign M&V methods.

    - Constant load, constant operating hours
    - Constant load and variable operating hours
    - Variable load and variable operating hours

If the measure is in first category, IPMVP Option A is more suitable because one key performance parameter, such as kW, could be measured and the operating hours could be stipulated. But, for the two other categories, IPMVP Option B is more appropriate for capturing all the variability of the measures to quantify the savings.

If multiple measures are installed in a single building, the savings of each measure may be related to the savings of the other measures, such as the interactive effects between lighting and HVAC measures or envelope measures. In this scenario, it may not be possible to isolate and measure one system to estimate savings. Therefore, for multiple interactive measures, whole facility IPMVP Option C or D may be most appropriate.

Defining the baseline is an important aspect of M&V because the energy savings cannot be directly measured. Energy savings is calculated by comparing the energy use of the newly installed technology with a baseline defined prior to the installation of the new technology.

4. **Verify installation and conduct data collection and analysis.** Verification activities include physical verification of installation of the new equipment and confirmation that they are operating as intended. Measurement activities include the data collection, monitoring and analysis necessary to document the energy and demand savings and expected costs of the energy efficiency project. Measurement activities involve recording or estimating:

    - Equipment specifications for both existing equipment (the baseline) and the new energy efficient equipment installed
    - Actual energy usage of the baseline equipment and the installed energy efficient measure(s)
    - Total cost of the new equipment being installed, including material, labor, shipping and taxes and any other costs incurred
    - Additional data that may also be needed to document the utilization of the equipment in order to reasonably estimate savings
    - Other factors affecting the measure's energy usage, such as weather for temperature sensitive uses

5. **Calculate energy and demand savings**. Energy savings reflect the difference in energy usage (gas or electric) between the existing equipment and the energy efficient technology installed in its place, adjusting for any significant changes that would impact the savings estimate.

    For example, when replacing a major HVAC system, it is necessary to perform M&V that includes direct metering of the existing HVAC unit during the cooling period and subsequent metering of its replacement in the next year. The direct metering of the old and new unit provides excellent data, but without taking into consideration changes in weather between the two years, the savings estimate could be biased. If the weather in the year the new unit was installed was warmer than the year before, without adjusting for weather, the savings estimate would be understated. If, in addition to replacing the

HVAC system, the structure was enlarged, and the HVAC size remained the same, one would also have to compensate for the increase in building size to get a more accurate estimate of energy savings attributable to the more efficient HVAC system.

Non-Routine Events (NREs): NREs are the adjustments or changes that occur from time to time in the buildings that affect their energy use. Such changes could increase or decrease load on the building HVAC and electrical systems, independent of the effect of the installed measures. Additionally, the NREs could be due to permanent or temporary changes in equipment, space load, building schedule, or occupancy. These changes could be constant or variable. Hence, these NREs should be identified, energy use of these events should be quantified, and finally should be accounted for in the analysis for determining project savings. To properly identify, quantify, and account for the NREs, adequate data need to be collected from the sites. Once the event types are determined, the evaluation team should develop a data collection plan and assess how the energy use of these events can be quantified.

6. **Technology assessment.** A technology assessment includes measuring the customer response to the technology, and assessing the technical and market potential of the technology. The technology assessment also evaluates the degree of market readiness for the technology and includes recommendations for future steps towards commercialization.
7. **Calculate co-benefits.** Co-benefits include avoided greenhouse gas emissions and other environmental benefits, energy price effects, economic impacts such as job creation and increases in income, non-energy benefits to program participants (e.g., health, comfort, and reduced maintenance), and other technical system benefits based on the objectives of the program policy. Data from a benefits questionnaire will be used to quantify these co-benefits.

Preparation for EM&V

In the following sections, we provide further detail on our approach to sample design and billing analysis.

Sample Design

For Lead Locally, the evaluation team will sample participants in two different phases. The first phase of sample selection will be performed in November 2020, approximately one year after the grand opening of the Advanced Energy Center in December 2019, and the second set of samples will be selected in May 2021. The team will primarily rely the EM&V analysis based on the first two phases of sample selection, unless the program participation level is fairly low during the first year of the program implementation. If that is the case, we will move the phase 2 sample selection to July 2021 to capture the full program activities. The sample design focuses on isolating technology specific impacts. Note that the program goals to achieve savings of 10% residential and 20% commercial across 300,000 square feet will be achieved with combinations of measures at sites.

For both residential and commercial sectors, we will design the sample to achieve a relative precision in line with CPUC's evaluation sampling protocol guidelines for gross energy and demand impacts.

Our sampling methodology will employ a stratified ratio estimation model that first places participants into segments of interest (by sector) and then into strata by size, measured in kWh savings. The methodology then will estimate appropriate sample sizes based on an assumed error ratio.

The error ratio is the ratio-based equivalent of a coefficient of variation (CV). The CV measures the variability (standard deviation or root-mean-square difference) of individual evaluated values around their mean value, as a fraction of that mean value. Similarly, the error ratio measures the variability (root-mean-square difference) of individual evaluated values from the ratio line Evaluated = Ratio* Reported, as a fraction of the mean evaluated value. Thus, to estimate the precision that can be achieved by the planned sample sizes, or conversely the sample sizes necessary to achieve a given precision level, it is necessary to develop a preliminary estimate of the error ratio for the sample components.

In practice, error ratios cannot be determined until after the data are collected; savings are evaluated, and therefore, they need to be estimated. The sample design and projected precision are, thus, based on assumed error ratios from experience with similar work. We will use an error ratio of 0.6 based on previous experience with similar studies.

For the sample design, first we will define sampling frames for each sector. The sampling frame for each sector is the list of records under that sector from which the sampling units are selected. In this project, we will have two sampling frames: one for the residential sector and the other for the commercial sector. Once sampling frames are defined, we will stratify the population on the claimed savings (kWh). Then we will determine the target precisions and design the sample to achieve target relative precision for each sector. Once the sample size is calculated, we will randomly choose primary sample points from the population in each stratum. We will select a sample large enough to achieve the targeted number of completed cases, after the response rates are considered. We will also select backup sample in case any sample points need to be replaced. This most often happens with sites that cannot be visited or evaluated for some reason.

A critical input for informing the sample design is program tracking data. Program tracking data are important for measuring program progress, tracking energy savings, and ultimately, successfully implementing energy efficiency programs. Comprehensive and clean tracking data are also critical for effective program evaluation. Poor data quality could limit the ability to quantify the energy savings of program measures. The evaluation team will work with Lead Locally staff and equipment vendors to ensure that all of the information entered into the tracking data is accurate and complete. After the Advanced Energy Center opens, we will review tracking data every two weeks to check for data accuracy and completeness and provide rapid feedback and recommendations on the tracking data to Lead Locally staff.

Billing Analysis

Because one of the primary goals of the Lead Locally project is to deliver site specific electric savings of 10% for residential and 20% for commercial properties that total 300,000 square feet of development, the EM&V team will perform site-level and aggregate billing analysis separately for both the residential and commercial sectors to validate the savings targets set forth by the project. The sample design will look to represent the most important technologies and looks to project expected savings out via the benefits questionnaire. Regardless of the sample design, the billing analysis facilitates identifying and documenting the sites that achieved site specific savings of 10% residential and 20% commercial across at least 300,000 square feet of properties.

The team will utilize the Normalized Annual Consumption (NAC), Option C method to quantify the savings. NAC models provide quick and cost-effective measurement of changes in energy use between pre- and post-intervention periods. These models normalize monthly or daily consumption data to uniform weather conditions in the pre- and post-intervention periods. Other drivers of consumption such as building occupancy may also be included in the normalization, if available.

With monthly data, NAC methods are only able to capture relatively large changes in consumption, unless large numbers of customers are included. However, with daily or hourly data, somewhat smaller savings can be reliably measured with a smaller number of customers.

Baselines

To appropriately measure and validate the impacts of certain technologies on household or facility load, one must employ a baseline that correctly controls for all possible exogenous factors other than the deployment of the technology itself. These differences can be related to weather, as well as geospatial, economic, or demographic/firmographic differences. An ideal appropriate counterfactual will account for all external factors aside from the implementation of the technology itself.

The team sees several challenges to estimating an accurate counterfactual or baseline, and thereby providing an accurate measure of technology-related impacts, including:

- Interactive effects of various technology deployments within individual sites and across all sites in the study
- Impacts of programs affecting energy and demand
- Limited number of participant sites with large number of technologies being tested
- Extrapolating results to technical and market potential application for a broad customer base
- Non-technology economic effects that may be intertwined with the technologies
- Changes to building occupancy and usage over time

Each of these challenges represents an area of concern related to producing counterfactual baselines with respect to evaluation of new technologies. In theory, the most appropriate way to measure a counterfactual in a technology deployment evaluation is to employ a well-randomized control trial for large samples. This experimental design establishes a control group that is statistically indistinguishable from the participant group prior to testing for any technology impacts. With the establishment of a well-randomized control group, a difference-in-difference approach allows for an unbiased estimate of technology-related impacts. In the absence of a control group and the other issues raised above, a fundamental technology specific baseline can be modeled using interval data not impacted by any technology deployment.

Each field test must include a well-established baseline that can be compared to the retrofit case for the purpose of calculating energy savings. The EM&V Framework and process also allows the baseline to change in future year scenarios as we project impacts of moving technologies forward into the market:

- **Pre-retrofit**. The most common baseline case is the site itself prior to the energy retrofit, because the space geometry, operating conditions, internal gains, climatic conditions, and other building attributes are usually identical. Also, recent legislation such as SB 350 and AB 802 ask the Energy Commission and California Public Utilities Commission to create paths forward for bringing existing building up to and above energy code and toward a zero-carbon future. However, year-to-year weather differences must be accounted for, and there must be verification that occupancy levels and usage patterns did not change significantly. In some cases, the retrofit may be part of a remodeling effort that corresponds to a change in occupancy. In those cases, the pre-retrofit case is not a viable control for the field test, except as a hypothetical scenario analyzed using building energy simulation.
- **Similar buildings**. Buildings with similar physical characteristics and occupancy types are sometimes used as the baseline case when pre-retrofit data are unavailable or inappropriate due to a change in occupancy or major remodeling that coincides with the energy retrofits. This approach is more common with new construction in residential neighborhoods with standard home models, and usually requires large sample sizes to achieve reasonable accuracy and overcome variations in occupant behavior. It is unlikely that similar buildings will be used as a control case for applied research or technology demonstration, but this quasi-experimental design may be used for deployment scenarios. Matching may be on the data available to SCP as well as usage patterns.
- **Similar spaces in the same building**. In larger commercial buildings, there may be very similar spaces on different floors or different sections of the buildings. This option can avoid challenges related to year-to-year weather differences, reduce the overall timeline for the field test, and be more efficient from a cost standpoint. However, spaces are never identical, and uncertainty can be introduced by small differences in geometry, layout, and occupant behavior. In some cases, controls improvements can also use this approach where optimization routines or sequences can be bypassed. This is similar to the case of using the same building to synthesize a baseline when a true pre-retrofit is not feasible.

- **Modeled baseline case**. When no physical control case is viable or when current or new energy code should be the baseline, such as new construction or major commercial tenant improvement, building simulation can be used to analyze the theoretical energy use of the test site prior to retrofit. Calibration of the pre-retrofit model is impossible in this scenario, so detailed documentation and spot measurements of the performance of pre-retrofit equipment may be necessary to ensure accuracy. When using a modeled baseline, a calibrated model should also be developed for the retrofit case, using the same modeling assumptions and weather conditions. This approach is sometimes referred to as "Model Enhanced Monitoring."

