CONSULTANT REPORT

# APPENDICES TO

# IMPACT EVALUATION REPORT OF THE ECAA-ARRA LOAN PROGRAM

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# APPENDIX A: DETAILED EVALUATION METHODOLOGY

This appendix discusses the data collection and analysis methods observed during the evaluation. The methods were developed in alignment with the procedures set forth in the evaluation plan.

## Data Collection Methods

This section discusses the evaluation team's approach to collecting site-specific evaluation data. Data collection fell into roughly five steps: data requests, site scheduling, site planning, site-specific measurement and verification (M&V) activities, and participant telephone surveys. Detailed data collection procedures are provided in Appendix B.

### Data Requests

In June 2011, the evaluation team requested documentation from the California Energy Commission related to Energy Conservation Assistance Act (ECAA-ARRA) projects funded by the American Recovery and Reinvestment Act of 2009 (ARRA). This initial data request included detailed measure descriptions; savings calculation spreadsheets and related documentation; feasibility studies (as appropriate); and contractor, vendor, and equipment manufacturer information (where available). In addition, further requests were made before the scheduling of and planning for on-site activities to ensure the evaluation team had the most up-to-date project information.

DNV KEMA worked with the Energy Commission to collect consistent data organized into a spreadsheet tracking database.

### Site Scheduling

For each sampled project, an evaluation engineer contacted the site via e-mail or telephone to initiate site planning and to schedule the site visit. The evaluation engineer confirmed project details and requested additional documentation, as necessary, to fill gaps not available from the Energy Commission, the site contact, and/or the project files. For example, for a typical lighting project, evaluation engineers requested a comprehensive list of installed lights, specifying fixture types and quantities, locations, and wattages of pre-existing and new fixtures. The evaluation team then notified the Energy Commission of upcoming site visits and obtained approval for the associated travel expenses.

### Site Planning

The evaluation engineers developed customized data collection and analysis plans for each sampled project. Different options for M&V were included in some of the plans, since not all of the needed project information was known before going on-site. Site plans typically included brief descriptions of the data requirements and analysis approaches that would be used to determine both the pre- and postinstallation assumptions and conditions. Site plans also

indicated specific M&V activities that could be conducted when site-specific constraints were known in advance—for example, evaluators could only take spot measurements at jail projects since long-term metering was disallowed by site contacts. Where possible, baseline conditions were evaluated with preinstallation site visits or monitoring. Sites were selected early in the evaluation for preinstallation monitoring, specifically for heating, ventilating, and air conditioning (HVAC) measures. These sites were chosen based on whether it was possible to collect useful data, either from an existing energy management system or from conducting an additional site visit and installing monitoring equipment. Since HVAC system operation is seasonally driven, sites were selected based on the type of equipment and the timing of the evaluation.

### *Site-Specific M&V Activities*

The evaluation team collected data to catalog pre- and post-retrofit operations and conditions. At each site visit, an evaluation engineer verified the installation and proper operation of each energy efficiency measure (EEM). The engineer also collected equipment nameplate data, feasibility study reviews, and self-reported operational data as the minimum data for all measures per site in the sample. The engineer interviewed site personnel to determine the pre- and postretrofit operations for each measure, including operating conditions, load, operating hours, and control strategies. In addition to physically observing an installed measure, the engineer collected relevant data available from the site contact, including any additional feasibility studies or updates, self-reported data from facility personnel, contractor or vendor information, cut sheets and performance curves, billing data, operational records, and research studies.

The evaluation team also requested copies of collected site data that presented pre- and postconditions, including logged equipment operating schedules, major equipment power and energy consumption or sensor records, and energy management system (EMS) trend data.

End-use metering data were collected to represent the pre- and postretrofit conditions when appropriate. The engineer took spot measurements, where feasible, to collect manufacturer's performance curves that would predict performance over the operation load profile and operating conditions. As needed, data loggers were installed, and long-term measurements were collected over a two-week or more period. Long-term monitoring was performed at all sites except for prison sites where it was not allowed.

Sampling was necessary for sites with multiple measures or a large number of installed measures. The evaluation engineer observed the pre-existing equipment whenever possible and collected metered electrical data and other data on pre-existing operations to establish a baseline.

### *Telephone Surveys*

Evaluators developed a participant survey instrument, which is located in Appendix C, to address research questions that could not be answered by other evaluation channels. One purpose of the survey was to provide the basis for determining net savings attributable to the program.

Evaluators screened facility contacts to identify the most appropriate person to interview based on his or her knowledge of the ECAA-ARRA program and involvement with project implementation and other details. Frequently, this person was the site contact or a staff member at the project location.

Respondents were asked questions that ranged from their overall impression of the ECAA-ARRA Program to their opinions about compliance with various application process requirements, to the financial criteria that helped the agency decide about participating, to the program's effect on jobs. An interview concluded with questions that asked about additional projects undertaken without program funding but may have been spurred by current program participation. These responses informed the spillover analysis, if participating sites implemented energy-efficient measures without incentives, grants, or loans from utility or government programs and were influenced by the Loan Fund Program. Although job creation resulting from ARRA programs will be addressed in a separate report, Loan Fund Program respondents were asked about the jobs created and retained as a result of the program to provide an on-the-ground indication of the perception of job creation. The survey instrument is provided in Appendix C.

## Site-Specific Analyses to Determine Energy Savings

Calculating energy savings depends on the estimated base-case energy use of a given end use before a retrofit and the estimated energy use after the retrofit. As defined in the International Performance Measurement and Verification Protocol[1] (IPMVP), there are two ways to estimate savings:

- Avoided energy basis. Avoided energy use quantifies savings in the reporting period relative to what energy use would have been without the EEM(s).
- Normalized savings. ". . .the reduction in energy use or cost that occurred in the reporting period, relative to what would have occurred if the facility had been equipped and operated as it was in the baseline period but under a normal set of conditions.[2]"

For this evaluation, evaluators used the normalized savings approach to estimate savings. This approach assumes a fixed set of conditions in both the pre- and postretrofit cases. Thus the base-case conditions were established for the preretrofit conditions as follows:

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1 Efficiency Valuation Organization. International Performance Measurement and Verification Protocol, *Concepts and Options for Determining Energy and Water Savings*, Volume 1. EVO 10000 – 1:2010, September 2010.

2 Efficiency Valuation Organization. *International Performance Measurement and Verification Protocol, Concepts and Options for Determining Energy and Water Savings*, Volume 1. EVO 10000 – 1:2010, September 2010., Section 4.6.1.

- Preretrofit data were collected to establish the control scheme, operating conditions, equipment load, and equipment efficiency. In the absence of metered data, information from the feasibility study, site contact, as-built drawings, and research and engineering judgment were used to establish the base-case parameters.
- Postretrofit data were similarly collected, and base-case parameters were established.

Both pre- and postretrofit data were normalized to the same operating conditions to establish consumption estimates that could be directly compared.

### Key Parameters and Terms

This study compares the forecasted energy savings (ex ante) with the savings calculated during the evaluation (ex post). The term *ex ante* refers to the savings estimates reported by the Energy Commission based on information from the loan subrecipient and its contractors. Savings estimates determined from the evaluation are referred to as *ex post* savings.

For each site within the sample, evaluators determined a measure's efficiency, measure life, and remaining useful life of the preretrofit equipment.

### Effective Useful Life of the Measure

California's Database for Energy Efficient Resources (DEER) was the primary source used to determine the EUL of a given EEM. For measures not represented in the DEER, the source of the EUL was based on technical research, such as published reports.

### Remaining Useful Life

For all retrofit projects, evaluators estimated the number of years a piece of preretrofit equipment would have continued operating without the retrofit. Typically, evaluators contacted knowledgeable facility contacts and asked for their best estimate of the remaining useful life (RUL) of the preretrofit equipment. This self-reported RUL, when available, is thought to provide a better estimate than the evaluation estimate. Evaluators also reviewed measure life data in the DEER to assess the reasonableness of an interviewee's estimated RUL. However, DEER RUL values typically did not exist for commercial or industrial systems. Equipment older than the measure life would be expected to have no additional RUL. However, based on the status of the equipment observed during the evaluation, state facilities often retain equipment beyond the EUL. For this evaluation, the site contact-reported RUL was the preferred value, DEER ULs were the second preferred value, and, in the absence of both, a minimum of one-year RUL was used when equipment was reported as functioning at the time of the retrofit.

### Equipment Efficiency

Equipment efficiency data for post-retrofit operations were available from the vendor for newly purchased equipment. For older preretrofit equipment, evaluators collected nameplate information during a site visit or from the project files and feasibility studies, in cases where the units' efficiencies were properly documented. In the absence of site-specific data, efficiency was

based on a preretrofit unit's age and corresponding (past) Title 24 standards. Information on equipment efficiency, based on nameplate information, is available for many units. For example, evaluators used *Preston's Guide* to determine efficiencies for HVAC equipment. This guide has a list of air-conditioning units built from 1960 through 2005 and has efficiency ratings based on a model's number and manufacture year.

### Life-cycle Savings Calculations

The evaluation team calculated life-cycle savings over the lifetime of the energy efficiency measures. Each measure was assigned an EUL, and the savings for each year of EUL were summed over the measure life to determine the life-cycle savings.

Energy savings calculated for this program are relative to two established baselines, referred to as Baseline 1 and Baseline 2.

- Baseline 1 corresponds to the existing conditions found before the energy efficiency measure's implementation and considers the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes that the pre-existing equipment would have operated for the full EUL of the new equipment regardless if the existing equipment was at the end of its useful life. The Energy Commission requested using this baseline to assist ARRA subrecipients that are comparing their observed pre- and postretrofit energy use and are using the savings to pay back loans.
- Baseline 2 uses the pre-existing equipment as the measure baseline only until the end of the existing equipment's RUL. After that, an expected replacement baseline (for example, standard practice or code minimum) is used until the EUL is reached.

### Gross Energy Savings Calculations

The gross site savings were calculated using the difference between energy usage for the measure-treated usage and the appropriate baseline. The savings associated with most EEMs were calculated using a spreadsheet analysis. In a few cases, calibrated end-use simulation or building energy simulation models were used to estimate savings.

### Spreadsheet Analysis

For lighting controls and interior lighting projects, the evaluation team's engineers determined savings by developing spreadsheets populated with the values gathered from site visits for each fixture type's wattage, counts by fixture type, and operating hours for both existing and preretrofit cases. Lighting logger data, which were deployed on representative circuits at the sites, were used to establish operating hours, where possible. Typically, the lighting loggers were installed at representative locations containing several occupancy and usage types (offices, hallways, garages) to establish annual operating hours for those types of locations. For exterior and streetlighting projects, the operating hours were established by the hours of darkness, determined from meteorological data for that city.

For most HVAC projects, evaluation engineers developed an annual load regression analysis that applied pre-existing and newly installed equipment efficiencies and conditions. The data collected on the pre-and postretrofit conditions were used to develop the regression analysis to establish the pre- and postretrofit energy consumption. To analyze the data, evaluators developed a regression curve relating the outdoor air temperature data to power draw for each unit. Either weather data collected on site or local weather station data was used as a basis for establishing weather conditions that affected HVAC use. If the data indicated that loads were internally driven (for example, the power drawn by the HVAC did not correlate with temperature), evaluators developed a relationship between time-of-day and power draw. Using the installed unit's efficiency (or an efficiency curve if available), evaluators translated the power draw data into load data. Finally, evaluators converted load data back into a preretrofit system power-draw estimate using the efficiency, operating parameters, and condition of the preretrofit system. In a few cases, end-use metered data were available for the preretrofit condition and were used to estimate preretrofit system power draw. Annual savings were assessed with a bin analysis using typical meteorological year (TMY3) data (assuming weather dependency) that corresponded to a local weather station. When multiple units were replaced or retrofitted, savings were extrapolated to the remaining units at the facility.

### Calibrated End-Use Simulation Models

If the ex ante savings were estimated via a building energy simulation model, evaluators made a data request to obtain these models, and in a few cases, such models were available. The models were inspected for general quality control, and when the models were of sufficient quality, the evaluation engineer determined the changes and manipulations that were made to the models to estimate the ex ante energy savings impacts. During a site visit, an evaluation engineer verified key assumptions and noted when on-site observations deviated from the assumptions or predictions of the model. After an on-site visit, the site engineer changed the as-built model to make it representative of actual conditions, creating an ex post as-built model. This model was run, and the results were used to estimate ex post savings.

# APPENDIX B: DATA COLLECTION FIELD MEASUREMENT PROCEDURES

# CHAPTER 1: Introduction

This document outlines guidelines and expectations for planning and performing site-level evaluations and developing reporting documents for projects executed under the Energy Efficiency and Conservation Block Grant (EECBG) and the Energy Conservation Assistance Act (ECAA-ARRA) programs. This guideline supplies general measure approaches, including data collection, field measurement, and analysis, for nearly all of the EECBG and ECAA-ARRA program project types. Consult this guide to determine a measure's appropriate data collection, field measurement, and analysis approach; this will help maintain consistency across the team of engineers who are working on these projects. The high-level measure approaches discussed in this guide indicate each measure's expected level of rigor consistent with the evaluation plans.

This document is designed for experienced energy efficiency engineers who can perform calculations for commercial energy efficiency measures. It is not intended to be a primer on how to calculate savings. Rather, it serves as a companion to the evaluation plans, Final Evaluation Plan for Energy Efficiency Financing Program (ECAA-ARRA), dated June 9, 2011, and Final Evaluation Plan for Energy Efficiency and Conservation Block Grants, dated August 15, 2011. All team members are required to read and thoroughly understand the evaluation plan for the project on which they are working. This document provides additional guidance for evaluating specific measures.

## Site Plans

Evaluators need to generate a clear, concise site plan before each site visit. Deliver this site plan with a travel request to DNV KEMA's task lead, Julia Vetromile, no later than the preceding Tuesday for the week of the proposed site visit. The site plan, which should not exceed 500 words, should briefly describe the on-site approach that will be used for each project measure. Evaluators should also discuss any proposed metering as well as the analysis type that the evaluator will use during the site visit. Sample evaluation plans are provided in Attachment III to illustrate the level of detail and clarity evaluators should capture in their evaluation plan drafts.

## Safety

Evaluators who visit project sites must have completed safety training relevant to each site. At a minimum, evaluators must complete, or be able to document completion of, driving safety, slips and falls, and ladder safety trainings. To conduct metering activities, electrical safety training is mandatory, as described in Attachment I. Evaluators must bring and use personal protective equipment (PPE) as applicable for each task where required or necessary. At a minimum, evaluators must bring work gloves, closed-toed work shoes, and earplugs to each site. In addition, evaluators who go on site must follow the visited facility's safety requirements,

including lockout and tagout requirements.

# CHAPTER 2: Measure Approaches for On-site Activities and Analysis

This section details general measure approaches for the most prevalent measure types in the EECBG and ECAA-ARRA programs.

## General Considerations

Site visits should require no more than eight hours on site. For sites with multiple measures or a large number of installed fixtures, sampling will be necessary. Sampling is discussed in more detail in Attachment II.

The Energy Commission developed and approved program-specific survey instruments for the EECBG and ECAA-ARRA Programs. The evaluator must deliver the survey to the person identified as the decision maker for the energy efficiency measures installed. Fully completed, legible copies of all surveys must be provided to DNV KEMA.

## Streetlighting and Traffic Signals

Streetlighting and traffic signal projects are strictly verification. The protocol for evaluating lighting projects is as follows:

- Obtain a comprehensive list of the installed lights for the project from the site contact or the Energy Commission's project manager. The list should specify fixture type and location for each newly installed fixture.
- Obtain specifications for the newly installed light-emitting diode (LED) or induction lights as well as the pre-existing lights. During the site visit, inspect a few pre-existing lights that have been removed from the lighting poles, if possible; this activity will allow verification of the baseline used in the ex ante analysis.
- Select a random sample of lighting fixtures throughout the city to verify in a day. Given a day's time frame, it may be reasonable to select a sample of only a few hundred lights, even if thousands were installed. Pick fixtures dispersed throughout the city when selecting lights to verify; do not focus too heavily on any area. Select a range of fixture wattages and types.
- When verifying lights, take pictures of a few fixtures. Bring a pair of binoculars to confirm lighting types if reviewing at a distance.
- Either photocells or timers typically control streetlighting fixtures. Site contacts should be able to provide lighting schedules if timers are in use. Obtain operating schedule data from an appropriate site contact. If photocells are in use, assume an average of 12 hours of operation per day unless there is a sound basis for a different estimate.
- Calculate savings using operating hours, fixture counts, and the difference between the pre-existing and installed fixture wattages.

## Exterior Lighting

Exterior lighting projects should follow the same protocol as used with streetlighting projects, with one exception. Evaluators should verify all fixtures for exterior lighting projects, unless the fixture quantities are too high to be counted on a one-day site visit. Similar to streetlights, outdoor lights typically operate either on a fixed schedule, which can be obtained from a site contact or on photo sensor controls. In both cases, there is insufficient schedule variability to necessitate data logging. As with streetlighting projects, it may be beneficial for the evaluator to bring a pair of binoculars to the site to verify information for hard-to-reach fixtures.

For large projects, select a sample of fixtures to verify, such that the site visit can be completed in one day. See Attachment II for additional guidance on sampling. Include a range of fixture types and wattages. Where fixtures have been installed in multiple locations, select representative areas for verification of measure installation.

## Interior Lighting and Lighting Controls

Lighting measures include a wide range of energy-efficient controls, fixtures, and lamps, including linear fluorescents, LEDs, exit signs, compact fluorescents, and high bay lighting,

Calculating direct savings from lighting measures are dependent on all of the following variables:

- Baseline and installed fixture wattages
- Baseline and installed fixture counts
- Baseline and installed fixture operating hours.

In retrofit projects, fixture wattages and counts typically change. In controls projects—which involve occupancy sensors, daylighting sensors and/or timer controls—operating hours are generally affected. For projects where both controls and new fixtures are installed, fixture wattages, counts, and hours of operation all become important. In all cases, the wattage, counts, and hours of operation for baseline and installed fixtures must be collected.

Determine savings by establishing values for each fixture type's wattage, counts by fixture type, and operating hours for both the installed and base cases for both lighting controls and interior lighting projects. For this evaluation, evaluators will verify the installation of all new fixtures for smaller projects, and a sample of fixtures for larger projects. If a given project involves more than 500 fixtures, or if the fixtures are distributed throughout multiple small rooms or many buildings, evaluators should sample fixtures. For those cases, sample fixtures so that all affected fixture types and a variety of space types (offices, halls, lobbies, restrooms, and so on) are represented. In the event that observed fixture counts or types vary markedly from those claimed in the application, evaluators should survey additional fixtures of the errant type.

After verifying fixture counts, evaluators should discuss the operating schedules of all affected lights with the site contact. For retrofit projects where the operating schedule is well-defined, metering is not necessary. Where the operating schedule is poorly defined, subject the fixture groups with the greatest expected usage variability to short-term (three to four weeks), time-of-use data logging to determine actual hours of operation; photocell based on/off loggers should be used for this task. For controls projects, the usage reductions attributable to the executed projects can be estimated or measured with time-of-use logging. Use appropriate references to estimate the fraction of annual lighting energy saved by lighting controls. [3] [4] In all cases, evaluators should ask site contacts for energy management system (EMS) trend data. If these data are available, it may be unnecessary to perform additional metered data collection.

Estimate values for fixture wattages by examining the power rating and ballast nameplate of the installed lamp. Again, evaluators should sample fixtures within reason, since accessing and opening fixtures to examine the ballasts adds considerable time to an audit. In most cases, examining three to five fixtures should suffice for evaluation purposes, since most projects typically use only a few types of ballast.

Evaluators should discuss the measure baseline specified in the project documentation with the site contact to verify that the fixture counts and types used in the ex ante analysis are appropriate for the ex post analysis. If not, request documentation specifying the actual pre-existing equipment (for example, an internally performed lighting inventory or a building lighting plan).

Following the retrieval of data loggers, evaluators should calculate savings for lighting projects using a spreadsheet analysis. Operating schedules (developed from logger data), fixture counts, and the difference between the pre-existing and installed fixture wattages serve as the basis for savings calculations.

## Vending Machine Misers

Direct savings calculations for vending machine misers are based on unit operating hours, number of units, energy load per unit, and number of occupants. Vending machine misers have occupancy sensors that detect users in the vicinity. If no occupant is detected, the vending machine will conserve energy by shutting off the compressor and lighting fixtures until a user is detected by the occupancy sensor. Typically, the more occupants there are in the building, the less downtime the vending machine will have and the less energy saved. However, if the vending machine is in a location with minimal foot traffic, then the vending machine misers can save a considerable amount of energy. Vending machine misers also have a built-in temperature sensor that will turn on the compressor to maintain a proper internal temperature for cold food

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3 Northeast Energy Efficiency Partnership. 2010. *Mid-Atlantic Technical Reference Manual, Version 1.0,* page 83ff.

4 *Business Programs Deemed Savings Manual V1.0*, State of Wisconsin (pages 4-192ff).

and beverages. A large part of the energy savings results from the reduced number of compressor cycles per day.

Upon assessing vending machine misers, evaluators should verify that the occupancy sensor on the vending machine is installed and operating properly. This verification may include testing the effectiveness of the occupancy sensor by determining if the machine truly powers off when no user is detected. Generally the on-mode power usage is not decreased, but the on-mode time-of-use will decrease with the use of vending machine misers. Two options are available for determining savings.

- The evaluator can collect and record a spot power measurement. The evaluator then used the measured power value and assumed the unit ran for all hours throughout the year in the pre retrofit case. Vending machine controls were assumed to reduce annual consumption by 46 percent in the post retrofit case. This value is claimed by the manufacturer and supported by various independent case studies. This value is also used in multiple technical resource manuals to estimate vending machine control savings.
- The evaluator can estimate the operating hours and load profiles of the misers by accounting for the number of occupants, the type of building, and the location of the vending machine. Several studies have documented typical energy use and percentage savings from both refrigerated and nonrefrigerated vending machines misers based on these factors.[5] A site contact can typically provide estimates for occupancy and foot traffic. Evaluators can calculate the energy savings resulting from the installation of vending machine misers from the difference between baseline and installed operating hours as well as the operational energy loads.

## Industrial Motors and Pumps

Generally, projects entail switching from less efficient motors and/or pumps to premium-efficiency motors and/or high-efficiency pumps or installing variable-frequency drives (VFD). Two factors dictate savings: the differing efficiencies between the installed and base case equipment and the equipment's load profile. Therefore, an evaluator's primary site visit goals are to verify the equipment specifications for the newly installed and removed pumps and/or motors and to determine the equipment's load profile. Evaluators should follow this generalized site procedure, which accounts for *both* new pumps and motors:

1. Verify the installation of the project's new motors and pumps. Record nameplate information from both the pumps and motors for all newly installed equipment. Clearly identify the pump type, such as centrifugal or positive displacement. Determine if logging will be possible at the site.

5 Massachusetts TRM: (pages 211-213) http://www.ma-eeac.org/docs/MA%20TRM_2011%20PLAN%20VERSION.PDF, *Business Programs Deemed Savings Manual V1.0*, State of Wisconsin (pages 4-81 to 4-83).

2. Discuss the process through which each motor or pump operates as a part with a site contact. For each piece of equipment, determine whether the process requires constant or variable motor loading. Similarly, determine for pump measures whether the corresponding application requires constant flow or variable flow (modulated by throttle valves, VFD, and so forth). The responses to these questions are fundamentally important because they will dictate whether the project requires amperage or true power data logging. True power data logging measures both current and voltage and therefore records power directly throughout the length of the metering period. If a motor load is constant—or equivalently, if the pump flow rate and system head are constant—then amperage logging is sufficient. If loading is not constant, a motor's power factor (PF) will vary with current draw. For motors with variable loading, evaluators should use true power logging.
3. With both constant load and variable-load motors, install data loggers on the lines leading to the motors when possible. For motors supplied by VFDs, install the loggers on the line side of the drives. It may be necessary to install data loggers live for these types of projects. As such, an evaluator should come prepared with appropriate PPE, including electrical gloves, face shield and/or goggles, and insulated shoes (see Attachment I).
4. After installing the data loggers, take spot measurements of true power, voltage, amperage, and PF to cross-reference with the metered data. If only amperage is logged, evaluators must use spot-checked voltage and PF readings to estimate motor power during the analysis phase. Evaluators should record these spot measurements, even if true power data are recorded, to confirm the validity of the metered data.
5. The evaluator should collect any measure related operating data available from a site's contacts. Evaluators should ask if any parameters, such as water flow, are trended as part of a supervisory control and data acquisition (SCADA) system. Evaluators may be able to correlate these data with the power data and use historical operational records to develop a site's annual usage profile.
6. Ask a site's contacts for data on the site's pre-existing equipment, if available. At a minimum, attempt to determine the nameplate efficiency of all removed pumps and motors.
7. Return to a site after three to four weeks to retrieve the loggers.
8. Where possible, evaluators will use metered data, including spot power measurements, in conjunction with interview data and SCADA data, to develop annual usage profiles for the new pumps and motors. To assess annual savings, use these data in conjunction with efficiency data for both the newly installed and prior pumps and motors. In its most basic form, the analysis can be generalized as:

$$E_{Saved} = \sum_{i=1}^{8760} kW_i \left( \frac{\eta_{mn}\eta_{pn}}{\eta_{mo}\eta_{po}} - 1 \right)$$

where,

- $E_{Saved}$ = Annual energy savings
- $kW_i$ = New system power draw during hour $i$
- $\eta_{mn}$ = New motor efficiency
- $\eta_{pn}$ = New pump efficiency
- $\eta_{mo}$ = Old motor efficiency
- $\eta_{po}$ = Old pump efficiency

If a project involves only motors, the pump efficiency terms cancel. Similarly, if the project involves only pumps, the motor efficiency terms cancel. It may be possible to vary the pump efficiency terms, which are not static values, depending on the availability of SCADA data.

## Personal Computer Power Management

Personal computer (PC) power management measures involve installation of control software on computers in order to manage computer power settings from a centralized location. The software puts the PCs into a reduced power state without interfering with end-user productivity, desktop maintenance or software upgrades. The PC power management software is installed at the server and subsequently distributed to each identified PC via the server.

Upon assessing a PC power management measure, evaluators should verify that the software is installed and operating properly on each PC. A general savings algorithm takes into account the number of computers, power requirements of the computers at various operation modes (on, off, suspend), and changes in hours of operation at each mode due to the power management software are used to determine savings. Hours of operation at these different modes are based on established studies for office equipment while the power draws at the various operating modes are based upon ENERGY STAR®-compiled data regarding computers. Using these two sources, DNV KEMA calculated the annual electrical energy savings for each desktop computer controlled by PC power management software. For the postretrofit case, the power draws for each mode were unchanged, but the operating hours at each mode shifted to reflect the power management software settings. Using this analysis, total energy savings for this measure were calculated.

## Packaged HVAC Equipment

Generally, evaluators determine savings from packaged heating, ventilation, and air-conditioning (HVAC) retrofit projects using one of four approaches. These approaches are defined in the HVAC evaluation flow sheets (Figures 1 and 2).

Four cases are defined, depending on whether preretrofit monitoring is performed (Cases 1A and 1B) or only postretrofit monitoring is performed (Cases 2A and 2B). For projects where a

major portion of the HVAC units at a facility are replaced, use the more rigorous approach of Case 1A or 2A. For Case 1A and 2A, use one of either a building hourly simulation model approved by the Energy Commission (eQuest or EnergyPro) or a bin model engineering analysis to estimate energy savings. For Case 1B and 2B, use a bin model calculation. The modeled data was calibrated using the best available data. Data specific to the units replaced or modified was preferred; such as with direct metering of equipment or energy management system data. Utility bills were collected when possible. In cases where the split of the utility bill into end-uses could reasonably be performed, the evaluator can calibrate with the utility bill. The utility bills were also assessed to determine the reasonableness of the savings estimation..

The following procedure provides evaluators with general guidelines for analyzing packaged HVAC projects. Steps one through six apply to all potential analysis options; the remaining steps present analysis strategies specific to each analysis approach.

1. Ask the site contact for access to each of the newly installed units. Verify that each unit has been installed as claimed. Record the model information for each newly installed unit in accordance with the fields provided on the site form.
2. Depending on the number of newly installed units for a project, evaluators may meter either a sample of the units or all of the units. As a general rule, evaluators should pick a representative sample if there are more than three units. The sample should represent both the sizes of units monitored as well as the space types served by the sampled units. Evaluators should not install more than four True power loggers at any site. Meter a sample or all units using a Micro Station/WattNode logger/transducer combination, according to the protocol outline for HVAC packaged units in Attachment I. Also, take spot measurements to ensure the validity of the metered data. Attachment I includes discussion of the proper protocol for spot measurements. When metering is not possible or practical, note the conditions why metering could not be reasonably performed.
3. In addition to installing power loggers, evaluators should install a weather station logger on a site roof to record temperature and relative humidity data for the duration of the monitoring period. The weather station should be located in the shade whenever possible. Synchronize the weather station's logging interval with the power logger's logging interval to make data postprocessing easier.
4. Discuss unit(s) schedules and operations with the site contact. Answer scheduling questions provided on the site form, as applicable. These data provide context for interpreting the metered data.
5. Gather any available data on a site's pre-existing units, especially nameplate data which can be used determine efficiency at time of purchase. Request information on the control system, how the system typically operated, the age of the equipment and operational maintenance issues. Ask about recent repairs or problems, indicating whether the equipment performance may have degraded over time (for example, thermostat problems, control overrides, refrigerant leakage, duct repairs, or leaks). At a minimum, evaluators shall collect the pre-existing units' sizes and vintage of the equipment. The

site contact may have building plans, as built drawings, or product manuals that will facilitate defining accurate base cases.

6. Remove the kWh data loggers and the weather station on the back-end site visit, which should occur roughly four weeks following the initial site visit. Review the weather station data; compare it to available regional weather station data to confirm validity. Attachment I discusses protocols for properly removing the power loggers.
7. Where a simulation modeling has been developed by the implementer, collect building information that affects the HVAC to verify a sample of the model inputs, including:
   - Schedules and Building shell characteristics. including dimensions and orientation (for hourly simulation)
   - Wall R-values, roof R-values, roof color (for hourly simulation); where R-value is a measure of thermal resistance of a material assembly
   - Window types, dimensions, orientations, U-values, and solar heat gain coefficients (if available) (for hourly simulation); where U value is a measure of non-solar heat loss or gain through a material assembly
   - Plugs loads (computers, monitors, copy machines, refrigerators, coffee machines, and so forth) and plug load schedules
   - Lighting loads (LPD) and lighting schedules
   - Process loads and schedules
   - HVAC system heating and cooling set points and scheduling
   - Nameplate information of HVAC equipment
   - Fan operating strategies (constant, cycling, nighttime set back, and so forth)

8. Use this information to verify the pre-existing building model.
9. Where a spreadsheet analysis is planned, create a spreadsheet to develop the load profiles for both pre- and postretrofit conditions. Evaluators should use the metered data to develop a regression curve relating the outdoor air temperature data to power draw for each unit. If the data indicate that loads are internally driven (for example, the power data does not correlate with temperature), develop a relationship between time of day and power. Using the efficiency of the installed unit (or an efficiency curve if available), translate the power draw data into load data. Where preretrofit metered data is available, calculate energy savings by developing and then comparing the pre-existing and newly installed units' regression curves. Where preretrofit data is not available, convert the load data back into an estimate of base case system power draw using the efficiency of the baseline system. Employ a degradation factor to the efficiency if warranted by the site observations and information collected. Annual savings can be assessed with a bin analysis using typical meteorological year (TMY3) data (assuming weather dependency) that corresponds to a local weather station. After determining

savings within the sample of metered units, extrapolate savings projections to the remaining units at the facility.

10. When using an existing simulation model of the building, verify that the installed equipment, operating and control strategy, and a sample of model inputs are correct based on the site observations. The HVAC end use of the model is then calibrated to metered data by adjusting loads and other parameters in the model to bring the observed and modeled demand profiles into agreement. Two more versions of the model are then created: one with existing equipment and the other with Title 24 baseline equipment. Each of the models is then run with the appropriate TMY3 weather file, and savings are calculated based on the differential between the installed and base case models (for example, the existing model according to the existing conditions [Baseline 1] and the Title 24 model for the dual baseline [Baseline 2] calculation).
11. In some cases, it may not be possible or practical to collect useful metered data. Air-conditioning projects that must be evaluated before the hot season are one example. As described on the Evaluation Flow Sheet, engineering spreadsheet models using bin weather data will be performed. These models are more theoretical and generally rely on spot-measured parameters and assumptions made using engineering judgment. This approach will typically be used in cases where a small size or small number of HVAC units are replaced.

## Figure 1: Evaluation Flow Sheet – Case 1A and Case 1B

Case 1A.

HVAC Project Evaluation with pre-retrofit site visit

Major portion of HVAC units replaced

1. Verify base equipment's efficiency, size, economizer operability, operating hours, and equipment condition (air distribution system condition, cooling tower leaking, dirty filters, plugged coils etc.)
2. If the replaced equipment's contribution to the site's energy consumption is greater than 30% then get 12 months of pre-installation utility bills for verification.
3. Use building hourly simulation model, bin model or engineering analysis that can determine the energy saving effect for reduced operating hours, improved duct/plenum leakage, equipment efficiency increase and improved control (including economizers and thermostat set back and lock out etc).

**For hourly simulation with Energy Pro, eQuest, Trace, HAP or other hourly simulation models)**

1. Use existing model provided by site contact or contractor who performed the ex ante analysis. Verify model inputs provided in the model to the extent practical. Collect building information that affects building HVAC including but not limited to:

Schedules and Building shell characteristics. including dimensions and orientation (for hourly simulation)
Wall R-values, roof R-values, roof color (for hourly simulation)
Window types, dimensions, orientations, U-values, and SHGCs (if available) (for hourly simulation)
Plugs loads (computers, monitors, copy machines, refrigerators, coffee machines, etc.) and plug load schedules
Lighting loads (LPD) and lighting schedules
Process loads and schedules
HVAC system heating and cooling set points and scheduling
Nameplate information of HVAC equipment
Fan operating strategies (constant, cycling, night time set back, etc.)
Occupancy Schedules

2. Simulate Pre- retrofit condition and calibrate the simulation results with the collected annual utility bills to within +-10% accuracy.
3. Simulate Post- retrofit energy use and calculate energy savings

**For Bin model and engineering calculation**
1. Use NOAA TMY (3) or California Climate Temperature Zone (CTZ) data ~~ASHRAE~~ to determine bin hours for the climate zone and the applicable operating hours or heating or cooling degree days or other justifiable load factors
2. Provide an estimated percent improvement from the existing conditions for each measure or improvement:
reduced operating hours,
measures designed to improved duct/plenum leakage or other changes in conditions or operations,
equipment efficiency increase
improved control (setback, lock out and economizer)
3. Simulate Pre- retrofit energy use with a degradation factor if observable factors indicates degradation is likely. Typically this will be for equipment over 10 years old.
4. Simulate Post- retrofit energy use with applicable improvements.
5. Use spreadsheet to calculate energy savings
6. Use available billing data to assess the reasonableness of the bin analysis results.
7. When post-retrofit end-use metered data is available, calibrate to bin model results.
8. When post-retrofit end-use metered data is not available, and where the measure is a significant portion of the utility bill and other non-HVAC measures do not confound the results, calibrate to the utility bill.

Case 1B.