The selection of an appropriate baseline depends on the nature of the technology and the characteristics of the test site. Further details on this topic are provided in the specific technology sections of this Framework.

Impact of Multiple Measures

This Framework describes our EM&V approach for four additional measures that are included in existing SCP programs and may provide additional savings when bundled together with one or more of the technologies (discussed in chapters 3 through 8) during the technology deployment phase of the project:

1. Heat pump water heaters
2. ENERGY STAR® products
3. U.S. Environmental Protection Agency Water Sense® products
4. Electric vehicles

These measures are examples among a larger group of established technologies that may be installed during deployment. We describe our approach to heat pump water heaters in Chapter 9, ENERGY STAR® products in Chapter 10, U.S. Environmental Protection Agency Water Sense® products in Chapter 11, and electric vehicles in Chapter 12.

We plan to review the deployment both by technology and by customer to look holistically at the package and expected and evaluated whole building impact. Where we are using both deemed and customized savings we will treat the applied research and technology demonstration measures as primary relative to existing conditions baseline, and then consider the bundled measures, since we will know the savings of new equipment relative to code. When performing billing analyses, interactive effects will be captured along with behavioral variables and calibrated simulation may be favored when needed to combine end-use approaches using IPMVP Option A or B with deemed savings and get accurate whole building energy impacts as well as the specific estimates for the technologies being demonstrated.

Technology Assessment

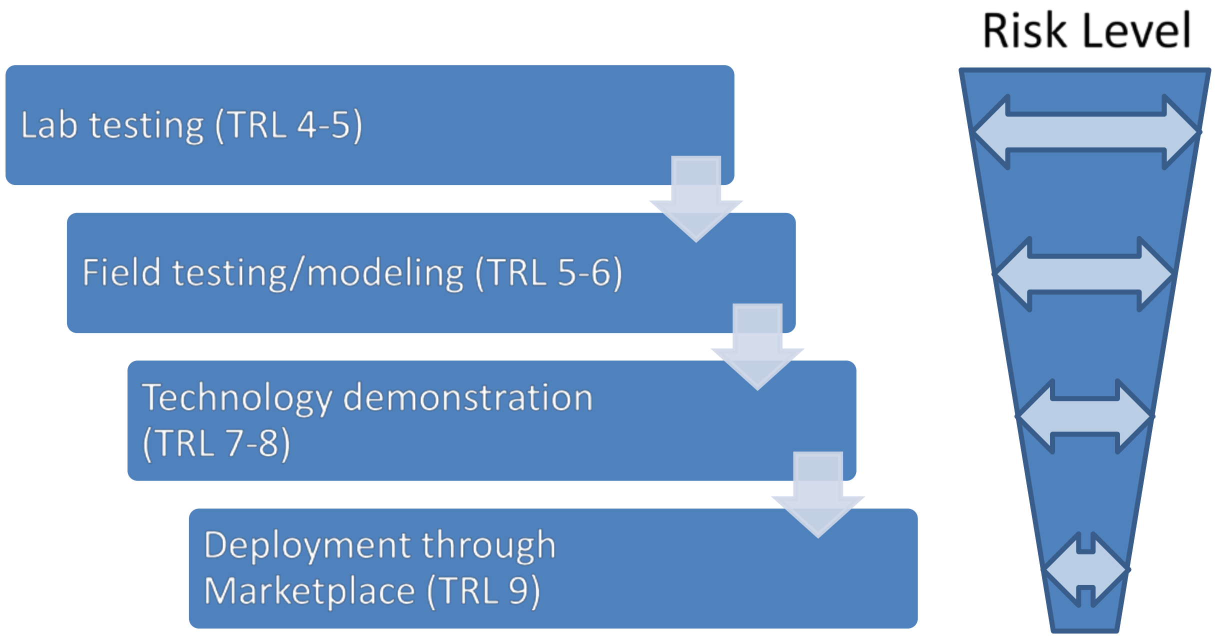
For each technology assessment, we define specific metrics for customer engagement and market readiness. We describe this in more detail below.

Customer engagement is a critical aspect of technology integration into the Advanced Energy Center. Therefore, for every technology studied, researchers will develop an approach to measure pre-installation customer awareness, needs, and expectations. SCP will also implement procedures for key participants in the test to maintain a log of their experiences, and conduct a post-test follow up survey or set of interviews. Technologies may work functionally, but it is also important to assess the extent of interaction that end users have with the technology, its ease of use, delivery of expected results, and overall impression given. A debriefing following the end of the test will reveal areas of improvement for the equipment and/or instructions, marketing messaging, etc., that may be required for either a wider pilot test or full-scale implementation.

Market readiness will be studied from the perspectives of technical and market potential as based on secondary data and surveys, integration into current infrastructure, and customer receptivity and willingness to adopt. We propose a methodology for combining these perspectives and indicating our conclusions as to whether a technology is market-ready, not ready, or at what stage of commercialization the technology is, given the research, and what barriers remain for SCP to accelerate adoption.

Technology Readiness Level (TRL) is a good indicator of the level of risk associated with a technology or product. The applied research projects for Lead Locally are considered either TRL 4 (component and/or system validation in laboratory environment) or TRL 5 (laboratory scale, similar system validation in relevant environment). Our objective is to move the technologies to TRL 8 (actual system completed and qualified through test and demonstration) over the course of the program. Lead Locally has adopted a gradual risk reduction process that includes lab testing, field testing, modeling, and technology demonstration, before proceeding with large scale deployment (see Figure 1).

Figure 1: Risk Reduction Strategy for Lead Locally



The proposed projects vary in stage of research and baselines that the measurement and verification (M&V) framework must address to quantify energy savings and other benefits. The differences between the applied research and technology demonstration projects are detailed later in the technical approach chapters below. The M&V framework provides guidance for site-specific instrumentation and monitoring plans.

The EM&V will weigh the gains and impacts the retrofit has had on energy savings, non-energy benefits such as reliability, public safety, lower operational cost, environmental improvement, and indoor environmental quality. The results will heavily impact the market readiness assessment. The applied research and EM&V teams will vet and discuss results. If SCP feels the findings indicate minimal non-energy impacts from the lighting retrofits and radiant heating panel with air-to-water heat pumps, for example, the market assessment funding will be allocated to assist other profiled technologies. If meaningful benefits are realized, we will assess the scope and readiness of the profiled technologies. We will assess the number of sites with the installed technologies found in Sonoma and Mendocino counties and track equipment costs with secondary research to understand if market adoption changes prior to deployment through the Advanced Energy Center. We will look at the scope and reliability of secondary research to determine if any significant conclusions about market readiness can be made from the data. If some estimates are possible, this will be reported in terms of number of sites, size and type of sites, and date range for adoption of the technologies.

Benefits Questionnaire

After data collection is completed, our team will develop sampling weights, to be used to expand the sample results to the population. The sampling weights will reflect the sample stratification and population counts, and completed sample counts.

The EM&V also requires looking at the broader evaluation of technologies in addition to quantifying energy benefits. All M&V results will require a standard step at completion to project future program savings based on the collected data. The pre-project savings estimates must be calculated using the References for Calculating Electricity End-Use, Electricity Demand, and GHG Emissions. At a high level, we will apply the specific technology impacts to a proportion of the reference consumption based on our customer response and degree of market readiness assessment.

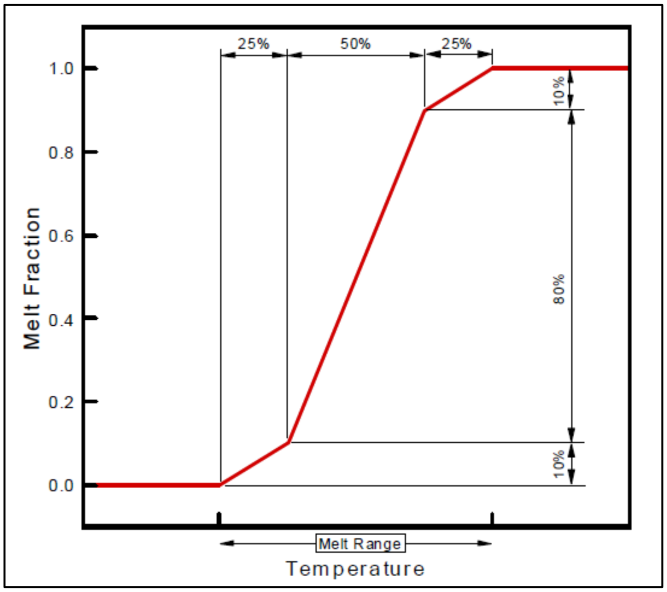
CHAPTER 3: Phase Change Materials in Commercial Applications

Phase Change Materials (PCM) have been used as a building insulation component for the last 40 years and help in improving building energy performance. Encapsulated PCM can be applied in building walls, roofs, and attics and help maintain stable space temperature by acting as a buffer against large outside air temperature swings.

Technology Description

PCM absorb energy and melt when exposed to warm temperatures or solar radiation. This reduces the cooling and heating demand on the building heating, ventilating, and air conditioning (HVAC) system. PCM absorb heat when they melt from solid to liquid, and release heat when they solidify from liquid to solid. Using PCM alters the temperature profile through the drop ceiling and reduces the building cooling need. Further, it can shift the time of peak load in commercial buildings to a time when the building air conditioning system operates more efficiently, thereby reducing energy costs if time-of-use rates are in place. For commercial buildings, it can reduce the building peak demand and develops more stable interior temperatures. As shown in Figure 2, any PCM has a defined melt-start and end temperature, and the majority of the melting occurs at the middle of this melting range. During day time, the heat flux through the PCM in the attic increases, and it can change its phase from solid to liquid. The absorbed heat is stored inside the PCM and given back to the ceiling space and to the indoor conditioned space at night. As the temperature drops at night, the PCM can freeze back to solid phases. This is how PCM helps both in reducing the heat transport and shifting the load to non-peak hours.

Figure 2: Typical Melt Curve of PCM



The effectiveness of the proposed PCM depends on different variables:

- Type of PCM material used
- Amount of PCM used
- Climate zones and diurnal temperature range for most part of the year
- PCM application, wall, ceiling or floor
- Midpoint of PCM melting and freezing range compared to indoor temperature setpoints during building occupied and unoccupied periods
- Time delay in heat transfer

One of the primary challenges associated with the effectiveness of PCM is having adequate air volume to transport heat between the PCM and the indoor conditioned space. By placing PCM inside the drop ceiling, insufficient attic air space may limit the transfer of heat from the PCM. This may not facilitate a completion of the freeze cycle during low attic temperature period. But as ceiling volume and outside air temperature profiles vary from site to site, PCM impacts may be different for different sites. We can assess the suitability of drop ceiling insulation quantity, suitable melt and freeze temperature of selected PCM, heat flux through the ceiling and dropped ceiling temperature profile change after this evaluation.

For the commercial application evaluation, PCM will be installed in ten different test sites within Sonoma and Mendocino counties to verify its effectiveness at reducing building energy consumption and to verify its impact during occupied versus unoccupied periods as well as during summer versus winter months.

For a more detailed description of this technology, please refer to Chapter 4 of the *Phase 2 Research, Instrumentation, and Monitoring Plan.*

Data Collection and Analysis

In this section, we describe the baseline definition, analysis approach, and market readiness for PCM.

Baseline Definition

Title 24 defines the minimum roofing insulation at various climate zones. Table 140.3-B of 2016 Title 24 provides the prescriptive building envelope requirement for commercial buildings. The baseline roofing insulation for commercial building varies based on building construction type, such as metal building or wood framed building.

The field test will include ten commercial buildings that will be retrofitted with PCM mats inside the drop ceilings. The commercial sites will ideally be single story buildings so that the entire floor space can get the effect of PCM mats laid underneath the drop ceilings. The commercial buildings that have dominant internal load and that operate during the entire week are the most suitable for preferred test sites. Retail stores, restaurants, and manufacturing buildings are ideal candidates for this evaluation as test sites. These building types have large internal loads for most of any given day and operate during both weekdays and weekends.

Baseline ceiling insulation will be checked for its thickness, amount, its specification and its installation appropriateness. This evaluation effort should ensure that both baseline and retrofitted conditions maintain similar leak tightness and installation practices.

Analysis Approach

IPMVP Option A, Retrofit Isolation will be used for our evaluation. The key parameter measurement will be the heating (kW or therms) and cooling kW of the building air conditioning unit to determine savings associated with PCM retrofits.

Energy Savings Analysis: A direct measurement approach is recommended to attain annual energy savings for zones receiving PCM insulation technologies. Both baseline and post-retrofit conditions include continuous power measurement of the building air conditioning units along with measurement of outside weather (dry-bulb temperature and wet-bulb temperature) collected from local weather stations or site installed weather station at the same interval. Both baseline and post-retrofit measurement periods should be for a minimum 6 months, which should include enough coverage of outside air temperature conditions.

The following steps will be utilized to calculate the impact of the PCM technology from the data collected from the test sites:

1. Base HVAC system kW will be compared to the actual ambient temperature to develop the relationship between the weather and the kW and use that relationship along with the typical meteorological year (TMY) to develop normalized annual baseline kWh consumption.

2. Once the PCM is installed, repeat the same steps with the actual weather and post kW data to determine the normalized annual post kWh consumption

3. If good correlation is not exhibited with the whole data sets, efforts will be made to develop correlations at small outside air temperature ranges along with their associated building HVAC units logged power.
4. Normalized kWh savings is the difference between normalized baseline kWh consumption and normalized post case kWh consumption.

   Normalized annual kWh savings = Normalized baseline kWh consumption – Normalized post case kWh consumption

   Baseline annual kWh = Based on baseline correlation of kW Vs. OAT, with TMY3 weather data

   Post case annual kWh = Based on post correlation of kW Vs. OAT, with TMY3 weather data

A similar process will be used to quantify the heating savings of the PCM technology by utilizing the monitored baseline and post-retrofit BTU and weather data.

System Performance Verification Review: As part of the PCM system performance review, we will compare the space temperatures of baseline (without PCM) and post-retrofit (with PCM) periods to evaluate the changes in room temperature profiles due to the PCM retrofit. The same sets of comparison will be carried out for the ceiling temperatures and drop ceiling temperatures to assess the impact of the PCM technology on the temperature profiles. Our team will also compare the monitored baseline and post-retrofit heat flux to observe the lowering of heat flux due to installation of PCM.

Market Readiness

The commercial PCM attic matts installed during the technology demonstration phase of the project are market-ready. Table 11 lists the market readiness and applicable market segments and for commercial PCM. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 2. Market Readiness for PCM Technologies

Technology	Market Readiness	Market Segments
PCM attic mats	Market-ready, used in practice	Single story restaurants, retail stores, and manufacturing buildings

The applied research effort seeks to move promising technologies forward and the Advanced Energy Center and technology demonstration stages will provide opportunities to discuss potential barriers to including PCM in retrofits. The evaluation team will conduct surveys to characterize participants' responses to the technology. These assessments will assess barriers to adoption of commercial PCM as well as non-energy impacts.

Project Timeline

Table 3 shows high level project timelines for the commercial PCM technology.

Table 3 Project EM&V Schedule for Commercial PCM Retrofit

Project Tasks	Completion Dates
EM&V Framework Development	May, 2019
Field Test-Pre-monitoring Strategy Review	September, 2019
Program Participants Survey review	February, 2021
Field Test-Retrofit Monitoring Strategy Review	December, 2020
Model Reviews	January, 2021
Market Readiness Interviews	April, 2021
Draft Report Review	August, 2021
Final Report Review	October, 2021

CHAPTER 4: Ducted Mini-Split Heat Pumps

Performing thermal load reduction measures, such as envelope sealing, increasing attic insulation, and replacing existing exhaust ventilation with energy recovery ventilation, allows installing smaller capacity forced air systems, such as mini-split heat pumps (MSHPs), in place of traditional large split systems. These smaller MSHPs use less energy, can be more efficient, and take up less space than traditional furnaces and air conditioners. This makes it easier to install them with more compact duct systems in conditioned space in existing homes.

Technology Description

A heat pump is a reversible air conditioner that can provide both cooling and heating to a conditioned space. A split system is one that is split into two primary components: an indoor air-handler unit and an outdoor coil unit. A mini-split heat pump is a small capacity system that is more physically compact and can vary the speed of its components to more closely match the heating and cooling loads, and as a result, operates more efficiently.

A ducted mini-split typically has a single indoor unit and distributes conditioned air throughout the house using compact ductwork. The ducted arrangement is in contrast to a ductless mini-split which typically distributes refrigerant to multiple small indoor units (sometimes called heads or cassettes), each with its own fan-coil (i.e. small indoor fan unit) and often with a separate thermostat controller.

Data Collection and Analysis

In this section, we describe the baseline definition, analysis approach for the technology deployment, and market readiness for ducted mini split heat pump systems. A more rigorous and in-depth analysis approach that includes air-side measurements and simulation modeling Option D approach will be executed in the technology demonstration phase of this effort. The approach proposed for the demonstration phase, which is described in detail within the Technology Demonstration Program Implementation Plan, may not feasible at the scale of the deployment because of cost constraints associated with its complexity and therefore an alternate direct measurement approach could be applied in the deployment phase.

Baseline Definition

The baseline system is a ducted (i.e. central) package or split furnace/ AC or heat pump.

Analysis Approach

In this section, we outline the approach to evaluate energy savings for installations of the MSHP technology.

Energy Savings Analysis: IPMVP Option A Retrofit Isolation, Key Parameter Measurement will be used to determine the energy savings of equipment. Pursuing an Option A methodology will provide an acceptably accurate estimate of savings without an extensively complex metering suite and analysis data set that Option B would require, or the uncertainty that would accompany an Option C methodology.

The key measurement parameters will be HVAC equipment electrical (kWh) consumption. Monitoring of the electrical energy consumption of both the baseline equipment and retrofit MSHP equipment will enable a direct measurement of electrical impacts, and where applicable, a direct or a proximate measurement of gas fuel consumption. Electrical energy consumption monitoring can include all electrically driven components of the system, so this may entail separately monitoring an air handler unit and an AC or condenser unit in the case of a split HVAC system. Separate consumption meter data may be combined to represent the system level energy use. The measurement interval should be daily, although finer measurement intervals can be collected and aggregated to the daily level. Observation periods of 1 year (12 months) are desirable; however, an observation period of 6 months could be utilized if it includes both the cooling and heating seasons (e.g. July through January) and if the pre- and post-retrofit periods are comparable.

In addition to the electrical consumption parameter, local ambient temperature data appropriate for the project site that covers both the observation periods and provides historically expected temperatures (e.g. TMY3) should be sourced. The temperature data will be leveraged to develop a relationship between the HVAC energy use and outdoor conditions—specifically, a regression relationship between consumption and cooling degree days (CDD) and heating degree days (HDD). Degree days are the difference between the daily mean ambient temperature and a base temperature above or below which no heating or cooling is required. A base temperature of 65 ˚F is common, but a base should be selected that provides the most fit model.

The regression models for the baseline and the retrofit cases can be developed using the daily kWh data and the daily calculated CDD and HDD values during the observation periods. The following equation, a baseline example, illustrates how the model should be structured using the data:

$$kWh_{baseline\ observed} = mHDD \cdot HDDobservedbaseline + mCDD \cdot CDDobserved_{baseline} + C$$

Where,

- kWh $_{baseline\ observed}$ is the model output [kWh]
- m $_{HDD\ or\ CDD}$ is the model coefficient for the HDD or CDD term
- HDD(observed $_{baseline}$) and CDD(observed $_{baseline}$) are the calculated HDD and CDD values for the observation period
- C is a constant that accounts for consumption independent of CDD or HDD.

The evaluator should develop the model on either a daily or a monthly interval, whichever is more appropriate for the data available and the project constraints. The evaluator should adjust the model coefficients and the HDD/CDD base temperatures to achieve the best fit, as in the difference between the model's predicted kWh output and the observed kWh value from the data, which is commonly quantified using the R-squared metric. Once an acceptable level of model fitness is achieved, the evaluator can determine the normalized consumption by calculating the expected annual HDD and CDD values from the historically expected temperature data (e.g., TMY3, CZ2010, CA2018), using the base temperature developed in the model. Using the model with these expected annual HDD and CDD values, as shown in the equation below, produces the baseline or retrofit case normalized kWh consumption.

$$kWh_{normalized} = m_{HDD} \cdot HDD(expected) + m_{CDD} \cdot CDD(expected) + Constant$$

Electrical energy savings for the measure is calculated as the difference between the normalized kWh values for the baseline and retrofit cases, as shown in the following equation:

$$kWh\ Savings = kWh_{normalized\ baseline} - kWh_{normalized\ retrofit}$$

For applications where the baseline equipment utilized electrical energy for heating, such as a heat pump or electric resistance, the savings will simply be the difference in kWh between the baseline and retrofit cases as discussed above, while instances that involved heating using a fuel other than electricity, such as with a gas-fired furnace, will require further calculations. In these instances, the evaluator can either utilize a non-intrusive gas consumption sub-metering or as an alternative, determine the relationship between the rated gas fuel consumption and the electric power consumption of the HVAC equipment (i.e., combustion and blower motor fans). The evaluator can utilize the nameplate fuel input for each heating stage and take spot measurements of the electric power consumption of the HVAC equipment in each stage so that the correlation between electric power consumption and gas fuel consumption can be understood and later inferred from the measurement data. With this information, it can be assumed that the furnace will consume the calculated amounts of gas energy when the system is operating during conditions that indicate a need for heating. Gas savings will be calculated using the follow equation and is derived from the baseline case alone:

$$Therm\ Savings = m_{HDD} \cdot HDD(expected) \cdot \frac{kBtu}{kWh} \cdot \frac{1\ therm}{100\ kBtu}$$

Market Readiness

The technology is on the market (Fujitsu, Daikin, LG, Mitsubishi, etc.) but availability of competent installers is a limiting factor to market adoption and market penetration. Table 4 lists the technology recommendations and our initial assessment of their current market readiness and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 4. Market Readiness for Ducted Mini-Split Heat Pumps

Technology	Market Readiness	Market Segments
Ducted Mini-Split Heat Pumps	Market ready, used in limited practice	Existing and new construction single family and multifamily buildings

Another important element of the Technology Assessment survey is to characterize the participant homeowner's response to the technology. Questions specific to this technology will assess barriers, such high upfront costs or the challenges of installation, and non-energy impacts, such as improved occupant comfort or reduced exposure to combustion by-products.

Project Timeline

Table 5 shows high level project timelines for the ducted mini-split heat pump technology.

Table 5: Project EM&V Schedule for Ducted Mini-Split Heat Pump Technology

Project Tasks	Completion Dates
EM&V Framework Development	May 2019
Baseline Measurements	November 2019
Post-retrofit Measurements	February 2021
Draft Report Review	July 2021
Final Report Review	October 2021

CHAPTER 5: Induction Cooking

Induction cooktops have been commercially available for both residential and commercial foodservice (CFS) applications for decades but are underrepresented in both markets because they are typically more expensive to purchase than their gas and electric-resistance counterparts. The most commonly sold residential induction range unit in the U.S. is a stand-alone portable single-burner hot plate, even though induction cooktops are energy efficient, safe, and perform better than their alternatives.