Small number of HVAC replaced

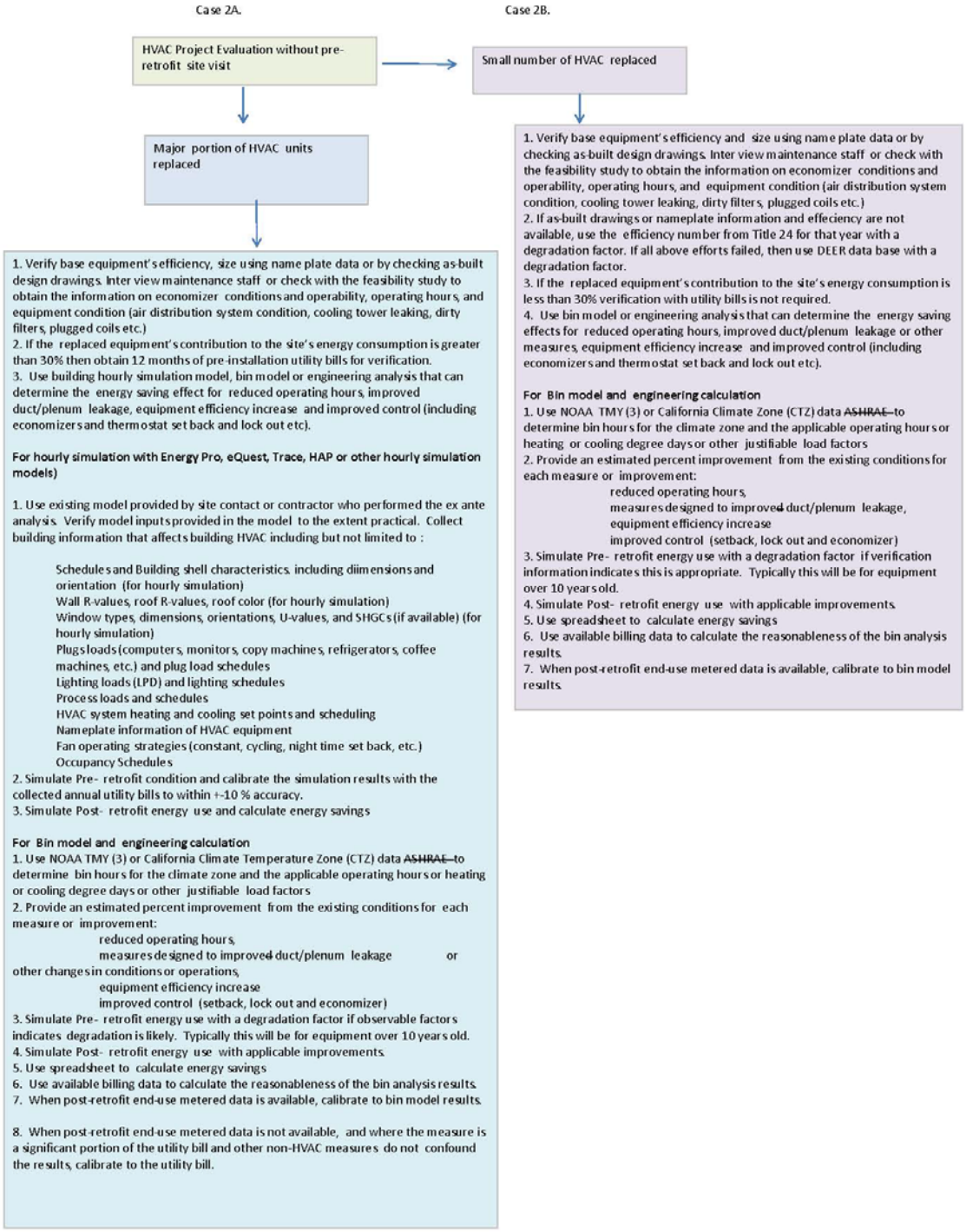
1. Verify existing equipment's efficiency and size, economizer operability, operating hours, and equipment condition (air distribution system condition, cooling tower leaking, dirty filters, plugged coils etc.)
2. If the equipment's contribution to the site's energy consumption is smaller than 30% , verification with utility bills is not required.
3. Use bin model or engineering analysis that can determine the energy saving effects for reduced operating hours, improved duct/plenum leakage, equipment efficiency increase and improved control (including economizers and thermostat set back and lock out etc).

**For Bin model and engineering calculation**
1. Use NOAA TMY (3) or California Climate Zone (CTZ) data ~~ASHRAE~~ to determine bin hours for the climate zone and the applicable operating hours or heating or cooling degree days or other justifiable load factors
2. Provide an estimated percent improvement from the existing conditions for each measure or improvement:
reduced operating hours,
measures designed to improved duct/plenum leakage or other changes in conditions or operations,

reduced operating hours,
improved duct/plenum leakage,
equipment efficiency increase
improved control (setback, lock out and economizer)
3. Simulate Pre- retrofit energy use with a degradation factor if verification information indicates this is appropriate. Typically this will be for equipment over 10 years old.
4. Simulate Post- retrofit energy use with applicable improvements.
5. Use spreadsheet to calculate energy savings
6. When post-retrofit end-use metered data is available, calibrate to bin model results.

Source: DNV KEMA analysis

## Figure 2: Evaluation Flow Sheet – Case 2A and Case 2B




Source: DNV KEMA analysis

## Built-Up HVAC Measures: Central Plant

Central plant HVAC measures include boiler retrofits, chiller retrofits, pump retrofits, and VFD installations, as well as many other possibilities. Use the Evaluation Flow Sheets (Figures 1 and 2) as a guide for the evaluation approach, as described in the preceding section (Packaged HVAC Equipment).

Evaluators must establish a load profile for newly installed central plant HVAC measures (pumps, cooling tower fans, chiller compressors, and so on). For most chilled-water projects, establishing a load profile for the loan- or grant-financed equipment requires determining a load profile for the chiller, regardless of whether the measure directly affects the chiller. Once the evaluator correlates the chiller's power draw to its corresponding outdoor conditions (or time of day for process chillers), most other parameters required to calculate the savings can reasonably be determined. For instance, consider a project that retrofits constant-speed chilled-water pumps, condenser water pumps, and cooling tower fans with VFDs. Once determined or estimated, the load of the chiller can be used to project the required chilled and condenser water flow rates using the temperature drop (delta-T) across each chilled-water loop. Likewise, determining the load of a chiller will allow evaluators to calculate the fan speed requirement of a cooling tower, provided that evaluators know the outdoor wet-bulb temperature and the performance of the tower under design conditions. In both scenarios, knowing the chiller's load profile effectively establishes the load profile for the equipment of interest. Establishing the chiller's load profile, via either kW metering or EMS data acquisition, is vital to determining savings for many plant HVAC measures.

The analysis approach for central plant HVAC measures is as follows:

1. Verify installation of a plant's new HVAC measure equipment. Record nameplate data.
2. Determine if an EMS system is available and collects true power data on the equipment of interest. If so, evaluators may not need to use outside monitoring equipment. Evaluators should also inquire about the availability of other EMS trend parameters of interest. Some commonly recorded plant parameters include pump and tower fan VFD hertz (Hz), pump and tower fan operating hours, chilled-water entering and leaving temperatures, and condenser water entering and leaving temperatures. If EMS system data is not available, install data loggers on the project's equipment of interest. Evaluators will want to install true power data loggers on the chiller(s), as well as any measure-specific equipment.
3. Confirm the validity of the metered data with spot measurements. Install a weather station on the site's building roof to record ambient temperature and relative humidity weather data. Synchronize the logging times for the loggers and weather station to ensure that all data line up during the analysis phase, if possible.
4. Discuss plant operations (for example, schedules, set points, and equipment configurations) with a site contact or building engineer. Determine control strategies for the project's equipment of interest and gain an understanding of the loads served by the

plant's equipment. For instance, does the chiller maintain a constant delta temperature across the evaporator, or does the delta temperature T shift under low load conditions? Does the plant use water-side economizing? Is the condenser water temperature set-point fixed, or is it allowed to float? Depending on a project's measures, all of these questions might be important.

5. Discuss the pre-existing equipment and the installed equipment with the project site's building engineer. Gather any available data on the pre-existing equipment, especially nameplate data that can be used to determine efficiency at time of purchase. If possible, review as-built building plans, which may include a mechanical schedule listing the pre-existing equipment. Ask the building engineer how the plant previously operated with the old equipment in place, including the control strategies. Request information on the age of the equipment and operational maintenance issues. Ask about recent repairs or problems, indicating whether the equipment performance may have degraded over time (for example, thermostat problems, control overrides, refrigerant leakage, and so forth).
6. Return to the facility and remove the logging equipment after a three- to four-week monitoring period.
7. Develop a regression relationship between chiller power and outdoor conditions using the metered data collected from a site. Using the chiller's part-load efficiency curve, translate this curve into a load (tons of refrigeration) versus an outdoor-conditions relationship. Relate the chiller load data to the remaining plant equipment using the operating data, gathered from the site's building engineer, and metered data from the plant's other equipment. Conduct a bin analysis using typical meteorological year data from a nearby weather station to quantify the measure's effects.[6]

The following example analysis shows a project's possible execution:

A facility receives a loan or grant for installing VFDs on its primary loop-chilled and condenser water pumps, which were previously controlled using manually throttle valves. While at the facility, the evaluator obtains the site EMS power data for the chiller and installs true power loggers on the project's pumps of interest and a weather station on the roof. Back in the office, the evaluator uses the chiller power data, weather data, and a chiller efficiency curve to estimate chiller load as a function of outdoor conditions. Using this load curve and knowledge of the fixed water loop Delta-T set points, the evaluator estimates the chilled and condenser water-flow rates under various load conditions. Next, the evaluator uses the flow estimates to predict the pumps motors loads using the baseline throttling valve control strategy. Lastly, the evaluator compares energy usage under the baseline control strategy to energy usage under the

6 For a given city, TMY3 weather data approximates the average 8,760 weather conditions using climate data from the 1991 to 2005 period of record. TMY data sets are designed to simultaneously maintain the range of typically observed extreme weather conditions and are aggregated to the annual average weather conditions.

VFD control strategy—obtained from monitoring—and annualizes the results using a bin analysis to determine overall project savings.

For gas-related plant measures (boilers, large domestic hot water [DHW] heaters), evaluators must use a different approach. In most instances, equipment specifications, schedule and set-point data, utility gas bills, and possibly verified combustion efficiency data will be the only data available to the evaluator. If the project boiler(s) or DHW heater(s) of interest are the only large gas users on the project participant's utility bills, the analysis will be straightforward. Evaluators will conduct an analysis using the differing efficiencies of the base case, installed boilers, and the project facility's gas load. If possible, evaluators should adjust these efficiencies from the manufacturers' claims using combustion test results, blow-down estimates, flash-gas estimates, and shell-loss projections.

If other large gas users comprise a significant portion of the participant's gas utility bills, evaluators should use a simplified building simulation-based analysis to assess project savings. See Attachment III for a brief discussion of building simulation modeling-based analysis for this measure type.

In some cases, it may not be possible to collect useful metered data. These projects will be determined on a case-by-case basis.

## Built-Up HVAC Measures: Air Side

Air-side HVAC measures may include air handler constant volume (CV) to variable air volume (VAV) conversions, economizer retrofits and retrocommissioning, automatic thermostat installations, EMS upgrades (which may also affect plant equipment), and building set-point adjustments. For mechanical measures, evaluators should use a spreadsheet analysis, informed by metered data, when a site's air delivery system changes in some measureable way. Use the Evaluation Flow Sheets (Figures 1 and 2) to determine the method. Evaluators may determine the impact of control measures using either spreadsheet analysis or simulation modeling. If spreadsheet models are used, savings are projected in terms of reduced equipment full-load hours or bin-hours. If evaluators are provided with simulation models used as part of the ex ante analysis, they may instead decide to use and modify these models to project savings. In cases where simulation models are not provided, the opportunity cost of spending additional time on control measure simulation at the expense of rigorously analyzing other measures is generally considerable. Therefore, evaluation engineers use simulation modeling for control measures only when ex ante simulation models are provided for review and modification.

The standard approach for air side measures is as follows:

1. Verify installation of the loan- or grant-financed equipment.
2. If necessary, install data loggers to track operation of the loan- or grant-financed equipment (kW meter for VFD applications and temperature data loggers for economizer applications).

3. Take spot measurements of the financed equipment, if necessary (supply- and return-fan-related measures only). Use these measurements to verify the validity of metered data.
4. If logging data, install a weather station logger on the project site roof to track local temperature and relative humidity conditions over the monitoring interval course. Synchronize the logging interval of the weather station with the logging intervals of other metering equipment. Review the weather station data for reasonableness compared to available regional data.
5. Discuss the equipment operations of the project with a participant's building engineer. Record relevant information as presented in the field forms to the interpretation of the metered data. For instance, ask a site contact to indicate the high-limit enthalpy for economizer operation and the minimum outside air set point if a single-point enthalpy economizer is recommissioned. These data can be cross-referenced with temperature logger data to verify the economizer's correct operation.
6. Discuss the pre-existing equipment with a site's contact or building engineer. Investigate the ways in which equipment operations may have changed as a result of the project (particularly important for control measures). Review an original set of as-built plans to record pre-existing system data, if possible.
7. For projects involving logger installations, retrieve data loggers after three to four weeks of equipment monitoring.
8. Construct a model correlating ambient weather conditions and/or time of day to equipment's operation. Estimate the baseline equipment operation from data gathered from a site contact. Determine the measure's annual savings using either a bin, EFLH, or 8760 model; in either case, use TMY3 weather data from a nearby weather station for all final savings projections.

### Custom Measures

Custom measures include a disparate array of project types, ranging from computer server virtualization to mechanical aerators used in wastewater treatment. Each project type requires that evaluators use their best engineering judgments to develop a measure-specific evaluation approach. Whatever the project, evaluators should consider the following questions:

- Given the number of analysis hours allocated to a project site, which analysis approach makes the best compromise between analytical rigor and cost-effectiveness?
- Is metering appropriate and practical?
- How will evaluators use metered data, together with information gleaned from a site contact's interviews, to develop an annual load/usage profile for the installed equipment?
- How can evaluators translate the load/usage profile for the installed equipment into base-case usage? Have they gathered enough data on the base case equipment to confidently estimate base-case usage under all operating modes?

- For industrial (primarily wastewater) measures, have evaluators asked a site contact for daily process records (for example, gallons per day of water) for the past year?

## CHAPTER 3: Reporting Requirements

Site reports should be succinct and should answer the following questions:

- Which measures were implemented?
- Were the measures installed as proposed?
- Does the baseline equipment listed for the project seem reasonable given the observed facility conditions?
- How were savings determined for each implemented measure? What were the savings for each measure?
- If savings differed drastically from ex ante projections, why?

All calculations, tabulated results, and figures showing measurements should be provided. The report will provide an explanation of the analysis performed; backup spreadsheets with the detailed calculations will become part of the project record.

The following results must be identified:

- Annual energy savings, based on the pre-existing equipment operation (Energy Commission baseline)
- Measure life
- Remaining useful life of the existing equipment, based on the decision-maker survey, information gathered during the site visit, and engineering judgment
- Normal replacement annual energy savings, if different from the Energy Commission baseline
- Lifetime savings, based on the existing equipment (Baseline 1)
- Lifetime savings, based on dual baseline (Baseline 2) of early replacement for the remaining useful life of the equipment, followed by normal replacement savings for the remaining years of the measure
- Realization rate, on a measure basis

DNV KEMA will distribute example reports once the first few reports are accepted by the Energy Commission. At that time, DNV KEMA will also distribute a reporting template to use for all site reports to maintain consistency.

# CHAPTER 4: Glossary

| Acronyms/Initials | Definition |
|---|---|
| AHU | air unit handler |
| CT | current transducer |
| CV | constant volume |
| DHW | domestic hot water |
| DOE | Department of Energy |
| Delta T | Delta temperature |
| ECAA | Energy Conservation Assistance Act |
| EECBG | Energy Efficiency and Conservation Block Grant |
| EEM | energy efficiency measure |
| EMS | energy management system |
| Energy Commission | California Energy Commission |
| EPRI | Electric Power Research Institute |
| HVAC | heating, ventilation, and air conditioning |
| LED | light-emitting diode |
| LPD | lighting power density |
| PF | power factor |
| PPE | personal protective equipment |
| RH | relative humidity |
| RMS | root mean square |
| SCADA | supervisory control and data acquisition |
| TYM3 | typical meteorological year 3 |
| VAV | variable air volume |
| VFD | variable frequency drive |

# Attachment I: Metering Protocols

Many projects executed under both the ECAA-ARRA and EECBG programs will require data logging of some kind. This section discusses the data logging instrumentation that evaluators should use for these projects. Evaluators should inform a site contact about any proposed metering during their initial scheduling call for any project that will require metering. Tell the site contact what will be installed, where it will be installed, and for how long. In this manner, equipment access or safety issues can be resolved before a site visit, and metering can occur as planned. Please address your software and metering equipment needs to Brandon Gill (Brandon.Gill@dnvkema.com).

Installing power meters requires opening electrical panels and poses certain safety risks. All field staff working on this project must complete DNV KEMA's courses on electrical safety, driving safety, and ladder safety, or provide documentation from another program indicating that similar training has been completed in these areas.

## Packaged HVAC – WattNode Metering

This section provides a specific, step-by-step metering protocol that evaluators should use for packaged HVAC equipment.

### *Meter Installation*

After gaining access to a project's roof by a site's contact, evaluators should follow these protocols to install the metering equipment and to verify its correct operation.

1. Before touching any energized equipment, remove all metallic jewelry and put on all safety gear as required by the National Fire Protection Association 70E standards.
2. Identify the power connection configuration at the disconnect box. It is single-phase if there are two lines leading from the fuse to the unit. If there are three power lines and a fuse, it is a three-phase Delta configuration. If there are three power lines and a neutral line, it is a 3-phase wye configuration.
3. Identify the source voltage provided to the unit by reading the nameplate. Some units installed at older facilities have ratings at 208V/3-phase, while more modern facilities typically have 480V/3-phase power supplied to the units. For 480V supplies, use the WNB-3D-480-P WattNode meter; for 208V supplies, use the WNB-3D-208-P WattNode meter.
4. Turn off the power to the unit by flipping the manual power switch. If there is no local disconnect, consult a site contact and call the field manager as needed to disable power. Open the unit service panels and observe the power lines feeding it. Confirm that the system is completely off before installing any equipment. Verify this by measuring the voltage at the terminals for each leg. If the voltage is not zero, there may be some residual power left in the system from the capacitors. Wait until the unit discharges completely before performing work on the system. If necessary, use a discharge rod to

achieve zero voltage on the terminals. Never touch the capacitor leads while working in the unit; capacitors may maintain charge for extended periods.

5. Use an insulated screwdriver to partially unscrew the connection from the first leg at the terminal block. Insert the Phase A wire from the WattNode into the unscrewed terminal leg. Retighten the screw so that both the power line feeding the unit and the Phase A wires from the WattNode are tight. Wiggle the wires to see if they become loose.
6. Take the current transducer (CT) (Phase A) coming from the WattNode and slip it around the first line. Install the CT on the line side (before the fuse) of the terminal block whenever possible. If the load side (after the fuse) must be used due to lack of space, take care to capture all wires exiting the load side of the terminal block for the desired phase. When installing the CT, make sure it is installed with the correct side facing the source. Magnelab's CTs typically have a sticker indicating the face that should be pointed toward the source. (See Figure 3 below.) Should the source face not be indicated, compare the teeth configuration of the split core to a marked CT to determine the correct direction for installation.

**Figure 3: Current Transducer**

Photo Credit: DNV KEMA

7. Repeat steps 4 and 5 for the second (phase B) and third lines (phase C) and make sure that the appropriate CTs are connected to the corresponding lines.

If the power configuration is *3-phase wye*, attach the neutral voltage lead from the WattNode meter to the unit's neutral connection and attach the ground voltage lead from the WattNode to the unit's ground connection. If the power configuration is single-phase or 3-phase Delta, attach only the ground voltage lead from the WattNode to the system's ground connection (and remove the pre-attached neutral wire from the WattNode). Note that 3-phase Delta units are most common.

The WattNode should be preconnected to the HOBO Micro Station using a pulse adapter cable.

8. Insert the serial communication cable into the Micro Station unit and a computer. Turn on the power to the system, and let it run.
9. Deploy the Micro Station. Verify that the lights on the WattNode are blinking green. If the lights are not blinking green, some combination of green, yellow, and red lights will flash. Refer to the WattNode troubleshooting guide (included in all site kits) to determine the WattNode error, and address the issue. Perform adjustments to the WattNode's set up only with the power OFF.

**Figure 4: WattNode Status Indicator Lights**

Photo Credit: DNV KEMA

10. Once the WattNode is operating correctly and the Micro Station has been launched, perform an installation quality check by comparing the WattNode power readings to root mean square (RMS) power readings captured using a spot power meter.

Refer to the conversion table presented in Table 1 to calculate the system's RMS power using the pulse data output from the WattNode unit.

**Table 1: WattNode Pulse Output Conversion Factors**

| Model | Watt-hours/Pulse/CT-rated Amp |
|---|---|
| WNB-3D-240-P | 0.02500 |
| WNB-3D-480-P | 0.05771 |

Source: http://www.ccontrolsys.com/ww/images/f/fb/Manual_WNB_Pulse.pdf

For an example to use this table, consider an application where 25A CTs are used with a WNB-3D-240-P WattNode. At a given time stamp, the Micro Station records an output of 25 pulses (over the 1-minute logging interval). The RMS power would be calculated as:

$$kW_{Wattnode} = (.025)(25A)(25\,pulse)(3600\,\frac{s}{hour})\left(\frac{1}{60s}\right)\left(\frac{1}{1000}\right) = .9375kW$$

See below for instructions on how to properly take spot power measurements. Since the WattNode and spot measurements will not correspond to identical time stamps, spot power readings within a range of +/- 25 percent relative to the WattNode readings are acceptable. WattNode power measurements should be taken from a time stamp beginning at least three minutes after a logger is launched and after turning back on a unit to allow for compressor operation to reach the steady state.

11. If the numbers are synchronized, remove the communication cable and place the Micro Station in a secure area away from the elements and in plain view.
12. Perform a final visual inspection of the equipment to ensure that the logger, WattNode, and CTs are installed correctly. Refrain from touching the equipment if any issues are identified. As always, first shut off the power to a unit before making adjustments.
13. After ensuring that the logging equipment and wires are safely situated, close the service panels. Turn the unit back on and make sure it runs. If necessary, adjust the thermostat in the building to force the unit on and check for correct operation.

### *Meter Removal*

Take the following steps during a return site visit to safely remove the metering equipment.

1. Before touching any energized equipment, remove all metallic jewelry and put on all personal protective equipment.
2. Turn off the power to the unit by removing the fuse at the disconnect box or flipping the manual power switch. Open the unit service panels and observe the power lines feeding it. Make sure that the system is completely off before removing any equipment. This can be verified by measuring the voltage at the terminals for each leg. If the voltage is not zero, there may be some residual power left in the system from the capacitors. Wait until the unit discharges completely or discharge the unit using a discharge rod before performing work on the system. If necessary, use a discharge rod to achieve zero voltage on the terminals. Never touch the capacitor leads while working in the unit; capacitors may maintain charge for extended periods.
3. Use an insulated screwdriver to partially unscrew the connection from the first leg at the terminal block. Remove the Phase A WattNode wire from the terminal block. Re-tighten the terminal block screw so that the power line feeding the unit is securely

fastened. Wiggle the power line to see if it comes loose. Repeat this process for the remaining phases and the ground connection.

4. Remove the CTs from each phase.
5. After removing all logging equipment from the unit, securely reinstall the panels.
6. Turn the unit back on, and make sure it runs. If necessary, adjust the thermostat in the building to force the unit on and check for correct operation.

### *Spot Power Measurement Check*

The accuracy of all meter installations must be verified using spot measurement checks with a power meter (typical full-range accuracy +/- 2 percent). While taking spot power measures, ensure that the thermostat is set sufficiently low to maintain compressor operation. Alternatively, use jumpers to override the thermostat during the test period. Spot measurements should consist of voltage, amperage, power factor, and true power readings. Take a minimum of three sets of spot measurements one minute apart. To ensure the consistency of readings, perform spot measurements using the phase-to-neutral method described below:

1. Connect the black voltage probe from the Fluke or Amprobe to a neutral/ground.
2. Connect the red voltage probe to Phase A.
3. Connect the amp clamp across Phase A and verify that it is facing in the correct direction.
4. Push the Phase Check button to verify the direction of the current or simply check the sign of the current. If current is negative, then the amp clamp is facing in the wrong direction.
5. Record the voltage, current, power, and power factor from the Fluke liquid crystal display (LCD) display.
6. Move the red voltage probe and amp clamp to Phase B.
7. Repeat steps 4 & 5.
8. Move the red voltage probe and amp clamp to Phase C.
9. Repeat steps 4 & 5.
10. Disconnect both the voltage probes and amp clamp.

Compare the readings to the concurrent readings from the metering suite. Spot measurements should be within +/- 25 percent of the metered value. Metered and spot measured readings should not be expected to match exactly since the logged value represents the time averaged power consumption over the logging interval (60 seconds). However, if the metered values over the course of a few timestamps are not in a close range to the spot checked values, reconfirm the meter's installation to check for these possible deficiencies:

- CTs installed in the wrong direction
- CT clamps not fully closed
- Mismatch between CT and voltage lead phases

- Improperly installed voltage leads (this is potentially dangerous and must be avoided)
- Poor connections to the WattNode from the voltage leads, current transducers, or pulse adapter.

If none of the aforementioned issues are the source of the problem, use the best engineering judgment to assess the likely cause of the problem. If the problem is clear, replace the failing component. If the problem cannot be identified, switch out the entire metering suite with a backup.

## True Power Metering, Current Logging, and Other Monitoring Instrumentation

Outside of packaged unit applications, perform true power logging using DENT ELITE*pro*™ meters. Unlike the WattNode-based loggers, which are hard wired into equipment and are generally suitable for only packaged applications, DENT ELITE*pro* loggers use alligator clamps to attach to exposed voltage sources ( for example, terminal blocks). As such, these loggers can be installed on live equipment, which may be necessary for large commercial and industrial projects. If you need training on how to use and install DENT loggers, please contact or Brandon Gill (Brandon.Gill@dnvkema.com). Be aware that ELITE*pro* loggers must be installed on the line side of VFDs since they are only capable of monitoring standard 60 Hz AC signals.

**Figure 5: DENT ELITEpro True Power Logger**

Photo Credit: DNV KEMA

For projects that only require current metering, DNV KEMA uses ACR OWL current loggers and/or Onset HOBO Micro Station data loggers fitted with a single current transducer. Both of these options employ split-core current transducers for installation ease.

**Figure 6: Onset Micro Station and ACR OWL Current Logging Solutions**

Photo Credit: DNV KEMA

In addition to power and current metering, DNV KEMA regularly uses indoor temperature and relative humidity data loggers, outdoor weather station data loggers (also Temp/RH), and time-of-use lighting loggers. Discuss DNV KEMA's available logger options with Brandon Gill.

## Attachment II: Sampling

Engineers will find it necessary to use sampling techniques both in the context of verifying equipment installations and metering equipment. As an example, it generally will not be reasonable within the limitations of a one-day site visit to verify the installation of lighting in 10 buildings for a single project. Similarly, it will not always be possible to meter every packaged unit installed as part of an HVAC retrofit project. Both of these examples require sampling that should be conducted on the basis on a few key considerations:

- **For installation verifications activities (typically light measures), as many units as possible should be verified within the limits of the on-site time allotted for the site *without* detracting from any other required on site activities.** As an example from an already completed Energy Commission evaluation project, an engineer had to verify lighting, remove a logger from a chiller, discuss and verify two boiler controls measures, discuss an EMS measure, and meter a few packaged HVAC units all in one day. In this case, it was not reasonable to verify the 1,000 lights retrofitted as part of this project. Instead, a sample of lights was verified.
- **If verification sampling must be performed in a limited time frame, maximize available time by** verifying **those units responsible for the greatest portion of the energy savings.** For instance, if lighting retrofits were performed in six buildings, but the retrofits in two of those buildings accounted for 85 percent of the savings, the engineer should make an effort to verify those two buildings before any of the others.
- **The scope of verification activities should partially be dictated by the accuracy of the verification sample.** If, while verifying lights at a given facility, an engineer determines that the lighting schedule provided by the site contact is grossly flawed, added time should be allocated during the site visit to verify more lights than initially planned—especially if the lighting portion of the project accounted for a large amount of the savings. Discretion must be used in the analysis phase when applying any savings degradation factor determined for the verified area to the unverified area. If the savings for unverified areas are reduced or increased for reasons unrelated to updated operating hour estimates, the verified sample needs to provide strong evidence that *all* areas of the project were not completed as proposed.
- **When sampling equipment for metering, attempt to cover a wide range of equipment sizes and unique usage profiles.** As an example, if a facility replaces 10 packaged HVAC units ranging in size from 3 to 10 tons, an engineer should attempt to install meters on one of the smaller units and one of the larger units, as well as units on different schedules and serving different end uses. In an idealized case in which five 3-ton units serve five similar small buildings in a county facility campus and five 10-ton units serve one large building in the same campus, a reasonable approach is to meter one of the 3-ton units and one of the 10-ton units.
- **In all cases, the number of power meters installed at any site should be minimized while attempting to maximize the quality and utility of the collected data.**

## Attachment III: Simulation Model-Based Analysis

This summary outlines the general data collection and simulation modeling procedures common to all model-based analyses.

Evaluating measures with a building simulation approach entails building a representative model of an affected facility and altering only a few select parameters that differentiate the baseline and installed case equipment. In contrast to spreadsheet-based analyses, which are conducted by isolating the measure of interest, simulation analyses require that a wide range of secondary building data are collected to inform the models. These data directly affect the loads imposed on both the base case and installed case models in the subsequent savings analysis.

With this consideration in mind, data related to the following building construction and operations characteristics should be collected for any commercial building modeling effort:

- Building shell properties
- Shell dimensions and orientation
- Wall R-values, roof R-values, roof color (affects absorptivity and emissivity)
- Window types, dimensions, orientations, U-values, and solar heat gain coefficients (SHGC) (if available)
- Zoning (for HVAC)
- Plugs loads (computers, monitors, copy machines, refrigerators, coffee machines, and so forth .) and plug-load schedules
- Lighting loads (lighting power density [LPD]) and lighting schedules
- Occupancy density and schedules
- Process loads and schedules
- HVAC system heating and cooling set points and scheduling
- Fan operating strategies (constant, cycling, nighttime setback, and so forth)

Using these data, in addition to any measure-specific data, the baseline and as-built models can be constructed using eQuest, EnergyPlus, or any other building simulation software. Depending on the budget allocated to a given site, it may not be reasonable to extend the modeling effort to calibration. If, however, the project has been allocated sufficient resources, then the model can be calibrated with metering data, EMS data, or possibly with billing data. In the former cases, metered and/or EMS data can be used to directly calibrate specific end uses in the model. As an example, an eQuest model could be calibrated using air handler metered data by adjusting model parameters until the modeled air-handler profile matches the metered profile (within reason). Savings can then be assessed by running the calibrated post implementation model and the base case model with TMY3 weather and calculating the difference in annual energy consumption.

If using billing data for calibration, calibrate the *whole building*. The billing data approach requires calibrating the pre implementation model, since a year's worth of post install billing data will not be available for any of the ECAA-ARRA or EECBG projects. This approach is in contrast to the metered data calibration approach, which requires calibrating the post implementation model.

Using a calibrated modeling approach is taking a calculated risk. Occasionally, it is very difficult to calibrate a given model to desired tolerances. In some cases, days can be spent on a calibration task that was originally anticipated to take a few hours. As a result, calibrated models should be proposed only for sites with multiple interacting measures, or measures that cannot be readily evaluated using other, more straightforward approaches.

# Attachment IV: Sample Evaluation Plans

## Example Plan 1:
## Site Specific Plan – Del Norte, County of (001-10-ECE-ARRA)

This project is for the replacement and repair of various heating units serving the Del Norte jail facility. Nine measures were implemented at this site. The measures include the installation of high-efficiency liquid petroleum gas (LPG) furnaces, replacement or repair of economizer units, and replacement of the existing domestic hot water (DHW) boilers with LPG condensing DHW heaters. Below is a list of all nine measures as described in the documents provided to DNV KEMA.

1. Install new LP gas condensing furnaces in place of MZ-4 in roof top penthouse (4-zones)
1. Install a heat recovery unit on roof for 100 percent outside air unit #MZ-4
2. Install new LP gas condensing furnaces in place of MZ-6 in basement (6-zones)
3. Repair and replace economizer and add new premium efficiency motor to return fan
4. Install new LP gas condensing furnaces in place of AHU-54 in basement (3-zones)
5. Install return air and economizer to AHU-54 system
6. Install a new LPG condensing DHW heater for the jail's old section DHW
7. Replace 2 rooftop furnaces with new LPG condensing furnaces
8. Install two new LPG condensing DHW heater for the jail's new section DHW

The contractor estimated energy saving using bin analysis coupled with general assumptions on the heating equipment's operation. Major parameters used in the algorithm include nameplate data such as capacity, airflow rate, and efficiency along with assumptions for the return air temperatures across different outside air temperature bins. Overall, the analysis appears reasonable. The same algorithms will be used in the evaluation's calculations but will be enhanced using spot combustion efficiency measurements and logged data at the mixing boxes, where feasible.

During the site audit, all major end-use equipment will be verified by examining their nameplate data. The major equipment for this site include the LPG furnaces (13 total based on the calculations provided) and (3 total) DHW heaters. The economizer operations for the different heating systems will also be examined for functionality. The site audit will also include spot measurements on the hot water heaters and furnaces. In addition, temperature sensors will be placed at the HVAC mixing boxes along with a weather station measuring outside air in order correlate outside air temperature with the mixed air temperatures seen at the heating coil. This information will be used to inform the final energy calculations.

## Example Plan 2

### SD101 – DMV Oakland Coliseum Field Office

This project consisted of an interior and exterior lighting retrofit. According to the original project documentation, 24 occupancy sensors were slated for installation in addition to 141 T8 fixtures and 4 compact fluorescent lights (CFLs). Additionally, 41 exterior high-intensity discharge (HID) fixtures were to be replaced with induction fixtures. The evaluation approach for these lighting measures will follow the process outlined in the "Lighting Retrofits and Lighting Controls" general procedure summary.[7]

In addition to the lighting measures, variable-frequency drives (VFDs) were proposed for the building's air handlers. Based on available project documentation, it's unclear if this measure was ultimately implemented. Nonetheless, DNV KEMA has been supplied with the energy simulation models used to project energy savings from this measure. If this measure was implemented, then savings will be calculated using an updated version of the energy model revised based on building data collected on site in accordance with the "Building Simulation Modeling Generalized Approach" in the *ECAA and EECBG: Data Collection Field Measurement, and Site Analysis Procedures*.[8] If air handler related EMS data are available (power, outside air flow, supply air temperature), these data will also be collected to assist in calibrating the air handler end use. If EMS power data related to the air handlers are not available, true power meters will be installed for a three- to four-week period to observe air handler operation. These data will then be used to calibrate the air handler end use in the building simulation model. The calibration will be completed by adjusting air handler parameters (for example, minimum flow rate and maximum power) and secondary variables, such as plug loads, that affect air handler loads.

## Example Plan 3

### Site-Specific Plan – Albany, City of (021-09-ECE-ARRA)

This project is for the replacement of streetlights in the city of Albany. High-pressure sodium (HPS) lamps at various wattages were replaced with light-emitting diode (LED) lamps. Energy savings are achieved from replacing the high-wattage HPS lamps with the more efficient LED lamps. Per the project file, 640 lamps were replaced in Albany with financing coming from both the federal government and the State of California. Out of the total replaced lamps, 451 were replaced under the ECAA-ARRA Loan Program.

The evaluator plans to calculate the energy savings from this measure using a simple spreadsheet calculation method. Inputs include pre-existing and installed fixture wattages, quantities, and operating hours. The evaluator will conduct a short interview with the site contact to verify hours of operation and existing fixture types. The evaluator will visually verify the fixture installation and count the LED streetlights throughout the city. Attempts to verify all

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7 *ECAA and EECBG: Data Collection Field Measurement, and Site Analysis Procedures*.

8 Ibid.

the lighting fixtures will not be feasible with the large quantity of fixtures installed. A smaller sample of a few hundred will be verified during the site visit. The sample will be selected across the city rather than focusing on a location and will take into account different LED fixture wattages.