Technology Description

Induction refers to the fact that a current can be 'induced' by creating or manipulating a magnetic field. Induction heating takes advantage of this phenomenon, and uses a magnetic coil to induce a current in a piece of ferromagnetic cookware (i.e. cast iron, some alloys of stainless steel, etc.). The cookware discharges this energy as heat, which means that the piece of cookware itself is the heating element. This is necessarily more efficient than electric resistance heating, where a current is passed through a heating element, which then needs to transfer heat to a piece of cookware. The resistance heating element suffers losses to the ambient air around it during this process and therefore cannot transfer heat to the cookware at 100% efficiency. Induction cooking obviates these losses. One major barrier to market entry for induction ranges is that only magnetic cookware can be used, so there are many cases where people would have to replace their cookware when upgrading to induction. This can be quite costly, especially for some commercial operations or for home chefs with many specialized pieces.

For the residential market, two main classes of induction cooktops exist: stand-alone models, which include portable models as well as cooktops intended to be integrated into a counter space or a kitchen island, and induction ranges that integrate an induction cooktop with a convection oven. Most models sold in the U.S. are designed to operate at either 120 or 240/208 volts to be easily installed and retrofittable.

Commercial induction cooking appliances are available in the same configurations as residential equipment. Commercial induction woks are also available but will not be considered for the purposes of this project, as there are many additional operator barriers to this technology.

The main benefit to this technology is that it is more efficient than any other cooktops on the market. Based on the Food Service Technology Center (FSTC) testing, induction cooktops are between 10 and 20% more efficient than other electric models and can be up to 40% more efficient than gas models. In addition to energy savings, induction equipment offers performance advantages over standard electric cooking equipment. Preheat times are faster, and because the element does not heat up (only the cookware), the surface cools off more quickly.

Data Collection and Analysis

In this section we discuss the baseline definition, analysis approach, and market readiness of induction cooking equipment.

Baseline Definition

The baseline technology for residential induction cooking products is a standard (coil or smooth element) electric cooktop or range. The baseline technology for commercial induction cooking products is a standard electric cooktop or range.

Analysis Approach

We will consider two options for assessing energy savings for induction cooking equipment. IPVMP Option B (retrofit isolation with all parameter measurement) would offer the most rigorous approach for assessing energy savings. This is the approach proposed for the technology demonstration project. The demonstration will meter existing equipment for three months to establish baseline energy consumption, and will have additional months of metering of the new equipment after it is installed.

While pre- and post-metering will produce the most reliable savings estimates, we do not believe it is practicable in the technology deployment stage. First, the cost of conducting pre- and post-metering is high, considering the relative share of household energy that typically goes to cooking, Second, evaluations conducted in the deployment stage would face significant barriers in metering existing equipment. This includes the possibility that the new equipment may be replacing failing equipment, the new equipment may be part of a comprehensive kitchen remodel in which the pre- and post-periods may be separated by months of construction, and the possibility that the new equipment may differ in configuration or performance (e.g., more elements, different heat output per element, or induction may be replacing base gas cooking equipment).

Given the relatively low level of household energy use devoted to cooking (only part of which is cooktop cooking), and that we expect induction cooking equipment to make up only a small share of overall portfolio savings, we believe that a deemed saving approach is more appropriate approach in the deployment stage.

Energy Savings Analysis: Energy savings from residential induction cooking depends on the power reduction of the device and how often and how intensely (how many elements in use) the device is used. The latter factors depend on how frequently a household cooks meals at home, how often food is cooked on the cooktop versus the oven, and cooking duration. Usage may vary from day to day, week to week, and seasonally.

There are few sources for deemed savings for induction residential cooking equipment. Neither DEER nor the California public utilities' Savings Estimation Technical Reference Manual 2017 contain induction cooking equipment. A review of technical reference manuals (TRMs) from other regions similarly turned up nothing. The best source we found for savings was the

Department of Energy's technical support document from its standards rulemaking process.[3] The document provides results of engineering analysis of standards options including inductive heating elements. Other EPIC and utility Emerging Technology research can be reviewed in addition to other TRMs.

Commercial cooking equipment has fewer elements of uncertainty compared to residential. While there may be variation in usage between commercial kitchens, there is less day-to-day variation in usage.

While commercial induction cooking equipment is not included in DEER or the public utilities' TRM, it is included in Minnesota's TRM.[4] These algorithms can be combined with site-specific estimates of hours of use, and number and types of meals served to estimate savings

Market Readiness

Induction cooktops have been commercially available for both residential and commercial foodservice (CFS) applications for decades. Table 6 lists the technology recommendations and our initial assessment of their current market readiness and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 6. Market Readiness for Induction Cooling Technology

Technology	Market Readiness	Market Segments
Residential induction cooktop	Market-ready, used in practice	Residential owner-occupied
Residential induction range	Market-ready, used in practice	Residential owner-occupied
Commercial induction cooktop	Market-ready, used in practice	Commercial food service
Commercial induction range	Market-ready, used in practice	Commercial food service

While induction cooking equipment is widely available through appliance retailers, there are nonetheless significant barriers to adoption. The Technology Assessment Survey provides an opportunity to assess these barriers, as well an any non-energy impacts attributable to the technology. Barriers for this technology that could be addressed include:

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[3] U.S. Department of Energy (DOE). 2016. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Conventional Cooking Products. August. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0005-0052. See Table 5.3.4.

[4] Minnesota Department of Commerce Division of Energy Resources, 2016. State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs. Version 3 Final. January 10, 2019. http://mn.gov/commerce-stat/pdfs/mn-trm-v3.0.pdf

- Lack of awareness of the technology
- Lack of experience using the technology
- Uncertainty about product performance
- Concerns about learning to use the new technology
- Incompatibility with non-ferromagnetic cookware

Barriers specific to the commercial sector include:

- Altered cooking times and processes in a production setting
- Training staff on new equipment and processes
- Impacts on kitchen performance during learning phase

Non-energy benefits that could be addressed include:

- Speed
- Safety
- Ease of cleaning

Project Timeline

Table 7 shows high level project timelines for the induction cooking technology.

Table 7: Project EM&V Schedule for Induction Cooking Technology

Project Tasks	Completion Dates
EM&V Framework Development	May 2019
Demonstration project baseline measurements	May 2020
Demonstration project retrofit measurements	December 2020
Literature review to develop algorithms and assumptions for deemed savings calculations for deployment stage	February 2021
Draft Report Review	July 2021
Final Report Review	October 2021

CHAPTER 6:
Waste Heat Recovery for Commercial Dishwashers

Heat exchangers and condensers are relatively common in industrial, commercial and residential settings alike, so it is only natural that dishmachine manufacturers have designed both exhaust-side heat recovery (EHR) and drain water-side heat recovery (DWHR) dishmachines. EHR is slowly generating some market share in the commercial foodservice industry and has shown some promise in previous lab and field testing conducted by researchers at FSTC. One big advantage to EHR is that these machines can be operated without auxiliary ventilation because they do not produce any steam or products of combustion. EHR is more market-ready than DWHR, and there are more companies that make EHR dishmachines than DWHR options. Exhaust heat recovery is also a superior choice because, in addition to its water heating savings, it offers direct HVAC savings by lessening the total air flow rate load, and therefore fan speed and associated energy use on commercial buildings. Test

Technology Description

High temperature door-type dishmachines use hot water in two ways: they recirculate and top-off tank water at about 150˚F (although this number varies between manufacturers) to wash any stuck-on debris from dishes, and they rinse the dishes with 180˚F water to sanitize them. In general, dishmachines are fed with hot water from the building water heater. They make up the difference between the building water heater's outlet temperature and operating temperatures by use of a tank heater for the wash water and a booster heater for the rinse water.

Exhaust heat recovery works by capturing the energy that would otherwise be released from a dishmachine as steam after the final rinse. EHR units preheat the cold feed water with the steam energy via either a heat exchanger or condenser to roughly 120˚F and uses an appropriately sized booster heater to raise the water to its specified rinsing temperature. This preheated water then runs through the booster heater and becomes the sanitizing rinse water for the next rinse cycle. This allows many door-type dishmachines to be fed exclusively with cold water, which allows for dishmachines to be removed from the building's hot water system. This saves energy by lessening the load on the building's hot water system. A typical high-temperature door-type dishmachine will be the highest load on the building's hot water system, using up to 75% of the system's hot water. By using heat recovery to make up most of that load, sites can realize multiple benefits in addition to the substantial energy savings. Conventional high-temperature dishmachines require an inlet temperature of 140˚F, which means that the hot water system must supply this temperature even though most fixtures only require an inlet temperature of 125˚F. This also reduces scald risks for sites that only have one hot water loop. By taking the dishmachine off the hot water system, the water heater setpoint can be turned down, which can yield additional energy savings. In some cases, the hot water system itself can also be downsized, which can allow for substantial savings and performance benefits such as decreased wait times at hand sinks and higher delivery efficiency. The magnitude of these benefits is dependent on design constraints specific to each site.

EHR saves energy directly on water heating by capturing heat, so for buildings with electric water heaters, retrofits involving this technology get direct kWh savings. Additionally, most EHR dishmachines are more water efficient and operate at lower flow rates than conventional models, so additional electric savings are possible at the dishmachine's booster and tank heaters.

EHR saves energy indirectly in two important ways. First, it can reduce or eliminate the need for ventilation in the dishroom. The dishmachine is the largest contributor of heat and moisture gain to the space in commercial dishrooms, so by condensing the steam that would otherwise be vented to the space, it is possible to make dishrooms substantially more comfortable working environments without high-volume mechanical ventilation. There are also associated savings elsewhere on the HVAC system, such as at the make-up air unit. Second, dishmachines are generally the largest load on building water systems in commercial foodservice, and they're typically located far from the building water heater. It is possible to use EHR dishmachines to design substantially smaller and more efficient water heating systems.

One major uncertainty with EHR lies in its ability to reliably deliver cost savings to customers with gas water heaters. 85% of CFS customers in California use gas water heaters. In some applications, the customer may end up using substantially less energy for water heating overall, but more electricity at the booster heater. The ventilation and HVAC savings will be mostly electric energy. The decommissioning of a ventilation hood can save up to 15% of a large restaurant's total HVAC cost, and the payback periods of carrying out this kind of retro commissioning tend to be less than 6 years. Another uncertainty is related to the maintenance of these new dishmachines. Because they're relatively new and underrepresented in the current dishmachine market, it's difficult to reliably estimate the lifespan of these machines. In particular, there may be maintenance issues with the heat exchanger or condenser such as fouling and depending on how often this happens and whether it's covered by the machine's warranty, it may translate into extra maintenance costs.

Data Collection and Analysis

In this section, we describe the baseline definition, the deployment phase analysis approach, and market readiness for waste heat recovery in commercial dishmachines. A more rigorous and in-depth analysis approach, that includes water-side measurements, will be executed in the technology demonstration phase of this effort. The approach proposed for the demonstration phase, which is described in detail within the Technology Demonstration Program Implementation Plan, is not feasible at the scale of the deployment because of cost constraints associated with its complexity and therefore a different approach is applied in the deployment phase.