# APPENDIX C: Participant In-Depth Interview Guide

**Energy Efficiency Financing Program**

**Energy Conservation Assistance Account (ECAA-ARRA)**

**Decision Maker Survey**

**Interview Date:**

**Name of Interviewer:**

**Name of Interviewee:**

**Decision Maker's Organization:**

**ECAA-ARRA Loan Number:**

**EECBG Loan Number (if applicable):**

**Introduction**

Hello. I'm contacting you from DNV KEMA, an energy efficiency consulting firm on behalf of the Energy Commission as part of the evaluation of the Energy Efficiency Financing Program which is funded through the Energy Conservation Assistance Account (which you may know as ECAA-ARRA). We are interviewing ECAA-ARRA Loan participants to gain a better understanding of why participants decided to install energy efficiency measures with funding from this loan program. We would also like your feedback on your satisfaction with the program, and your assessment of job creation.

The interview and any information that is provided will remain strictly confidential. We will not identify or attribute any of your comments or organization information

**CONFIRMATION OF CORRECT RESPONDENT/ WARM-UP QUESTIONS**

W1. May I please speak with **<%CONTACT>**? According to our records, your organization implemented a project involving **<%MEASURES>** on approximately **<%INSTALL_DATE>,** is that correct?

W2. I was told by**<REFERENCE NAME**> that you were the most knowledgeable and the most involved with the decision to implement the project. Is that correct?

**[IF YES, SKIP TO W4.**

**IF NO, CONTINUE]**

W3. Who would be the person most knowledgeable about the decision to implement the energy efficiency project that I just described?

**Record <NEW CONTACT NAME> _____**

**and ask:** May I speak with him/her?

W4. What was your specific role in the project? _____

W5. Were others involved with the project decision making, particularly the go/no-go decision? If so, what are their names and contact information?

**Name: _____ Phone: _____**

W6. First, as I mentioned previously, our records indicate there was a project implemented at **<%SITE NAME>** consisting of **<%MEASURES>** . **[MENTION THE PROJECT DETAILS, INCLUDING MEASURE NAME(S) AND QUANTITIES, DATES IF KNOWN]**. Was this the project you were involved with?

| | | |
|---|---|---|
| 1 | Yes | Continue |
| 2 | No | Probe further until reconciled |
| 88 | Don't know | Can you refer me to someone that would know? |

W7. Were all of these measures installed as just described?

1 Yes
2 Yes, but the measure count is different _____(record here)
3 No Probe further until reconciled (such as final measure details are confirmed)

77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

W8. In deciding to do a project of this type, there are usually a number of reasons why it may be undertaken. In your own words, can you tell me why your organization decided to implement this project? Were there any other reasons? **DO NOT READ**

1 To replace old or outdated equipment
2 As part of a planned remodeling, build-out, or expansion
3 To gain more control over how the equipment was used
4 The maintenance downtime and associated expenses for the old equipment were too high
5 Had process problems and were seeking a solution
6 To improve measure performance
7 To improve the product quality
8 To comply with codes set by regulatory agencies
9 To improve facility safety
10 To comply with government policies regarding regular/normal maintenance/replacement policy
11 To get funding from the program

12 To protect the environment
13 To reduce energy costs
14 To reduce energy use/power outages
15 To update to the latest technology
77 Other (RECORD VERBATIM) _____

88 Don't know

99 Refused

W9. Were you actively involved in the ECAA-ARRA Loan for **<%SITE NAME>?**

1 Yes Continue

2 No Can you refer me to someone that would know?

**Name: _____ Phone: _____**

**A. Attribution QUESTIONS**

A1. When and how did the idea for this project originate?

**DO NOT READ PROMPTS**

1. Internally proposed
   Outside vendor or consultant (Probe: If applicable, was this person provided by the
   a. Energy Commission,
   b. a Utility Program,
   c. a local government program,
   d. a non-profit,
   e. some other type of Program or
   f. non-program affiliated?)\
2. Audit (Probe:
   a. Energy Commission
   b. other program or
   c. non-program)?
3. Information provided by the Energy Commission
4. Part of a larger modernization or remodeling effort
5. Part of an expansion

77. Other _____**(RECORD VERBATIM)**
88. Don't Know, Can't remember

A2. What was or were the roles for the ECAA-ARRA Loan program in making this project happen.

1. Funding, essential (was needed to move project forward),
2. Funding, helpful,
    a. (project may have proceeded without it, but loan helped somewhat)
3. Funding, non-essential,(loan did not influence implementation)

77. Other _____ **(RECORD VERBATIM)**
88. Don't Know, Can't remember

**If this project was funded by both an ARRA loan and an EECBG ARRA block grant, ask question A2a,:**

A2a. I understand that this city/county has both an ECAA-ARRA loan and a grant from the Energy Efficiency and Conservation Block Grant program. What was or were the roles for the combined ECAA-ARRA Loan and EECBG programs in making this project happen.

1. Funding, essential (was needed to move project forward),
2. Funding, helpful,
    a. (project may have proceeded without it, but loan helped somewhat)
3. Funding, non-essential,(loan did not influence implementation)

A3. Using a scale from 1 to 5, where 1 is "Not at all influential" and 5 is "Very influential" How influential was the ECAA-ARRA Loan Program to the implementation of the project,

**(Make sure it is consistent with the responses above)**

1. Not at all influential
2.
3.
4.
5. Very Influential

A4. Without assistance from the ECAA-ARRA Loan Program, the project

1. Would have been implemented exactly the same at exactly the same time
2. Would have been implemented at the same time but with less efficient equipment
3. Would have been delayed until another funding source was located or the existing equipment failed.
4. Would not have proceeded

77. Other _____**(RECORD VERBATIM)**

A5. Was the project "co-funded" with other federal funding, state funding, utility or third party energy efficiency program incentives?

1 Yes **(continue)**

2 No **(Skip to F1)**

88 Don't know (If you don't who would be the person that would know?)

A6. What other co-funding was obtained for this project in addition to the ECAA-ARRA Loan? (Include all that apply)

1 Utility funding **(continue to A7**)
2 ARRA Federal program funding **(continue to A7)**
3 Other non-ARRA Federal program funding **(continue to A7)**
4 Other state funding**(continue to A7)**
5 None. **(skip to F1)**
88 Don't know (If you don't who would be the person that would know?_____) **(skip to F1)**

**Co-Funding Questions (Ask for each source of Co-Funding)**

A7. What were the roles for the Co-funding source **(source #).**

1. Funding, essential (was needed to move project forward),
2. Funding, helpful, -
   a. (project may have proceeded without it, but this co-funding source helped somewhat)
3. Funding, non-essential,(this co-funding source did not influence implementation)

77. Other _____ **(RECORD VERBATIM)**
88. Don't Know Can't remember

A8. Using a scale from 1 to 5, where 1 is "Not at all influential" and 5 is "Very influential" How influential was the Co-funding program **(source #)** to the implementation of the project

**(Make sure it is consistent with the responses above)**

1. Not at all influential
2.
3.
4.
5.
6. Very Influential

A9. Without participation in and influence of the co-funding program **(source #)** that co-funded the project, the project

1. Would have implemented exactly the same at exactly the same time
2. Would have implemented at the same time but with less efficient equipment

3. Would have been delayed until another funding source was located or the pre-existing equipment failed.
4. Would not have proceeded

77. Other _____**(RECORD VERBATIM)**
88. Don't know, can't remember

**Repeat questions for A-7 to A9 for Each Co-Funding Source**

| Question | CF Source 1 | CF Source 2 | CF Source 3 | CF Source 4 |
|---|---|---|---|---|
| **Source Name** | | | | |
| **A7** | | | | |
| **A8** | | | | |
| **A9** | | | | |

**F. Financial BATTERY (ASK ALL)**

F1. Are there criteria that your city/county use before you update your energy equipment? (Probe: such as group relamping or HVAC upgrade every 10 years? Or rate of return on investment should be 3 years? Or payback should be 10 years?)

77 RECORD VERBATIM_____

88 Don't know

99 Refused

F2. What, if any, financial calculations does your organization make before proceeding with a project like this one?

77 RECORD VERBATIM_____

88 Don't know

99 Refused

F3. [IF PAYBACK OR RETURN ON INVESTMENT MENTIONED] Using a scale of 1 to 5, where 1 is very difficult and 5 is not difficult at all, How difficult or easy was it to develop a project that met the required payback period in order to qualify for the ECAA-ARRA loan?

1. Very difficult
2.

3.
4.
5. Not difficult at all
88 Don't know

99 Refused

**[If 1 or 2, ask: What made it difficult? RECORD VERBATIM_____]**

F4. How often does your organization consider the entire life-cycle cost of the equipment, including energy costs, maintenance cost, when purchasing equipment? Would you say it was **[read unbracketed items, select one]:**

1 Never,
2 Rarely,
3 Sometimes,
4 Most of the time, or
5 Always
88 [Don't know]

99 [Refused]

**Ask these questions for each measure or measure group:**

F5. Next we would like to know about the age and condition of the equipment that was replaced. Approximately when was the old equipment purchased?

1 Record Verbatim _____
88 [Don't know]

99 [Refused]

F6. On the average, how many years do you normally use such equipment?

1 Record Verbatim _____
88 [Don't know]

99 [Refused]

F7. Which of the following best describes the condition of the existing equipment when it was replaced?

1 Fully functional
2 Fully functional but with significant problems
3 Non-functional
88 [Don't know]

99 [Refused]

**S. Satisfaction Section**

Next I have some questions about your satisfaction with different aspects of this program. Using a scale of 1 to 5 where 1 = Very dissatisfied and 5= Very satisfied, how dissatisfied or satisfied are you with the:

| | Very Dissatisfied | | | | Very Satisfied | |
|---|---|---|---|---|---|---|
| C1. Equipment installed as part of this project | 1 | 2 | 3 | 4 | 5 | NA |
| C2. Loan amount received for the project | 1 | 2 | 3 | 4 | 5 | NA |
| C3. Loan structure and amortization schedule | 1 | 2 | 3 | 4 | 5 | NA |

Next I have some questions about the difficulty or ease of complying with various requirements of this program.

On a scale of 1 to 5, where 1 is very difficult and 5 is not difficult at all, how difficult was it to comply with the:

| | Very Difficult | | | | Not Difficult at all | |
|---|---|---|---|---|---|---|
| C4. Loan application requirements | 1 | 2 | 3 | 4 | 5 | NA |

**If difficult or very difficult (1or 2),** Can you please elaborate?

_____

| | | | | | | |
|---|---|---|---|---|---|---|
| C5. Davis Bacon Act (define if needed) | 1 | 2 | 3 | 4 | 5 | NA |

**If difficult or very difficult (1or 2),** Can you please elaborate?

_____

| | | | | | | |
|---|---|---|---|---|---|---|
| C6. Buy American Act requirements | 1 | 2 | 3 | 4 | 5 | NA |

**If difficult or very difficult (1or 2),** Can you please elaborate?

_____
_____

C7. National Historic Preservation Act 1 2 3 4 5 NA

**If difficult or very difficult (1or 2),** Can you please elaborate?

_____
_____

C8. Waste Management requirements 1 2 3 4 5 NA

**If difficult or very difficult (1or 2),** Can you please elaborate?

_____
_____

C12. Reporting Requirements to the Energy Commission 1 2 3 4 5 NA

**If difficult or very difficult (1or 2),** Can you please elaborate?

_____
_____

Next I have some questions about your satisfaction with your interactions with the Energy Commission. On a scale of 1 to 5, where 1 is very dissatisfied and 5 is very satisfied, how dissatisfied or satisfied were you with the:

Very Dissatisfied Very Satisfied

C13. Energy Commission's project management of the loan?

1 2 3 4 5 NA

C14. Communications with the Energy Commission's staff 1 2 3 4 5 NA

C16. Technical assistance from Energy Commission to develop projects

1 2 3 4 5 NA

C20. Do you have any comments or suggestions on how to improve the Loan Fund program?

_____

_____

## J. Job Creation

J1. You've accepted funding for the ECAA-ARRA loans under the ARRA program. I'd like to ask you about how this project has affected jobs at your operation. Are you the most knowledgeable person about jobs created or retained related to the ECAA-ARRA loan project?

1 Yes
2 No (ask J1a)
77 Other (RECORD VERBATIM)_____ (ask J1a)
_____
88 Don't know (ask J1a)

99 Refused

J1a. If not, who would be the person most knowledgeable about the decision to implement the energy efficiency project that I just described?

(Record Contact Name and Contact Information)

Were any jobs retained because of this project, that perhaps would have been eliminated if the project did not go forward?

3 Yes (Record Number)
4 No
77 Other (RECORD VERBATIM)_____

88 Don't know

99 Refused

J2. Were additional people hired retained because of this project?

5 Yes (Record Number)
1 No
77 Other (RECORD VERBATIM)_____

88 Don't know

99 Refused

J3. Do you know of jobs outside your operation that were retained because of the project?

1 Yes (Record Number)
2 No
77 Other (RECORD VERBATIM)_____

88 Don't know

99 Refused

J4. Do you know of jobs outside your operation that were added because of the project?

1 Yes (Record Number)
2 No
77 Other (RECORD VERBATIM)_____

88 Don't know

99 Refused

J5. Describe how the ARRA funding created jobs (probe, request anecdotes)

1 Layoffs avoided (RECORD Number and ADDITIONAL DETAILS VERBATIM)
2 Staff retained (RECORD Number and ADDITIONAL DETAILS VERBATIM)
3 New hires (RECORD Number and ADDITIONAL DETAILS VERBATIM)
4 Contract hires (RECORD Number and ADDITIONAL DETAILS VERBATIM)
5 Jobs for contractors or other outsiders (RECORD ADDITIONAL DETAILS VERBATIM)
77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

J6. What type of jobs were added or retained? What skills were required? (Probe, don't read the list). Fill out the table:

| Job Number | Job Type | Job Skills | Industry Category | Permanent or Temporary |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

(don't read this list – but fill in for each line after the survey is complete)

1 Administration
2 Administration (Sales )
3 Architecture and Engineering
4 Building Envelope (Construction Trades)
5 Building Envelope (Performance Trades)
6 Management (Blue-Collar)
7 Management (White-Collar)
8 Manufacturing
9 Mechanical and Electrical Trades
77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

Now I'd like to get your personal perspective on jobs.

J7.Is there anything we haven't talked about that you found interesting and would like to share related to jobs as part of your experience in the ECAA-ARRA program?

(RECORD VERBATIM)

_____

_____

**SP. SPILLOVER QUESTIONS [ASK ONLY IF Program Influence response A4 was somewhat or very influential]**

SP1. Did you implement any additional energy efficiency measures at your organization that were directly influenced through your participation in the Loan PROGRAM that did not receive incentives, grants or loans through any utility or government program?

1 YesSP2

2 No THANK AND TERMINATE

88 Refused THANK AND TERMINATE

99 Don't know THANK AND TERMINATE

SP2 Would you please describe these measures in detail? Type of influence, details of the measure (count, efficiency, and so forth ), what would have occurred in the absence of influence.

_____

_____

Thank and Terminate

# APPENDIX D:
# Population Level Program Tracking Data

**Table 2 – ECAA-ARRA Loan Projects – Ex Ante Electric and Therms Savings**

| ECAA-ARRA Loan Number | ECAA-ARRA Loan Recipient | Annual Ex Ante Electric Savings (kWh) | Annual Ex Ante Therm-Equivalent Savings (therms) | Measures |
|---|---|---|---|---|
| 001-09-ECE-ARRA | Marin, County of | 194,848 | - | Chiller Replacement, Air Handler repair, Lighting Retrofit |
| 001-10-ECE-ARRA | Del Norte, County of | (2,296) | 11,213 | DHW, HVAC furnaces, Economizers |
| 002-09-ECE-ARRA | Hillsborough, Town of | 184,531 | | Pumps/Fans/Motors, HVAC – Controls |
| 002-10-ECE-ARRA | Arroyo Grande, City of | 73,460 | 754 | HVAC Retrofit, Programmable Thermostats, Lighting Retrofit, Computer Power Management |
| 002-11-ECE-ARRA | Glenn, County of | 193,276 | 1,708 | HVAC packaged units, Lighting Retrofit |
| 003-10-ECE-ARRA | Duarte, City of | 149,790 | 348 | HVAC packaged units, Lighting Retrofit, HVAC Controls |
| 003-11-ECE-ARRA | Burlingame, City of | 473,000 | - | Streetlighting |
| 004-09-ECE-ARRA | Carlsbad, City of | 3,078,049 | - | Streetlighting |
| 004-11-ECE-ARRA | Ceres, City of | 1,321,960 | - | Streetlighting |
| 005-09-ECE-ARRA | Clovis, City of | 892,425 | 3,000 | HVAC, Lighting Retrofit, PC Power Management |
| 005-11-ECE-ARRA | Kerman, City of | 216,969 | - | Streetlighting |
| 006-09-ECE-ARRA | Chula Vista, City of | 881,314 | - | Streetlighting |
| 006-10-ECE-ARRA | Alameda, County of | 2,108,952 | - | Streetlighting |
| 006-11-ECE-ARRA | Salinas, City of | 318,368 | - | Lighting Retrofit |
| 007-10-ECE-ARRA | Hillsborough, Town of | 21,280 | - | Lighting Retrofit, Pumps/Fans/Motors |

| ECAA-ARRA Loan Number | ECAA-ARRA Loan Recipient | Annual Ex Ante Electric Savings (kWh) | Annual Ex Ante Therm-Equivalent Savings (therms) | Measures |
|---|---|---|---|---|
| 008-09-ECA-ARRA | Marin, County of | 311,655 | 44,723 | HVAC - Boilers, Building Shell Measures, Lighting Retrofit |
| 008-09-ECE-ARRA | Fairfield, City of | 2,578,116 | - | Streetlighting |
| 009-09-ECE-ARRA | Rancho Mirage, City of | 162,593 | - | Chiller and Controls Retrofit |
| 009-10-ECE-ARRA | Calimesa, City of | 11,350 | - | Heat Pumps and Controls |
| 010-09-ECE-ARRA | Grover Beach, City of | 171,020 | 1,837 | HVAC packaged units and controls, Traffic and Interior Lighting Retrofits, Computer Power Management, Vending Machine Miser |
| 011-09-ECE-ARRA | San Buenaventura, City of | 739,522 | - | Streetlighting, HVAC - Chillers, Pumps/Fans/Motors, Lighting Retrofit |
| 012-09-ECE-ARRA | Dinuba, City of | 522,602 | - | Pumps/Fans/Motors, Wastewater Treatment Measures |
| 013-09-ECE-ARRA | McKinleyville Community Services District | 56,900 | - | Pumps/Fans/Motors |
| 015-09-ECE-ARRA | Monterey, City of | 907,120 | - | Lighting Retrofit, Streetlighting |
| 020-09-ECE-ARRA | Sonoma Valley Health Care District | 328,584 | 1,463 | Lighting Retrofit, PC Power Management Measures, HVAC - Packaged Units |
| 021-09-ECE-ARRA | Albany, City of | 188,869 | - | Streetlighting |
| 022-09-ECE-ARRA | Butte Glenn Community College District | 369,551 | - | HVAC Retrofit, Pumps/Fans/Motors, Lighting Retrofit |
| 023-09-ECE-ARRA | Seaside, City of | 46,965 | 2,380 | Streetlighting, HVAC - Boiler |

| ECAA-ARRA Loan Number | ECAA-ARRA Loan Recipient | Annual Ex Ante Electric Savings (kWh) | Annual Ex Ante Therm-Equivalent Savings (therms) | Measures |
|---|---|---|---|---|
| 024-09-ECE-ARRA | Brisbane, City of | 107,114 | - | Streetlighting |
| 025-09-ECE-ARRA | San Benito, County of | 51,232 | - | HVAC – Chillers, Streetlighting |
| 027-09-ECE-ARRA | Hollister, City of | 14,840 | 229 | HVAC- Packaged units |
| Total | | 16,673,959 | 67,655 | |

Source: California Energy Commission

**Table 3 - ECAA-ARRA Loan Projects – Ex Ante Electric Generation**

| ECAA-ARRA Loan Number | ECAA-ARRA Loan Recipient | Annual Ex Ante Electric Generation (kWh) | Measures |
|---|---|---|---|
| 008-10-ECE-ARRA | Clovis, City of | 695,348 | Solar PV Project |
| 017-09-ECE-ARRA | Alameda, County of | 412,102 | Solar PV Project |
| Total | | 1,107,450 | |

Source: California Energy Commission

# APPENDIX E:
# On-site Evaluation Reports

## Alameda, County of (017-09-ECE-ARRA)

### Site Summary

The County of Alameda applied for Energy Conservation Assistance Act (ECAA-ARRA) loans for electric generating photovoltaic (PV) systems at the Castro Valley Library. This energy efficiency/generating measure (EEM) consisted of installing PV arrays on the library rooftop, DC-AC grid-tied inverters, a performance monitoring unit, and the balance of the system.

Katin Engineering Consulting (KEC), on behalf of DNV KEMA, visited the site to verify measure implementation. During the site visit, KEC verified the panel module and inverter manufacturers, model numbers, and quantities, as well as array characteristics such as orientation and tilt angle values. Estimates of annual electrical generation were computed by entering data from the site findings and product specification sheets into the California Solar Initiative Expected Performance Based Buydown (EPBB) Calculator found at www.csi-epbb.com. This ex post analysis, together with the ex ante calculations, was compared against the first-year electrical energy production logged by the performance monitoring unit for reasonableness. This performance monitoring data yielded an overall annual electric energy generation of 108.1 percent when compared to ex ante estimates. The energy generation by measure is provided in Table 4.

**Table 4: Energy Generation Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM1- PV Castro Valley Public Library | 412,102 | Not reported | N/A | 445,393 | 120 | N/A | 108% | N/A |
| Total | 412,102 | Not reported | N/A | 445,393 | 120 | N/A | 108% | N/A |

Source: DNV KEMA analysis

Ex post electrical energy generation are similar to ex ante estimates. One measure was evaluated (EEM1), which consisted of:

- Planned 250 kW output versus installed 245 kW.
- Recorded energy generation compared to the clean power estimator and CSI-EPBB calculator modeling.

Life-cycle generation was calculated relative to Baseline 1: the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures. The installed measures did not replace any existing electricity generating equipment; therefore, the life-cycle electricity generation is calculated as the total electrical energy generation over the EUL of the installation.

Results from Table 4 yield a life-cycle electrical energy generation of 11,424,336 kWh and 3,078 kW-years (Table 3).

**Table 5: Ex Post Life-cycle Electricity Generation Summary**

| Baseline Type | Electrical Energy Generation (kWh) | Electrical Demand Generation (kW-years) |
|---|---|---|
| Baseline 1 | 11,424,336 | 3,078 |

Source: DNV KEMA analysis

## Project Description

### **Measure 1:** PV Castro Valley Public Library

Six rooftop PV arrays totaling 880 solar panel modules were installed at the public library. The modules were wired to a single 250 kW DC-AC grid-tied inverter also installed under this project. Additionally, a performance data acquisition module was installed on the system so that visitors to the library lobby view the performance of the electric generation system. The system performance information is also available on the Internet through the library's website located at http://www.aclibrary.org/branches/csv/.

## Ex Ante Generation

### **Measure 1:** PV Castro Valley Public Library

Ex ante annual electrical energy generation calculations were performed by the Alameda County General Services Agency (GSA) and reported in its feasibility report of the Castro Valley Library solar photovoltaic project. The GSA modeled their proposed 249.4 kW AC system using the Go Solar California Clean Power Estimator. The results of the Clean Power Estimator model can be seen below in Table 6.

**Table 6: Ex Ante Hourly Output by Month of Proposed 249.4 kW AC System**

| Hour | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5:00 AM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6:00 AM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7:00 AM | 5 | 145 | 666 | 149 | 771 | 740 | 427 | 162 | 34 | 3 | 235 | 24 | 3,361 |
| 8:00 AM | 674 | 1,058 | 2,004 | 1499 | 2,239 | 2,005 | 2,051 | 1,502 | 1,169 | 839 | 1,334 | 814 | 17,188 |
| 9:00 AM | 1,636 | 1,948 | 2,959 | 2944 | 3,566 | 3,313 | 3,625 | 2,907 | 2,651 | 2,190 | 2,186 | 1,556 | 31,481 |
| 10:00 AM | 2,482 | 3,002 | 3,830 | 4039 | 4,597 | 4,307 | 4,922 | 4,159 | 3,953 | 3,121 | 2,921 | 2,221 | 43,554 |
| 11:00 AM | 3,054 | 3,419 | 4,302 | 4766 | 5,333 | 5,317 | 5,823 | 5,387 | 5,030 | 4,217 | 3,203 | 2,984 | 52,835 |
| 12:00 PM | 3,274 | 3,517 | 4,531 | 5269 | 5,829 | 5,853 | 6,469 | 5,972 | 5,504 | 4,471 | 3,223 | 2,876 | 56,788 |
| 1:00 PM | 2,954 | 3,483 | 4,428 | 5391 | 5,919 | 6,124 | 6,678 | 6,305 | 5,724 | 4,614 | 2,950 | 2,645 | 57,215 |
| 2:00 PM | 2,308 | 3,058 | 4,107 | 5083 | 5,626 | 5,932 | 6,468 | 6,160 | 5,418 | 4,233 | 2,107 | 2,065 | 52,565 |
| 3:00 PM | 1,431 | 2,146 | 3,133 | 4388 | 5,252 | 5,284 | 5,820 | 5,312 | 4,623 | 3,443 | 1,077 | 1,139 | 43,048 |
| 4:00 PM | 408 | 992 | 1,792 | 3590 | 4,030 | 4,375 | 4,754 | 4,179 | 3,462 | 2,312 | 130 | 142 | 30,166 |
| 5:00 PM | 0 | 25 | 273 | 2090 | 2,727 | 2,987 | 3,368 | 2,841 | 1,789 | 862 | 0 | 0 | 16,962 |

| Hour | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6:00 PM | 0 | 0 | 0 | 738 | 1,284 | 1,596 | 1,747 | 1,239 | 299 | 2 | 0 | 0 | 6,905 |
| 7:00 PM | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| 8:00 PM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| kWh | 18,226 | 22,793 | 32,025 | 39,946 | 47,173 | 47,868 | 52,152 | 46,125 | 39,656 | 30,307 | 19,366 | 16,466 | 412,103 |

Source: DNV KEMA analysis

* Rounding errors result in this reproduced table displaying 412,103 kWh, while the actual Clean Power Estimator output 412,102 kWh total annual electric energy generation.

DNV KEMA spoke with Adel Suleiman, the California Energy Commission project manager for this ECAA-ARRA loan, to verify their energy generation calculation method. Suleiman reported to DNV KEMA that the Energy Commission confirmed the GSA's estimate for annual electric energy generation was realistic for the size and geographic location of the proposed PV system. The estimated 412,102 kWh output for a 282.2 kW DC system gives an annual energy production factor of 1,460 kWh/ kW DC. This value is conservative for the San Francisco region, which can range from 1,379 to 1,724 kWh/ kW DC according to the California Energy Commission's Guide to Photovoltaic (PV) System Design and Installation.

## Project Evaluation

The KEC engineering team visited the project site on November 22, 2011, to verify measure installations and gather data on equipment model numbers and quantity as well as panel array characteristics. Table 7 summarizes the results of the installation verification.

**Table 7: Verification Summary**

| Site | Equipment | Reported | Verified | Site Notes |
|---|---|---|---|---|
| Castro Valley Public Library | PV modules | 896 modules (284.24 kW DC) | 880 modules (277.2 kW DC) | Original system design for 896 modules but fire codes necessitated reduction to 880 modules |
| Castro Valley Public Library | DC-AC inverter | 1 (250 kW DC) | 1 (250 kW DC) | Verified 240.1 kW AC rated power output. |
| Castro Valley Public Library | Performance data acquisition module | 1 | 1 | Includes flat-screen monitor in Library lobby and web-based system performance displays |

Source: DNV KEMA analysis

DNV KEMA calculated the DC and AC power output values for the system using the following two equations:

$$DC\ power\ output\ (kW) = \frac{\#_{panels} \times W_{STC}}{1000 \frac{W}{kW}}$$

$$AC\ power\ output\ (kW) = \frac{\#_{panels} \times W_{PTC} \times \eta_{inverter} \times \eta_{derate}}{1000 \frac{W}{kW}}$$

where,

- $\#_{panels}$ is the quantity of panel modules
- $W_{STC}$ is the power output (watts) of the panel module under standard test conditions (STC)
- $W_{PTC}$ is the power output (watts) of the panel module under PVUSA test conditions (PTC)
- $_{inverter}$ is the efficiency of the inverter module
- $_{derate}$ is a system derate factor that accounts for panel mismatch, wiring losses, panel soiling, and so forth. This value is 98 percent (two percent loss).

DNV KEMA calculated summer on peak demand reduction to be the average power output of the system minus the average building load during the peak electricity demand period from 2-3 p.m. in early August 2011, as shown in the equation below:

$$Summer\ On\ Peak\ Demand\ Reduction\ (kW) = Power_{Generated}(kW) - Power_{Load}\ (kW)$$

The ex post annual electric energy generation was modeled using the CSI-EPBB online calculator, which is driven by the National Renewable Energy Laboratory (NREL) PV Watts v.2 calculator. Pertinent input values for the calculator include postal zip code of system location, PV module make and model, quantity of modules, array standoff height, inverter make and model, array shading, array tracking, array tilt, and array azimuth. Results from the calculator include capacity factors, available incentive values, system size, and annual kWh generated. Only the annual kWh generated result was used in this evaluation. Site-specific equipment and array characteristics are presented in the three measure sections below. Table 8 summarizes the verified array characteristics for the site.

**Table 8: Panel Array Summary**

| Site | Verified Array Characteristics | | | |
|---|---|---|---|---|
| | Array Tilt (degrees) | Array Azimuth (degrees) | Standoff Height (inches) | Shading |
| Castro Valley Public Library | 10 | 180 | >6 | Minimal |

Source: DNV KEMA analysis

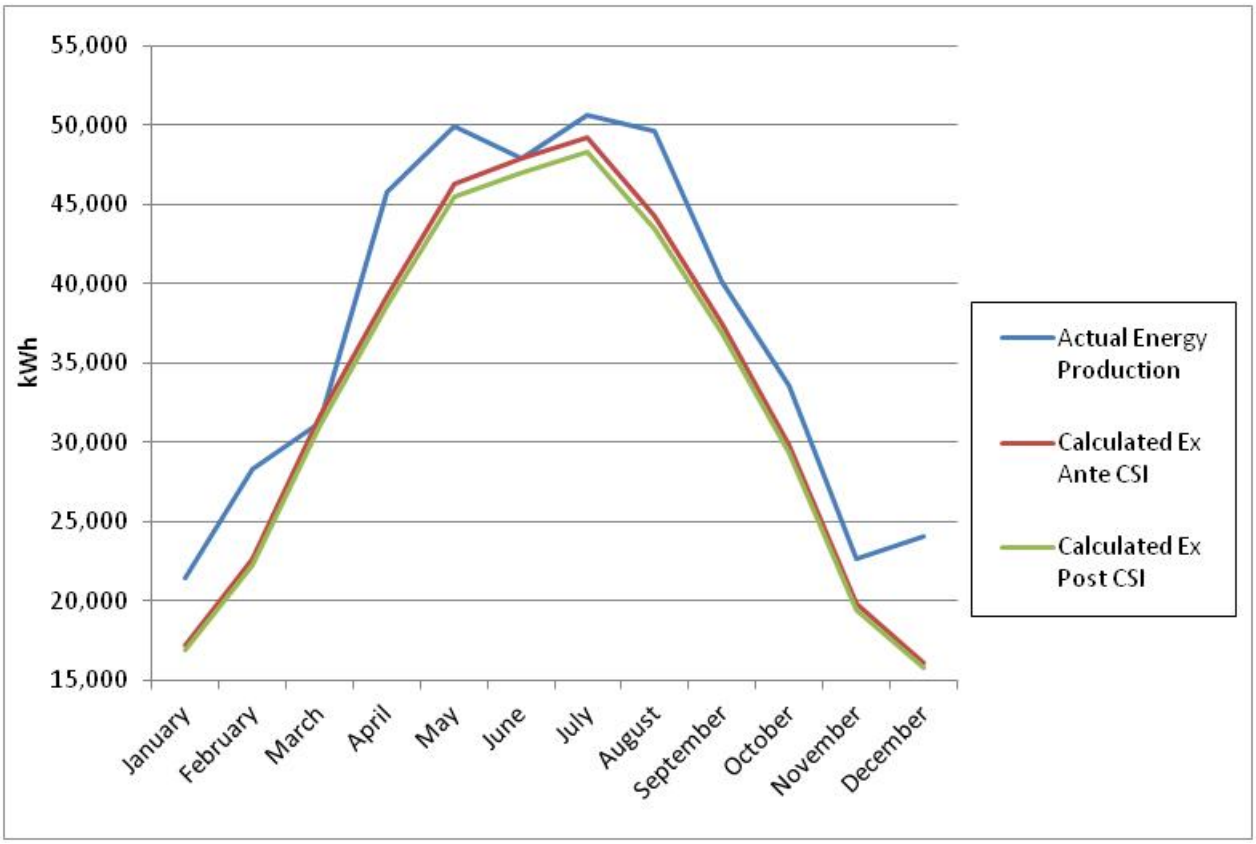
**Measure 1:** PV Castro Valley Public Library

At the public library the KEC engineering team verified the installation of six PV arrays totaling 880 SunPower Corp. SPR-315E-WHT-U panel modules, one SatCon Technology PVS-250 (208V) 250 kW DC-AC inverter, and one EMB Acqui Suite Model A8819 performance data acquisition system. Originally the system array was designed for installation of 896 panel modules to output 249.4 kW AC. However, because fire codes require an access aisle in the middle of the arrays, the total number of panel modules installed was reduced to 880. On the main library roof, four large arrays (800 panels) are mounted on racks parallel to the roof surface, which is tilted 10 degrees relative to a horizontal plane and oriented south. Two smaller arrays (80 panels) are located on flat roof sections of the library and so are mounted on racks that are themselves tilted at 10 degrees relative to a horizontal plane and oriented south. Standoff height of all the arrays is greater than six inches. The system was commissioned on March 2, 2011, and was generating electricity at the time of the site visit.

## Generation Results

The CSI-EPBB online calculator estimated the project would generate 394,393 kWh of electrical energy in the first year, while the performance monitoring system recorded generation to be 445,393 kWh of electrical energy in the first year. Figure 7 shows the ex ante, ex post, and the actual first -ear recorded annual energy production for each month of the year.

**Figure 7: Actual Versus Calculated First Year Electrical Energy Production**




Source: DNV KEMA analysis

From the above figure, it is clear that the recorded generation is greater than either of the calculation estimates, with the exception of the months of March and June, where the three values are nearly equal. The reason for these decreases in actual output for March and June could be below-average solar insolation; however, on-site insolation data was not provided for verification of this hypothesis.

The difference of the ex post calculated and the metered annual generation values is below 12 percent. Given the number of variables and assumptions involved in the estimation of annual energy generation, the metering data is in reasonable agreement with the estimation method. Therefore, the annual generation value from the performance monitoring system will be the reported value. This figure represent a realization rate 108.1 percent, compared to the ex ante estimates. Based upon the performance monitoring data and calculation method described above, the project reduced summer on peak demand by 120 kW in the first year.

## Discussion

The Castro Valley Library PV system that was actually installed is 5 kW smaller, or about 1.8 percent less, than the ex ante calculated system. The result of the smaller system is a proportional 1.8 percent reduction in calculated annual kWh and kW demand reduction.

Compared to the Clean Power Estimator calculation of annual electric energy generation, the CSI-EPBB calculator estimates are around 2.6 percent lower when modeling an optimally sited and oriented system. Moreover, all the units have low tilt angles that reduce the total annual kWh output, further reducing the ex post annual electric energy output. The lower tilt angle increases the system output during the summer production period, and so it increases the summer on peak demand reduction of the system.

Compared to the ex ante and ex post calculation, the actual metered annual generation is generally greater than either calculation predicted—with the exceptions March and June, as mentioned in the proceeding section. The better-than-expected performance of this system is not easily explained, given the available information on array and equipment characteristics or with the annual generation data provided by the Energy Commission. A variety of factors could be contributing to high performance of this system, with the three most likely influences being a higher overall DC-to-AC derate (calculations use default of 0.77), greater solar insolation during the metered year than TYM3 average solar insolation, or possibly a greater array tilt angle than what was recorded by Katin Engineering Consulting. Taken collectively, minor discrepancies of these factors could cause the production of the system to increase by the magnitude in question. While it is beyond the scope of this evaluation to determine exactly why the system has over performed the output expectations, it is not unreasonable to claim that this system can perform at the level indicated by the performance monitoring data.