Baseline Definition

The baseline systems are existing high temperature door-type or hood-type dishmachines without exhaust or drain heat recovery capability. Furthermore, the water heating source should be via storage (tank) or instantaneous, i.e. tankless domestic hot water (DHW) equipment, and not via a heat exchanger connected to a larger centralized heating source (steam boiler, chiller heat recovery, etc.). The fuel source for the water heating in the pre-retrofit case can be either electricity or gas.

Analysis Approach

In this section, we outline the approach to calculate energy savings for installations of the Exhaust heat recovery dishmachine technology.

Energy Savings Analysis:

Electric Water Heating

For sites with electric water heating IPMVP Option A Retrofit Isolation, Key Parameter Measurement will be used to determine energy savings of equipment. Pursuing an Option A methodology will provide an acceptably accurate estimate of savings without an extensively complex metering suite and analysis data set that Option B, retrofit isolation approach would require.

This scenario calls for pre- and post-retrofit electrical sub metering of the DHW, the dishwasher itself, and the affected HVAC (e.g. exhaust and makeup air unit) equipment. Monitoring pre- and post-retrofit should occur for at least 6 months as the energy use of the systems are weather-dependent, so winter days (characterized by low outside ambient air and cold inlet water temperatures) and summer days can both be represented in the final data set. The pre- and post-retrofit monitoring periods should include relatively equivalent periods of cooler and warmer conditions to reduce potential bias and errors into the calculation of savings. Likewise, similar productivity or activity levels should be present in the pre- and post-retrofit periods. If dissimilar ambient conditions or activity levels are not avoidable, then the measurements should be normalized to the conditions (e.g. CDD/HDD or operating hours) and the baseline energy use should be scaled to mimic the conditions observed during the post-retrofit measurement period or both scaled to represent expected conditions. Measurements should be extrapolated from the observation period length to represent an annualized estimate of energy consumption. Savings should be calculated as the difference in normalized, annualized energy consumption (Δ kWh) for each of the system components as represented in the equation below.

$$kWh\ Savings = \Delta\ \mathrm{kWh}_{DHW} + \Delta\ \mathrm{kWh}_{dishmachine} + \Delta\ \mathrm{kWh}_{HVAC}$$

Gas Water Heating

For smaller sites with localized gas water heating IPMVP Option C Whole Facility, will be employed to determine the gas savings impacts from this measure, while the electric savings from the dishmachine and HVAC will remain unchanged from the electric water heating analysis description above. In this scenario, instead of determining the DHW component of savings by measuring the electricity consumption of the water heater, gas consumption is measured at the utility gas meter and savings calculated from a normalized, annualized delta between the pre- and post-retrofit gas fuel consumption.

For larger sites where the gas meter also serves considerable other gas fueled equipment, Option C is not a viable means for observing the gas savings from this measure. In place of this approach, an Option A approach where an operating parameter is metered as an indicator of operating hours will be substituted in lieu of electrical sub-metering or whole facility measurements. The measurement parameter could be an on/off logger on the gas solenoid or on the servo/motor for a flue damper. A third option is to measure the flue gas temperature. Operating hours can be approximated from flue gas temperature measurements by assuming the equipment is firing when the measured flue gas temperature is above a reasonable ambient threshold, such as 130 ˚F. Gas energy consumption, in therms, can then be determined by multiplying the measured operating hours with the rated input of the equipment and the conversion factor from kBtu to therms as shown in the equation below.

$$Therms = operating\ hrs \cdot \frac{rated\ input\ (kBtuh)}{100\ \frac{kBtu}{therm}}$$

Gas savings from the DHW equipment is then calculated as the difference in normalized, annualized energy consumption pre- and pos-retrofit (see equation below) as was performed for the electrically fueled DHW equipment scenario.

$$Therms\ savings = \Delta\ \text{Therms}_{DHW}$$

Market Readiness

EHR dishmachines are available in the market, but high upfront equipment and installation costs likely dampen market adoption and market penetration. Table 8 lists the technology recommendations and our initial assessment of their current market readiness and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 8. Market Readiness for Waste Heat Recovery for Commercial Dishwashers

Technology	Market Readiness	Market Segments
Exhaust-side heat recovery (EHR) dishmachines	Market ready, used in limited practice	Commercial kitchens

Another important element of the Technology Assessment survey is to characterize the participant end-user’s response to the technology. Questions specific to this technology will assess barriers, such as high up-front cost for early equipment replacement or the limited time opportunities these businesses have to accommodate downtime for the retrofit, and non-energy impacts, such as improved thermal comfort or reduced dishmachine maintenance.

Project Timeline

Table 9 shows high level project timelines for the waste heat recovery for water heating and ventilation technology.

Table 9: Project EM&V Schedule for Waste Heat Recovery for Commercial Dishwashers

Project Tasks	Completion Dates
EM&V Framework Development	May 2019
Baseline measurements	February 2020
Post retrofit Measurements	December 2020
Draft Report Review	April 2021
Final Report Review	October 2021

CHAPTER 7: Aerosol Duct and Envelope Sealing

For many years energy efficiency technicians have been using manual techniques to seal ductwork and building envelopes to reduce the heating and cooling energy lost through holes in the duct or building envelope. Although not always addressed as such, duct sealing is, in fact, a subset of envelope sealing since conditioned house air will escape through holes in the ducts (when the HVAC system is off) in the same way that it escapes through holes in the building shell. Duct leakage is often targeted before envelope sealing since it frequently has a higher energy impact. This chapter will address an aerosol sealing technique developed in the mid-1990's known as Aeroseal when used on ducts and Aerobarrier (developed later) when used on the building envelope.

Technology Description

The aerosol duct and envelope sealing process uses a vinyl glue compound suspended in a water solution, which is atomized, driven by airflow and deposited at leakage points where turbulence causes the suspended particles to deposit. For the duct sealing process, a fog of particles is pumped into the system with air from a duct blaster which pressurizes a duct system. The intentional openings (registers) are sealed before the process begins, leaving the unintentional system leaks to be sealed by deposition of sticky particles as the air escapes the pressurized duct system. For envelope sealing the process is similar, pressurizing the building using a blower door, while injecting the aerosol "fog". As the air escapes through leaks in the exterior shell of the building, the aerosolized sealant deposits and seals the leaks as the pressurized air leaves the building. Both of these processes save HVAC energy: duct sealing saves it because more of the conditioned air is delivered to the conditioned building space and envelope sealing because a tighter envelope means less conditioned air leaks to outside, driven by wind or temperature induced pressure differences between inside and outside.

Data Collection and Analysis

In this section we will describe the baseline definition, analysis approach, and market readiness for aerosol sealing technology.

Baseline Definition

The sealing technology can be used in either new construction or in a retrofit situation. In new construction the baseline is the required minimum duct leakage (5% of fan flow) and the CA Title-24 reference house envelope leakage, 5 air changes per hour at 50 Pa pressure. The baseline for each of these technologies in a retrofit situation is the pre-existing measured leakage condition of the envelope and duct system.

Analysis Approach

Since both duct sealing and envelope sealing save HVAC energy, the highest rigor approach would be an IPMVP option B retrofit isolation approach where we monitor the gas and power input to the HVAC system starting one year pre-retrofit continuing to one year post retrofit, assuming the ducted system is used for both heating and cooling. Then we would weather normalize the consumption both pre- and post-retrofit before taking the annual energy difference to calculate the annual energy savings. This method characterizes the savings for the actual operating conditions pre- and post-retrofit.

Lacking time or budget to do the highest rigor approach, the next best M&V approach would be to measure the duct or envelope leakage pre- and post-retrofit and calculate the savings based on engineering formulas, described below.

Measuring duct leakage

Duct leakage is generally measured using a duct blaster to do a pressurization test to obtain total duct leakage or duct leakage to outside at 25 Pascals (Pa) of pressure in the duct system. There is another test called DeltaQ that measures the duct leakage at HVAC system operating pressures using a blower door. This test more accurately characterizes duct leakage during normal HVAC operation (since the other tests measure all leaks at 25 Pa), but it is more affected by outdoor wind gusts, therefore not as repeatable as the duct blaster test methods. We recommend using the DeltaQ test if wind conditions allow, substituting the pressurization leakage to outside test if necessary.

Measuring envelope leakage

Envelope leakage is measured using a blower door set up in an exterior door of the home, pressurizing the home to 50 Pa, and measuring the flow (in CFM) required to maintain the 50 Pa pressure difference. The testing procedure is more accurate if a five-point test is used where the flow through the envelope is measured at five different pressures below 50 Pa, and a regression used to determine the leakage coefficients, C and n shown in the equation:

$$Leakage\ Flow\ (Q) = C * \Delta P^n$$

A single point test can only determine that value of one unknown, using that method we determine a value for C assuming a value for n, often 0.5. The value of n is related to the physical shape of the leaks in the envelope. If they are round, the value of n will be 0.5 and if they are linear slot shaped, the value of n will be 1.0. Since the type of leaks vary from house to house, we recommend using the five-point envelope leakage test.

Energy Savings Analysis: IPMVP Option A: Retrofit isolation, key parameter measurement

Duct savings

Since duct sealing improves the HVAC delivery efficiency, the savings can be calculated by applying the change in delivery effectiveness (defined by ASHRAE Standard 152) directly to the total heating/cooling load of the house. A delivery effectiveness calculator can be downloaded from the Office of Energy Efficiency and Renewable Energy website.[5] Required inputs to the calculator include house location, floor area, volume, number of stories, number of registers, supply and return duct surface area, supply and return duct leakage, duct location, duct insulation, duct material, HVAC type, HVAC fan flow, HVAC capacity,

DNV GL will calculate the normalized heating and cooling energy using a PRISM-type analysis on billing data where the weather dependent energy consumption is disaggregated from the baseload using utility billing data regression analysis. The process will be performed twice—once for heating using either electric or gas consumption data (in the case of a heat pump or gas furnace) and once for cooling on the electric data if the home has cooling. Once determined, we apply the heating-only or cooling-only regression coefficients to normalized weather data (TMY) to obtain the normalized annual heating and/or cooling load of the home.

To calculate energy savings for aerosol duct sealing we multiply the change in delivery effectiveness by the pre-retrofit HVAC heating and cooling load as shown in the equation below.

$$\text{Energy Savings [kWh]} = \Delta\text{DE}_{cooling,seasonal} * \text{ Normalized annual cooling load [kWh]}$$

$$\text{Energy Savings [therm or kWh]} = \Delta\text{DE}_{heating,seasonal} * \text{ Normalized annual heating load [therm or kWh]}$$

Envelope savings

Envelope leakage has a more complicated relationship to the building HVAC load than duct leakage since it only makes up a portion of the building HVAC losses. There are two ways to calculate savings from envelope leakage measurements: modeling or engineering equations. In this case we recommend engineering equations, given the time required to perform site-specific modeling and the uncertainty associated with such models.