### *Ex Post Life-cycle Electricity Generation*

Electricity generation for this program is calculated relative to an established baseline. Baseline 1 considers the existing conditions found before the energy generation measure implementation and takes into account the existing equipment's operating efficiency along with the control strategies found at that time. Life-cycle generation for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. Because this electrical generation measure is an add-on and does not replace any existing equipment, the life-cycle electrical generation is calculated as the total electrical energy generation over the EUL of the installation.

First-year electric energy generation for the measure is 445,393 kWh, and first-year electrical demand generation is 120 kW. Power performance degradation caused by aging and weathering of the modules and components has been included in the life-cycle generation calculation. Studies suggest that the range of system power performance degradation is between negative 0.2 and 2 percent per year. A value of negative 1 percent per year of operation has been factored into the annual electric energy generation to account for the power performance degradation.

**Table 9: Values Used in Ex Post Life-cycle Generation Calculations**

| Measure | Early Replacement | | EUL (years) |
|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | |
| EEM1- PV Public library | 445,393 | 0 | 30 |

Source: DNV KEMA analysis

**Table 10: Baseline 1 Life-cycle Generation**

| EUL Year | Year | Electric Energy Generation(kWh/ yr) | Electrical Demand (kW) |
|---|---|---|---|
| 1 | 2011 | 445,393 | 120 |
| 2 | 2012 | 440,939 | 119 |
| 3 | 2013 | 436,485 | 118 |
| 4 | 2014 | 432,031 | 116 |
| 5 | 2015 | 427,577 | 115 |
| 6 | 2016 | 423,124 | 114 |
| 7 | 2017 | 418,670 | 113 |
| 8 | 2018 | 414,216 | 112 |
| 9 | 2019 | 409,762 | 110 |
| 10 | 2020 | 405,308 | 109 |
| 11 | 2021 | 400,854 | 108 |
| 12 | 2022 | 396,400 | 107 |
| 13 | 2023 | 391,946 | 106 |
| 14 | 2024 | 387,492 | 104 |
| 15 | 2025 | 383,038 | 103 |
| 16 | 2026 | 378,584 | 102 |
| 17 | 2027 | 374,130 | 101 |
| 18 | 2028 | 369,676 | 100 |
| 19 | 2029 | 365,222 | 98 |
| 20 | 2030 | 360,768 | 97 |
| 21 | 2031 | 356,315 | 96 |
| 22 | 2032 | 351,861 | 95 |
| 23 | 2033 | 347,407 | 94 |
| 24 | 2034 | 342,953 | 92 |
| 25 | 2035 | 338,499 | 91 |
| 26 | 2036 | 334,045 | 90 |
| 27 | 2037 | 329,591 | 89 |

| EUL Year | Year | Electric Energy Generation(kWh/yr) | Electrical Demand (kW) |
|---|---|---|---|
| 28 | 2038 | 325,137 | 88 |
| 29 | 2039 | 320,683 | 86 |
| 30 | 2040 | 316,229 | 85 |
| Life-cycle | Total | 11,424,335 kWh | 3,078 kW-years |

Source: DNV KEMA analysis

## Alameda, County of (006-10-ECE-ARRA)

### Site Summary

The County of Alameda applied for Energy Conservation Assistance Act (ECAA-ARRA) loans to replace high-pressure sodium (HPS) streetlight fixtures with high-efficiency light-emitting-diode (LED) streetlight fixtures in unincorporated Alameda County. The original plan was to replace 7,500 fixtures; however, the final number was reduced to 6,820 fixtures before implementation. The evaluation is based on the final plan, following confirmation from the Energy Commission that the project scope was reduced to 6,820 fixtures.

Katin Engineering Consulting (KEC), on behalf of DNV KEMA, visited the site to verify the implementation of this measure. During the site visit, KEC verified the installation by visually sighting a sample of the newly installed street-light fixtures. The project yielded an overall annual electric energy savings of 90.9 percent when compared to the Baseline 1 ex ante estimates. There were no natural gas savings for this project. Table 11 summarizes the ex ante and ex post savings estimates.

**Table 11: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| 23 W LED Streetlighting | 965,657 | Not reported | N/A | 794,287 | N/A | N/A | 82.3% | N/A |
| 49 W LED Streetlighting | 518,122 | Not reported | N/A | 503,288 | N/A | N/A | 97.1% | N/A |
| 77 W LED Streetlighting | 315,571 | Not reported | N/A | 295,694 | N/A | N/A | 93.7% | N/A |
| 105 W LED Streetlighting | 135,000 | Not reported | N/A | 143,445 | N/A | N/A | 106.3% | N/A |
| 135 W LED Streetlighting | 174,602 | Not reported | N/A | 179,422 | N/A | N/A | 102.8% | N/A |
| Total | 2,108,952 | Not reported | N/A | 1,916,136 | N/A | N/A | 90.9% | N/A |

Source: DNV KEMA analysis

The difference in energy savings is based on the method PG&E uses to calculate savings. It assesses a monthly energy consumption for streetlights for both the existing and new fixtures. This assessment results in some differences compared to the calculation using actual fixture wattages and operating hours.

The life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful (RUL) of the pre-existing equipment is exceeded.

For this project, the life-cycle savings estimated relative to Baseline 1 and Baseline 2 are the same. The life-cycle savings summary can be found in Table 12.

**Table 12: Ex Post Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 28,742,042 | 6,562 | - |

Source: DNV KEMA analysis

## Project Description

This project was implemented throughout unincorporated areas of Alameda County. LED streetlighting fixtures are higher efficacy and produce more accurate color rendering than the traditional HPS fixtures. Photographs indicating the visual difference between the HPS fixtures and the new LED fixtures are shown below.

**Figure 8: A High-Pressure Sodium (HPS) Streetlight Fixture**

Photo Credit: Katin Engineering

**Figure 9: Light-Emitting Diode (LED) Streetlight Fixture**

Photo Credit: Katin Engineering

***Measure 1:*** *Street lighting retrofit*

This measure was for the replacement of pre-existing HPS streetlighting fixtures with more efficient LED streetlighting fixtures. A total of 6,820 new street lights were installed under this measure. The pre-existing street light wattages range from 70 to 250 watts, while the new energy-efficient fixture wattages range from 23 to 135 watts. A comparison of the pre-existing and new streetlighting fixtures can be found in Table 13.

**Table 13: Summary of Pre- and Postretrofit Fixtures**

| Preretrofit Fixtures | | | Postretrofit Fixtures | | |
|---|---|---|---|---|---|
| Fixture Wattage | No. of Fixtures | Fixture Type | Fixture Wattage | No. of Fixtures | Fixture Type |
| 70 | 3,778 | HPS | 23 | 3,778 | LED |
| 100 | 1,741 | HPS | 49 | 1,741 | LED |
| 150 | 785 | HPS | 77 | 785 | LED |
| 200 | 250 | HPS | 105 | 250 | LED |
| 250 | 266 | HPS | 135 | 266 | LED |
| | Total: 6,820 | | | Total: 6,820 | |

Source: DNV KEMA analysis

## Ex Ante Savings

Ex ante savings were calculated using a spreadsheet analysis based on kWh/month for a given nominal fixture wattage, quantity of fixtures, and estimated annual operating hours. Savings were first calculated by fixture groups, and the fixture group savings were summed to estimate gross project savings. Fixture group savings were calculated using the following equation:

$$Annual\ electric\ savings\ (kWh) = \frac{n \times (W_{HPS} - W_{LED}) \times hours_{annual}}{1000 \frac{W}{kW}}$$

where,

- n is the number of affected fixtures in the fixture group
- WHPS is the wattage of the existing HPS fixture
- WLED is the wattage of the new LED fixture
- Hours annual is the estimated annual operating hours for the fixture. All of the streetlights are controlled by photocells that sense daylight. Because of this, the fixtures operate an average of 12 hours throughout the year. Therefore, annual operating hours for all fixtures is 4,380 hours.

## Project Evaluation

A KEC engineer visited the project site on November 28, 2011, to verify measure installations, acquire specific nameplate information, and gather operating schedules to assist in the energy saving analysis. The engineer visually verified the installation of nearly 6 percent (404 of 6,820) of the new LED streetlighting fixtures. Ex post energy savings were calculated using the same method using spreadsheet analysis based on fixture wattages, quantity of fixtures, and estimated annual operating hours. Savings were first calculated by fixture groups, and the fixture group savings were summed to estimate gross project savings. Fixture group savings were calculated using the following equation:

$$Annual\ electric\ savings\ (kWh) = \frac{n \times (W_{HPS} - W_{LED}) \times hours_{annual}}{1000 \frac{W}{kW}}$$

where,

- n is the number of affected fixtures in the fixture group
- WHPS is the actual wattage of the existing HPS fixture
- WLED is the actual wattage of the new LED fixture
- Hours annual is the estimated annual operating hours for the fixture. All of the streetlights are controlled by photocells that sense daylight. Because of this, the fixtures operate an average of 12 hours a throughout the year. Therefore, annual operating hours for all fixtures is 4,380 hours.

A summary of the measure installation sampling can be found in Table 14, and the ex post savings analysis can be found in Table 15.

**Table 14: Summary of Verified Street Lighting Locations**

| Community | Street | No. of Fixtures |
|---|---|---|
| San Lorenzo | On Hesperian Blvd. between West A St. and Grant Ave. | 76 |
| San Lorenzo | On Grant Ave. between Hesperian blvd. and Channel St. | 18 |
| San Lorenzo | On Channel St. between Grant Ave. and Bockman Rd. | 11 |
| San Lorenzo | On Bockman Rd between Channel St. and Hesperian Blvd. | 20 |
| Cherryland | On Hacienda Ave. between Hesperian Blvd. and Hathaway Ave. | 10 |
| Cherryland | On Hathaway Ave. between Hacienda Ave. and W Blossom Way | 5 |
| Cherryland | O Blossom Way between Hathaway Ave. and Mission Blvd. | 30 |
| Cherryland | On Mission Ave. between Blossom Way and Mattox Rd. | 20 |
| Cherryland | On Mattox Ave. between Mission Ave. and Foothill Blvd. | 17 |
| Castro Valley | On Castro Valley Blvd. between Mattox Ave. and Redwood Rd. | 111 |
| Castro Valley | On Redwood Rd. between Castro Valley Blvd. and A St. | 79 |
| Castro Valley | On A St. between Redwood Rd. and East A St. | 7 |
| | Total new LED lamps sighted | 404 |

Source: DNV KEMA analysis

**Table 15: Ex Post Savings Analysis**

| Number of Lights Replaced | Annual Operating Hours | Lighting Type | Actual Fixture Watts | kWh/yr for This Fixture Group | Lighting Type | Actual Fixture Watts | kWh/yr for This Fixture Group | Total Annual kWh Savings |
|---|---|---|---|---|---|---|---|---|
| 3778 | 4380 | HPS | 85 | 1,406,549 | LED | 37 | 612,263 | 794,287 |
| 1741 | 4380 | HPS | 120 | 915,070 | LED | 54 | 411,781 | 503,288 |
| 785 | 4380 | HPS | 176 | 605,141 | LED | 90 | 309,447 | 295,694 |

| Number of Lights Replaced | Annual Operating Hours | Lighting Type | Actual Fixture Watts | kWh/yr for This Fixture Group | Lighting Type | Actual Fixture Watts | kWh/yr for This Fixture Group | Total Annual kWh Savings |
|---|---|---|---|---|---|---|---|---|
| 250 | 4380 | HPS | 237 | 259,515 | LED | 106 | 116,070 | 143,445 |
| 266 | 4380 | HPS | 293 | 341,368 | LED | 139 | 161,946 | 179,422 |
| Total: 6,820 | | | | Total: 3,527,643 | | | Total: 1,611,507 | Total: 1,916,136 |

Source: DNV KEMA analysis

## Savings Results

The project saved 1,916,136 kWh of energy in the first year and represents a 90.9 percent realization rate compared to the ex ante estimates.

### *Ex Post Life-cycle Savings*

Energy savings for this program are calculated relative to an established baseline. Baseline 1 considers the existing conditions found before energy efficiency measure implementation and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the expected-replacement baseline of the measure is used. This baseline considers either minimally code-compliant conditions or standard practice when no code is applicable.

The table below provides life-cycle savings for the project relative to Baseline 1 on a year-by-year basis through the EUL of the longest-lived measure. Under this baseline, energy savings were presumed to occur relative to the pre-existing equipment for the duration of the life of each measure. For this project, the life-cycle savings estimates relative to Baseline 2 (dual baseline) are the same as the life-cycle savings relative to Baseline 1.

First-year electric energy savings for the measures implemented is 1,916,136 kWh. There are no peak demand savings, as the lights only operate off peak. Life-cycle savings for the streetlighting measure was calculated on the basis of a 15-year effective useful life (EUL) estimate from the California Database for Energy Efficient Resources (DEER).

**Table 16: Values Used in Ex Post Life-cycle Savings Calculations**

| Measure | Early Replacement | | EUL (years) |
|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | |
| 23 W LED Streetlighting | 794,287 | N/A | 15 |
| 49 W LED Streetlighting | 503,288 | N/A | 15 |
| 77 W LED Streetlighting | 295,694 | N/A | 15 |
| 105 W LED Streetlighting | 143,445 | N/A | 15 |
| 135 W LED Streetlighting | 179,422 | N/A | 15 |
| Total | 1,916,136 | N/A | - |

Source: DNV KEMA analysis

**Table 17: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) |
|---|---|---|
| 1 | 2011 | 1,916,136 |
| 2 | 2012 | 1,916,136 |
| 3 | 2013 | 1,916,136 |
| 4 | 2014 | 1,916,136 |
| 5 | 2015 | 1,916,136 |
| 6 | 2016 | 1,916,136 |
| 7 | 2017 | 1,916,136 |
| 8 | 2018 | 1,916,136 |
| 9 | 2019 | 1,916,136 |
| 10 | 2020 | 1,916,136 |
| 11 | 2021 | 1,916,136 |
| 12 | 2022 | 1,916,136 |
| 13 | 2023 | 1,916,136 |
| 14 | 2024 | 1,916,136 |
| 15 | 2025 | 1,916,136 |
| 16 | 2026 | 0 |
| Life-cycle | Total | 28,742,040 kWh |

Source: DNV KEMA analysis

## Albany, City of (021-09-ECE-ARRA)

### Site Summary

This streetlight project consists of replacing 651 HPS fixtures (70 W to 400 W) with LED fixtures (20 W to 90 W). Funding for this project comes both from EECBG and ECAA-ARRA programs. Only the portion of the lighting coming from the ECAA-ARRA program is considered in the energy savings analysis reported here. In the original application, 451 fixtures received funding from ECAA-ARRA but were later revised to 453. In contrast, a total of 189 fixtures received funding from EECBG. The portion of fixtures attributed to ECAA-ARRA, therefore, represent 70.6 percent of all fixtures. Since there were nine extra fixtures that were ultimately installed (based on the tracking data from the city), a proportional percentage based on total fixtures reported in the original study will be considered part of the ECAA-ARRA funds (70.6 percent or 6 out of 9 of the fixtures).

Annual operating hours for all fixtures that were photocell-controlled are 4,309 and are based on an analysis of the sunrise and sunset times for the city location. Installation verification was performed by randomly sampling 14 percent of the total fixtures that were selected across the city and included all the fixture wattage types for this project. All sampled fixtures were found to have been retrofitted exactly as described in the tracking spreadsheet provided by the city. Ex post energy savings is 106 percent of ex ante estimates as a result of to higher annual operating hours and additional fixture replacement quantities.

There was one HPS fixture that was replaced with a higher wattage LED fixture. This fixture was not sampled during the site visit, but based on the consistent results found during the verification, it is assumed that the records provided by the city of Albany were correct. Life-cycle savings are calculated at 3,001,177 kWh using a standard 15-year EUL for LED streetlights.

**Table 18: Annual Energy Savings Summary**

| Measure | Ex-Ante Electric Savings (kWh) | Ex-Post Electric Savings (kWh) | Realization Rate |
|---|---|---|---|
| Street Lighting Retrofit | 188,869 | 200,078 | 106% |

**Source: DNV KEMA analysis**

**Table 19: City Retrofit Claims**

| Pre-existing Fixtures | | | Installed Fixtures | | | |
|---|---|---|---|---|---|---|
| Type | Nominal Wattage | Functional Wattage | Type | Nominal Wattage | Functional Wattage | Fixture Count |
| HPS | 70 | 85 | LED | 20 | 37 | 188 |
| HPS | 70 | 85 | LED | 30 | 54 | 2 |
| HPS | 70 | 85 | LED | 60 | 106 | 1 |
| HPS | 100 | 120 | LED | 30 | 54 | 6 |
| HPS | 150 | 176 | LED | 30 | 54 | 23 |
| HPS | 150 | 176 | LED | 50 | 90 | 24 |
| HPS | 200 | 234 | LED | 60 | 106 | 2 |
| HPS | 200 | 234 | LED | 90 | 163 | 1 |
| HPS | 400 | 468 | LED | 90 | 163 | 1 |
| HPS | 150 | 176 | LED | 20 | 37 | 1 |
| HPS | 70 | 100 | LED | 20 | 37 | 1 |
| HPS | 100 | 138 | LED | 30 | 54 | 1 |
| HPS | 150 | 201 | LED | 50 | 90 | 3 |
| HPS | 200 | 237 | LED | 60 | 106 | 84 |
| HPS | 200 | 237 | LED | 90 | 163 | 10 |
| HPS | 250 | 293 | LED | 60 | 106 | 2 |
| HPS | 250 | 293 | LED | 90 | 163 | 2 |
| HPS | 400 | 451 | LED | 80 | 139 | 1 |
| HPS | 400 | 451 | LED | 90 | 163 | 19 |
| HPS | 200 | 237 | LED | 80 | 139 | 2 |
| HPS | 250 | 293 | LED | 80 | 139 | 79 |

Source: DNV KEMA analysis

**Table 20: Verified Revised Fixtures**

| Pre-existing Fixtures | | | Installed Fixtures | | | | |
|---|---|---|---|---|---|---|---|
| Type | Nominal Wattage | Functional Wattage | Type | Nominal Wattage | Functional Wattage | Fixture Count | Energy Savings |
| HPS | 100 | 138 | LED | 30 | 54 | 1 | 362 |
| HPS | 150 | 201 | LED | 50 | 90 | 3 | 1,435 |
| HPS | 200 | 237 | LED | 90 | 163 | 10 | 3,189 |
| HPS | 200 | 237 | LED | 60 | 106 | 84 | 47,419 |
| HPS | 200 | 237 | LED | 80 | 139 | 2 | 845 |
| HPS | 250 | 293 | LED | 90 | 163 | 2 | 1,120 |
| HPS | 250 | 293 | LED | 60 | 106 | 2 | 1,612 |
| HPS | 250 | 293 | LED | 80 | 139 | 79 | 52,426 |

| Pre-existing Fixtures | | | Installed Fixtures | | | | |
|---|---|---|---|---|---|---|---|
| Type | Nominal Wattage | Functional Wattage | Type | Nominal Wattage | Functional Wattage | Fixture Count | Energy Savings |
| HPS | 400 | 451 | LED | 80 | 139 | 1 | 1,344 |
| HPS | 400 | 451 | LED | 90 | 163 | 19 | 23,580 |
| HPS | 70 | 100 | LED | 20 | 37 | 1 | 271 |
| HPS | 100 | 120 | LED | 30 | 54 | 6 | 1,706 |
| HPS | 150 | 176 | LED | 50 | 90 | 23 | 8,524 |
| HPS | 150 | 176 | LED | 30 | 54 | 24 | 12,617 |
| HPS | 150 | 176 | LED | 20 | 37 | 1 | 599 |
| HPS | 200 | 234 | LED | 60 | 106 | 2 | 1,103 |
| HPS | 200 | 234 | LED | 90 | 163 | 1 | 306 |
| HPS | 400 | 468 | LED | 90 | 163 | 1 | 1,314 |
| HPS | 70 | 85 | LED | 20 | 37 | 194 | 40,128 |
| HPS | 70 | 85 | LED | 30 | 54 | 2 | 267 |
| HPS | 70 | 85 | LED | 60 | 106 | 1 | -90 |
| | | | | | | Total | 200,077 |

Source: DNV KEMA analysis

**Figure 10: Verified Sample Area**

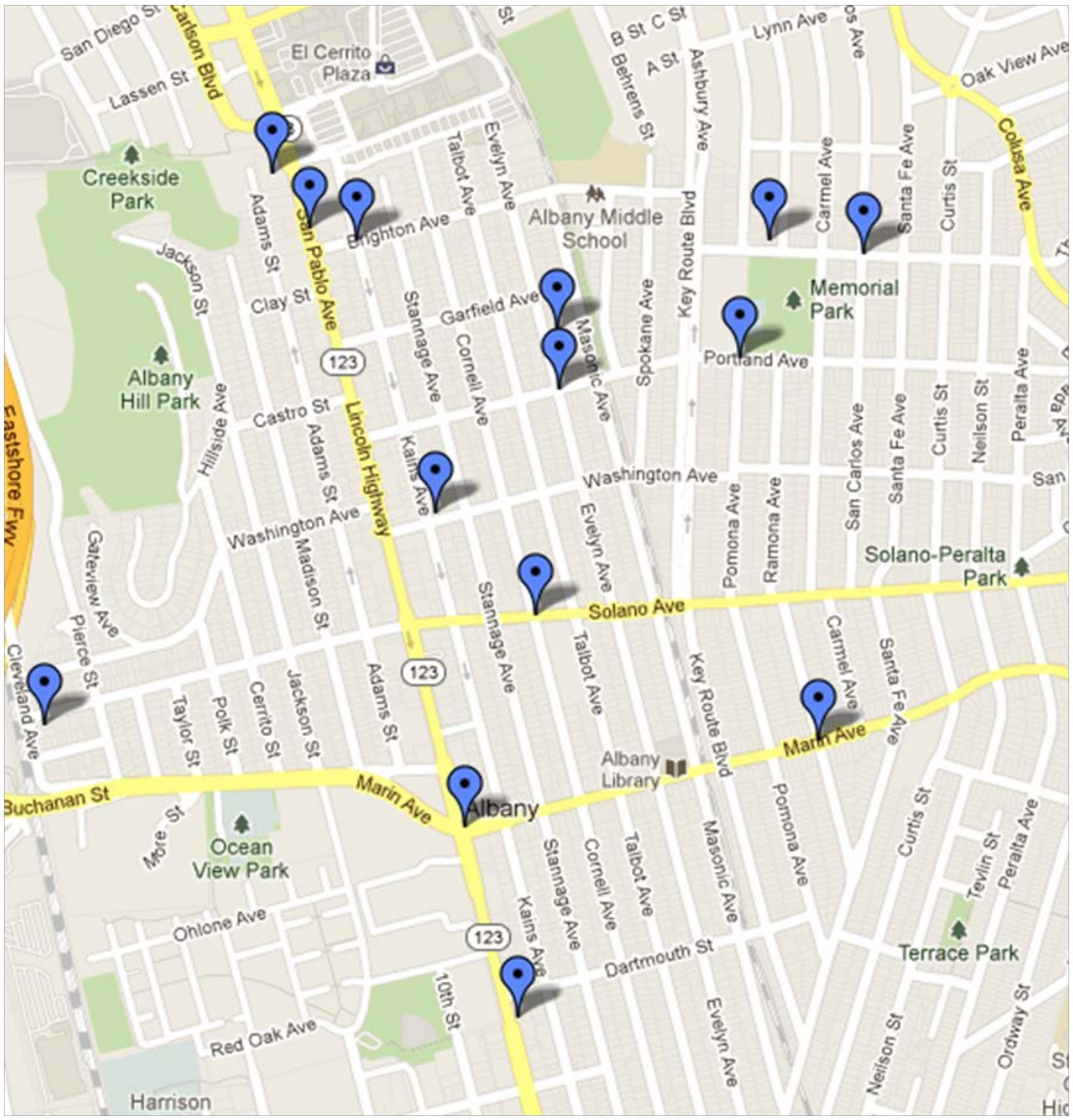



Photo Credit: DNV KEMA

## Arroyo Grande, City of (002-10-ECE-ARRA)

### Site Summary

The city of Arroyo Grande applied for Energy Conservation Assistance Act (ECAA-ARRA) loans for various energy efficiency projects throughout the city. The projects consisted of six energy efficiency measures (EEM). The measures included retrofitting several buildings with new heating, ventilation, and air-conditioning (HVAC) units; replacing existing analog thermostats to seven-day programmable digital thermostats; upgrading the interior lighting system; replacing two cathode ray tube (CRT) monitors; and the installing vending machine and computer power management controls.

DNV KEMA performed a site visit and verified the implementation of these measures. During the site visit, the interior lighting fixtures were monitored to determine hours of use. Spreadsheet analyses were used to estimate energy savings for all measures using a combination of site findings, data from the lighting loggers, spot power measurements, and literature reviews. The analysis yielded an overall electric energy savings of 64 percent and 127 percent for gas when compared to the ex ante estimates. The energy savings by measure are provided in Table 21.

**Table 21: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Elec-tric | Gas |
| EEM1-Lighting | 20,455 | Not reported | 0 | 15,444 | 7.99 | 0 | 76% | N/A |
| EEM2-Computer Power Management | 17,767 | Not reported | 0 | 16,272 | 0 | 0 | 92% | N/A |
| EEM3-LCD Monitors | 460 | Not reported | 0 | 277 | 0 | 0 | 60% | N/A |
| EEM4-High Efficiency HVAC | 5,354 | Not reported | 263 | 4,840 | 10.45 | 141 | 90% | 54% |
| EEM5-Building Controls, programmable thermostats | 27,550 | Not reported | 491 | 7,891 | 0 | 816 | 29% | 166% |
| EEM6-Vending Machines | 1,874 | Not reported | 0 | 2,563 | 0 | 0 | 137% | N/A |

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Elec-tric | Gas |
| Total | 73,460 | Not Reported | 754 | 47,287 | 18.44 | 957 | 64% | 127% |

Source: DNV KEMA analysis

Ex post electric energy savings are lower than the savings reported to DNV KEMA chiefly due to EEM 5. The details for this measure were not available for review, and, thus, DNV KEMA cannot definitively identify why the values are so different. DNV KEMA requested the calculation workbook for this measure but was provided only a table with hard entered values.

However, based on one of the buildings that represent more than half of the energy savings for this measure, the total annual electric consumption for the building (measured from the billing data) is actually less than the ex ante estimated existing HVAC end use, suggesting that the algorithms used in the analysis overestimated the energy savings potential. Evidence of this is also found in the feasibility study; a total reduction in hours of use of 40 percent for this measure resulted in a disproportionate energy savings gain of 64 percent for the HVAC energy consumption end use and would explain why ex ante values are so high.

In contrast, ex post analysis for EEM 5 yielded HVAC energy savings proportional to the reductions in hours of use, which is more in line with expectations.

There are other differences for the remaining measures that were smaller in scale relative to EEM 5. A full discussion for these differences by measure is provided toward the end of this report.

Gas energy savings were higher for the ex post estimates because DNV KEMA found that more heating capacity were being controlled by the new thermostats (EEM 5) than otherwise would not be, absent the measure.

Table 22 below shows the life-cycle energy savings for this site. Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

Results from Table 22 yield a life-cycle energy savings of 470,062 kWh and 11,094 therms when considering only Baseline 1, where s the life-cycle energy savings comes to 429,847 kWh and 10,232 therms when using Baseline 2.

**Table 22: Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 470,062 | 276.6 | 11,094 |
| Baseline 2 | 429,847 | 199.2 | 10,232 |

Source: DNV KEMA analysis

## Project Description

This project was implemented at various buildings throughout the Arroyo Grande. The measures affected energy consumption at seven locations: Parks and Recreation, Soto Sports Complex, Fire Station, Farm Credit Bureau, Council Chambers, Corporate Yard, and Community Center buildings. Cooling and heating are supplied by a mix of heat pumps, split and packaged air conditioners (AC), gas furnaces, and unitary gas heaters. There were six measures implemented throughout the city, consisting of the following.

**EEM 1: Lighting Retrofit** — This measure was a fixture-for-fixture replacement of the pre-existing T-12 and T-8 linear fluorescent lighting system with next-generation T8 lamps and electronic ballasts. Occupancy controls were also installed on a number of fixtures as part of this measure.

**EEM 2: Computer Power Management**—This measure was for installation of control software on computers and monitors to manage computer power settings from a centralized source. The measure affected a combined total of 98 laptops and desktops along with 101 associated monitors.

**EEM 3: LCD Monitors**—This measure was for the replacement of two CRT monitors with LCD monitors.

**EEM 4: High Efficiency HVAC**—This measure was for the replacement of the existing HVAC equipment with higher-efficiency units. The ex ante analysis shows that a total of 12 tons of direct expansion (DX) air-conditioning capacity,[9] 9 tons of heat pump capacity, and 485 kBtu/h of furnace or heater capacity were replaced throughout the city. Details were not provided to DNV KEMA before the site visit as to the actual efficiency of the units, but the feasibility study shows the average efficiency for the new units are estimated at SEER 17 for cooling and 90 percent thermal efficiency for heating.

**EEM 5: Building Controls, Programmable Thermostats**—This measure was for installation of seven-day programmable thermostats for all HVAC units throughout the city. According to the

9 Refers to non-heat-pump type direct expansion units.

ex ante calculations, this affected 25.5 tons of heat pump capacity, 12.5 tons of DX AC capacity, and 267 MBH of furnace capacity throughout the city.

**EEM 6: Vending Machine Controls**—This measure was for installation of control software on two vending machines. The software allows the vending machine units to power down during times when there is no occupancy.

### Ex Ante Savings

Ex ante energy savings were derived by Pacific West Energy Solutions using standard spreadsheet analysis for all measures. The following lists how energy savings for each measure were calculated under Pacific West Energy Solution's algorithms.

**EEM 1: Lighting** — Spreadsheet analysis using pre- and post-installation fixture quantities and wattages was used to determine the demand savings. Next, hours of operations were applied to the space types using an estimate of annual hours of operation for both pre and post cases. Similar lighting hours of use were assumed for most of the buildings. Documentation provided to DNV KEMA states that Pacific West returned to monitor the lighting hours for verification and further states that the results show the hours were within 5 percent of the original estimates. However, based on the information provided, there were large discrepancies in the hours of use from the loggers compared to the hours of use in the analysis, some as high as 77 percent.

**EEM 2: Computer Power Management**—A general algorithm taking into account the number of computers, power requirements of the computers at various operation modes (on, off, suspend), and changes in hours of operation at each mode due to the power management software was by Pacific West to determine savings. The algorithm also assumes that for every 3 kWh that is saved from the measure during times when the air conditioner is running, 1 kWh of energy of HVAC is saved due to interactive effects.

All values in the documentation provided by Pacific West are assumed without source citations. For measures involving energy management software, the savings are highly uncertain due to various unknown factors such as typical power draws at various operational states and fraction of hours at each operational state with or without energy management software. Savings can be easily overestimated or underestimated as a result of these factors.

**EEM 3: LCD Monitors**—The algorithm is similar to EEM 2 except that no energy management software is used. The method also suffers from the same uncertainty as EEM 2 since all the values are assumed by the author of the ex ante savings.

**EEM 4: High Efficiency HVAC**—The results spreadsheet provided to DNV KEMA shows that the analysis is done separately and then is normalized by tonnage. The actual analysis was not available for DNV KEMA's review, but from the available feasibility study, the analysis appears to use 5 degree weather bins and assumes a linear load profile to predict energy consumption for the baseline and efficient cases. The baseline uses a SEER 13 equivalent while the efficient case uses a SEER 17.5 equivalent for cooling. Baseline heating efficiency is assumed at 75 percent while the efficient case is 90 percent. However, it is not clear whether these values are

actually used in the final analysis since the final analysis spreadsheet was not provided for review.

**EEM 5: Building Controls, Programmable Thermostats**—The analysis is similar to EEM 4 except weekend hours of use were eliminated in the efficient case. In addition, the HVAC units were predicted to start one hour later and end one hour earlier than the baseline case.

**EEM 6: Vending Machine Controls**—The analysis is similar to EEM 2 and takes into account the power requirement of the vending machine and hours of operation with and without the controls. Similarly an HVAC interaction factor is applied to account for savings from reduced HVAC usage due to a decreased building load from the vending machines turning off.

## Project Evaluation

A DNV KEMA field engineer visited the project site on October 26, 2011, to verify measure installation and install time-of-use photocell data loggers for determining lighting hours of operation. Since the site visit occurred during fall season, no monitoring of the condenser units were done since it is not expected to yield useful data for analysis. However, for heat pumps, it is still possible to monitor the units during the winter to establish a heating load profile. However, it was found on-site that the affected units were very small and it was not safe to leave the monitoring equipment on. (If left on, the units were accessible to the public and posed electrical shock hazards if tampered with.) Additionally, a spot power measurement was taken for the vending machine for use in the analysis. Table 23 summarizes the monitoring equipment details.

**Table 23: Monitoring Details**

| Monitored Equipment | Logger Type | Measurement Type | Measurement Interval | Duration |
|---|---|---|---|---|
| (13) Light fixtures | DENT TOU lighting loggers | On/Off (time-of-use) | Continuous | 6 weeks |
| Vending Machine | WattsUp Power Meter | Spot Power | Once | N/A |

Source: DNV KEMA analysis

The engineer returned on December 7, 2011, to retrieve the lighting loggers. Of the 13 loggers, one was lost, and two had unusable data because the loggers fell out of place shortly after placement.

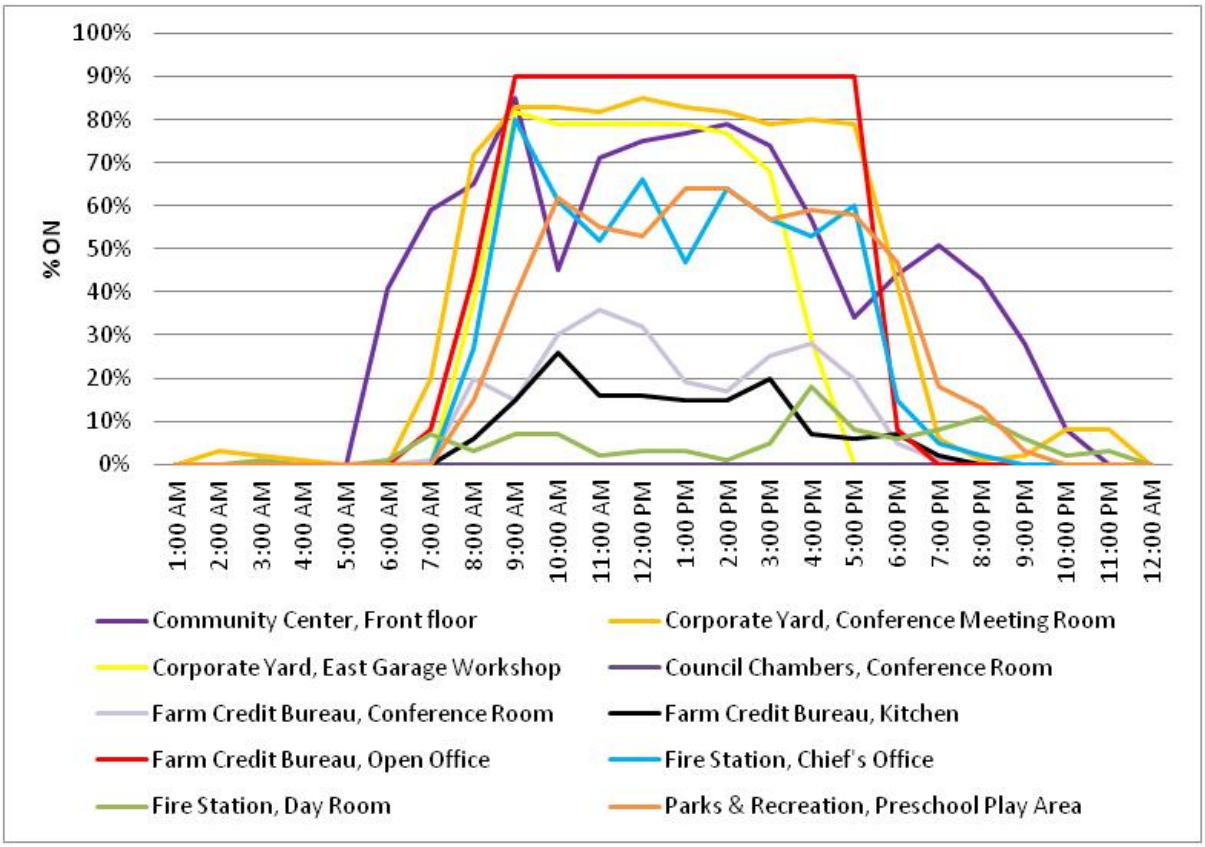
### *EEM 1- Lighting*

Lighting loggers were placed at fixtures throughout various buildings. DNV KEMA sampled fixtures that were expected to represent the majority of the energy savings for the project. The sampling accounted for building and space types when possible, but more focus was placed at fixtures where energy savings were expected to be highest.