The envelope leakage is measured pre- and post-retrofit. The leakage measurements are used in the following equations to calculate the reduced energy load on the house, and from there reduced HVAC energy is calculated.[6] The Equivalent Leakage Area (ELA) is calculated using the following equation.

$$ELA = CP_r^{n-0.5}\sqrt{\frac{\rho}{2}}$$

Where the reference pressure (P_r) is 4 Pa and ρ is the density of air at the testing conditions. Calculate the ELA_{pre} and ELA_{post} and subtract the two to get ΔELA. The ΔELA can be substituted in the following equation to determine the change in normalized leakage (ΔNL.)

$$NL = 1000\frac{ELA}{Af}\left(\frac{H}{2.5m}\right)^{0.3}$$

[5] https://www.energy.gov/eere/buildings/downloads/ashrae-standard-152-spreadsheet

[6] These equations were developed by Max Sherman at LBNL and can be found in Sherman, M.L. "The Use of Blower Door Data" LBNL Publication #35173. Lawrence Berkeley National Laboratory. 1998. http://www.inive.org/members_area/medias/pdf/Inive/LBL/LBL-35173.pdf

Where H is the height of the building (in meters) and A_f is the floor area (in the same units as ELA). The change in Envelope Leakage Energy Load (ELEL) due to envelope sealing can then be determined using the equation

$$\Delta ELEL = 75 * IDD * \Delta NL$$

Where IDD is Infiltration Degree Days for the location of the home, defined for each the heating and cooling season in ASHRAE Standard 119.

$$kWh\ saved = \frac{\Delta ELEL_{cool}}{Cooling\ Equipment\ SEER}$$

$$therm\ saved = \frac{\Delta ELEL_{heat}}{Heating\ Equipment\ AFUE}$$

Market Readiness

Aerosol duct sealing technology has been in the market since the early 2000's, though is not commonly used due to the higher cost compared to manual sealing. Table 10 lists the technology recommendations, our initial assessment of their current market readiness and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 10. Market Readiness for Aerosol Duct and Envelope Sealing Technology

Technology	Market Readiness	Market Segments
Aerosol duct sealing	Market ready, used in practice	Residential owner-occupied with ducted HVAC distribution system
Aerosol envelope sealing	Less common, but market-ready for new homes, used in practice.	Residential tenant occupied

Another important element of the Technology Assessment survey is to characterize the participant homeowner's response to the technology. Questions specific to this technology will assess barriers, such as contractor and homeowner resistance to using aerosol for envelope sealing in a furnished home and non-energy impacts, such as improved thermal comfort.

Project Timeline

Table 11 shows high level project timelines for the aerosol duct and envelope sealing technology.

Table 11: Project EM&V Schedule for Aerosol Duct and Envelope Sealing Technology

Project Tasks	Completion Dates
EM&V Framework Development	May 2019
Baseline measurements	January 2020
Measure	February 2020
Draft Report Review	July 2021
Final Report Review	October 2021

CHAPTER 8: Residential Nighttime Ventilation

Nighttime ventilation can help to offset mechanical cooling in climates where night time temperatures drop to comfortable levels. Flushing the house with cooler air during the night reduces the temperature of the thermal mass of the building, potentially reducing the need for mechanical cooling during the hot part of the day. A whole house fan is traditionally used for nighttime ventilation; however, it requires that the occupants manually open their windows in the evening. The system investigated here differs from a whole house fan because it does not require opening windows and all the outside ventilation air passes through a filter before being delivered to the living space.

Technology Description

The nighttime ventilation technology investigated in this study consists of a damper assembly and control system retrofitted to bring outside air into the return plenum of a pre-existing ducted HVAC system. Nighttime ventilation saves energy by preventing the installation of mechanical cooling. The components of the system are the same as a traditional economizer with an inlet damper and relief damper that open in tandem, so the building pressure remains neutral when the ventilation system is activated (i.e., dampers opened). The nighttime ventilation system controls will be designed to optimize thermal comfort.

Data Collection and Analysis

In this section, we describe the baseline definition, analysis approach, and market readiness for nighttime ventilation.

Baseline Definition

The baseline for nighttime ventilation is a home with a mechanical cooling system since the system saves energy by offsetting mechanical cooling either by supplementing an existing system or by preventing the installation of a new system in an existing home. A typical energy savings calculation would use consistent thermostat settings in the baseline and post-retrofit conditions. This study will investigate occupant acceptance of higher thermostat setpoints with a nighttime cooling ventilation strategy.

Analysis Approach

There are multiple savings methodology approaches that can be used for this technology and the most appropriate method will be chosen based on the number of participants, the desired rigor level, and the available budget. For the technology deployment phase, IPMVP Option D makes sense to explore multiple baseline or control strategy scenarios. IPMVP Option C makes sense when there are a large number of participants or when energy savings are greater than 10% of the overall building consumption. IPMVP Option B can be used as a stand-alone evaluation methodology when the sample is large enough to account for the variability in the population, or the data collected can supplement Option D. All methods are described below. .

Energy Savings Analysis: IPMVP Option B, Retrofit isolation: all parameter measurement; IPMVP Option C, Whole facility; IPMVP Option D, Calibrated simulation

The first method is direct monitoring of HVAC and ventilation system energy before and after the retrofit corresponding to IPMVP Option B. Ideally, the pre/post measurements would include a full year to span the full range of weather conditions experienced by the system. If one year is not feasible, a partial year can be used if it spans the expected summer weather conditions, since the measure is expected to have a higher impact on summer cooling energy than on winter heating energy. (Heating energy is only affected if the inlet air damper does not seal tightly.) After end-use data collection, the data analysis will include regressing energy use with local weather for the pre- and post-retrofit data sets. The regression results would be applied to normalized (TMY) data to determine the energy savings of the retrofit. If end-use monitoring is out of scope, and if the dataset is large, or if the savings are greater than 10% of the total consumption, billing data can be used with a similar analysis methodology, requiring the extra step of adjusting for the non-weather dependent baseload. If billing data is used, the IPMVP Option is C, whole building.

The final applicable methodology is IPMVP Option D: calibrated simulation where a building simulation model is created to represent the home in its pre-retrofit in-situ baseline condition including actual mechanical equipment operation and setpoints. The model is calibrated using pre-retrofit billing data. This is an important step since uncalibrated building models may not accurately represent the energy consumption of the building. Since ventilation cooling does not save energy compared to a building with no cooling, the energy savings baseline will be a home with mechanical cooling even if the in-situ baseline home does not have a mechanical cooling system. Part of the objective of this technology demonstration is to see if occupants will accept higher cooling setpoints than those used in the average California home with mechanical cooling so the thermostat setpoints will be parametrically varied to put bounds on the potential energy savings. The baseline setpoint will be based on those in the DEER prototypes used to evaluate other energy efficiency measures in the state, and the post retrofit setpoints will range from those same setpoints to those found acceptable by the occupants of the technology demonstration homes. The modeling software must be able to model the specific energy efficiency measure, i.e. the ventilation control algorithm that is being tested. For instance, eQuest or EnergyPlus are flexible enough to model an economizer control algorithm based on a timed schedule or based on outdoor temperature or enthalpy conditions, but BeOpt is not. The energy consumption of the post-retrofit nighttime ventilation model is compared to the baseline model energy consumption to determine energy savings.

Market Readiness

The equipment used for this technology deployment consists of two components: the damper assembly and the control system. Damper assemblies for residential systems have been in use for many years in zoned duct systems, but the quality of the dampers varies. Some do not seal tightly, and some are prone to failure. The control system for this technology is provided by the manufacturer of the damper assembly. Table 12 lists the technology recommendations, our initial assessment of their current market readiness and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 12. Market Readiness for Residential Nighttime Ventilation Technology

Technology	Market Readiness	Market Sectors
Damper assembly	Market ready, used in practice	Residential single family with ducted HVAC distribution.
Controls equipment	Market ready, used in practice	Residential single family with ducted HVAC distribution.

Another important element of the Technology Assessment survey is to characterize the participant homeowner's response to the technology. Questions specific to this technology will assess potential barriers, such as homeowner thermal comfort and acceptance of nighttime cooling in lieu of mechanical cooling. Non-energy impacts will also be investigated, such as improved indoor air quality since the outdoor air will be filtered before entering the building.

Project Timeline

Table 13 shows high level project timelines for the residential nighttime ventilation technology.

Table 13: Project EM&V Schedule for Residential Nighttime Ventilation

Project Tasks	Completion Dates
EM&V Framework Development	May 2019
Baseline measurements	November 2019
Post retrofit monitoring	October 2020
Draft Report Review	July 2021
Final Report Review	October 2021

CHAPTER 9: Heat Pump Water Heaters

With almost triple the efficiency, heat pump water heaters are becoming a popular alternative to electric storage tank water heaters.

Technology Description

Heat pump water heaters (HPWHs) are storage tank style water heaters where the heat is provided by a compressor-powered direct expansion heat pump with electric resistance backup heat. The energy input to these water heaters is electricity, but in contrast to a conventional electric water heater with an energy factor (EF) of 0.95, the heat pump water heater has an EF of 2.5 to 3.5 due to the efficiency of the heat pump system. These water heaters tend to have a longer recovery time than the standard electric or gas storage water heaters. Detailed descriptions of the technology and possible control strategies are provided in the *Phase 2 Research, Instrumentation, and Monitoring Plan*.

Data Collection and Analysis

In this section, we describe the baseline definition, analysis approach, and market readiness for heat pump water heater systems.

Baseline Definition

The baseline system is a standard electric resistance or gas storage/tankless water heater connected to a standard household water distribution system, situated in a space with temperatures between typical indoor and outdoor temperatures.

Analysis Approach

In this section, we outline the approach to calculate energy savings for installations HPWH technology. Although a billing analysis approach would be possible, the relatively small change in overall building energy consumption due to a water heater changeout would require a relatively large sample of homes to produce a statically significant result.

Energy Savings Analysis: IPMVP Option A, Retrofit Isolation, Key Parameter Measurement, will be used to determine energy savings of equipment installed in Sonoma and Mendocino County homes. The savings are determined using the following equation:

$$Energy\ saved\ [kBtu] = \left(\frac{1}{UEF_{base}} - \frac{1}{UEF_{eff}}\right)\left(GPD * 365.25 * Cp * \gamma Water(T_{out} - T_{in})\right)/1000$$

Where

UEF_{base} = the baseline water heater uniform energy factor

UEF_{eff} = the HPWH uniform energy factor

GPD = gallons per day

C_p = the heat capacity of water = 1.0 Btu/lb °F

γWater = the specific weight of water = 8.33 pounds per gallon

T_{out} = tank temperature [°F]

T_{in} = incoming water temperature [°F]

The rated water heater Uniform Energy Factor (UEF) for the baseline and installed water heaters are important inputs to the equation and can be obtained from the AHRI directory.[7] The measured parameters are:

- T_{in}, the incoming cold water temperature, measured when water is flowing through the pipe and as far from the hot water tank as possible,
- T_{out}, the hot water temperature, measured when temperature has reached steady state at the closest tap to the water heater.
- N, the number of people in the household will be measured using a survey and used to determine GPD from the following table based on the work of Kruis et al.[8]

N	GPD
1	18.2
2	28.2
3	34.6
4	41.9
5	50.8
6+	N * 10.2

Market Readiness

Heat pump water heaters have been on the market since the early 2000's, but they are only recently beginning to gain traction. Their slightly larger size has been a barrier in the retrofit market. Table 14 lists the technology recommendations, our initial assessment of their current market readiness, and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

[7] https://www.ahridirectory.org/NewSearch?programId=24&searchTypeId=3

[8] Kruis, Neal, Bruce Wilcox, Jim Lutz, Chip Barnaby, "Development of Realistic Water Draw Profiles for California Residential Water Heating Energy Estimation." Building Simulation 2017 Proceedings, International Building Performance Simulation Association.

Table 14. Market Readiness for Heat Pump Water Heaters

Technology	Market Readiness	Market Sectors
Heat pump water heater	Market-ready, used in practice	Residential single family and small commercial
Add-on heat pump for domestic hot water storage tank	Less common, but market-ready, used in practice.	Residential single family and small commercial with existing electric hot water heaters

Another important element of the Technology Assessment survey is to characterize the participant homeowner's response to the technology. Questions specific to this technology will assess potential barriers, such as actual and perceived upfront and operating costs of heat pump water heaters compared to natural gas storage water heaters. Non-energy impacts will also be investigated, such as the heat pump exhaust flow that can provide free cooling in some installations.