The ex post savings estimate for the lighting retrofit was generated with a spreadsheet analysis using time-of-use data from the photocell data loggers. Data from the lighting loggers were

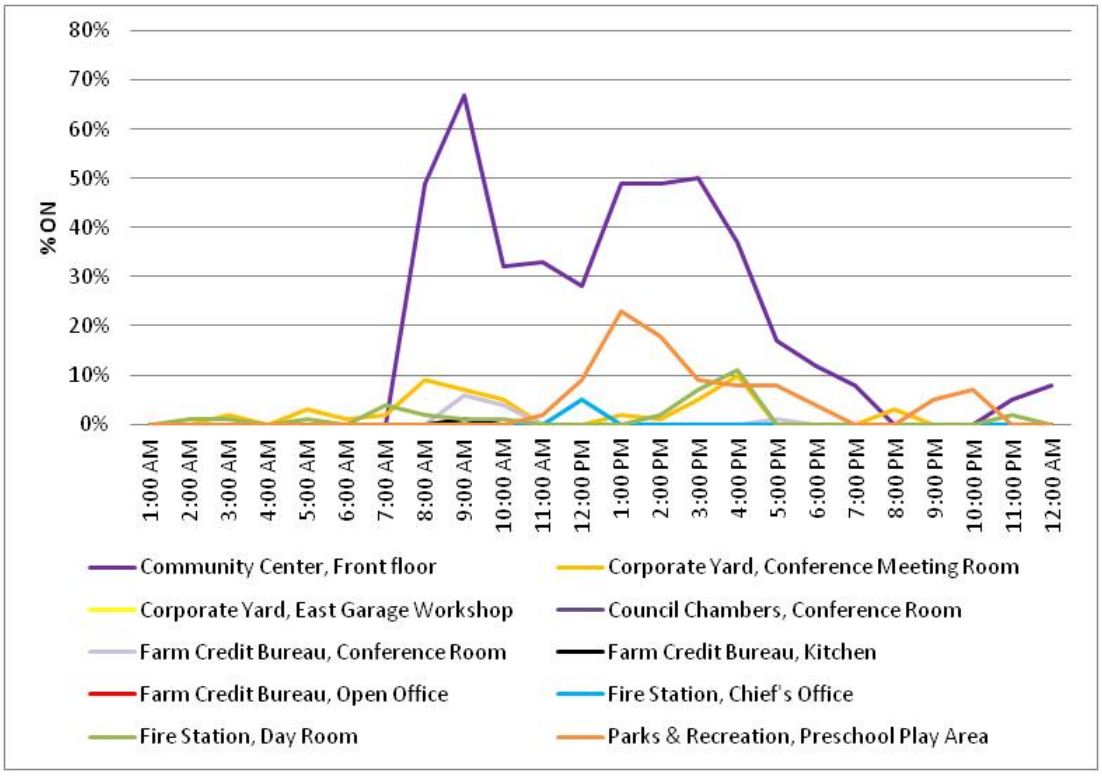
processed into weekend day and weekday time-of-use profiles. These profiles are shown in Figure 12 and Figure 13 below. Fixture types were also verified and found to be consistent with what was recorded in the spreadsheet from the project files, except for a few minor differences in lighting quantities and technology types for a small number of locations that did not significantly affect the savings estimates.

**Figure 11: Typical 24-hour Weekday Lighting Usage Profile at Various Locations**




Source: DNV KEMA analysis

**Figure 12: Typical 24-hour Weekend Day Lighting Usage Profile at Various Locations**




Source: DNV KEMA analysis

Extrapolated hours of use are shown in Table 24 below and overall are lower than the hours of use assumed in the ex ante calculations. This difference reflects the high variability of use from building to building due to the diversity in predominate space types for each building. Energy savings were calculated using the following equation supplemented with the hours from the data loggers:

$$Energy\ Savings = Quantity \times Annual\ Hours \times (kW_{Pre} - kW_{Post})$$

where,

- *Energy Savings* is the annual energy savings for all fixtures covered by the measure in kWh,
- *Quantity* is the total number of affected fixtures
- *kW* is the pre and post installation fixture wattages in kW,
- And *Annual Hours* are the estimated hours using data from the loggers.

DNV KEMA reverted to the estimated hours from the original spreadsheet for spaces that do not have logger data that fit the descriptions well, particularly for low-use rooms such as storage areas where the evaluators did not monitor time-of-use. These make up a small fraction of the total energy savings for this measure and are therefore not significant in the analysis. The total ex post savings for this measure using this analysis method is 15,444 kWh of energy and 7.99 kW of demand savings.

**Table 24: Annual Lighting Hours of Operation by Fixture Location**

| Fixture Location | Annual hours |
|---|---|
| Community Center, Front floor | 2,799 |
| Corporate Yard, Conference Meeting Room | 2,273 |
| Corporate Yard, East Garage Workshop | 1,501 |
| Council Chambers, Conference Room | 0 |
| Farm Credit Bureau, Conference Room | 628 |
| Farm Credit Bureau, Kitchen | 373 |
| Farm Credit Bureau, Open Office | 2,140 |
| Fire Station, Chief's Office | 1,491 |
| Fire Station, Day Room | 324 |
| Parks & Recreation, Preschool Play Area | 1,591 |

Source: DNV KEMA analysis

### *EEM 2 – Computer Power Management*

Installation of the computer power management software was verified with the site contact. The DNV KEMA engineer observed a number of inactive computers in the office areas were on standby mode, confirming the site contact's assertion that the software was installed.

Ex post analysis for this measure used the following equation to determine energy consumption for the preretrofit case.

$$Energy = 8{,}760 \times \left(Hours_{on} \times Power_{on} + Hours_{sleep} \times Power_{sleep} + Hours_{off} \times Power_{off}\right)$$

where,

- *Energy* is the annual energy consumption in kWh,
- *Hours* is the estimated percentage of hours the computer is in *on*, *sleep*, or *off* modes

- *Power* is the respective power draws at those modes.

Hours of operation at these different modes are based on established studies for office equipment[10] while the power draws at the different modes come from compiled ENERGY STAR data on computers.[11]

For the post-retrofit case, the power draws were unchanged, but the hours of use were augmented to reflect power management software settings. DNV KEMA assumed that the power management software will decrease the initial "on" time hours by 46 percent, resulting in more hours in the standby mode.[12] Using this analysis, total energy savings for this measure was calculated at 16,272 kWh.

### *EEM 3 – LCD Monitors*

A similar analysis as in EEM 2 is applied to the LCD monitors. Baseline power draw for the CRT monitor comes from an established Lawrence Berkeley National Laboratory study.[13] This measure saved 277 kWh of energy for the replacement of two monitors.

### *EEM 4 – High-Efficiency HVAC*

DNV KEMA verified the installation of nine total new HVAC units at three buildings. The capacity ratings for all nine units matched those described in the project files except for the location at the Farm Credit Building. At this location, three heat pumps with a capacity of 9 tons were found. No furnaces were found at this location in contrast to what was assumed in the ex ante analysis (Table 25).

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10 *After-Hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment,* Roberson et al., 2004.

11 ENERGY STAR 5.0 Dataset for Computers, using category B computers.

12 *Enterprise PC Power Management Tools: Greening IT from the Top Down,* Barr et al, 2010.

13 *Energy Use and Power Levels in New Monitors and Personal Computers,* Roberson et al., 2002.

**Table 25: New High-Efficiency HVAC Unit Capacities Verified On-site**

| Location | Ex Ante | | | | Ex Post | | | |
|---|---|---|---|---|---|---|---|---|
| | DX Unit Tons | Heat Pump Tonnage | Furnace (MBH) | Unit Efficiency | DX Unit Tons | Heat Pump Tonnage | Furnace (MBH) | Unit Efficiency |
| Corporate Yard | 3 | | 305 | Not Provided | 3 | | 306 | SEER 14 for DX, 80-83% for furnaces/unit heaters |
| Farm Credit Building | | 9 | 180 | Not Provided | | 9 | 0 | SEER 14, 7.7 HSPF |
| Parks and Recreation | | 9 | | Not Provided | | 9 | | 9.5 EER, 3 COP |

Source: DNV KEMA analysis

Ex post energy savings were estimated using 5°F weather bins and assuming linear building loads. Building loads begin at the 65-70°F bin and are maximum at the 90-95°F bin. For heating, the start point is at the 60-65°F bin, and the maximum is at the "below 30°F" bin. The closest TMY 3 weather data was used to establish the load profile for the site (Santa Maria Airport). The spreadsheet model considers the hours of operation along with flags for the heating/cooling months. The latter was necessary so that hours during the summer are not erroneously used in the heating application when cooling is expected. Actual efficiencies of the HVAC units were used in the analysis. This analysis yielded 4,840 kWh and 141 therms of energy savings.

*EEM 5 – Building Controls, Programmable Thermostats*

DNV KEMA observed that there were indeed programmable thermostats installed throughout all the buildings at the facility. The site contact confirmed the thermostats are set so that the units turned off during the weekends. Ex post energy savings were calculated using a similar binning approach as in EEM 4 except weekend hours were eliminated from the analysis in the postretrofit case. All HVAC units that had nonprogrammable or analog-type thermostats were considered in the calculations. A total of 3 tons of non-heat pump DX capacity, 27 tons of heat pump capacity, and 456 MBH of furnace/unit heater capacity were considered in the analysis. These values were slightly different from the ones used in the ex ante analysis (Table 26). Total savings for this measure is calculated at 7,891 kWh and 816 therms.

**Table 26: Analyses HVAC Capacity Controlled by Thermostat Units**

| Location | Ex Ante | | | Ex Post | | |
|---|---|---|---|---|---|---|
| | DX unit tons | Heat pump tonnage | Furnace (MBH) | DX unit tons | Heat pump tonnage | Furnace (MBH) |
| Corporate Yard | 3.5 | | 155 | 3 | | 306 |
| Farm Credit Building | 9 | 7.5 | | | 9 | |
| Parks and Recreation | | 18 | | | 18 | |
| Soto Sports Complex | | | 112 | | | 150 |

Source: DNV KEMA analysis

### *EEM 6 – Vending Machine Controls*

DNV KEMA verified the installation of occupancy controls on the vending machine. A spot power measurement of 318 watts was recorded using a WattsUp plug in power meter. The analysis used this value and assumed the unit ran for all hours throughout the year in the preretrofit case. Vending machine controls were assumed to reduce annual consumption by 46 percent[14] in the postretrofit case. Energy savings for this measure is calculated at 2,563 kWh for the two vending machine controls.

## Savings Results

Considering the implementation of all six EEMS, this site saved 47,286 kWh and 957 therms of energy. Table 26 breaks down the ex post energy savings by measure. The ex ante energy savings are also provided for comparison.

## Discussion

### *EEM 1 – Lighting*

Discrepancies in lighting energy savings come from the hours of use employed in the algorithm. Ex ante values assumed predominately 2,860 hours of use per year for the majority of the office lighting fixtures and applied this value throughout all city buildings with office type spaces. This generalization makes the calculations easier to perform but suffers from accuracy since the hours of use for each building are rather different as seen in Table 27 as well as provided from the ex ante information. The documentation in the project files stated that the light fixtures were later metered to verify hours of use. When the ex ante logged hours of use were compared to the actual hours of use found in the spreadsheet, the difference ranged from 23-77 percent, not 5 percent as reported.

14 Claimed by manufacturer and supported by various independent case studies. This value is also used in multiple technical resource manuals to estimate vending machine control savings.

DNV KEMA used actual hours of use from lighting data independently taken over a six-week period and should accurately reflect typical hours of use.

### *EEM 2 – Computer Power Management*

DNV KEMA employed a set of values for power draws and hours of use at different computer operation states (on, sleep, off) using findings from the literature. For this measure, deemed savings from the literature are typically used when pre and post data are not available due to the potential for high variability in savings estimates. A great deal of uncertainty is introduced when the calculations are based on generalized estimates, as was done in the ex ante energy savings calculation. DNV KEMA's lower ex post savings estimate (92 percent) is a reflection of eliminating this uncertainty inherent in the ex ante algorithm.

Ex ante analysis also considered an HVAC interaction factor. Typically, reduction in plug loads will result in some small savings due to interaction with the HVAC units. However, considering the mild climate zone, and the fact that the majority of the energy savings are generated when the HVAC units are not operating, this value is negligible and should not be factored into this measure. HVAC interaction is much more complex and cannot be accurately captured in a spreadsheet model.

### *EEM 3 – LCD Monitors*

Ex post savings for EEM 3 is lower than ex ante claims due to differing assumptions used in the hours of operation and typical power draws for each monitor type. DNV KEMA used established values from the literature. In contrast, there are no sources for the assumptions found in the ex ante analysis.

Similar to EEM 2, an HVAC interaction factor was also calculated but for reasons described above is not used in the DNV KEMA analysis.

### *EEM 4 – High-Efficiency HVAC*

The ex post analysis yielded 90 percent and 54 percent of the ex ante electric and gas energy savings claim, respectively, despite using similar analysis methods. While details of the ex ante analysis are not available for review, the line item energy savings by building suggests that the new heat pumps at the Farm Credit Building were treated like typical DX type units equipped with a furnace for heat. In reality, furnaces were not used for the heating application; the heat pumps were used for both cooling and heating. Hence, therm savings are overestimated, and electric savings are underestimated for this building in the ex ante calculations.

**Table 27: EEM 4 Ex Ante and Ex Post Energy Savings by Building**

| Location | Ex Ante | | Ex Post | |
|---|---|---|---|---|
| | kWh Savings | therms Savings | kWh Savings | therms Savings |
| Corporate Yard | 156 | 166 | 334 | 141 |
| Farm Credit Building | 467 | 98 | 1898 | 0 |
| Parks and Recreation | 4,731 | 0 | 2,607 | 0 |

Source: DNV KEMA analysis

Heat pumps at the Park and Recreation building, on the other hand, have much higher ex ante energy savings than the ex post estimates. These energy savings may be due to a variety of factors, such as the baseline and efficient case efficiencies, weather files (TMY2 versus TMY3) used in the analysis, building load profile, and binning methodology. However, without the ex ante analysis details, differences in the energy savings estimates remain unknown.

*EEM 5 – Building Controls, Programmable Thermostats*

Details of the ex ante analysis were not provided, and thus a definitive reason for the discrepancy cannot be identified. However, inspection of the feasibility report provides some useful insight as to the quality of the ex ante estimates.

The initial electric energy savings in the feasibility report were calculated at 21,639 kWh for 79 tons of total cooling capacity. This energy savings alone represents 63.5 percent of the predicted baseline cooling energy use, a remarkably high percentage when considering that programmable thermostats is the measure being implemented. The savings rate for this end use is plausible if indeed 63.5 percent of the hours of operation were eliminated. That is, if the hours of use were reduced from 72 hours per week to 26 hours per week, the energy savings rate for this measure can be justified. However, only weekend day hours and two hours for each weekday (start and end hours) are eliminated, representing a reduction from 72 hours per week to 50 hours per week or a 40 percent reduction in potential hours. At best, 40 percent of the HVAC energy can be saved with this measure. The energy savings claimed are likely too optimistic to begin with.

DNV KEMA examined billing data for the building to assess the actual energy consumption before the installation of the programmable thermostats. The total billed annual electric consumption was 27,120 kWh for *all* end uses. According to ex ante estimates, the Parks and Recreation building would have an existing energy consumption for the HVAC end use *alone* of 35,720 kWh, [15] which exceeds the total billed consumption. Thus, the ex ante estimate for EEM 5 at 15,851 kWh is not realistic for a simple thermostat measure.

15 Value derived from the final energy savings spreadsheet in the project files provided to KEMA.

There are also electric savings associated with furnaces or unit heaters on thermostat controls. According to the ex ante analysis, for every 80 kBtu/h of furnace capacity, there is an associated 1 horsepower of fan energy dedicated to delivering that capacity. While this may be valid for packaged or split furnaces, it is not true for unitary heaters, which make up the bulk of the heating capacity associated with thermostat controls. DNV KEMA observed that the larger unitary heaters are treated the same even though only ¾ horsepower of fan energy runs the entire 250 kBtu/h input rated unit. The result is a general overstatement of savings in fan energy for this measure, which contributes to the discrepancy found in the ex post and ex ante electric energy savings values.

Therms savings are higher for this measure because DNV KEMA found that a total of 456 kBtu/h were controlled by the new thermostats versus the 267 kBtu/h assumed in the ex ante calculations.

#### *EEM 6 – Vending Machine Controls*

The discrepancy in energy savings for this measure cannot be definitively explained because the ex ante analysis worksheet provided does not match the final ex ante savings reported to DNV KEMA from the Energy Commission's tracking data. However, based on the assumptions used in the ex ante analysis worksheet, the power draw of the machine is likely overstated since it does not match the unit's power measured during DNV KEMA's site visit.

### Life-cycle Savings

In essence, life-cycle savings is the sum of annual savings over the expected life of the measure. For replacement measures, the initial period considers the pre-existing conditions as the baseline for remaining useful life. This baseline is considered as Baseline 1. After the remaining useful-life period (RUL) and up until the end of the expected useful life (EUL) of the installed measure, a different baseline is used. This baseline considers minimally code-compliant conditions or standard practice where no code is applicable. This baseline is considered as Baseline 2.

According to the feasibility study for Arroyo Grande, the HVAC equipment had exceeded its useful life, so Baseline 1 is used for the first-year energy savings calculations. For the heat pumps, Baseline 1 uses SEER 10 in accordance with what was specified in the feasibility report for the existing HVAC efficiency. Since no heating efficiency was specified, DNV KEMA assumed a 6.8 HSPF based on 1998 Title 24 standards. Baseline 2 uses efficiencies rated at SEER 13 and 7.7 HSPF in line with federal minimum standards. For wall mount heat pumps, Baseline 1 was estimated at 6.1 EER and 2.2 COP using similar 1969 year models. Baseline 2 uses an EER of 9.5 and COP of 2.43; both values were taken from ASHRAE standards.

In the case of lighting, the existing conditions will be used for both baselines since the existing conditions are already code-compliant. The vending machine and computer measures are add-on measures, so the replacement baselines are not applicable. The standard baseline is machine operation without the new controls, except in the case of the LCD monitors, which will use CRT monitors as the baseline.

Table 28 summarizes the energy savings and life-cycle parameters by measure used in the life-cycle savings calculations.

**Table 28: Values Used in Life-cycle Savings Calculations by Measure**

| Measure | Early Replacement | | Expected Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| Lighting | 15,444 | 0 | 15,444 | 0 | 15 | 0 |
| Computer Power Management | 16,272 | 0 | 16,272 | 0 | 4 | 0 |
| LCD Monitors | 277 | 0 | 277 | 0 | 4 | 0 |
| High Efficiency HVAC | 4,840 | 141 | 1,967 | 80 | 15 | 0 |
| Building Controls | 7,891 | 816 | 7,891 | 816 | 11 | 0 |
| Vending Machines | 2,563 | 0 | 2,563 | 0 | 5 | 0 |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 470,062 kWh and 11,094 therms (Table 29). However, if Baseline 2 is used, the life-cycle savings comes to 429,847 kWh and 10,232 therms. Table 30 shows the energy savings by year starting with 2011 using the Baseline 2.

**Table 29: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 47,286 | 18 | 957 |
| 2 | 2012 | 47,286 | 18 | 957 |
| 3 | 2013 | 47,286 | 18 | 957 |
| 4 | 2014 | 47,286 | 18 | 957 |
| 5 | 2015 | 30,737 | 18 | 957 |
| 6 | 2016 | 28,174 | 18 | 957 |
| 7 | 2017 | 28,174 | 18 | 957 |

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 8 | 2018 | 28,174 | 18 | 957 |
| 9 | 2019 | 28,174 | 18 | 957 |
| 10 | 2020 | 28,174 | 18 | 957 |
| 11 | 2021 | 28,174 | 18 | 957 |
| 12 | 2022 | 20,284 | 18 | 141 |
| 13 | 2023 | 20,284 | 18 | 141 |
| 14 | 2024 | 20,284 | 18 | 141 |
| 15 | 2025 | 20,284 | 18 | 141 |
| 16 | 2026 | 0 | 0 | 0 |
| Life-cycle | Total | 470,061 | 270 | 11,091 |

Source: DNV KEMA analysis

**Table 30: Baseline 2 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 47,286 | 18 | 957 |
| 2 | 2012 | 44,414 | 13 | 896 |
| 3 | 2013 | 44,414 | 13 | 896 |
| 4 | 2014 | 44,414 | 13 | 896 |
| 5 | 2015 | 27,864 | 13 | 896 |
| 6 | 2016 | 25,302 | 13 | 896 |
| 7 | 2017 | 25,302 | 13 | 896 |
| 8 | 2018 | 25,302 | 13 | 896 |
| 9 | 2019 | 25,302 | 13 | 896 |
| 10 | 2020 | 25,302 | 13 | 896 |
| 11 | 2021 | 25,302 | 13 | 896 |
| 12 | 2022 | 17,411 | 13 | 80 |
| 13 | 2023 | 17,411 | 13 | 80 |
| 14 | 2024 | 17,411 | 13 | 80 |
| 15 | 2025 | 17,411 | 13 | 80 |
| 16 | 2026 | 0 | 0 | 0 |
| Life-cycle | Total | 429,848 | 200 | 10,237 |

Source: DNV KEMA analysis

## Brisbane, City of (024-09-ECE-ARRA)

### Site Summary

The city of Brisbane upgraded 365 street-lighting fixtures throughout the city from high-pressure sodium (HPS) fixtures to light-emitting diode (LED) fixtures.

A Katin Engineering Consulting engineer verified installation and operation by sampling the newly installed street lights. The project yielded an overall electric energy savings of 105.7 percent compared to the Baseline 1 ex ante savings. There were no natural gas savings. Table 31 below summarizes the ex post and ex ante savings estimates.

**Table 31: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| Street Lighting Retrofit | 107,114 | None Claimed | 0 | 113,214 | 25.8 | 0 | 105.7% | N/A |

Source: DNV KEMA analysis

Increased electric energy savings resulted primarily from fewer operating hours in the ex ante calculation (4,100 compared to 4,380 hours in the ex post calculation). Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

For this project, the life-cycle savings estimated relative to Baseline 1 and Baseline 2 are the same. The life-cycle savings summary can be found in Table 32.

**Table 32: Life-cycle Savings Summary**

| Baseline Type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 1,698,210 | 387 | 0 |
| Baseline 2 | 1,698,210 | 387 | 0 |

Source: DNV KEMA analysis

## Project Description

This project was implemented throughout the Brisbane. LED streetlighting fixtures provide a much brighter light than the previous HPS lights. Photographs indicating the difference between the old style HPS lights versus the new style LED lights are shown below. The project consisted of one measure.

**Figure 13: Old Streetlights – High-Pressure Sodium**

Photo Credit: Katin Engineering

**Figure 14: New Streetlights – Light-Emitting Diode**

Photo Credit: Katin Engineering

*Measure 1:*

Streetlighting Retrofit – This measure was for the replacement of pre-existing HPS streetlighting fixtures with new more efficient LED streetlighting fixtures. A total of 365 new streetlights were installed. The old streetlight wattages ranged from 85 to 293 watts, while the new efficient streetlight wattages ranged from 37 to 139 watts. A summary of the pre-existing equipment compared to the new equipment can be found in Table 33.

**Table 33: Summary of Pre- and Postinstalled Equipment Efficiencies**

| Preretrofit Fixtures (HPS) | | | Postretrofit Fixtures (LED) | | |
|---|---|---|---|---|---|
| Fixture Wattage | Number of Fixtures | Type | Fixture Wattage | Number of Fixtures | Type |
| 85 | 161 | HPS | 37 | 140 | LED |
| 120 | 13 | HPS | 54 | 31 | LED |
| 138 | 140 | HPS | 90 | 155 | LED |
| 176 | 5 | HPS | 106 | 32 | LED |
| 201 | 19 | HPS | 139 | 7 | LED |
| 237 | 23 | HPS | | | |
| 293 | 4 | HPS | | | |
| | Total: 365 | | | Total: 365 | |

Source: DNV KEMA analysis

## Ex Ante Savings

Pacific Gas and Electric developed ex ante savings based on fixture wattages, number of fixtures, and 4,100 estimated operating hours. The exact calculation was not provided in the pdf file.

## Project Evaluation

A Katin engineer visited the project site on November 16, 2011, to verify measure installation, acquire specific nameplate information, if available, and gather operating schedules to help assess the energy savings. The engineer spot checked that the 365 new LED lamps were installed by visually sighting roughly 30 percent or 108 LED lights. All of the sampled fixtures were verified and confirmed to be operating properly. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same general method used in the ex ante analysis**.** A summary of the streetlights sampled can be found in Table 34, and the ex post savings spreadsheet can be found in Table 35.

**Table 34: Summary of Verified Streetlighting Locations**

| Location | No. of Fixtures |
|---|---|
| On Mariposa between Visitacion to Alvarado | 2 |
| On Alvarado between Mariposa and Klamath | 14 |
| On Sierra point between Klamath and Glen Parkway | 8 |
| On Glen Parkway between Humboldt and Solana | 19 |
| On Solana between Monterey and Geneva | 1 |
| On Geneva between Bayshore and Valley | 9 |
| On Valley between Bayshore and West Hill | 55 |
| Total new LED lamps sighted | 108 |

Source: DNV KEMA analysis

Ex post savings were developed by a spreadsheet analysis based on fixture wattages, number of fixtures, and estimated operating hours. Savings from all affected fixture groups were then summed to estimate gross project savings. In general, for any fixture group, savings were calculated as:

$$kWh_{saved} = \frac{n}{1000}(W_{bl}h_{bl} - W_{ins}h_{ins})$$

where,

- $n$ = Number of affected fixtures
- $W_{bl}$ = Baseline Fixture Wattage [W]
- $h_{bl}$ = Baseline Operating Hours [h]
- $W_{ins}$ = Installed Fixture Wattage [W]
- $h_{ins}$ = Installed Operating Hours [h]
- 1,000 = [W/kW] conversion

All of the streetlights are controlled by photocells, so they operate for 12 hours per day based on average sunrise and sunset times for Brisbane. Thus, the annual operating hours for both preretrofit and postretrofit fixtures are 4,380 hours.

**Table 35: Ex Post Savings Spreadsheet**

| No Lights Replaced | Annual Operating Hours | Lighting Type | Fixture Wattage, Actual Watts | kWh/yr-HPS for This Set of Lights | kW Demand | Lighting Type | Fixture Wattage, Actual Watts | kWh/yr-LED for This Set of lights | kW Demand | Total Annual kWh Savings |
|---|---|---|---|---|---|---|---|---|---|---|
| 140 | 4,380 | HPS | 70,85 | 52,122 | 11.9 | LED | 20,37 | 22,688 | 5.2 | 29,434 |
| 13 | 4,380 | HPS | 100,120 | 6,833 | 1.6 | LED | 30,54 | 3,075 | 0.7 | 3,758 |
| 140 | 4,380 | HPS | 150,176 | 107,923 | 24.6 | LED | 50,90 | 55,188 | 12.6 | 52,735 |
| 10 | 4,380 | HPS | 70,85 | 3,723 | 0.9 | LED | 30,54 | 2,365 | 0.5 | 1,358 |
| 11 | 4,380 | HPS | 70,85 | 4,095 | 0.9 | LED | 60,106 | 5,107 | 1.2 | -1,012 |
| 5 | 4,380 | HPS | 100,138 | 3,022 | 0.7 | LED | 30,54 | 1,183 | 0.3 | 1,839 |
| 15 | 4,380 | HPS | 150,201 | 13,206 | 3 | LED | 50,90 | 5,913 | 1.4 | 7,293 |
| 19 | 4,380 | HPS | 200,237 | 19,723 | 4.5 | LED | 60,106 | 8,821 | 2 | 10,902 |
| 3 | 4,380 | HPS | 250,293 | 3,850 | 0.9 | LED | 80,139 | 1,826 | 0.4 | 2,024 |
| 1 | 4,380 | HPS | 250,293 | 1,283 | 0.3 | LED | 60,106 | 464 | 0.1 | 819 |
| 3 | 4,380 | HPS | 150,201 | 2,641 | 0.6 | LED | 30,54 | 710 | 0.2 | 1,931 |
| 1 | 4,380 | HPS | 150,201 | 880 | 0.2 | LED | 60,106 | 464 | 0.1 | 416 |
| 4 | 4,380 | HPS | 200,237 | 4,152 | 0.9 | LED | 80,139 | 2,435 | 0.6 | 1,717 |
| Total: 365 | | | | Total: 223,453 | | | | Total: 110,239 | | Total: 113,214 |

Source: DNV KEMA analysis

## Discussion

The ex post analysis yielded 113,214 kWh in savings compared to the ex ante savings of 107,114 kWh, or a realization rate of 105.7 percent. The difference in savings is primarily due to differences in operating hours.

## Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the energy efficiency measure implementation and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the expected-replacement baseline of the measure is used. This baseline considers either minimally code-compliant conditions or standard practice when no code is applicable. According to the decision-maker survey completed with the site contact, the site contact did not know when the old streetlights were installed, but they are assumed to be beyond their EUL.

Table 36 provides life-cycle savings for the project relative to Baseline 1 on a year-by-year basis through the EUL of the longest-lived measure. Under this baseline, energy savings were presumed to occur relative to the pre-existing equipment for the duration of the life of each measure. For this project, the life-cycle savings estimates relative to Baseline 2 (dual baseline) are the same as the life-cycle savings relative to Baseline 1.

**Table 36: Life-cycle Savings**

| Life-cycle | Year | Electric Energy Savings (kWh/yr) |
|---|---|---|
| 1 | 2011 | 113,214 |
| 2 | 2012 | 113,214 |
| 3 | 2013 | 113,214 |
| 4 | 2014 | 113,214 |
| 5 | 2015 | 113,214 |
| 6 | 2016 | 113,214 |
| 7 | 2017 | 113,214 |
| 8 | 2018 | 113,214 |
| 9 | 2019 | 113,214 |
| 10 | 2020 | 113,214 |

| Life-cycle | Year | Electric Energy Savings (kWh/yr) |
|---|---|---|
| 11 | 2021 | 113,214 |
| 12 | 2022 | 113,214 |
| 13 | 2023 | 113,214 |
| 14 | 2024 | 113,214 |
| 15 | 2025 | 113,214 |
| 16 | 2026 | 0 |
| Totals: | | 1,698,210 kWh |

Source: DNV KEMA analysis

## Butte Glenn Community College District, (022-09-ECE-ARRA)

### Site Summary

Butte-Glenn Community College District in Oroville, California, applied for Energy Conservation Assistance Act (ECAA-ARRA) loans for various energy efficiency projects throughout the Butte Community College campus. The campus has multiple facilities and office buildings used by students and faculty throughout the year. The campus is open year-round except for two breaks. It is shut down for four weeks in December-January for winter break and six weeks in May-June for summer break. During the school days, the campus is open from 5 a.m. until 11 p.m. Monday through Friday. However, each building has its own independent operating hours and does not necessarily follow this schedule.

The project consisted of 11 energy efficiency measures (EEM) done throughout the campus. The measures included lighting retrofits of several buildings, installation of lighting occupancy sensors, replacing packaged air-conditioning units at the Child Development Center, retrofitting air-handling units at the Campus Center, replacing split air-conditioning unit condensers at the Facilities Building, installing high-efficiency motors for hot water and chilled water pumps at the Campus Center, and installing tankless gas hot water heaters at the men's and women's locker rooms.

DNV KEMA visited the site to verify the implementation of these measures. During the site visit, the site contact stated that the tankless gas hot water heaters have been removed from the project. The DNV KEMA engineer confirmed that this measure was not installed on-site and adjusted the ex post energy savings accordingly. Also, the original lighting retrofits planned in the Admin Annex, Automotive Technologies, and Automotive Transmission buildings were not installed because the buildings were going to be vacated in the near future. Both the ex ante and ex post savings were adjusted accordingly to reflect these changes. Thus, 10 energy efficiency measures were implemented for this project. The collected data was analyzed to yield an overall Baseline 1 electric energy savings of 468,630 kWh and natural gas savings of 967 therms when compared to the estimated ex ante savings.

**Table 37: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM1 - Lighting Retrofit, 125W MV to 14W LED | 20,375 | 6.7 | 0 | 18,946 | 6.7 | 0 | 93% | N/A |
| EEM2 - Lighting Retrofit, Incand/Halogen to CFL/T8 | 2,767[2] | 3.1 | 0 | 2,766 | 3.0 | 0 | 100% | N/A |
| EEM3 - Lighting Retrofit, T-12 to T8 and delamping | 75,495[2] | 34.6 | 0 | 89,091 | 41.3 | 0 | 118% | N/A |
| EEM4 - Lighting Retrofit, 8ft T12 to 4ft T8 w/ occup sens | 130,081[2] | 33.6 | 0 | 128,770 | 33.3 | 0 | 99% | N/A |
| EEM5 - Lighting Retrofit, 400W MV to 200W HPS street lights | 11,038 | 7.3 | 0 | 31,974 | 17.5 | 0 | 290% | N/A |
| EEM6 - Lighting Retrofit, install occupancy sensors | 22,303[2] | 0.0 | 0 | 24,272 | 0.0 | 0 | 109% | N/A |
| EEM7 - Packaged AC | 7,530 | 12.9 | 0 | 14,848[1] | 9.7[1] | 967[1] | 197% | N/A |
| EEM8 - Split AC | 17,783[3] | 11.2 | 0 | 22,353[1] | 5.1[1] | 0 | 126% | N/A |
| EEM9 - Water Pump Motors | 6,205 | 2.0 | 0 | 7,303 | 2.0 | 0 | 118% | N/A |

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM10 - Air Handling Units | 75,974 | 9.7 | 0 | 128,307 | 34.1 | 0 | 169% | 0% |
| Total | 369,551 | 121 | 0 | 468,630 | 157 | 967 | 127% | 0% |

[1]Degradation of 10 percent applied to preretrofit HVAC equipment

[2]Savings for cancelled lighting retrofits have been removed

[3]Savings adjusted to account for additional HVAC unit added to the project and confirmed on-site

Source: DNV KEMA analysis

Discrepancies between the project savings compared to the ex ante calculations occurred for many reasons, ranging from incomplete implementation of the measures to incorrect assumptions in the ex ante savings calculation.

- EEM1 – Interior Lighting Retrofit – Savings were different because the number of fixtures installed in the ex ante report was inconsistent with what was verified on-site.
- EEM2 – Interior Lighting Retrofit – The ex post savings were consistent with the ex ante savings.
- EEM3 – Interior Lighting Retrofit – Savings exceeded the ex ante estimates because of operating hour differences and newly installed fixtures that were unaccounted for in the ex ante savings.
- EEM4 – Interior Lighting Retrofit – The ex post savings were consistent with the ex ante savings.
- EEM5 – Streetlighting Retrofit – Savings exceeded the ex ante estimates because the project installed more efficient equipment than what was originally stated in the ex ante report.
- EEM6 – Lighting Occupancy Controls – Savings exceeded the ex ante estimates due to differences in operating hours and newly installed fixtures that were unaccounted for in the ex ante savings.
- EEM7 – HVAC Retrofit – Savings differed from the ex ante estimates because different baseline assumptions were used in the different savings methods. The ex ante also claimed no therms savings, when there actually were.
- EEM8 – HVAC Retrofit – Savings differed from the ex ante estimates because the ex ante savings only reported three air-conditioning units being replaced when the project included four retrofitted units.

- EEM9 – Motor Retrofit – Savings were higher than the ex ante savings due to difference in operating hours.
- EEM10 – HVAC Retrofit – Savings exceeded the ex ante savings because the ex ante eQuest building models used incorrect baseline assumptions, while the ex post eQuest models used the proper assumptions.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1, which uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures
- Baseline 2, the dual baseline, which uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded

The overall results from Table 38 yields a life-cycle energy savings of 7,029,450 kWh and 2,362 therms when considering only the building's existing conditions. However, if a dual baseline that considers remaining useful life is considered, the life-cycle savings comes to 6,545,120 kWh and 2,176 therms (Table 38).

**Table 38: Life-cycle Savings Summary**

| Baseline Type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 7,029,450 | 2,362 | 14,505 |
| Baseline 2 | 6,545,120 | 2,176 | 1,331 |

Source: DNV KEMA analysis

## Project Description

This project was implemented at the Butte Community College campus in Oroville. The retrofits were installed in a variety of different campus buildings, including the Child Development Center, Campus Center, Facilities Building, Main Gymnasium, and multiple classrooms and offices. Cooling and heating are supplied by a mix of split and packaged air conditioners, gas furnaces, and air handling units. All the buildings had temperature set points of 72˚ F for their HVAC measures as stated by the campus energy management system. The individual measures are described below.

**EEM 1 - Lighting Retrofit: 125W MV to 14W LED** – This measure was a fixture-for-fixture replacement of the pre-existing 100W mercury vapor (MV) fixtures in the Gymnasium Lobby

with 13.5W LED fixtures. These fixtures are controlled via wall switch and typically operate for 12 hours per day from Monday to Friday during the school year. The preinstallation and postinstallation operating hours remained the same.

**EEM2 - Lighting Retrofit: Incandescent and/Halogen to CFL/T8** – This measure was a fixture-for-fixture replacement of the pre-existing incandescent and halogen fixtures with compact fluorescent lamps (CFL) and T8 fluorescent fixtures. The pre-existing fixture wattages ranged from 52W to 500W, while the new fixture wattages range from 15W to 48W. These fixtures were retrofitted in multiple campus buildings, including the Child Development Center, Environmental Horticulture, Gymnasium, Life Sciences, Mechanized Agriculture, Men's Locker Room, Women's Locker Room, Physical Sciences, and Welding Manufacturing. The operating hours varied by building, but the preinstallation and postinstallation operating hours remained the same.

**EEM3 – Lighting Retrofit: T12 to T8 and delamping** – This measure retrofitted 34W T-12 fluorescent fixtures with magnetic ballasts to 28W T-8 fixtures with more efficient electronic ballasts. Multiple fixtures were also delamped for further energy savings. The pre-existing fixture wattages ranged from 43W to 222W, while the new fixture wattages ranged from 25W to 96W. These fixtures were retrofitted in multiple campus buildings, including the Child Development Center, Environmental Horticulture, Farm Service Center, Field House, Gymnasium, Life Sciences, Physical Sciences, Mechanized Agriculture, Welding Manufacturing, Women's Locker Room, and Men's Locker Room. The operating hours varied by building, but the preinstallation and postinstallation operating hours remained the same.

**EEM4 – Lighting Retrofit: 8ft T12 to 4ft T8 w/ occup. sens.** – This measure retrofitted 8ft T12HO fixtures with magnetic ballasts and metal halide fixtures to 4ft T8HO fixtures with electronic ballasts and occupancy sensors. The pre-existing fixture wattages ranged from 58W to 500W, while the new fixtures ranged from 96W to 130W. The new occupancy sensors installed on the fixtures reduced the operating hours and further increased the energy savings. From the reported operating hours, the occupancy sensors on average reduced the operating hours by 38 percent. For each location in a given building, the feasibility study[16] estimated reduced operating hours as a result of the occupancy sensors. These individual savings percentages were deemed to be a better estimation of actual building operating hours by the site contact, compared to the typical occupancy savings of 30 percent as stated in the *2010 NEEP Mid-Atlantic Technical Reference Manual Version 1.1*

**EEM5 – Lighting Retrofit: Streetlights** – This measure was a fixture-for-fixture replacement of the 48 existing street lights found along Butte Campus Drive. The original plan was to replace the 400W mercury vapor (MV) fixtures with 200W high-pressure sodium (HPS) fixtures, but the city chose to install 40W LED fixtures instead. This change resulted in drastically more savings as seen in Table 38. All of the pre- and postretrofit streetlights were controlled by photocell and

16 Servidyne Systems. 2008. *Energy Efficiency Study for Butte College, Oroville– Appendix B: Energy Savings Calculations*" Prepared for the California Energy Commission. March.

operated for about five hours per day because all of the exterior campus lights are shut off daily at 11 p.m. by the campus EMS system.

**EEM6 – Lighting Retrofit: Occupancy Sensors** – This measure installed occupancy sensors on the new T8 fixtures installed as part of energy efficiency measure 3 (EEM3). EEM3 retrofitted numerous T12 fixtures into T8 fixtures, and the installation of occupancy sensors (EEM6) reduced the new operating hours and further increased energy savings. The occupancy sensors were installed on the ceilings and walls of the affected rooms in the Child Development Center, Environmental Horticulture, Farm Service Center, Field House, Gymnasium, Life Sciences, Physical Sciences, Mechanized Agriculture, Welding Manufacturing, Women's Locker Room, and Men's Locker Room. According to the reported operating hours, the occupancy sensors on average reduced the operating hours by 23 percent. Each building had unique reduced operating hours due to the occupancy sensors. These individual savings percentages were deemed to be a more accurate representation of actual building operating hours compared to the typical occupancy savings of 30 percent as stated in the *2010 NEEP Mid-Atlantic Technical Reference Manual Version 1.1*. In total, 1086 fixtures were controlled by 141 occupancy sensors.

A summary of the pre-existing and newly installed lighting fixture types is shown in Table 39.

**Table 39: Summary of Pre- and Postretrofit Lighting Fixture Counts**

| Pre-existing | | | Installed | |
|---|---|---|---|---|
| **Fixture Type** | **Quantity** | | **Fixture Type** | **Quantity** |
| 100W Incandescent | 1 | | 14W LED | 60 |
| 100W Mercury Vapor | 60 | | 15W CFL | 47 |
| 200W Incandescent | 2 | | 40W LED | 48 |
| 250W Mercury Vapor | 15 | | 8CFL Sportlite | 12 |
| 250W Metal Hallide | 11 | | T5HO 3ft 2 Lamp | 46 |
| 400W Mercury Vapor | 45 | | T8 4ft 1 Lamp | 555 |
| 500W Incandescent | 2 | | T8 4ft 2 Lamp | 871 |
| 500W Quartz | 3 | | T8 4ft 3 Lamp | 32 |
| 52W Halogen | 14 | | T8 4ft 4 Lamp | 88 |
| 52W Incandescent | 32 | | T8 U-tube | 55 |
| T12 2ft 2 Lamp | 8 | | T8HO 4ft 3 Lamp | 145 |
| T12 3ft 2 Lamp | 1 | | Total | 1,959 |
| T12 4ft 1 Lamp | 570 | | | |
| T12 4ft 2 Lamp | 861 | | | |
| T12 4ft 4 Lamp | 31 | | | |
| T12 4ft 6 Lamp | 29 | | | |
| T12 4ft 8 Lamp | 2 | | | |
| T12 8ft 2 Lamp | 26 | | | |
| T12 U-tube 2'x2' | 30 | | | |

| Pre-existing | | | Installed | |
|---|---|---|---|---|
| **Fixture Type** | **Quantity** | | **Fixture Type** | **Quantity** |
| T12HO 4ft 2Lamp | 59 | | | |
| T12HO 8ft 2 Lamp | 134 | | | |
| T12VHO 8ft 1 Lamp | 88 | | | |
| T12VHO 8ft 2 Lamp | 4 | | | |
| T8 4' 2 Lamp | 32 | | | |
| T8 4ft 4 Lamp | 7 | | | |
| T8HO 8ft 2 Lamp | 11 | | | |
| Total | 2,078 | | | |

Source: DNV KEMA analysis

**EEM 7: Packaged Air Conditioners With Gas-Fired Furnaces –** This measure was for the replacement of the existing packaged HVAC equipment with higher efficiency units at the Child Development Center. The Child Development Center was a one-story office-like building with multiple classrooms and offices. There were a total of six new rooftop packaged air conditioners (five 5-ton units and one 3-ton unit). The pre-existing units (five 5-ton units and one 3-ton unit) were installed when the building was built in 1996, so they were 18 years old. In total, 28 tons of direct expansion (DX) air conditioning capacity and 300 kBtu/h of furnace capacity were replaced for this energy efficiency measure. The old units had an average efficiency rating of 8.5 EER for cooling and 80 percent AFUE for heating, while the new units have an average efficiency rating of 12.5 EER for cooling and 81 percent AFUE for heating. According to the campus energy management system (EMS), the typical operating hours for the Child Development Center HVAC units are from 6 a.m. to 6 p.m. Monday through Friday during the school year. The building is unoccupied during the school breaks, so the HVAC system is typically off. The pre- and postinstallation operating hours were confirmed to be the same. A summary of the pre-existing packaged HVAC equipment compared to the new equipment can be found in Table 40.

**Table 40: Summary of Pre- and Postinstalled Packaged AC Efficiencies**

| | Preretrofit | | | | | | Post-retrofit | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Manuf.** | **Model** | **Tons** | **Heating Output (Btu/hr)** | **EER** | **AFUE** | **Manuf.** | **Model** | **Tons** | **Heating Output (Btu/hr)** | **EER** | **AFUE** |
| **AC1** | Carrier | 48TJ006 | 5 | 59,200 | 8.5 | 0.8 | Carrier | 48HCLA 06 | 5 | 50,000 | 12.5 | 0.81 |
| **AC2** | Carrier | 48TJ006 | 5 | 59,200 | 8.5 | 0.8 | Carrier | 48HCLA 06 | 5 | 50,000 | 12.5 | 0.81 |
| **AC3** | Carrier | 48TJ006 | 5 | 59,200 | 8.5 | 0.8 | Carrier | 48HCLA 06 | 5 | 50,000 | 12.5 | 0.81 |
| **AC4** | Carrier | 48TJ004 | 3 | 59,200 | 8.7 | 0.8 | Carrier | 48HCLA 04 | 3 | 50,000 | 12.5 | 0.81 |
| **AC5** | Carrier | 48TJ006 | 5 | 59,200 | 8.5 | 0.8 | Carrier | 48HCLA 06 | 5 | 50,000 | 12.5 | 0.81 |
| **AC6** | Carrier | 48TJ006 | 5 | 59,200 | 8.5 | 0.8 | Carrier | 48HCLA 06 | 5 | 50,000 | 12.5 | 0.81 |
| Totals | | | 28 | 355,200 | | | | | 28 | 300,000 | | |

Source: DNV KEMA analysis

**EEM 8: Split Air-Conditioning Units** – This measure was for the replacement of existing split air-conditioning units with higher efficiency units at the Facilities Planning & Maintenance Building. The Facilities Planning & Maintenance building was a two-story office-like building with multiple offices, unconditioned garages, as well as an unconditioned storage warehouse. The building is conditioned by four split air-conditioning units with gas-fired furnaces. Under this project, only the four outdoor condenser units were retrofitted, while the furnaces were not replaced. The furnaces were eventually changed under a different project. Thus, the energy savings for this project were strictly from replacement of the condenser units. In total, 23 tons of direct expansion (DX) air conditioning capacity was replaced for this energy efficiency measures. The four pre-existing units (two 5-ton units, one 4-ton unit, one 9-ton unit) had an average efficiency rating of 9.5 EER, while the four newly installed units (two 5-ton units, one 4-ton unit, one 10-ton unit) had an average efficiency rating of 12.6 EER. Since the Facilities Planning & Maintenance building also housed the campus police department, the building was occupied 24 hours per day for 365 days per year. The pre- and postinstallation operating hours were confirmed to be the same. According to the campus EMS system, the HVAC system is always operating. A summary of the pre-existing split AC equipment compared to the new equipment can be found in Table 41.

**Table 41: Summary of Pre- and Postinstalled Split System AC Efficiencies**

| | Pre-existing | | | | | Newly Installed | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Unit** | **Manu-facturer** | **Model** | **Tons** | **Cooling Capacity (Btuh)** | **EER** | **Manuf** | **Model** | **Tons** | **Cooling Capacity (Btuh)** | **EER** |
| **AC1** | Carrier | 38TH-060-30 | 5 | 57,000 | 9.2 | Carrier | 24ABC660A0 | 5 | 60,000 | 13 |
| **AC2** | Carrier | 38TH-060-30 | 5 | 57,000 | 9.2 | Carrier | 24ABC660A0 | 5 | 60,000 | 13 |
| **AC3** | Carrier | 38BA009 | 9 | 108,400 | 9.6 | Carrier | 38AUZA12A0 | 10 | 117,000 | 11 |
| **AC4** | Carrier | 561CJX018 | 4 | 48,000 | 10 | Carrier | 24ABC648A0 | 4 | 48,000 | 13 |
| Totals | | | 23 | 270,400 | | | | 24 | 285,000 | |

Source: DNV KEMA analysis

**EEM 9: Water Pump Motors** – This measure was for the replacement of six existing motors with high-efficiency motors for the hot and chilled water pumps at the Campus Center. The Campus Center building was a one-story office-like building with multiple offices, kitchen, cafeteria, auditorium, and conditioned storage. The building's water supply is managed by six pumps powered by the six retrofitted motors (two at 3-hp, one at 5-hp, two at 7.5hp, one at 15-hp). The pre-existing motors had an average weighted efficiency of 85 percent, while the newly installed motors have an average weighted efficiency of 91 percent. The pre- and postinstallation operating hours were confirmed to be the same by the site contact. A summary of the pre-existing water pump motors compared to the new motors can be found in Table 42.

**Table 42: Summary of Pre- and Postinstalled Water Pump Motor Efficiencies**

| System | Quantity | Hp | Preretrofit Nominal Efficiency | Postretrofit Nominal Efficiency |
|---|---|---|---|---|
| hot water pump motor #1 | 1 | 3.0 | 0.812 | 0.895 |
| hot water pump motor #2 | 1 | 3.0 | 0.812 | 0.895 |
| hot water pump motor #3 | 1 | 5.0 | 0.839 | 0.895 |
| chilled water pump motor #1 | 1 | 7.5 | 0.848 | 0.910 |
| chilled water pump motor #2 | 1 | 7.5 | 0.848 | 0.910 |
| chilled water pump motor #3 | 1 | 15.0 | 0.870 | 0.930 |
| Weighted Average | | | 0.84 | 0.91 |

Source: DNV KEMA analysis

**EEM10: Air Handling Units** – This measure was for the retrofit of three large air handling units on the roof of the Campus Center. The air handlers were changed from constant volume to variable volume and had variable-frequency drives (VFD) installed. Premium supply and return motors, centralized neutral and cold decks, individual hot water reheat for each zone, and new outside air economizers were also retrofitted on the air handling units. According to the campus EMS system, Air handlers 1 and 2 operated from 5 p.m. to 6 p.m., while air handler 3 operated from 5 a.m. to 8 p.m. The operating hours pre- and postretrofit were confirmed to be the same.

## Ex Ante Savings

Servidyne Systems prepared the ex ante savings in March 2008. All the lighting measures were calculated using spreadsheet calculations based on fixture wattages, number of fixtures, and estimated operating hours. Savings from all affected fixture groups were then summed to estimate gross project savings. In general, for any fixture group, savings were calculated as:

$$kWh_{saved} = \frac{n}{1000}(W_{bl}h_{bl} - W_{ins}h_{ins})$$

where,

- $n$ = Number of affected fixtures
- $W_{bl}$ = Baseline Fixture Wattage [W]
- $h_{bl}$ = Baseline Operating Hours [h]
- $W_{ins}$ = Installed Fixture Wattage [W]
- $h_{ins}$ = Installed Operating Hours [h]
- 1,000 = [W/kW] conversion

Similarly, the motor measures were also calculated using a spreadsheet analysis based on motor horsepower, motor efficiency, and estimated operating hours. The motor savings were calculated as:

$$kWh_{saved} = \left\{\left(\frac{hp_{bl}}{eff_{bl}}\right) - \left(\frac{hp_{ins}}{eff_{lins}}\right)\right\}(0.746)(0.8)(\text{hours})(\text{n})$$

where,

- $hp_{bl}$ = Baseline Motor Horsepower [hp]
- $eff_{bl}$ = Baseline Motor efficiency [ percent]
- $hp_{ins}$ = Installed Motor Horsepower [hp]
- $eff_{ins}$ = Installed Motor Efficiency [ percent]
- 0.746 = [horsepower/kW] conversion
- 0.8 = assumed full load factor for motors
- Hours = Annual Operating Hours [h]
- $n$ = Number of motors

All the HVAC measures were estimated using eQuest, a building energy modeling application that uses the DOE 2.2 simulation engine. The savings estimates uses pre- minus postmodeled

energy usage based on the retrofitted HVAC equipment. The eQuest models used in the ex ante calculations were requested from the site contact but were not available for review, so DNV KEMA could not verify the baseline assumptions and energy savings method. Only the eQuest model for the Campus Center building was available for review. Thus, it is unclear which baseline assumptions were actually used in the savings calculations. Also, some of the ex ante savings documented in the feasibility study[17] and tracking data reviewed by the Energy Commission[18] differed from the savings spreadsheets provided by the city.

The ex ante savings for the split system air-conditioning condensers were adjusted because the initial feasibility report only accounted for three new units when there were actually four units installed. The initial ex ante savings of 14,690 kWh for 19 tons of cooling capacity was adjusted to 17,783 for 23 tons of cooling capacity, based on the size and efficiencies of the units.

### Project Evaluation

A DNV KEMA engineer visited the project site on January 18, 2012, to verify measure installation, acquire specific nameplate information, and gather facility operating data to assist in assessing energy savings. The verification and energy savings method for each energy efficiency measure is described below.

**EEM1 – Lighting Retrofit: 125W MV to 14W LED –** A total of 60 new fixtures were installed for this measure. During the site visit, all 60 fixtures were verified and confirmed to be operating properly. Operating hours stated in the ex ante reports were confirmed by the site contact. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same method used in the ex ante analysis**.**

**EEM2 – Lighting Retrofit: Incand/Halogen to CFL/Fluorescent –** A total of 51 new fixtures were installed for this measure. During the site visit, 21 out of the 51 fixtures were verified and confirmed to be operating properly. Many of the fixtures were located in mechanical and maintenance rooms that were difficult to access. Due to the accessibility issues and time constraints, not all fixtures could be verified. The unconfirmed fixtures were assumed to be installed and operating properly, based on the sample of fixtures confirmed. Operating hours stated in the ex ante reports were confirmed by the site contact. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same method used in the ex ante analysis.

**EEM3 – Lighting Retrofit: T12 to T8 Conversion and Delamping –** A total of 1,539 fixtures were retrofitted for this measure. During the site visit, 1,226 fixtures were verified and confirmed to be operating properly. Installation verifications from monitored areas were applied to unmonitored areas, if reasonably applicable. For instance, the fixtures confirmed in one office of a building were applied to the rest of the identical offices in the same building and fixtures confirmed in the men's locker room were assumed to be similarly installed in the

17 Servidyne 2008, "Energy Efficiency Study for Butte College, Oroville" Prepared for the California Energy Commission. March.

18 ECAA 1 percent tracking data011912.xls, received from Anne Fisher.

women's locker room. Some fixture counts from the ex ante report were found to be incorrect, and the savings were adjusted to accommodate the new fixtures confirmed on-site. Operating hours stated in the ex ante reports were confirmed by the site contact. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same method used in the ex ante analysis.

**EEM4 – Lighting Retrofit: 8′ T12 to 4′ T8 w/ occup. sens.** – A total of 261 new fixtures were installed for this measure. During the site visit, 251 out of the 261 fixtures were verified and confirmed to be operating properly. Ceiling-mounted occupancy sensors were also confirmed in the rooms. Operating hours stated in the ex ante reports were confirmed by the site contact. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same method used in the ex ante analysis.

**EEM5 – Lighting Retrofit: Streetlight Conversion** – The ex ante report stated 31 retrofitted streetlights for this measure. However, during the on-site verification, the site contact stated that 48 fixtures were retrofitted. Thirty-six out of the 48 streetlight fixtures were confirmed during the site visit. The original plan was to replace the pre-existing 400W mercury vapor (MV) fixtures with new 200W high-pressure sodium (HPS) fixtures, but the city chose to install new 40W LED fixtures instead. Both the pre-existing and newly installed streetlights were controlled via photocell. The campus had a lighting control system that shut off all the exterior lights, including the streetlights, from 11 p.m. until 5 a.m. daily. Thus, according to the sunset times taken from the United States Naval Observatory (USNO), the streetlights operated for roughly five hours per day compared to the ex ante estimated 4.5 hours per day. The savings were adjusted for the new operating hours. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same method used in the ex ante analysis.

**EEM6 – Lighting Retrofit: Occupancy Sensors** – A total of 141 occupancy sensors controlling 1,086 fixtures were installed for this measure. Most of the classrooms had ceiling-mounted occupancy sensors, while the smaller offices had wall-mounted occupancy sensors. During the site visit, 112 occupancy sensors were verified and confirmed to be operating properly. Installation verifications from monitored areas were applied to unmonitored areas if reasonably applicable. For instance, the fixtures confirmed in one private office of a building were applied to the rest of the identical private offices in the same building. Typically, to approximate lighting usage conditions, it is necessary to scale the operating hours by a factor of

$$\frac{1}{(1-.3)},$$

which followed from standard practice assumption that occupancy sensors yield a 30 percent reduction in lighting time of use.[19] However, the ex ante report stated estimated operating hours per room as a result of the occupancy sensors. These were deemed to be a better estimation of operating hours by the site contact, so the ex post savings numbers were calculated using these values. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same general method used in the ex ante analysis.

Table 43 shows a summary of the lighting fixtures verified during the site visit.

**Table 43: Summary of Verified Lighting Fixtures**

| Type of Fixture | Number of Fixtures Installed | Number of Fixtures Verified |
|---|---|---|
| 14W LED Recessed | 60 | 60 |
| CFLs | 46 | 21 |
| T8 fixtures | 1,800 | 1,477 |
| LED Streetlights | 48 | 36 |
| Occupancy Sensors | 141 | 112 |

Source: DNV KEMA analysis

**EEM7 – Packaged Air Conditioners** – A total of six rooftop packaged air conditioners with gas-fired furnaces were installed at the Child Development Center. During the site visit, nameplate information and operating hours were gathered. Economizers were also verified on the new HVAC units and were confirmed to be functional by the site contact. The operating hours were recorded from the campus EMS system that programmed daily operating hours for the HVAC measures of each building. Since the site visit occurred during the winter season, no monitoring of the air conditioners was done since it is not expected to yield useful data for analysis.

The ex post savings used a bin analysis approach based on the pre-existing unit efficiency and size, newly installed unit efficiency and size, estimated building cooling/heating load, and operating hours. The bin analysis assumed the HVAC units were sized appropriately for the building and were able to meet the building loads at all times. Also, the bin analysis assumed the load is weather-dependent and can be described using linear regression data or approximate with a linear relationship. It used 5 degree weather bins and assumed a linear load profile between building loads and temperature bins. Building cooling loads begin at the 65-70°F bin and are maximum at the 100-105°F bin. For heating, the start point is at the 60-65°F bin and is maximum at the "below 30°F" bin. The closest TMY 3 weather data from the National Oceanic and Atmospheric Administration (NOAA) was used to establish a load profile for the

19 *NEEP Mid-Atlantic Technical Reference Manual Version 1.1*, pg. 83, October 2010.

site (Red Bluff Municipal Airport). The spreadsheet model considered the hours of operation along with flags for the heating/cooling months. The latter was necessary so that hours during the summer are not erroneously used in the heating application when cooling is expected, such as during a cold summer morning. Actual efficiencies of the HVAC units were used in the analysis. Degradation of the packaged air conditioners was included in the bin analysis by lowering the effective EER rating of the pre-existing units by 10 percent.

**EEM8 – Split Air Conditioners** –Four condenser units for the split air-conditioning units were installed at the Facilities Building. During the site visit, nameplate information, cooling loads, and operating hours were gathered. The operating hours were recorded from the campus EMS system that programmed daily operating hours for each building's HVAC measures. Since the site visit occurred during the winter season, no monitoring of the air-conditioning unit was done since it is not expected to yield useful data for analysis.

The ex post savings used a bin analysis approach based on the pre-existing unit efficiency and size, newly installed unit efficiency and size, estimated building cooling/heating load, and operating hours. The bin analysis assumed the HVAC units were sized appropriately for the building and was able to meet the building loads at all times. Also, the bin analysis assumed the load is weather-dependent and can be described using linear regression data or approximate with a linear relationship. It used 5 degree weather bins and assumed a linear load profile between building loads and temperature bins. Building cooling loads begin at the 65-70°F bin and are maximum at the 90-95°F bin. For heating, the start point is at the 60-65°F bin and is maximum at the "below 30°F" bin. The closest TMY 3 weather data from the National Oceanic and Atmospheric Administration (NOAA) was used to establish a load profile for the site (Red Bluff Municipal Airport). The spreadsheet model considered the hours of operation along with flags for the heating/cooling months. The latter was necessary so that hours during the summer are not erroneously used in the heating application when cooling is expected such as during a cold summer morning. Actual efficiencies of the HVAC units were used in the analysis. Degradation of the air-conditioning condensers was included in the bin analysis by lowering the effective EER rating of the pre-existing units by 10 percent.

**EEM9 – Water Pump Motors** – A total of six new high-efficiency motors (two 3-hp, one 5-hp, two 7.5hp, and one 10-hp) were installed on the hot water and chilled water system at the Campus Center. During the site visit, nameplate information and operating hours were gathered from the site contact. The site contact confirmed that the operating hours for these pumps were identical to the operating hours of the air handling units at the Campus Center. The corresponding operating hours were recorded from the campus EMS system. No metering or spot power measurements were done because the pumps were in use at the time, and the site contact refused to have them shut down. Energy savings with respect to the Energy Commission's pre-existing equipment baseline were calculated using the same general method used in the ex ante analysis.

**EEM10 – Air Handling Units** – Three air handling units (AHU) were retrofitted at the Campus Center. During the site visit, nameplate information and operating hours were gathered from the site contact. The operating hours were recorded from the campus EMS system that

programmed daily operating hours for the HVAC measures of each building. No metering or spot power measurements were done because the AHU were in use at the time, and the site contact refused to have them shut down.

The site contact provided the eQuest files used for the Campus Center in the ex ante savings . However upon inspection of the models, it was found that they did not accurately portray the variable-frequency drives (VFD) in the ex ante model. The VFDs were confirmed to be installed by the site contact, but they were not represented in the ex ante eQuest model. The VFDs were added to the ex post eQuest model, which resulted in additional savings. All of the other building characteristics and run hours were left the same as the ex ante model.

### Savings Results

Taking into account all 10 EEMs, the Butte Community College project saved a total of 444,770 kWh and 662 therms in gross energy savings. Table 37 provides a breakdown of the ex post energy savings along with the ex ante energy savings for comparison.

### Discussion

Billing data for the campus was deemed to be not applicable because it encompassed the entire campus and not the individual buildings. Thus the specific energy efficiency measures wouldn't be identifiable from the campus billing data. Actual weather conditions differing from the assumed TMY3 weather data used in the bin analysis for the HVAC measures also attributed to the differences between ex ante and ex post savings. Also, the bin analysis assumed that the heating/cooling load is weather dependent and can be approximated with a linear relationship. However, the relationship between actual building heating and cooling loads relative to outside weather conditions is not always exactly linear, which can cause additional uncertainty. The specific savings differences for each energy efficiency measure can be found below.

**EEM1 - Lighting Retrofit: 125W MV to 14W LED** – The ex post savings are lower than the ex ante savings because the actual number of fixtures installed on site was more than what the ex ante report had stated. Also, there was a reduction in reported operating hours. The operating hours used in the ex post analysis were confirmed by the site contact. As a result, the kWh savings was adjusted to account for the additional new fixtures.

**EEM2 - Lighting Retrofit: Incandescent/Halogen to CFL/Fluorescent** – The ex post savings were less than the ex ante estimates due to differences in operating hours. The ex post savings calculations were done using the hours confirmed by the site contact, while it is unclear where the ex ante operating hours were taken from. The initially planned lighting measures at the "Automotive Technology" building were removed from both the ex ante and ex post savings and the savings were adjusted accordingly.

**EEM3 - Lighting Retrofit: T12 to T8 conversion and delamping** – The ex post savings were more than the ex ante estimates because of operating hour differences and installed fixtures that were unaccounted for in the ex ante savings. Additional rooms with lighting retrofits in the "Child Development Center" were found during the on-site visit that were excluded in the ex ante report. The ex post savings accounts for these additional fixtures.

**EEM4 - Lighting Retrofit: 8′T12 to 4′T8 w/ occup. sens.** – The ex post savings were less than the ex ante estimates due to difference in operating hours and incomplete fixture installations. The initially planned lighting measures at the "Automotive Technology" building were removed from both the ex ante and ex post savings and the savings were adjusted accordingly.

**EEM5 - Lighting Retrofit: Street Light Conversion** – The ex post savings exceeded the ex ante estimates because instead of replacing the original 400W mercury vapor (MV) street lights with 200W high pressure sodium (HPS) street lights as planned in the ex ante report, the site used 40W LED street lights instead. This greatly increased the ex post savings for this energy efficiency measure. The operating hours remained the same because both preretrofit and post-retrofit fixtures were controlled by photocells and the same campus EMS system.

**EEM6 - Lighting Retrofit: Occupancy Sensors** – The ex post savings exceeded the ex ante estimates because the ex ante report did not include the new fixtures installed in the "Child Development Center" that were confirmed during the site visit. The savings from the additional fixtures were included in the ex post savings. Ex ante operating hours were confirmed by the site contact, so respective operating hours per building were used in the ex post report instead of applying a typical savings percentage for occupancy sensors. This provided a more accurate representation of the actual operating hours for the lighting fixtures controlled by occupancy sensors.

**EEM7 – Packaged Air Conditioners** – The ex post savings differed from the ex ante estimates because different baseline assumptions and measurement approaches were used in the ex ante and ex post savings methodologies. The ex ante also claimed no therms savings, when there actually were because the post-retrofit HVAC units were more efficient than the preretrofit units. However, the ex ante analysis was not available for review so DNV KEMA could not definitively identify why the differences occur. Ex ante assumed pre and post installation heating and cooling tonnage to be the same, but the heating tonnage was actually downsized while the cooling tonnage remained the same, which lead to additional therms savings. The degradation factor applied to the preretrofit HVAC units also led to additional savings.

**EEM8 – Split Air Conditioners** – The ex post savings differed than the ex ante estimates because the ex ante report only accounted for three new AC units when four were actually installed. The air handlers were not retrofitted, so the energy savings were only from the direct cooling loads and did not include savings from pumps and fans since they were not changed under this project. The ex post savings reflected the additional air conditioning unit. Unfortunately, the details of the ex ante analysis were not available for DNV KEMA to review, so the analysis methodologies could not be compared. The degradation factor applied to the preretrofit HVAC units also lead to additional savings.

**EEM9 – Water Pump Motors** – The ex post savings were higher than the ex ante savings due to differences in operating hours. The ex post savings used the operating hours confirmed by the site contact on-site, while it is unclear from where the ex ante operating hours were taken. The reported efficiencies were confirmed during the on-site verification.

**EEM10 – Air Handling Units** – The ex post savings exceeded the ex ante savings because the eQuest building models that were used in the ex ante report did not incorporate VFDs on the supply and return motors in the air handling units when they were actually installed as part of this retrofit. The ex post eQuest models included the VFDs on both the supply and return motors resulting in more savings. Except for the VFDs, the same building characteristics and operating schedules were used in the ex post models as the original ex ante models.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the energy efficiency measure implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's remaining useful life (RUL). After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

According to the site contact at Butte Community College, the lighting, HVAC, and motors at the campus were installed at different times. The EUL ratings were stated by DEER 2008 values. A summary of the lifespan of each measure can be found in Table 44.

**Table 44: Summary of Measure Lifespans**

| Measure | Equipment Age (years) | EUL (years) |
|---|---|---|
| Lighting | 39 | 15 |
| Occupancy Sensors | New Install | 8 |
| Campus Center AHU | 39 | 15 |
| Facilities Building Split AC Systems | 18 | 15 |
| Child Development Center Packaged AC Systems | 16 | 15 |
| Water Pump Motors | 39 | 15 |

Source: DNV KEMA analysis

HVAC degradation depends on a multitude of factors such as operating hours and operating conditions. Since the split air-conditioner systems and packaged air-conditioner units were used past their effective useful life, an average degradation value of 10 percent was applied to the preretrofit equipment efficiencies to account for the loss of performance over the lifespan of the units.

The lighting measures were assumed to be installed according to code at the time, so there are no adjustments made between Baseline 1 and 2 efficiencies. The newly installed occupancy sensors were add-on measures, so the two baselines remained the same. For the packaged air-conditioner systems at the Child Development Center, Baseline 1 used efficiencies of EER 8.52 and 80 AFUE based on the preretrofit equipment, while Baseline 2 used efficiencies of EER 11.2 and 80 AFUE based on 2008 Title 24 and federal standards. For the split air-conditioner systems in the Facilities Building, Baseline 1 used efficiencies of EER 9.5 based on preretrofit equipment, while Baseline 2 used efficiencies of EER 11.2 from 2008 Title 24 and federal standards. No AFUE values were recorded for the split air-conditioner systems because only the condensers were retrofitted, so there were no therm savings. Since all the measures installed on the air handling units at the Campus Center were add-on measures, both the baselines are the same. The efficiencies for the water pump motors at the Campus Center can be found in Table 45. Baseline 1 was based on preretrofit equipment, and Baseline 2 was based on federal standards.

**Table 45: Baseline 1 and Baseline 2 Motor Efficiencies**

| Measure | Baseline 1 Efficiency | Baseline 2 Efficiency |
|---|---|---|
| 3.0 hp motor | 81.2% | 85.5% |
| 5.0 hp motor | 83.9% | 87.5% |
| 7.5 hp motor | 84.8% | 88.5% |
| 15.0 hp motor | 87.0% | 90.2% |

Source: DNV KEMA analysis

Table 46 below provides the annual energy savings estimates used into the life-cycle savings calculations (same as those in Table 45), as well as the EULs and RULs for each of the 10 energy efficiency measures.

**Table 46: Values Used in Life-cycle Savings Calculations**

| Measure | Early Replacement | | Expected Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| EEM1 - Lighting Retrofit, 125W MV to 14W LED | 18,946 | 0 | 18,946 | 0 | 15 | 1 |
| EEM2 - Lighting Retrofit, Incand/Halogen to CFL/T8 | 2,766 | 0 | 2,766 | 3 | 15 | 1 |

| Measure | Early Replacement | | Expected Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| EEM3 - Lighting Retrofit, T-12 to T8 and delamping | 89,091 | 0 | 89,091 | 0 | 15 | 1 |
| EEM4 - Lighting Retrofit, 8ft T12 to 4ft T8 w/ occup sens | 128,770 | 0 | 128,770 | 0 | 15 | 1 |
| EEM5 - Lighting Retrofit, 400W MV to 200W HPS street lights | 31,974 | 0 | 31,974 | 0 | 15 | 1 |
| EEM6 - Lighting Retrofit, install occupancy sensors | 24,272 | 0 | 24,272 | 0 | 8 | N/A |
| EEM7 - Packaged AC | 11,409 | 662 | 2,094 | 26 | 15 | 1 |
| EEM8 - Split AC | 17,620 | 0 | 5,988 | 0 | 15 | 1 |
| EEM9 - Water Pump Motors | 7,303 | 0 | 3,709 | 0 | 15 | 1 |
| EEM10 - Air Handling Units | 128,307 | 0 | 128,307 | 0 | 15 | 1 |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 6,671,550 kWh and 9,930 therms. However, if Baseline 2 is used, the life-cycle savings becomes 6,327,976 kWh and 1,026 therms. Table 47 and Table 48 tabulate the energy savings by year starting with 2011 using this dual baseline.