CHAPTER 10:
ENERGY STAR® Products

ENERGY STAR® Products cover a range of commercial and residential technologies.[9] These products have been certified to meet or exceed the energy efficiency requirements set by ENERGY STAR product specifications.[10] The U.S. Environmental Protection Agency (EPA) establishes these specifications with a goal of reducing energy use while achieving performance expectation. In general, specifications are revised when 50% of the market share is ENERGY STAR® certified products. Additional consideration is given to changes in federal efficiency standards or technology changes. Products displaying the ENERGY STAR® name help inform consumer purchase decisions. ENERGY STAR® maintains a list of qualifying equipment on their website.

Technology Description

There are 58 products that fall into eight categories. The products and categories are as follows:

- **Appliances:** Clothes Dryers, Clothes Washers, Commercial Clothes Washers, Dishwashers, Refrigerators & Freezers
- **Building Products:** Residential Storm Windows, Residential Windows, Doors, and Skylights, Roof Products
- **Commercial Food Service Equipment**: Commercial Coffee Brewers, Commercial Dishwashers, Commercial Fryers, Commercial Griddles, Commercial Hot Food Holding Cabinets, Commercial Ice Makers, Commercial Ovens, Commercial Refrigerators & Freezers, Commercial Steam Cookers
- **Data Center Equipment:** Data Center Storage, Uninterruptible Power Supplies
- **Electronics and Office Equipment:** Audio/Video, Computers, Displays, Enterprise Servers, Game Consoles, Imaging Equipment, Large Network Equipment, Data Center Storage, Set-top Boxes & Cable Boxes, Small Network Equipment, Telephony, Televisions
- **Heating & Cooling:** Air Conditioner, Central, Air Conditioner, Room, Boilers, Commercial Boilers, Commercial Water Heaters, Connected Thermostats, Dehumidifiers, Furnaces, Heat Pumps, Air Source, Heat Pumps, Geothermal, Light Commercial Heating & Cooling, Room Air Cleaners & Purifiers, Water Heater, Gas Condensing, Water Heater, Heat Pump, Water Heater, High Efficiency Gas Storage, Water Heater, Solar, Water Heater, Whole Home Gas Tankless
- **Lighting & Fans:** Decorative Light Strings, Fans Ceiling, Fans Ventilating, Lamps, Light Fixtures (Luminaires)

[9] ENERGY STAR® Products website: https://www.energystar.gov/products/energy-star-most-efficient

[10] ENERGY STAR® Product specifications can be found here: https://www.energystar.gov/products/spec

- **Other:** Electric Vehicle Supply Equipment, Laboratory Grade Refrigerators and Freezers, Pool Pumps, Vending Machines, Water Coolers

Data Collection and Analysis

In this section we discuss the baseline definition, analysis approach, and market readiness of ENERGY STAR® products.

Baseline Definition

These measures should assume a replace-on-burnout baseline condition. Therefore, new standard performance equipment is the baseline. Consumer product standards are set by the Federal Office of Energy Efficiency & Renewable Energy.[11] An exception to this is the lighting standards, which are set by the Energy Independence and Security Act (EISA) passed by Congress. Most of the equipment types in ENERGY STAR® products will have a minimum energy performance defined by the respective federal standards. The baseline energy performance standards use metrics specific to each technology.

Analysis Approach

ENERGY STAR® products should use a deemed savings approach. Deemed savings are predetermined savings estimates that can be based on metering studies, building simulations, expert assumptions and engineering algorithms. Deemed savings are appropriate for residential HVAC, appliances, and lighting where savings estimates have been well documented and considered to be reasonably accurate. Typically, a number of factors are applied including: equipment capacity, efficiency, and operating hours. The primary advantage of using a deemed approach is that it is cost-effective and leverages existing research.

This approach has a varying degree of accuracy at the project-level, but greatly improved accuracy across a program portfolio. This is largely due to the variability in operating parameters and behavioral factors. For example, the number of residents in a home will have a significant impact on hot water use. Similarly, space conditioning temperature setpoints or using temperature setbacks during unoccupied periods have a significant impact on HVAC equipment energy use.

There are a number of sources for deemed savings estimates. We suggest the following sources:

- **CA IOU Workpapers[12]:** Significant effort has gone into developing workpapers. California has a review process that reduces uncertainties in savings estimates. Some measures rely on the Database for Energy Efficiency Resources (DEER),[13] which is a well-developed resource for estimating energy savings. Weather-sensitive measures will be applicable as utilities have savings estimates for California climate zones.

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[11] Federal standards can be found here: https://www.energy.gov/eere/buildings/standards-and-test-procedures

[12] Workpapers can be found at: http://deeresources.net/workpapers

[13] DEER website: http://www.deeresources.com/index.php/homepage

- **Technical Reference Manuals (TRM)s:** These documents may be specific to utility, state, or regional jurisdictions. TRMs document energy savings estimates, algorithms, and parameter references. The algorithms are widely accepted, and their assumptions are transparent. TRMs may have varying degree of dependency on site-specific or equipment specific parameters. The Lawrence Berkeley National Lab (LBNL) published a TRM guide document that highlights some of the key TRMs throughout the country.[14]
- **Savings Calculators:** Savings calculators are built-out tools to calculate site-specific savings. ENERGY STAR® has developed calculators for a number of measures, including commercial kitchen food service, appliances, and consumer electronics.[15] The methods behind these calculators may compare to TRM algorithms; however, they rely on site specific inputs—for example, pounds of food fried and operating hours for a commercial kitchen. The Regional Technical Forums (RTF) have developed some savings estimates relying on calculators and applying deemed inputs.[16] They have developed those inputs through engineering assumptions, industry expert perspective, and industry studies.

We recommend relying on California workpapers for measures that are available. For other measures, savings calculators with research-based deemed inputs should be used, similar to the RTF savings for commercial cooking measures. If these approaches are not available for a given measure, TRM savings estimates should be applied.

Deemed savings can be modified using site-specific inputs that are based on application data and equipment specifications. When assessing the extent of tailoring deemed savings to an individual project, several factors should be considered:

- **The level of research and rigor in existing deemed estimates.** California IOU workpapers, in general have had significant scrutiny. These estimates are reasonable and reliable. However, some TRMs simply cite assumptions made by other TRMs or use dated sources. In these cases, additional data collection and modifications to deemed savings should be considered.
- **The percentage of portfolio savings or measure quantity.** If only a few projects are completed, more uncertainty can be afforded. However, high frequency of installation or a higher percentage of portfolio savings should receive more attention.
- **The ease of collecting and modifying inputs.** Some deemed savings estimates can be modified with site-specific inputs with minimal effort. In these cases, site-specific parameters can replace default assumptions from TRMs. A good example of this, is the operating hours of a restaurant or installed equipment performance metrics.

Market Readiness

ENERGY STAR® Products have existed since 1992. The availability and recognizability of ENERGY STAR® Products have contributed to their success. As the market becomes saturated

[14] The guide can be downloaded here: https://emp.lbl.gov/publications/technical-reference-manuals-trms

[15] ENERGY STAR® tools can be downloaded here: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products

[16] RTF Website: https://rtf.nwcouncil.org/

with a product, specifications are revised to encourage improvements in equipment performance. Additionally, The Consortium for Energy Efficiency (CEE) assigns CEE Tiers to differentiate between performance levels. Many utility programs use these tiers to set requirements and incentive levels. ENERGY STAR® Products inherently are market ready as the specification are designed to be achievable by manufactures.

CHAPTER 11: U.S. Environmental Protection Agency Water Sense® Products

WaterSense is a U.S. Environmental Protection Agency (EPA) labeling program for water-conserving fixtures and devices. The labeling program currently covers showerheads, bathroom faucets, residential and commercial toilets, and urinals. Additional labels are proposed for cation exchange water softeners, soil moisture-based control technologies for irrigation, bath and shower diverters, and pool covers.

Water-saving faucets and showerheads save energy by reducing hot water use. Additional energy savings for these and other water-conserving devices come from the impacts on water supply and wastewater infrastructure. Water/wastewater systems can represent 30-40% of a municipality's energy consumption due to pumping and other processes.[17] Assessing water system savings is beyond the scope of this study, so we will limit our evaluation to only the water-heating impacts of applicable products.

Sonoma Clean Power currently offers low-flow showerheads and faucet aerators through its DIY [do-it-yourself] Home Energy Toolkits.

Technology Description

Faucet aerators are accessories that screw into faucets to restrict the flow of water, saving both water and energy. Installation is a simple do-it-yourself project. WaterSense aerators reduce the flow of water to no more than 1.5 gallons per minute (gpm), but California efficiency standards require that aerators meet a flow of 1.2 gpm, the same as the standard for faucets.

WaterSense low-flow showerheads have a flow rate of no more than 2 gpm. Note that this is higher than California's minimum efficiency standard for showerheads, which was reduced to 1.8 gpm in 2018. From 2016-2018, the California standard was equal to 2 gpm, the same as the WaterSense level. Due to the standards, replacing a relatively new showerhead (manufacture date of mid-2016 or later) with a WaterSense showerhead will not save water or energy. Replacing an older showerhead meeting only the federal minimum efficiency standard of 2.5 gpm with any new showerhead complying with Title 20 will save 0.7 gpm, or 28% percent of water use from showers.

[17] Copeland, Claudia, and Nicole Carter, 2017. Energy-Water Nexus: The Water Sector's Energy Use. Congressional Research Service, January 24, 2017, https://fas.org/sgp/crs/misc/R43200.pdf.

Data Collection and Analysis

In this section we discuss the baseline definition, analysis approach, and market readiness of WaterSense products.

Baseline Definition

Because of California's Title 20 minimum efficiency standards, low-flow showerheads and faucet aerators are only appropriate as retrofits of equipment manufactured prior to September 1, 2015 for faucets and July 1, 2016 for showerheads. All faucets and showerheads allowed to be sold in California after those dates already meet the WaterSense flow requirements. Prior to those dates, products had to meet federal minimum efficiency standards of 2.5 gpm for showerheads and 2.2 gpm for lavatory faucets, enacted in 1994. Table 14 summarizes the standards landscape for applicable WaterSense products. WaterSense products offer no additional savings over new equipment sold in California.

Because of the stringency of the California standards, WaterSense products are appropriate only as a retrofit measure for older (pre-2016) equipment. Savings should be based on the existing showerhead or faucet (plus existing aerator, if applicable). Table 15 provides a summary of different flow rates standards.

Table 15: Summary of WaterSense flow rates and applicable federal and California standards

	Federal minimum efficiency (gpm)	California minimum efficiency (gpm)	WaterSense requirement (gpm)*
Showerheads	2.5	1.8**	2
Residential lavatory faucets	2.2	1.2	1.5
Faucet aerators			1.5
Public lavatory faucets	2.2	0.5	1.2

*These values represent the requirements of the national WaterSense program. WaterSense products sold in California must meet the California standard.

**The California standard for showerheads was 2 gpm from January 2016 through June 2018, before stepping down to the current level.

Analysis Approach

Energy Savings Analysis: Energy savings from water-saving devices depends on the reduction in hot water use, the efficiency of the water heater in the home, the distance of fixtures from the water heater, the presence of pipe insulation, input water temperatures, and the water heater thermostat set point. Due to this complexity, and the do-it-yourself nature of the products, we believe that a deemed savings approach is the most appropriate way to evaluate savings from WaterSense products. Deemed savings are predetermined savings estimates that can be based on metering studies, building simulations, and engineering algorithms. Deemed savings are appropriate when savings estimates have been well documented and represent a reasonable average savings across the various factors impacting energy use. The deemed approach is cost-effective, particularly given the complexity of measuring water flows and assessing the impacts on water heating energy use.