**Table 47: Baseline 1 Life-cycle Savings**

| Life Cycle | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 468,630 | 157.5 | 967 |
| 2 | 2012 | 468,630 | 157.5 | 967 |
| 3 | 2013 | 468,630 | 157.5 | 967 |
| 4 | 2014 | 468,630 | 157.5 | 967 |
| 5 | 2015 | 468,630 | 157.5 | 967 |
| 6 | 2016 | 468,630 | 157.5 | 967 |
| 7 | 2017 | 468,630 | 157.5 | 967 |

| Life Cycle | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 8 | 2018 | 468,630 | 157.5 | 967 |
| 9 | 2019 | 468,630 | 157.5 | 967 |
| 10 | 2020 | 468,630 | 157.5 | 967 |
| 11 | 2021 | 468,630 | 157.5 | 967 |
| 12 | 2022 | 468,630 | 157.5 | 967 |
| 13 | 2023 | 468,630 | 157.5 | 967 |
| 14 | 2024 | 468,630 | 157.5 | 967 |
| 15 | 2025 | 468,630 | 157.5 | 967 |
| 16 | 2026 | 0 | 0 | 0 |
| | Total | 7,029,450 kWh | 2,363 kW-years | 14,505 therms |

Source: DNV KEMA analysis

**Table 48: Baseline 2 Life-cycle Savings**

| Life-cycle | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 460,630 | 157.5 | 967 |
| 2 | 2012 | 434,035 | 144.2 | 26 |
| 3 | 2013 | 434,035 | 144.2 | 26 |
| 4 | 2014 | 434,035 | 144.2 | 26 |
| 5 | 2015 | 434,035 | 144.2 | 26 |
| 6 | 2016 | 434,035 | 144.2 | 26 |
| 7 | 2017 | 434,035 | 144.2 | 26 |
| 8 | 2018 | 434,035 | 144.2 | 26 |
| 9 | 2019 | 434,035 | 144.2 | 26 |
| 10 | 2020 | 434,035 | 144.2 | 26 |
| 11 | 2021 | 434,035 | 144.2 | 26 |
| 12 | 2022 | 434,035 | 144.2 | 26 |
| 13 | 2023 | 434,035 | 144.2 | 26 |
| 14 | 2024 | 434,035 | 144.2 | 26 |
| 15 | 2025 | 434,035 | 144.2 | 26 |
| 16 | 2026 | 0 | 0 | 0 |
| | Total | 6,537,120 kWh | 2,176 kW-years | 1,331 therms |

Source: DNV KEMA analysis

## Calimesa, City of (009-10-ECE-ARRA)

### Site Summary

The city of Calimesa applied for an Energy Conservation Assistance Act (ECAA-ARRA) loan to retrofit the existing heat pump units with higher efficiency units. The project consisted of six heat pump replacements at the Calimesa Senior Center. Each unit was also provided with two-way programmable thermostats to keep conditioned spaces within a narrow temperature band. A seventh package HVAC unit at the City Hall Annex was replaced with a package unit, using the old thermostat.

DNV KEMA visited the site and verified implementation of this measure. Bin analysis was used to estimate energy savings using a combination of site findings and data collected from monitoring energy consumption of three of the seven heat pumps. The analysis for this site yielded an overall electric energy savings of 156 percent in the first year when compared to the ex ante estimates (Table 49).

**Table 49: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM1A High Efficiency Heat Pumps | Not reported separately | Not reported | N/A | 5,185 | 2.62 | 0 | N/A | N/A |
| EEM1B Two Way Programmable Thermostats | Not reported separately | Not reported | N/A | 12,557 | 0.00 | 0 | N/A | N/A |
| Total | 11,350 | Not reported | N/A | 17,742 | 2.62 | 0 | 156% | N/A |

Source: DNV KEMA analysis

Ex post energy savings are higher than ex ante estimates because the analysis used in the ex ante estimates was did not reflect the project adequately. The ex ante method did not account for the thermostat controls and heating electric savings from the heat pumps, and understated the total HVAC capacity that was replaced.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

Results from Table 50 yield a life-cycle energy savings of 215,910 kWh under Baseline 1 conditions and 147,729 kWh under Baseline 2.

**Table 50: Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 215,910 | 39.3 | 0 |
| Baseline 2 | 147,729 | 2.6 | 0 |

Source: DNV KEMA analysis

### Project Description

This project affected the Senior Center and City Hall Annex buildings. Typical hours of operation for the buildings are from 8 a.m. to 5 p.m. Monday through Thursday with a shortened Friday schedule at the Senior Center. The six heat pumps mentioned in the project files were replaced with higher-efficiency heat pumps. A seventh package HVAC unit at the City Hall Annex was replaced with a package unit. New two-way thermostats replaced existing nonprogrammable thermostats for six Senior Center units and were included as part of the project scope.

### Ex Ante Savings

Ex ante energy savings were calculated using spreadsheet analysis. The calculations assumed the units were used to cool the buildings 40 hours a week throughout the year. Energy consumption is calculated as the SEER value of the unit multiplied by the unit's effective full load hour (EFLH). Based on the simplified algorithm, a total of 2,000 annual hours of cooling was derated by 40 percent to account for a load factor resulting in an EFLH of 800 annual hours of cooling. The baseline SEER was assumed to be 9.29, and the efficient case SEER was assumed to be 13.

### Project Evaluation

A DNV KEMA field engineer visited the project's site on December 8, 2011, to verify measure installation and install data loggers to measure energy consumption of the heat pumps. The engineer returned January 12, 2012, to retrieve the loggers. Outside air temperatures ranged from 27.8°F to 84.6 °F during this period. Since the site visit occurred during the winter, it is not

possible to measure the cooling performance of the heat pumps. However, it is still possible to monitor the units to measure the heating performance of the heat pumps. DNV KEMA installed data loggers on three of the seven heat pumps to help establish a load profile for analysis (Table 51).

**Table 51: Monitoring Details**

| Monitored Equipment | Logger Type | Measurement Type | Measurement Interval | Duration |
|---|---|---|---|---|
| (2) Five-ton heat pump unit | WattNode, Microstation | Pulse output (kW) | 1 minute | 5 weeks |
| (1) Seven and half-ton heat pump unit | WattNode, Microstation | Pulse output (kW) | 1 minute | 5 weeks |

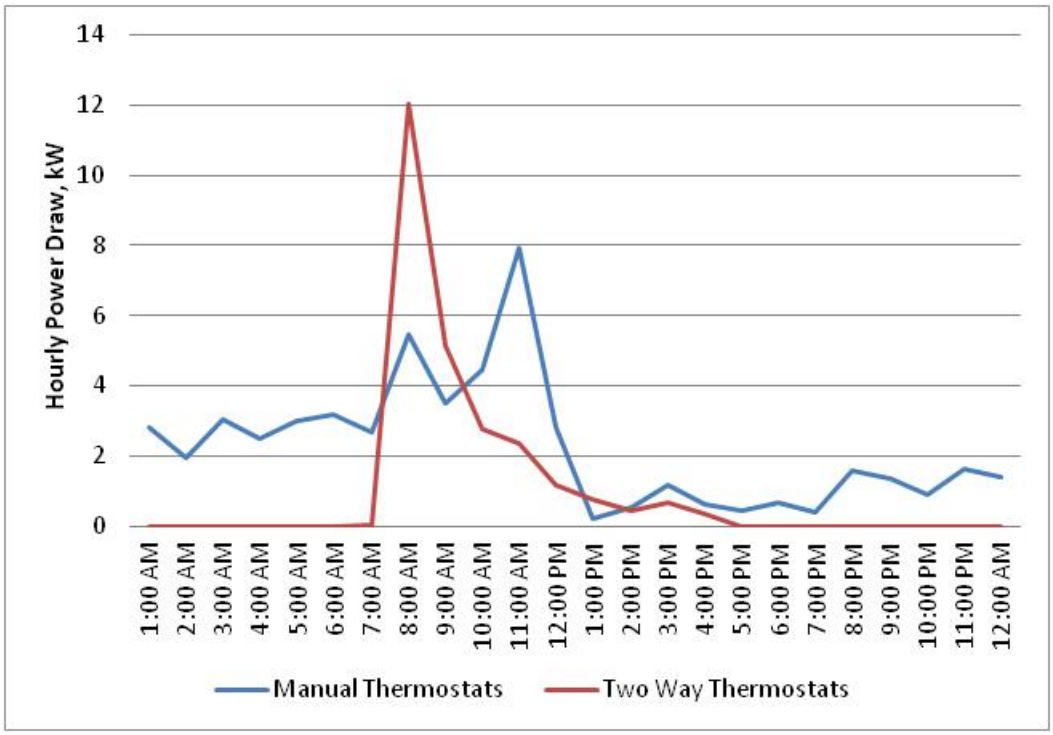
Source: DNV KEMA analysis

At the time of installation, the new two-way thermostats had not yet been installed. DNV KEMA observed that the temperature control was done manually even though some of the units had programmable thermostats. At the time of the logger retrievals one month later, the new two-way thermostats were observed to be installed. The thermostats were programmed and locked out to eliminate manual control. DNV KEMA also found a total of seven heat pump units with a total capacity of 31.5 tons with efficiencies of 13 SEER and 8.0 HSPF.

After processing and examining the data, it was obvious that there were substantial savings from the thermostat controls that would need to be taken into account. Typical weekday operation pre- and postimplementation of the two-way thermostat is shown in Figure 15. Without the two way thermostats, the heat pumps tend to turn on randomly at night when outside air temperatures are low. When the two-way thermostats were installed, there was a substantial peak in energy consumption during the morning time, but it was generously offset by energy savings at night when the temperature set points of the units were set back.

In Figure 15, a typical weekday hourly power draw of metered heat pumps is shown before and after implementation of two-way thermostats. The power draw is a composite of all three units metered.

**Figure 15: Typical Weekday Hourly Power Draw of Metered Heat Pumps**




Source: DNV KEMA analysis

The weekend profile (not shown) of the heat pumps before implementation of the thermostats is similar to the weekday profile. In contrast, the weekend profile of the heat pumps after implementation is estimated at zero even though one of the metered units kicks on during Sundays. However, the same unit shows no usage on Fridays, suggesting that this unit is on the same setback schedule, but the date was inputted incorrectly. To simplify the analysis, the heat pumps are assumed off during the weekends, even though one of the units has an atypical schedule likely due to an error in programming. The other two units show no usage during the weekends after implementation of the two-way thermostats.

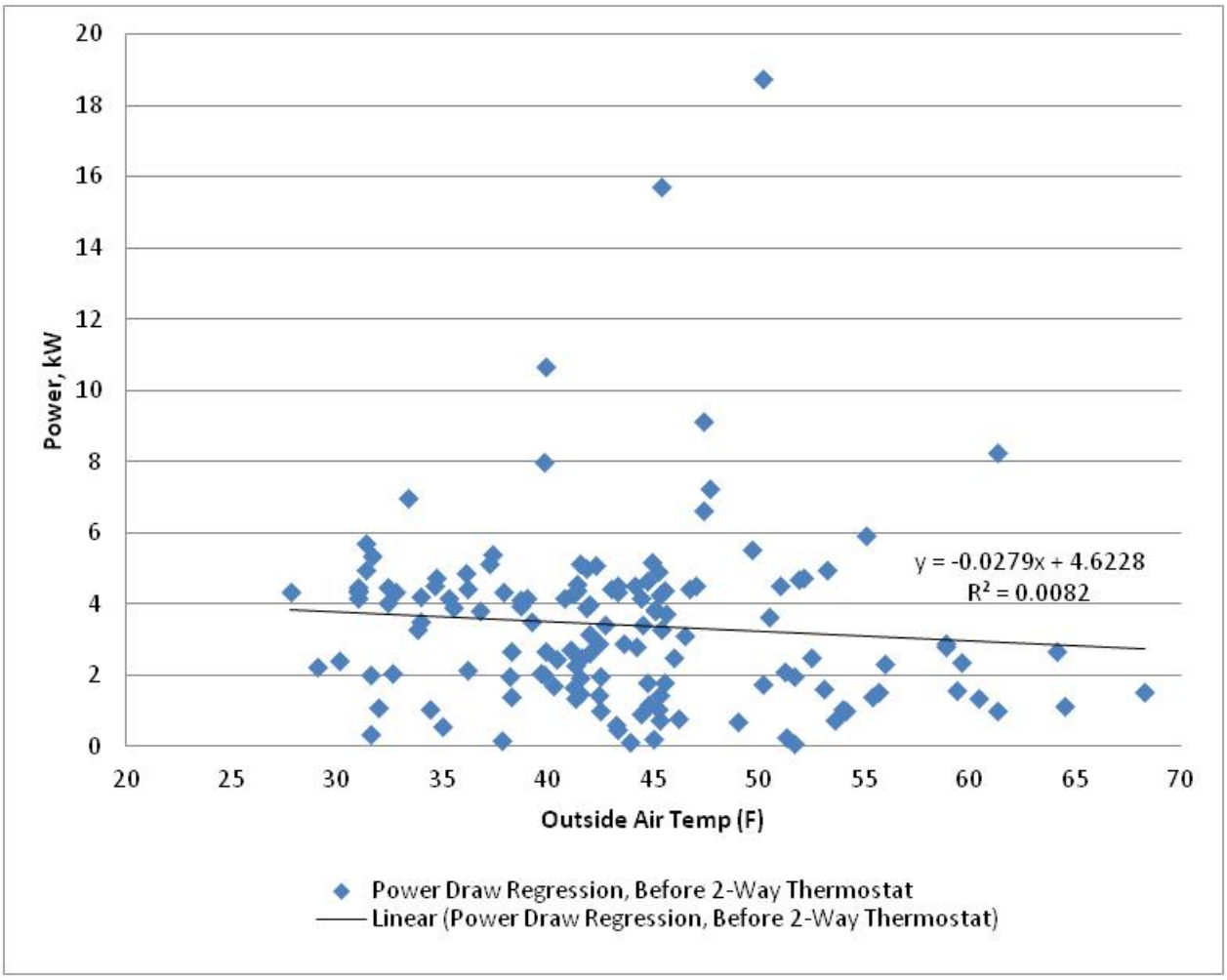
### *Measure 1A − High Efficiency Heat Pumps*

Both regression analysis and billing data analysis were used to estimate savings for this measure.

Bin analysis was used to calculate energy savings from the heat pump retrofit. Using data from the monitoring effort, a regression of the power draw versus outside air temperature was done to estimate heat pump power draws at different bin temperatures. The data was divided into two periods: before and after installation of the new thermostats. Result of the regression analysis pre installation of the thermostat is shown in Figure 16 below. As Figure 2 shows, the data did not closely align to a linear expression, as observed in a low R squared value. The poor R squared value reflects the random cycling of the heat pump during occupied and unoccupied times. These values were used to predict the power draw of the units at different bin

temperatures. The billing data was compared to the total HVAC load predicted by the regression analysis to make sure the energy savings are representative for this measure, as described on page 6.

**Figure 16: Regression Analysis, Power Draw Versus Outside Air Temperature of Heat Pump Units Before Implementation of Two-Way Thermostats**




Source: DNV KEMA analysis

Next, the power draw values were then converted to a percentage load based on the full load power draw of the monitored heat pumps. This step is performed to account for the other units that were not monitored.

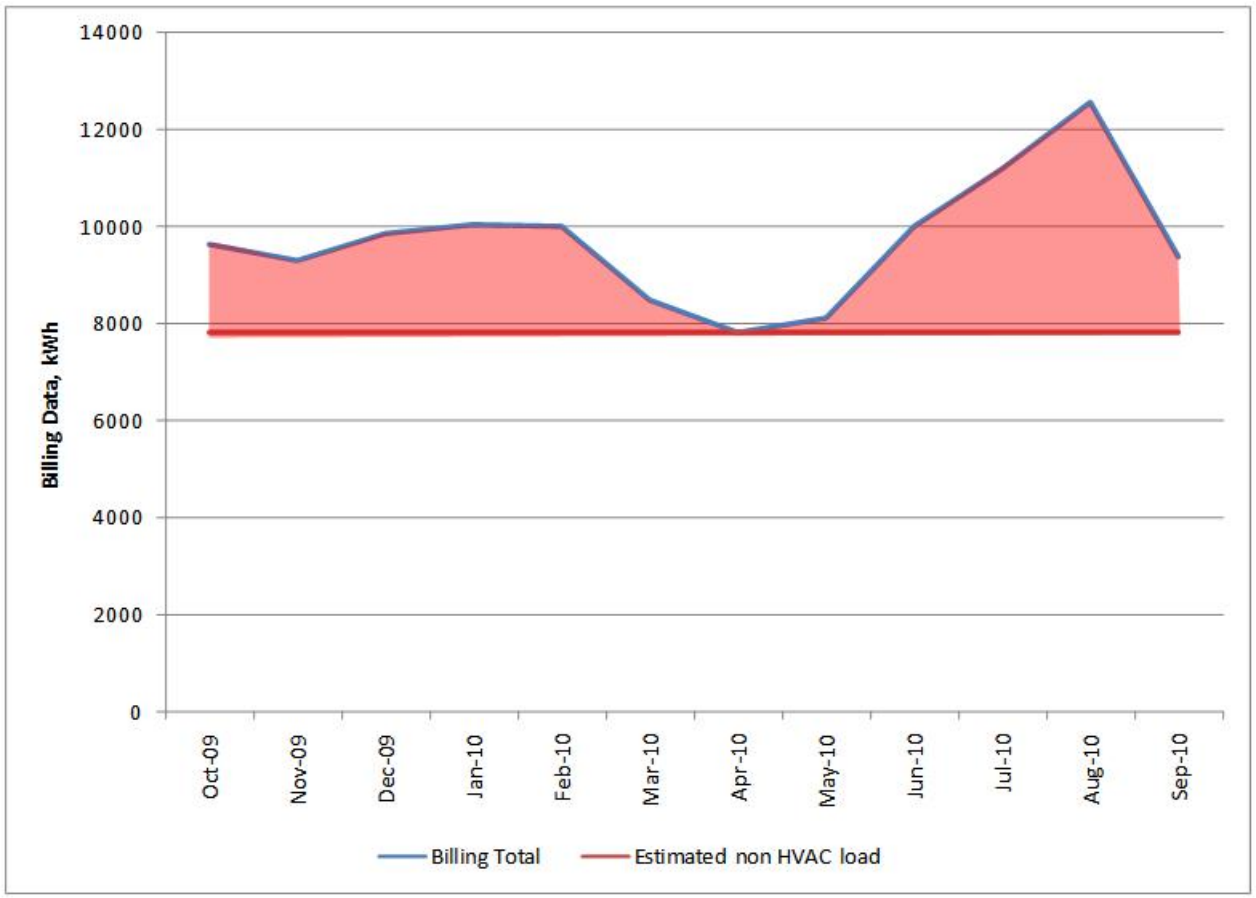
The bin analysis was performed using the efficiency of the new units to reflect the postretrofit case. For the preretrofit case, the bin analysis was repeated using the same building loads and the estimated efficiency of the preretrofit equipment. Degradation of the preretrofit equipment is considered because the analysis is compared to billing data, which reflects actual energy

consumption. Nameplate data was not available at the site visit or in the documents provided for review. The efficiency of the preretrofit units were set at Title 24 minimum standards. After 1992, the minimum Title 24 efficiency is SEER 10 and HSPF of 6.8.

Energy savings for the higher efficiency heat pump using the bin analysis and data from the metering effort was calculated at 5,185 kWh. The analysis includes both heating and cooling loads. Cooling loads were estimated as linear since the evaluation of this project occurred during the winter and power monitoring to estimate cooling load is not possible.

Results of the baseline case were compared with estimates for HVAC energy consumption using billing data. HVAC energy consumption from billing data will typically show a peak during the summer and winter, which represents the energy consumed by the heat pumps. The preretrofit billing data for this site did indeed show this pattern as seen in Figure 17.

**Figure 17: Billing Data Showing Peaks During Winter and Summer Months When HVAC Use Is Expected to Be High − Shaded Area Is Estimate of HVAC Load**



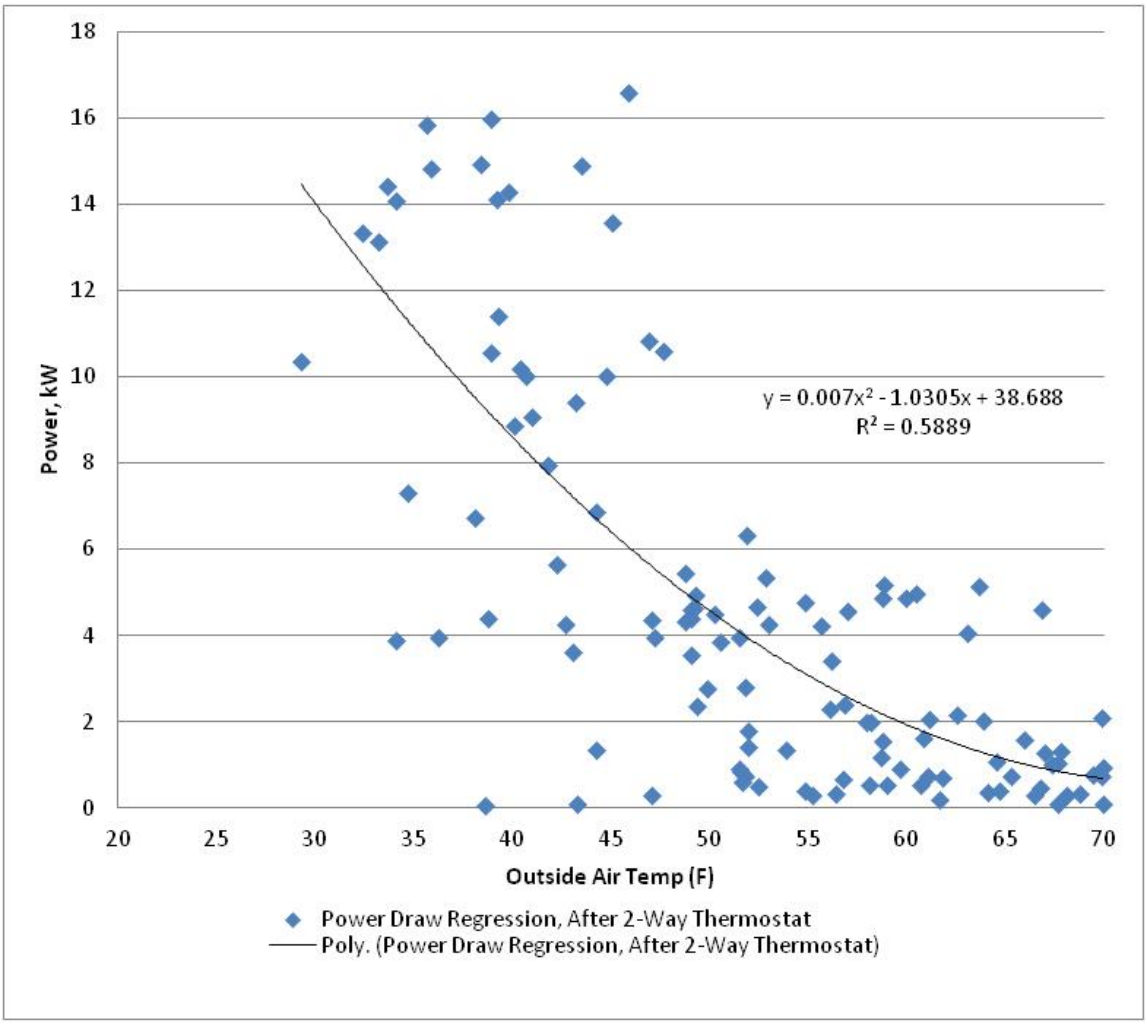

Source: DNV KEMA analysis

DNV KEMA employed this pattern to estimate typical energy consumption from the heat pumps. This value is estimated at 24,940 kWh and was used as a sanity check for the baseline energy consumption calculated from the bin analysis. The bin analysis result for the baseline case of 25,788 kWh was in line with the billing estimate, suggesting that the bin analysis is a fair predictor of the HVAC energy consumption.

### *Measure 1B – "Two-Way" Thermostat*

To evaluate the effects of the two-way thermostats, a second regression analysis was done that examined the power draw data after the thermostats were installed. As seen in Figure 18, there is a definite correlation between power draw and outside air temperature based on the R square value. A building load profile was created from these data using a similar approach as described above.

**Figure 18: Regression Analysis, Power Draw Versus Outside Air Temperature of Heat Pump Units After Implementing Two-Way Thermostats**




Source: DNV KEMA analysis

While the load profile for each heating temperature bin is higher post implementation of the thermostats, the elimination of weekend hours and unoccupied hours resulted in substantial energy savings when the bin analysis was performed. This resulted in an energy savings of 12,557 kWh due to the new thermostats.

### Savings Results

This project saved 17,743 kWh of energy in the first year, and these savings represent a 156 percent realization rate compared to the ex ante estimates. The savings include change out of the existing heat pumps with higher efficiency units and inclusion of two-way programmable thermostats.

### Discussion

The ex ante energy savings calculation was performed incorrectly. Energy savings were calculated using the SEER rating of each unit and assuming a total full load hours for the year. Based on the spreadsheet provided, the units were assumed as being in cooling mode all year round, which is not realistic. The units are heat pumps and will operate only in the cooling mode during the cooling season and heating mode during the heating season. The latter is important because there are also potential energy savings from the heating component if the HSPF of the unit is higher than the rating of the existing unit. The ex ante method essentially overestimates cooling savings and does not account for heating savings from the heat pumps. The total HVAC tonnage used in the ex ante analysis is also incorrect with the equipment observed on-site. DNV KEMA found a total of 31.5 tons of new heat pump capacity versus the 28.5 specified. Furthermore, the ex ante savings estimate did not consider the thermostat controls, which contribute significantly to the energy savings for this site.

All these reasons, along with differences in analysis method, contribute to the higher energy savings realization rate.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the energy efficiency measure implementation and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have operated for the full effective useful life (EUL) of the new equipment regardless if the existing equipment was at the end of its useful life. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period and up until the end of the EUL of the installed measure, an expected replacement baseline is used. This baseline considers minimally code-compliant conditions or standard practice when no code is applicable.

According to the site contact, the HVAC equipment at the facility was more than 15 years old and operated with significant problems. In cases where the units are past their useful lives, Baseline 1 is not used except for in the first-year energy savings calculations. Baseline 2 uses an

HVAC cooling efficiency of SEER 13 and HSPF of 7.7. This is in line with federal minimum standards. The installed unit meets but does not exceed federal minimum standards for cooling, and exceeds federal standards for heating. Thus, for Baseline 2, there are savings only in the heating seasons.

For the thermostat control measure, the expected replacement for the unit at the end of the EUL would have been standard thermostats, which are the same as the existing equipment. Because of this, Baselines 1 and 2 result in the same life-cycle savings.

Table 52 summarizes the energy savings and life-cycle parameters by measure used in the life-cycle savings calculations.

**Table 52: Values Used in Life-cycle Savings Calculations by Measure**

| Measure | Early Replacement | | Expected Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric Energy (kWh) | Gas Energy (therms) | | |
| EEM1-HVAC | 5,185 | 0 | 315 | 0 | 15 | 0 |
| EEM2-2-way thermostats | 12,557 | 0 | 12,557 | 0 | 11 | 0 |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 215,910 kWh (Table 52). However, if the dual baseline is used, the life-cycle savings comes to 147,729 kWh. Table 53 tabulates the energy savings by year starting with 2011 using this dual baseline.

**Table 53: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 17,743 | 2.6 | 0 |
| 2 | 2012 | 17,743 | 2.6 | 0 |
| 3 | 2013 | 17,743 | 2.6 | 0 |
| 4 | 2014 | 17,743 | 2.6 | 0 |
| 5 | 2015 | 17,743 | 2.6 | 0 |
| 6 | 2016 | 17,743 | 2.6 | 0 |
| 7 | 2017 | 17,743 | 2.6 | 0 |
| 8 | 2018 | 17,743 | 2.6 | 0 |

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 9 | 2019 | 17,743 | 2.6 | 0 |
| 10 | 2020 | 17,743 | 2.6 | 0 |
| 11 | 2021 | 17,743 | 2.6 | 0 |
| 12 | 2022 | 5,185 | 2.6 | 0 |
| 13 | 2023 | 5,185 | 2.6 | 0 |
| 14 | 2024 | 5,185 | 2.6 | 0 |
| 15 | 2025 | 5,185 | 2.6 | 0 |
| 16 | 2026 | 0 | 0.0 | 0 |
| Life-cycle | Total | 215,913 | 39.0 | 0 |

Source: DNV KEMA analysis

**Table 54: Dual Baseline Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 17,743 | 2.6 | 0 |
| 2 | 2012 | 12,873 | 0.0 | 0 |
| 3 | 2013 | 12,873 | 0.0 | 0 |
| 4 | 2014 | 12,873 | 0.0 | 0 |
| 5 | 2015 | 12,873 | 0.0 | 0 |
| 6 | 2016 | 12,873 | 0.0 | 0 |
| 7 | 2017 | 12,873 | 0.0 | 0 |
| 8 | 2018 | 12,873 | 0.0 | 0 |
| 9 | 2019 | 12,873 | 0.0 | 0 |
| 10 | 2020 | 12,873 | 0.0 | 0 |
| 11 | 2021 | 12,873 | 0.0 | 0 |
| 12 | 2022 | 315 | 0.0 | 0 |
| 13 | 2023 | 315 | 0.0 | 0 |
| 14 | 2024 | 315 | 0.0 | 0 |
| 15 | 2025 | 315 | 0.0 | 0 |
| 16 | 2026 | 0 | 0.0 | 0 |
| Life-cycle | Total | 147,733 | 2.6 | 0 |

Source: DNV KEMA analysis

## Carlsbad, City of (004-09-ECE-ARRA)

### Site Summary

This streetlight project consisted of replacing 7,149 HPS fixtures (70 W to 400 W) with Induction fixtures (40 W to 200 W). The application originally claimed 7,040 fixtures, but the total grew slightly as the project progressed. In the tracking spreadsheet provided by the site contact, there were multiple instances where either the pre-existing fixture type or the installed fixture type was missing for a given entry. In these cases, the "most probable" fixture wattages were estimated based on other fully defined pre/post fixture pairs. For instance, if 95% of 70 W (95 W power draw) HPS fixtures were replaced with 40W (45 W power draw) induction fixtures, and the other 5% were replaced with 100 W (110 W power draw) induction fixtures, the most probable installed fixture wattage was calculated as 0.95*45 + 0.05*110. Annual operating hours for all fixtures (photo cell controlled) were assumed to be 4,380. Installation verification was performed by randomly sampling 25 fixtures from the city's installation tracking spreadsheet. A few fixtures in the vicinity on these randomly selected fixtures were verified in each case, yielding a total verification sample of 108. Of the 108 verified fixtures, all fixtures were found to have been retrofitted, and only one fixture had a wattage different from that listed in the tracking spreadsheet. Except for this fixture, no modifications to the city's tracking quantities or fixture wattages were made based on the verification sample.