Due to the factors affecting savings, a deemed savings approach may not offer accuracy at the project level, but across a program portfolio has high accuracy. This is largely due to the numerous factors that can impact savings.

DEER is a ready source for deemed savings estimates for showerheads and faucet aerators. The savings values in DEER are drawn from IOU workpapers.

A more complex approach would verify pre-existing conditions, including an estimate of the vintage of the original equipment (and therefore what standard was applicable at purchase) and characteristics of the home's water heater. These data would inform engineering calculations to estimate energy savings.

Market Readiness

The WaterSense label identifies products on the market that meet the program's efficiency requirements. EPA's website provides a search that identifies thousands of qualifying products.[18] Table 16 lists the technology recommendations and our initial assessment of their current market readiness and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 16. Market Readiness for EPA Water Sense Products

Technology	Market Readiness	Market Segments
Showerhead < 2 gpm	Market-ready, used in practice	All residential segments
Bathroom faucet < 1.5 gpm	Market-ready, used in practice	All residential segments
Faucet aerator < 1.5 gpm	Market-ready, used in practice	All residential segments

The Technology Assessment Survey will also serve to characterize the participant homeowner's response to the technology. Questions specific to water conservation measures will assess barriers such as lack of awareness of the products, concerns about adequate water flow and pressure, and a lack of understanding of installation process for DIY measures.

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[18] For the EPA search tool, please see: https://www.epa.gov/watersense/product-search

CHAPTER 12: Electric Vehicles

Unlike other distributed energy resources, Electric vehicles (EVs) increase grid electricity consumption. However, they are considered clean technology because they have the potential to reduce overall emissions. For SCP, since the default service CleanStart contains 87% carbon-free power grid energy, vehicles powered by grid electricity is cleaner than vehicles burning fossil fuel. Moreover, if the EVs charge only during hours when renewable energy is curtailed or when the grid electricity is the cleanest, it adds additional carbon savings to the service territory. SCP offers 2 electrical vehicle programs: Drive EV and the GridSavvy Community. Drive EV offers discounts on the purchase of new or used electric vehicles. GridSavvy offers free electric vehicle charging stations and a $5/month bill credit for EV customers that connect their charging station to a demand response (DR) platform to respond to remote signals from SCP.

Technology Description

Plugged-in EV has been available to consumers for decades, but only recently has it been considered as a grid resource. Unlike traditional behind-the-meter resources, EV does not generate energy but consumes energy; however, managed charging could yield grid benefits. When there is excess energy on the grid, especially when renewable energy is curtailed, EVs can charge up their battery to consume the excess clean energy. When there is high energy demand on the grid, especially when dirtier and less efficient peaker plants need to operate, EVs can delay their charging to a time with less demand. By shifting energy consumption from a utility's peak period to a non-peak period, the program could reduce carbon emissions, reduce generation capacity needs, and delay infrastructure upgrades.

SCP's GridSavvy can remotely control consumption by controlling a customer's EV charging station. Based on open market prices, GridSavvy sends a signal over the internet to a controller that ramps up or down customer's EV charging in response to grid needs. GridSavvy events are typically 1 to 2 hours duration and no more than 4 hours long. Events generally occur several times a month, but no more than 24 hours within a single month. EV customers are allowed to override GridSavvy events and schedule EV charging based on their rates and personal needs.

Data Collection and Analysis

In this section, we outline the baseline definition, analysis approach, and market readiness for EV and GridSavvy technologies.

Baseline Definition

The baseline EV charger is a charger that optimizes charging based on the customer's rates and personal needs; it does not take into account the grid's needs. For example, a residential customer's charging schedule would be optimized based on personal usage and convenience. If the customer has TOU rates, then it would add in restrictions to ensure charging does not occur during peak hours. For commercial customers, it would optimize charging based on avoiding demand charges, so the charging would occur when building demand is low. EV customers would schedule their charger based on these preferences. To develop the baseline load, the evaluation team could either obtain the customer's programmed charging schedule or develop a charging schedule based on the customer's utility rates and daily charging demand.

Analysis Approach

In this section, we outline the approach for analyzing the benefits of GridSavvy EV charging technology in regard to emission savings, capacity deferral, and transmission and distribution (T&D) deferral.

Emissions Savings Analysis: The analysis compares the emissions from EV charging for a customer with GridSavvy charger versus the baseline EV charger that is not internet-connected. Based on SCP's electricity mix and emissions for each hour, the evaluation team would calculate the differences in emissions between a baseline EV load versus a GridSavvy-enabled EV load.

Capacity benefit: Capacity is based on a system's peak demand. When GridSavvy shifts EV charging from peak hours, it reduces capacity needs of the system. The capacity benefits can be determined by the marginal cost during the peak hours.

T&D benefit: Shifting demand from peak periods could relieve stress on the transmission and distribution system. Depending on the location of the EV chargers, demand shifts can reduce transmission and distribution line loading. These metrics can be analyzed by reviewing line loading as a percentage of the line's rated capacity. If the line loading is high on particular areas, then T&D deferral benefits can be calculated based on typical costs to implement mitigation measures.

Market Readiness

EV technology has been in the market for decades, and EVs have been manufactured at scale for the past decade. However, only in the past few years has EV been considered a grid resource. Theoretically, as EV adoption is expected to grow exponentially, demand response on EV charging (sometimes named V1G) holds immense promise. Although there are emerging companies that facilitate demand response on EV chargers, there is little public data on the effectiveness of these programs. Table 18 lists the technology recommendations and our initial assessment of their current market readiness and applicable market segments. The participant survey described in the Technology Assessment section in Chapter 2 will assess how willing the respondents would be to adopt these new technologies given various upfront costs and levels of savings, based on findings from the technology demonstration.

Table 17. Market Readiness for Demand Response for EV Chargers

Technology	Market Readiness	Market Segments
Electric vehicles	Commercialized and competitive	Residential, commercial, industrial, public sector (e.g., school buses), public transportation sector (e.g., buses)
Wi-Fi-enabled EV charger with JuiceNet App	Commercialized but limited deployment data	

Another important element of the Technology Assessment survey is to characterize the participant homeowner's response to the technology. Questions specific to this technology will assess barriers, such as lack of awareness of the technology, uncertainty about the technology's performance (e.g., ability to drive when needed and ability to have a fully charged battery when needed), and concerns about the technology's impact on electricity bill. Non-energy benefits that could be addressed include: lower maintenance cost, less noise pollution, less vulnerable to fluctuating prices of fossil fuel, and increased energy independence.

CHAPTER 13: Reporting

Below the approach to reporting on the Benefits Questionnaire and Technology Transfer Results is documented.

Benefits Questionnaire

Benefits of the project will be evaluated through completing benefit questionnaires. This task will include the following:

- Complete three Project Benefits Questionnaires that correspond to three main intervals in the Agreement: (1) *Kick-off Meeting Benefits Questionnaire*; (2) *Mid-term Benefits Questionnaire*; and (3) *Final Meeting Benefits Questionnaire*.
- Provide all key assumptions used to estimate projected benefits, including targeted market sector (e.g., population and geographic location), projected market penetration, baseline and projected energy use and cost, operating conditions, and emission reduction calculations. Examples of information that may be requested in the questionnaires include:
    - **For Applied Research and Technology Demonstration Projects:**
        - Published documents, including date, title, and periodical name
        - Estimated or actual energy and cost savings, and estimated statewide energy savings once market potential has been realized; identify all assumptions used in the estimates
        - Greenhouse gas and criteria emissions reductions
        - Other non-energy benefits such as reliability, public safety, lower operational cost, environmental improvement, indoor environmental quality, and societal benefits
        - Data on potential job creation, market potential, economic development, and increased state revenue as a result of the project
        - Energy savings estimates and overall economic benefits of the optimal deployment retrofit packages by combining successful applied research and technology demonstration projects with market-ready technologies
        - A discussion of project product downloads from websites, and publications in technical journals
        - A comparison of project expectations and performance; discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any

        - **Additional Information for Technology Demonstrations:**
            - Outcome of demonstrations and status of technology
            - Number of similar installations
            - Jobs created/retained as a result of the Agreement
    - **For Information/Tools and Other Research Studies:**
        - Outcome of project
        - Published documents, including date, title, and periodical name
        - A discussion of policy development; state if the project has been cited in government policy publications or technical journals, or has been used to inform regulatory bodies
        - The number of website downloads
        - An estimate of how the project information has affected energy use and cost, or have resulted in other non-energy benefits
        - An estimate of energy and non-energy benefits using the best available data, including ongoing research on emerging technologies as well as other technologies available in the market place across the state
        - Data on potential job creation, market potential, economic development, and increased state revenue as a result of project
        - A discussion of project product downloads from websites, and publications in technical journals
        - A comparison of project expectations and performance; discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any
- Respond to the California Energy Commission Agreement Manager's (CAM) questions regarding responses to the questionnaires.

Technology Transfer Results

As part of the technology transfer activities a plan will be developed to make the knowledge gained, experimental results and lessons learned available to the public and key decision makers.

The Project team will:

- Prepare an Initial Fact Sheet at start of the project that describes the project.
- Prepare a Final Project Fact Sheet at the project's conclusion that discusses results.
- Prepare a Technology/Knowledge Transfer Plan that includes:

- An explanation of how the knowledge gained from the project will be made available to the public, including the targeted market sector and potential outreach to end users, utilities, regulatory agencies, and others
    - A description of the intended use(s) for and users of the project results
    - Published documents, including date, title, and periodical name
    - Copies of documents, fact sheets, journal articles, press releases, and other documents prepared for public dissemination; these documents must include the Legal Notice required in the terms and conditions; indicate where and when the documents were disseminated
    - A discussion of policy development; state if project has been or will be cited in government policy publications, or used to inform regulatory bodies
    - The number of website downloads or public requests for project results
    - Additional areas as determined by the CAM
- Conduct technology transfer activities in accordance with the Technology/Knowledge Transfer Plan; these activities will be reported in the Progress Reports
- When directed by the CAM, develop Presentation Materials for an Energy Commission-sponsored conference/workshop(s) on the project
- When directed by the CAM, participate in annual EPIC symposium(s) sponsored by the Energy Commission
- Provide at least (6) six High Quality Digital Photographs (minimum resolution of 1300x500 pixels in landscape ratio) of pre- and post-technology installation at the project sites or related project photographs
- Prepare a Technology/Knowledge Transfer Report on technology transfer activities conducted during the project

GLOSSARY

Term	Definition
AMI	Advanced Metering Infrastructure
AMY	Actual Meteorological Year
AWHP	Air to Water Heat Pump
CAM	California Energy Commission Agreement Manager
CCA	Community Choice Aggregator
CEC	California Energy Commission
CLTC	California Lighting Technology Center
CPUC	California Public Utilities Commission
EE	Energy Efficiency
EM&V	Evaluation, Measurement and Verification
EMS	Energy Management System
EPIC	Electric Program Investment Charge
Framework	EM&V Framework
GIHPWH	Grid-Interactive Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
HPWH	Heat Pump Water Heater
IPMVP	International Performance Measurement and Verification Protocol
LED	Light-Emitting Diode
MSHP	Mini-Split Heat Pump
OAT	Outside Air Temperature
PCM	Phase Change Materials
Plan	Research, Instrumentation, and Monitoring Plan
SCP	Sonoma Clean Power
Team	All Lead Locally Program Partners
TMY	Typical Meteorological Year
TRL	Technology Readiness Level