**Table 55: Energy Savings Summary**

| Measure | Ex-Ante Electric Savings (kWh) | Ex-Post Electric Savings (kWh) | Realization Rate |
|---|---|---|---|
| Street Lighting Retrofit | 3,078,049 | 3,054,356 | 99.20% |

Source: DNV KEMA analysis

**Table 56: City Tracking Retrofit Claims**

| Pre-Existing Fixtures | | | Installed Fixtures | | | Fixture Count |
|---|---|---|---|---|---|---|
| Type | Nominal Wattage | Functional Wattage | Type | Nominal Wattage | Functional Wattage | |
| HPS | 70 | 95 | Induction | 40 | 45 | 1348 |
| HPS | 70 | 95 | Induction | 100 | 110 | 43 |
| HPS | 70 | 95 | Induction | 150 | 160 | 0 |
| HPS | 70 | 95 | Induction | 200 | 210 | 0 |
| HPS | 70 | 95 | Induction | Unknown | 47 | 45 |
| HPS | 100 | 138 | Induction | 40 | 45 | 3093 |
| HPS | 100 | 138 | Induction | 100 | 110 | 70 |
| HPS | 100 | 138 | Induction | 150 | 160 | 2 |
| HPS | 100 | 138 | Induction | 200 | 210 | 0 |

| Pre-Existing Fixtures | | | Installed Fixtures | | | Fixture Count |
|---|---|---|---|---|---|---|
| Type | Nominal Wattage | Functional Wattage | Type | Nominal Wattage | Functional Wattage | |
| HPS | 100 | 138 | Induction | Unknown | 47 | 280 |
| HPS | 150 | 188 | Induction | 40 | 45 | 5 |
| HPS | 150 | 188 | Induction | 100 | 110 | 75 |
| HPS | 150 | 188 | Induction | 150 | 160 | 3 |
| HPS | 150 | 188 | Induction | 200 | 210 | 0 |
| HPS | 150 | 188 | Induction | Unknown | 108 | 11 |
| HPS | 200 | 250 | Induction | 40 | 45 | 54 |
| HPS | 200 | 250 | Induction | 100 | 110 | 999 |
| HPS | 200 | 250 | Induction | 150 | 160 | 20 |
| HPS | 200 | 250 | Induction | 200 | 210 | 12 |
| HPS | 200 | 250 | Induction | Unknown | 109 | 163 |
| HPS | 250 | 295 | Induction | 40 | 45 | 8 |
| HPS | 250 | 295 | Induction | 100 | 110 | 213 |
| HPS | 250 | 295 | Induction | 150 | 160 | 480 |
| HPS | 250 | 295 | Induction | 200 | 210 | 136 |
| HPS | 250 | 295 | Induction | Unknown | 167 | 44 |
| HPS | 400 | 466 | Induction | 40 | 45 | 0 |
| HPS | 400 | 466 | Induction | 100 | 110 | 3 |
| HPS | 400 | 466 | Induction | 150 | 160 | 0 |
| HPS | 400 | 466 | Induction | 200 | 210 | 4 |
| HPS | 400 | 466 | Induction | Unknown | 88 | 0 |
| HPS | Unknown | 127 | Induction | 40 | 45 | 19 |
| HPS | Unknown | 244 | Induction | 100 | 110 | 5 |
| HPS | Unknown | 292 | Induction | 150 | 160 | 14 |
| HPS | Unknown | 296 | Induction | 200 | 210 | 0 |
| HPS | Unknown | - | Induction | Unknown | - | 0 |

Source: DNV KEMA analysis

**Table 57: Verified Sample Findings**

| Pre-Existing Fixtures | | Installed Fixtures | | Verified Fixture Count | % of Verification Sample Properly Installed | Average functional wattage of fixtures with discrepancies |
|---|---|---|---|---|---|---|
| Type | Nominal Wattage | Type | Nominal Wattage | | | |
| HPS | 70 | Induction | 40 | 16 | 100% | - |
| HPS | 70 | Induction | 100 | 0 | - | - |

| Pre-Existing Fixtures | | Installed Fixtures | | Verified Fixture Count | % of Verification Sample Properly Installed | Average functional wattage of fixtures with discrepancies |
|---|---|---|---|---|---|---|
| Type | Nominal Wattage | Type | Nominal Wattage | | | |
| HPS | 70 | Induction | 150 | 0 | - | - |
| HPS | 70 | Induction | 200 | 0 | - | - |
| HPS | 70 | Induction | Unknown | 0 | - | - |
| HPS | 100 | Induction | 40 | 45 | 100% | - |
| HPS | 100 | Induction | 100 | 0 | - | - |
| HPS | 100 | Induction | 150 | 0 | - | - |
| HPS | 100 | Induction | 200 | 0 | - | - |
| HPS | 100 | Induction | Unknown | 0 | - | - |
| HPS | 150 | Induction | 40 | 0 | - | - |
| HPS | 150 | Induction | 100 | 0 | - | - |
| HPS | 150 | Induction | 150 | 0 | - | - |
| HPS | 150 | Induction | 200 | 0 | - | - |
| HPS | 150 | Induction | Unknown | 0 | - | - |
| HPS | 200 | Induction | 40 | 1 | 0% | 100 |
| HPS | 200 | Induction | 100 | 6 | 100% | - |
| HPS | 200 | Induction | 150 | 0 | - | - |
| HPS | 200 | Induction | 200 | 4 | 100% | - |
| HPS | 200 | Induction | Unknown | 0 | - | - |
| HPS | 250 | Induction | 40 | 0 | - | - |
| HPS | 250 | Induction | 100 | 2 | 100% | - |
| HPS | 250 | Induction | 150 | 14 | 100% | - |
| HPS | 250 | Induction | 200 | 19 | 100% | - |
| HPS | 250 | Induction | Unknown | 1 | 100% | - |
| HPS | 400 | Induction | 40 | 0 | - | - |
| HPS | 400 | Induction | 100 | 0 | - | - |
| HPS | 400 | Induction | 150 | 0 | - | - |
| HPS | 400 | Induction | 200 | 0 | - | - |
| HPS | 400 | Induction | Unknown | 0 | - | - |
| HPS | Unknown | Induction | 40 | 0 | - | - |
| HPS | Unknown | Induction | 100 | 0 | - | - |
| HPS | Unknown | Induction | 150 | 0 | - | - |
| HPS | Unknown | Induction | 200 | 0 | - | - |
| HPS | Unknown | Induction | Unknown | 0 | - | - |
| Total | - | - | - | 25 | 99% | - |

Source: DNV KEMA analysis

**Table 58: Verification Revised Fixture**

| Pre-Existing Fixtures | | | Installed Fixtures | | Revised Functional Wattage Based on Verification | Fixture Count | Verified Demand Reduction (kW) | Verified Energy Savings (kWh) |
|---|---|---|---|---|---|---|---|---|
| Type | Nom-inal Watt-age | Functional Wattage | Type | Nominal Wattage | | | | |
| HPS | 70 | 95 | Induction | 40 | 45 | 1,348 | 67.40 | 295,212 |
| HPS | 70 | 95 | Induction | 100 | 110 | 43 | -0.65 | (2,825) |
| HPS | 70 | 95 | Induction | 150 | 160 | 0 | - | - |
| HPS | 70 | 95 | Induction | 200 | 210 | 0 | - | - |
| HPS | 70 | 95 | Induction | Unknown | 47 | 45 | 2.16 | 9,458 |
| HPS | 100 | 138 | Induction | 40 | 45 | 3,093 | 287.65 | 1,259,902 |
| HPS | 100 | 138 | Induction | 100 | 110 | 70 | 1.96 | 8,585 |
| HPS | 100 | 138 | Induction | 150 | 160 | 2 | -0.04 | (193) |
| HPS | 100 | 138 | Induction | 200 | 210 | 0 | | |
| HPS | 100 | 138 | Induction | Unknown | 47 | 280 | 25.62 | 112,203 |
| HPS | 150 | 188 | Induction | 40 | 45 | 5 | 0.72 | 3,132 |
| HPS | 150 | 188 | Induction | 100 | 110 | 75 | 5.85 | 25,623 |
| HPS | 150 | 188 | Induction | 150 | 160 | 3 | 0.08 | 368 |
| HPS | 150 | 188 | Induction | 200 | 210 | 0 | - | - |
| HPS | 150 | 188 | Induction | Unknown | 108 | 11 | 0.88 | 3,860 |
| HPS | 200 | 250 | Induction | 40 | 45 | 53 | 10.87 | 47,589 |
| HPS | 200 | 250 | Induction | 100 | 110 | 1,000 | 140 | 613,200 |
| HPS | 200 | 250 | Induction | 150 | 160 | 20 | 1.80 | 7,884 |
| HPS | 200 | 250 | Induction | 200 | 210 | 12 | 0.48 | 2,102 |
| HPS | 200 | 250 | Induction | Unknown | 109 | 163 | 23.02 | 100,814 |
| HPS | 250 | 295 | Induction | 40 | 45 | 8 | 2.00 | 8,760 |
| HPS | 250 | 295 | Induction | 100 | 110 | 213 | 39.41 | 172,594 |
| HPS | 250 | 295 | Induction | 150 | 160 | 480 | 64.80 | 283,824 |
| HPS | 250 | 295 | Induction | 200 | 210 | 136 | 11.56 | 50,633 |
| HPS | 250 | 295 | Induction | Unknown | 167 | 44 | 5.63 | 24,641 |
| HPS | 400 | 466 | Induction | 40 | 45 | 0 | - | - |
| HPS | 400 | 466 | Induction | 100 | 110 | 3 | 1.07 | 4,678 |
| HPS | 400 | 466 | Induction | 150 | 160 | 0 | - | - |
| HPS | 400 | 466 | Induction | 200 | 210 | 4 | 1.02 | 4,485 |
| HPS | 400 | 466 | Induction | Unknown | 88 | 0 | | |
| HPS | Unknown | 127 | Induction | 40 | 45 | 19 | 1.55 | 6,809 |
| HPS | Unknown | 244 | Induction | 100 | 110 | 5 | 0.67 | 2,927 |

| Pre-Existing Fixtures | | | Installed Fixtures | | Revised Functional Wattage Based on Verification | Fixture Count | Verified Demand Reduction (kW) | Verified Energy Savings (kWh) |
|---|---|---|---|---|---|---|---|---|
| Type | Nom-inal Watt-age | Functional Wattage | Type | Nominal Wattage | | | | |
| HPS | Unknown | 292 | Induction | 150 | 160 | 14 | 1.85 | 8,091 |
| HPS | Unknown | 296 | Induction | 200 | 210 | 0 | - | - |
| HPS | Unknown | - | Induction | Unknown | - | 0 | - | - |
| Total | | | | | | | 697.34 | 3,054,356 |

Source: DNV KEMA analysis

**Figure 19: Verification Sample Area Map:**

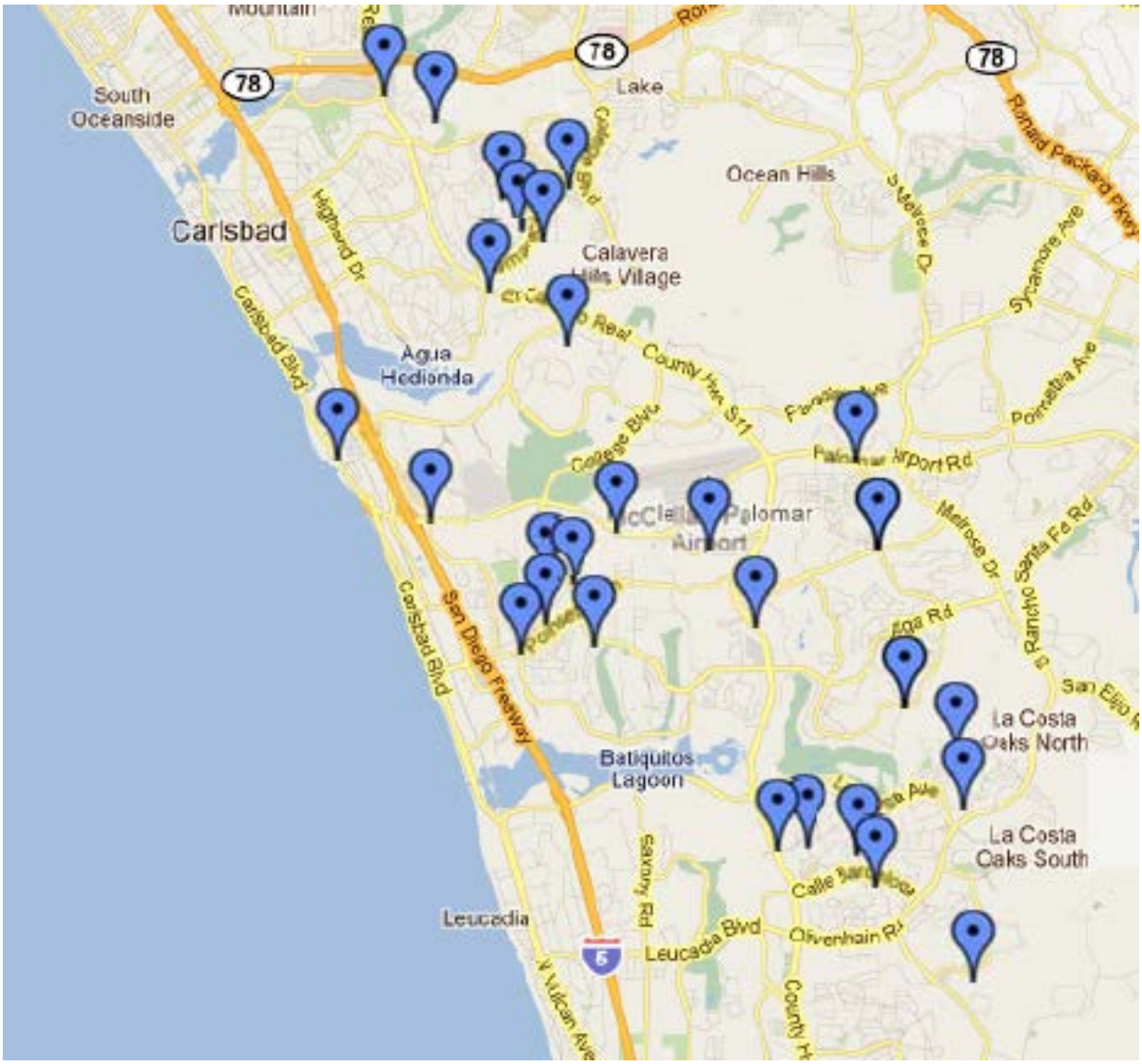



Photo Credit: DNV KEMA

## Clovis, City of (005-09-ECE-ARRA)

### Site Summary

The city of Clovis applied for Energy Conservation Assistance Act (ECAA-ARRA) loans for four energy efficiency measures (EEM): PC power management software implementation, indoor and outdoor lighting fixture and control retrofits, Public Safety Building heating, ventilation, and air-conditioning (HVAC) equipment replacements, and Senior Center HVAC equipment replacements. The PC power management software was installed on computers throughout the city's offices. More than 4,000 lighting replacements or retrofits were performed at the city's many facilities, including the city's public safety department and fire stations. The majority of lighting upgrades consisted of retrofitting T12 lamps or replacing older T8 lamps with new, lower wattage T8 800 series lamps. Some metal halide and high-pressure sodium fixtures and lamps were also retrofitted to T5 fixtures. Four new 50-ton, direct-expansion (DX), packaged air conditioners and two new condensing HVAC boilers with new water pumps and associated VFDs replaced existing units at the Public Safety Building. One new 50-ton air-cooled chiller and water pump along with one new condensing HVAC boiler and pump replaced the existing units at the city's Senior Center.

DNV KEMA visited the Public Safety Building, Senior Center, Fire Station #1, and Fire Station #5 to verify the implementation of these measures. During the site visits, DNV KEMA sampled installation of the PC power management software system, as well as sampled the lighting retrofits to verify installations and fixture types. DNV KEMA also verified the quantity, manufacturers, and model numbers of all the installed HVAC equipment.

Spreadsheet analysis was used to estimate energy savings for all measures using a combination of site findings and literature reviews. The analysis yielded an overall annual electric energy savings of 110 percent and natural gas savings of 79 percent when compared to ex ante estimates. The energy and power savings by measure are provided in Table 59.

**Table 59: Energy Savings Summary by Measure Category**

| Measure Category | Ex ante | | | Ex post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM1-PC power management, city-wide | 120,000 | Not reported | N/A | 66,792 | 0.0 | N/A | 56% | N/A |
| EEM2-Lighting, city-wide | 588,495 | Not reported | N/A | 697,498 | 100.3 | N/A | 119% | N/A |
| EEM3-Police Dept. HVAC | 166,518 | Not reported | 2,000 | 195,650 | 172.0 | 1,871 | 117% | 94% |

| Measure Category | Ex ante | | | Ex post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM4-Senior Center HVAC | 17,412 | Not reported | 1,000 | 17,280 | 9.0 | 511 | 99% | 51% |
| Totals | 892,425 | Not reported | 3,000 | 977,220 | 281.3 | 2,382 | 110% | 79% |

Source: DNV KEMA analysis

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

The overall results from Table 59 yields a life-cycle energy savings of 14,988,227 kWh, life-cycle demand savings of 5,125 kW-years, and life-cycle natural gas energy savings of 47,632 therms when considering only the existing conditions of the buildings. Using a dual baseline that accounts for the remaining useful life of the pre-existing equipment, the life-cycle savings total 11,340,953 kWh, 1,975 kW-years, and 63,156 therms, as shown in Table 60.

**Table 60: Ex Post Life-cycle Savings Totals**

| Baseline type | Electric Energy Savings (kWh) | Electric Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 14,988,227 | 5,125 | 47,632 |
| Baseline 2 | 11,340,953 | 1,975 | 63,156 |

Source: DNV KEMA analysis

## Project Description

### *Measure 1: City-wide Power Management of PCs*

This measure involved installation of control software on city computers in order to manage computer power settings from a centralized location. The software puts the PCs into a reduced power state without interfering with end-user productivity, desktop maintenance or software upgrades. The PC power management software is installed at the server and subsequently

distributed to each identified PC via the Server. The measure affected a total of 354 desktop computers and monitors.

### *Measure 2: City-wide Lighting*

This measure consisted of 3,826 lighting fixture retrofits and 225 lighting control retrofits throughout the city's facilities. Most often, the lighting fixture upgrades involved replacing existing interior, multi-lamp T8 and T12 fixtures with lower wattage bulbs and more efficient ballasts. Less often, existing exterior metal halide and high-pressure sodium fixtures were retrofitted with high output, multi-lamp T5 fixtures. The lighting control retrofits involved installing ceiling-mounted occupancy sensors at the retrofitted interior lighting fixtures to further save energy by reducing hours of operation during unoccupied periods.

### *Measure 3: Public Safety Building HVAC*

This measure consisted of installing the following at the Public Safety Building:

- four new 50 ton, air-cooled, packaged rooftop air conditioning units (RTUs), Trane model SXHLF5040*67C7B, to replace four existing 50 ton rooftop units, Trane model SXHFC5040168C7A, installed in 2002; and
- two new 750 kBTU/hr, condensing boilers for space heating, Lochinvar model KBN 800, and new 7.5 - hp VFD-controlled water pumps to replace two 756 kBTU/hr boilers, Raypack model H3-0902, and 7.5 –hp pumps installed approximately 20 years ago.

### *Measure 4: Senior Center HVAC*

This measure consisted of installing the following equipment at the Senior Center:

- a new 50 ton, air-cooled chiller, Trane model CGAM052A, and 2 hp water pump serving the chilled water loop to replace a 30-year-old, 50 ton, air-cooled chiller, Trane model CGABC50AB, and 2- hp water pump; and
- a new condensing boiler for space heating, Lochinvar model KBN500, with a new 3/4 hp pump to replace the existing boiler, Teledyne Laars model HO-500 HVAC, and accompanying pump.

## Ex Ante Savings

### *Measure 1 − Citywide PC Power Management*

A general algorithm taking into account the number of computers, power requirements of the computers at various operation modes (on, off, suspend), and changes in hours of operation at each mode due to the power management software are used to determine savings. All values are assumed without source citations. This method produced an estimated annual savings of 200 kWh per combined desktop computer and monitor. This savings was applied to an estimated 600 combined desktop computers and monitors for a total measure savings of 120,000 kWh per year. For measures involving energy management software, the savings can be very difficult to verify and uncertain as a result of various unknown factors such as typical power draws at various operational states, and fraction of hours at each operational state with or

without energy management software. Savings can be easily overestimated or underestimated due to this.

### *Measure 2 − Citywide Lighting*

The site contact used a comprehensive lighting calculation spreadsheet to estimate the potential savings from the lighting fixture and control retrofits. This spreadsheet was made available to the DNV KEMA engineering team for verification and review. This spreadsheet organizes unique building area and fixture type combinations into a single row within the spreadsheet. The spreadsheet contains around 600 rows of lighting retrofit savings calculations for 4,276 lighting fixture and control retrofits. The savings calculations were performed using the following three equations for lighting kW, lighting kW savings, and lighting kWh savings:

$$Lighting\ kW_{existing/\ replacemennt} = \frac{Watts\ per\ lamp \times lamps\ per\ fixture}{1000\frac{Watts}{kW}} \times fixture\ quantity$$

$$Lighting\ kW\ savings = Lighting\ kW_{existing} - Lighting\ kW_{replacement}$$

$$Lighting\ kWh\ savings = (Lighting\ kW \times hours)_{existing} - (Lighting\ kW \times hours)_{replacement}$$

where,

- *Watts per lamp* is the electric power consumption of a single lamp.
- *Lamps per fixture* is the number of lamps installed on each fixture.
- *Fixture quantity* is the number of identical fixtures within a specific building area.
- *Hours* is the number of annual hours of operation for a specific lighting row. (Note: Annual hours of operation for replacement fixtures may be different than existing fixtures if occupancy sensor controls were installed.)

### *Measure 3 − Public Safety Building HVAC*

The ex ante savings calculations for the air-conditioning rooftop units and the condensing boilers were both performed using simple spreadsheet tables. Savings calculations for the rooftop AC primarily uses a full-load kW/ton value, adjusted for age-related degradation of the existing units,[20] with an average load factor and weather data-based annual cooling hours. The following four equations were used to determine ex ante savings for the rooftop AC units:

20 The adjusted kW per ton is used only for calculating the energy consumption of the existing units, which have experienced noticeable decline in performance due their age. For calculating energy

$$Adjusted\ kW\ per\ ton = \ kW\ per\ ton\ \times\ (1 + Degradation\ factor)^{unit\ age}$$

$$RTU\ kW_{existing/\ replacement} = Cooling\ capacity[tons] \times Adjusted\ kW\ per\ ton \times Quantity$$

$$RTU\ kW\ savings = \ (RTU\ kW)_{existing} - (RTU\ kW)_{replacement}$$

$$RTU\ kWh\ savings = RTU\ kW\ savings\ \times Load\ factor\ (\%) \times Hours$$

where,

- *kW per ton* is the quotient of power consumption to cooling capacity at full load. Ex ante calculations used 2.00 kW/ton for existing units and 1.15 for replacement units.
- *Degradation* factor is the estimated annual performance decline, reported as 0.1 percent.
- *Unit age* is the age of the existing unit, reported as seven years.
- *Cooling* capacity is the units maximum capacity for removing heat energy from the conditioned air , reported as 50 tons (one ton of cooling equals 12,000 BTU/h).
- *Quantity* is the number of RTUs, reported as four units.
- *Load* factor is the average load level that the unit operate at over the year, reported as 22 percent of full load.
- *Hours* is the number of annual cooling hours, based upon weather data (the type of and source of this data was not provided to DNV KEMA) and reported as 4,380 hours.

Savings calculations for the boilers use an average load factor and hours of operation at average load together with heating rate output and boiler efficiency to determine annual therm savings. The following three equations were used to determine ex ante savings for HVAC boiler units:

$$Boiler\ heating\ input_{existing/replacement}\ = \frac{Heating\ output\left[\frac{BTU}{h}\right] \times Quantity}{\eta_{boiler}}$$

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consumption of the replacement unit, the standard kW per ton value is used directly in the RTU kW equation.

$$Boiler\ therms_{\ existing/replacement} = \frac{Boiler\ heating\ input \times Average\ load\ factor \times Hours}{100{,}000\ \frac{BTUs}{therm}}$$

$$Boiler\ therms\ savings = Boiler\ therms_{existing} - Boiler\ therms_{replacement}$$

where,

- *Heating output* is the maximum rate of heat delivered by the existing or replacement boiler, reported as 700,000 BTU/h.
- *Quantity* is the number of boiler units, existing or replaced, reported as two.
- $_{boiler}$ is the thermal efficiency of the existing or replacement units, reported as 0.80 and 0.92 respectively.
- *Boiler heating input* is the maximum rate of heating value input to the boiler.
- *Average load factor* is the average load level that the unit operate at over the year, reported as 20 percent of full load.
- *Hours* is the annual hours of operation at the average load level, reported as 4,380 hours.

No electric savings were claimed for the hot water pumps and associated VFDs.

### *Measure 4 − Senior Center HVAC*

The ex ante savings calculation methods for the air-cooled chiller and condensing boiler at the Senior Center were the same as those used for the Public Safety Building. The ex ante values used for the chiller calculations are as follows:

- *kW per ton* for the existing and replacement units are 1.00 and 0.80, respectively.
- Degradation factor is 0.5 percent.
- *Unit age* is 30 years.
- *Cooling capacity* is 50 tons (one ton of cooling equals 12,000 BTU/h).
- *Quantity* is one unit
    - Load factor is percent of full load
    - Hours is 4,380 annual hours.

The ex ante values used for the condensing boiler calculations are as follows:

- *Heating output* is 700,000 BTU/h.

- *Quantity* is one.
- $_{boiler}$ of the existing or replacement units is 0.80 and 0.92, respectively.
- *Average load factor* is 20 percent of full load.
- *Hours* is 4,380 hours annual.

No electric savings were claimed for the hot water pumps and associated VFDs.

### Project Evaluation

Two DNV KEMA field engineers visited the project sites on January 19th, 2012, to verify the measure installations and gather data on equipment model numbers and quantities. Table 61 summarizes the results of the installation verification.

**Table 61: Verification Summary**

| Site | Equipment | Quantity Reported | Quantity Verified | Site Notes |
|---|---|---|---|---|
| Multiple city facilities | PC power management software | 354 | 354 | Verified software installed on 354 desktop computers. |
| Multiple city facilities | Lighting retrofits | 4,051 | 4,051 | Verified sample of 400 lighting retrofits throughout city facilities. |
| Public Safety Building | Direct exchange packaged air conditioners | 4 | 4 | 50 ton units |
| Public Safety Building | Condensing boilers | 2 | 2 | 750 kBTU/hr units replacing 756 kBTU/hr units |
| Public Safety Building | 7.5 hp water pump with VFD | 2 | 2 | |
| Senior Center | Direct exchange chiller | 1 | 1 | 49.5 ton unit replacing a 45.4 ton unit |
| Senior Center | 2 HP water pump for chiller loop | 1 | 1 | |
| Senior Center | Condensing boiler with 0.75 hp pump | 1 | 1 | 450 kBUT/hr units replacing a 408 kBTU/hr unit |

Source: DNV KEMA analysis

#### *Measure 1 − Citywide PC Power Management*

Installation of the computer power management software was verified with the site contact via the software's Sustainability Dashboard interactive reporting tool. A total of 354 desktop computers have the power management software installed, whereas the initial scope of work estimated 600 installations.

Ex post analysis for this measure used the following equation to determine energy consumption for the preretrofit case:

$$Energy = 8{,}760 \times \left(Hours_{on} \times Power_{on} + Hours_{sleep} \times Power_{sleep} + Hours_{off} \times Power_{off}\right)$$

where,

- *Energy* is the annual energy consumption in kWh.
- *Hours* is the estimated number of hours the computer is in *on, sleep*, or *off* modes.
- *Power* is the respective power draws at those modes.

Hours of operation at these different modes are based on established studies for office equipment[21] while the power draws at the various operating modes are based upon ENERGY STAR®-compiled data regarding computers.[22] Using these two sources, DNV KEMA calculated the annual electrical energy savings for each desktop computer and monitor combination to be 189 kWh.

For the postretrofit case, the power draws for each mode were unchanged, but the operating hours at each mode shifted to reflect the power management software settings. DNV KEMA assumed that the power management software decreased the initial "on" mode hours by 46 percent, thus increasing the hours in the standby mode.[23] Using this analysis, total energy savings for this measure were calculated to be 66,792 kWh. This value represents a realization rate of 56 percent compared to ex ante savings claims. The principal reason for the lower realization rate is that the software was installed on fewer PCs than had been initially estimated in the ex ante savings estimate.

### *Measure 2 − Citywide Lighting*

The ex post lighting savings analysis is based upon the information contained in the lighting calculation spreadsheet provided to DNV KEMA by the Clovis site contact. The total first-year annual savings claimed in the aforementioned lighting spreadsheet was 679,498 kWh, as shown in Table 62. This savings value is 91,003 kWh greater than the 588,495 kWh claimed in the savings tracking spreadsheet that the Energy Commission provided to DNV KEMA. It is possible that the scope of work for the lighting measure was reduced, but this information was not provided to the DNV KEMA evaluation team.

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21 *After-Hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment,* Roberson et al., 2004.

22 ENERGY STAR® 5.0 Dataset for Computers, using category B computers.

23 *Enterprise PC Power Management Tools: Greening IT from the Top Down,* Barr et al, 2010.

During the site visit, the DNV KEMA engineering team was able to visually verify the installation of about 400 lighting fixtures in the Public Safety Building, Senior Center, Fire Station #1 and Fire Station #5. The majority of the verified lighting consisted of two-lamp fixtures with F32T8/28W lamps, the most common lighting retrofit performed under this measure.

DNV KEMA reviewed the ex ante savings calculations values and equations for the 17 lighting entries having more than 10,000 kWh of annual savings; combined, these represent more than 53 percent of the total lighting savings claimed. The equations were checked for validity and reproduced to ensure they had been executed correctly. Fixture wattages were checked against available sales literature or the Consortium for Energy Efficiency (CEE) lighting database. Annual operating hours used in the ex ante calculation were checked for reasonableness given the listed location and application of the lighting fixture. On the following page, Table 62 shows the annual electric energy savings for the 17 lighting entries that claimed more than 10,000 kWh of annual savings, as well as the values of the existing and replacement equipment used to determine those savings figures. Total ex post energy savings for the measure were determined to be 679,498 kWh.

Demand savings were calculated by filtering the lighting calculation spreadsheet to exclude fixtures that primarily operate at night (during off peak times) and summing the kW power savings for the resulting lighting entries. Filtering was achieved by excluding the following installations from the lighting list:

- Areas: canopy, flag flood, flag pole, exterior, parking, patio
- Fixture type: metal halide exterior
- Annual hours: 4,100 (street or parking annual hours).

Using the above described methods, the total demand savings for this measure were determined to be 100.3 kW.

**Table 62: Verification of Lighting Retrofits With ≥10,000 KWh Ex Ante Savings**

| Existing | | | | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fixture Description** | **Fixture Watt** | **Fixture Count** | **Annual Hours** | **Annual Savings, kWh** | **Fixture Description** | **Fixture Watt** | **Fixture Count** | **Annual Hours** | **Annual kWh** | **Annual Savings, kWh** |
| 400 W MH High bay | 460 | 13 | 7,488 | 44,778 | 4-lamp T5HO High bay | 216 | 13 | 2,434 | 6,835 | 37,944 |
| 2-lamp F32T8 | 59 | 404 | 4,920 | 117,273 | 2-lamp F32T8/28W | 41 | 404 | 4,920 | 81,495 | 35,778 |
| 400W HPS | 465 | 33 | 4,100 | 62,915 | 4-lamp T5HO Shoebox | 216 | 33 | 4,100 | 29,225 | 33,690 |
| MH Parking Lights | 850 | 18 | 4,100 | 62,730 | 8-lamp T5HO Shoebox | 432 | 18 | 4,100 | 31,882 | 30,848 |
| 400 W MH High bay | 460 | 12 | 7,488 | 41,334 | 4-lamp T5HO High bay | 216 | 12 | 4,992 | 12,939 | 28,394 |
| 400 W MH High bay | 460 | 11 | 7,488 | 37,889 | 4-lamp T5HO High bay | 216 | 11 | 4,992 | 11,861 | 26,028 |
| 4-lamp F32T8 | 118 | 92 | 6,490 | 70,455 | 4-lamp F32T8/28W | 76 | 92 | 6,490 | 45,378 | 25,077 |
| 4-lamp F32T8 | 118 | 82 | 6,490 | 62,797 | 4-lamp F32T8/28W | 76 | 82 | 6,490 | 40,446 | 22,352 |
| 250W MH | 295 | 37 | 4,100 | 44,752 | 3-lamp T5HO Shoebox | 162 | 37 | 4,100 | 24,575 | 20,176 |
| 40W MH | 460 | 20 | 4,100 | 37,720 | 4-lamp T5HO Canopy | 216 | 20 | 4,100 | 17,712 | 20,008 |
| 4-lamp F32/741 | 114 | 125 | 4,100 | 58,425 | 4-lamp F32T8/28W | 76 | 125 | 4,100 | 38,950 | 19,475 |
| 3-lamp F32T8 | 89 | 72 | 6,552 | 42,032 | 3-lamp F32T8/28W | 58 | 72 | 6,552 | 27,314 | 14,718 |
| 100W HPS | 120 | 52 | 4,100 | 25,584 | 2-lamp F32T8/841 | 57 | 52 | 4,100 | 12,152 | 13,432 |
| 400 W MH High bay | 460 | 4 | 7,488 | 13,778 | 4-lamp T5HO High bay | 216 | 4 | 2,434 | 2,103 | 11,675 |

| Existing | | | | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fixture Description** | **Fixture Watt** | **Fixture Count** | **Annual Hours** | **Annual Savings, kWh** | **Fixture Description** | **Fixture Watt** | **Fixture Count** | **Annual Hours** | **Annual kWh** | **Annual Savings, kWh** |
| 2-lamp F32T8 | 59 | 96 | 6,490 | 36,759 | 2-lamp F32T8/28W | 41 | 96 | 6,490 | 25,545 | 11,215 |
| CFL Triple Biax | 44 | 193 | 4,920 | 41,781 | PTL3W EW | 33 | 193 | 4,920 | 31,335 | 10,445 |
| 100W MH | 130 | 26 | 4,100 | 13,858 | JM42W/33 CFL | 35 | 26 | 4,100 | 3,731 | 10,127 |
| Totals | 4,761 | 1,290 | | 814,860 | Totals | 2,383 | 1,290 | | 443,478 | 371,382 |

Source: DNV KEMA analysis

*Measure 3− Public Safety Building HVAC*

The ex post HVAC measure savings analysis is based upon a 5-degree (˚F), weather-bin analysis spreadsheet method using the local TMY3 weather data set, operating schedules, and set point temperatures to derive heating and cooling loads. The bin analysis method is based upon these assumptions: The HVAC equipment is properly sized to meet heating and cooling loads of buildings, and the heating and cooling loads are ambient-temperature driven and have a linear relationship with ambient temperature.

During the site visit, DNV KEMA verified the installations of the HVAC equipment, acquired model numbers and capacity nameplate information, and gathered from the site contact the operational schedules and set point temperatures for the cooling and heating equipment. Subsequently, DNV KEMA gathered thermal efficiency values for the boilers and TMY3 hourly, ambient dry-bulb temperature data from the nearby Fresno-Yosemite airport. The thermal efficiency used for the replacement boiler is 0.93; the existing boiler efficiency was 0.84; and the normal replacement efficiency was 0.80 for Baseline 2 savings determinations.

DNV KEMA attempted to gather kW-per-ton efficiency values for the RTUs from several Trane sales representatives, but these attempts were unsuccessful. In place of independently verified kW-per-ton efficiency values, DNV KEMA used the efficiency values in the ex ante savings analysis for the RTU bin analysis. The kW-per-ton value used for the replacement unit was 1.15, while that of the existing unit was 2.01; the normal replacement efficiency for Baseline 2 conditions was 1.24 kW/ton.

As per the set point temperature information provided by the site contact, the building cooling load occurs between the 70-75 °F ambient temperature bin and the 105-110 °F bin; the building heating load occurs between the ≤30 °F bin and the 65-70 °F bin. The bin analysis model considers the hours of operation along with flags set to indicate heating and cooling months. According to the site contact, the HVAC systems for the facility operate 24 hours per day, seven days per week, and the heating season months for this location are November through April. A gas consumption normalization factor of 0.51 was used to calibrate the bin analysis full-load hours to equal the full-load hour estimate provided by the site contact.[24] This analysis yielded the first-year annual energy savings of 195,650 kWh and 1,871 therms.

Electric demand savings for the cooling equipment were calculated at full-load cooling capacity by taking the difference between the energy consumption of the high-efficiency replacement units and, for Baseline 1 conditions, that of the low-efficiency existing units and, for the Baseline 2 conditions, that of normal-efficiency replacement units. The first-year electric demand savings yielded by this analysis were 172 kW for Baseline 1 conditions.

24 Pre- and postretrofit billing data was requested from the site contact and Energy Commission CPM to match the bin analysis them consumption to the actual measured consumption using the gas consumption normalization factor. This information was not provided to KEMA by either party, so the ex ante full-load hours estimate was used in its place.

### *Measure 4 − Senior Center HVAC*

The Measure 4 HVAC analysis used the same 5-degree weather bin analysis spreadsheet method employed in the Measure 3 HVAC analysis described in the section above. The following information on schedules, capacity, efficiency values, and scaling factors were used to determine this measure savings:

- The heating season months remain November through April. On average, the facility HVAC systems operate from 8 a.m. to 9 p.m. on weekdays and from 9 a.m. to 1 p.m. on weekends.
- Cooling load begins in the 65-70 °F bin and is maximum at the 95-100 °F bin.
- Heating load begins in the 65-70 °F bin and is maximum at the 30-35 °F bin.
- A third-degree polynomial partial load efficiency curve was developed from the 100, 75, 50, and 25 percent cooling load energy consumption for the replacement chiller.
- The cooling capacity of the existing chiller was reduced by 10 percent, down to 45.4 tons, to account for age-induced performance degradation
- A second-degree polynomial, partial-load efficiency curve was developed from the full-load efficiency for the existing chiller.
- A performance curve scale factor of 1.022, based on the quotient of the standard practice IPLV and the replacement IPLV, was applied to the replacement unit input power for each temperature bin to calculate the normal efficiency baseline input power.
- Thermal efficiency for the replacement unit was 0.902, the existing unit was 0.81, and the normal efficiency replacement was 0.80.
- A gas consumption normalization factor of 1.24 was used to adjust the bin analysis full-load hours into agreement with the full-load hour estimate provided by the site contact.

Analysis of this measure yielded first-year annual energy savings of 17,280 kWh and 511 therms.

Electric demand savings for the cooling equipment was calculated by taking the difference in electric energy consumption of the replacement unit and existing unit at the existing units modified full-load cooling level of 45.4 tons for the Baseline 1 condition. For Baseline 2 conditions, electric energy demand savings was calculated as the difference in energy consumption at full-load cooling capacity between the existing unit and the normal efficiency replacement unit. This analysis yielded a first-year electric demand savings of 9 kW for Baseline 1 conditions.

## Savings Results and Discussion

The project saved 977,220 kWh of electric energy and 2,382 therms of natural gas energy in the first year and represents a realization rate of 110 percent and 79 percent compared to the ex ante

estimated savings, respectively. Furthermore, the project reduced summer on-peak demand by 281 kW in the first year, although none were claimed ex ante.

### *Measure 1 − Citywide PC Power Management*

Using previously cited literature, DNV KEMA established power draws and hours of use associated with three computer operation states: on, sleep and off. From these, deemed savings were determined since pre and post data were unavailable to the evaluation team. While uncertainty can be a concern when savings calculations are based on generalized estimates, as is the case for the ex ante energy savings, it was not practical to monitor the PC power draws. DNV KEMA's lower ex post savings estimate (56 percent) is primarily a result of the reduced number of PCs found to be controlled by the software when compared to the initial scope of work and ex ante savings estimate. To a lesser extent the lower ex post saving estimate is also a reflection of eliminating the uncertainty inherent in the ex ante algorithm.

### *Measure 2 − Citywide Lighting*

As mentioned in the lighting section of the Project Evaluation section, it is not clear to DNV KEMA why the claimed savings from the Energy Commission and the savings calculation data from the site contact differ significantly. This situation introduced additional uncertainty regarding the measure savings. It seems more plausible that the scope of work was altered and reduced, but DNV KEMA was not informed of such a change. It is also plausible, though less likely given the magnitude of disagreement between the two savings claims, that the Energy Commission performed its own savings calculations for the listed equipment retrofits to lower the energy savings claimed. Other sources of uncertainty for this measure include the following: the subsample verified on site was composed of 10 percent of the total claimed installations; the subsample verified by calculation consisted of 53 percent of the total claimed measure savings; and the use of site-contact-reported operating hours for the fixtures and occupancy sensor control retrofits.

### *Measure 3 − Public Safety Building HVAC*

Sources of uncertainty regarding these HVAC calculations includes assuming linear partial load energy consumption in place of actual IPLV information for the RTUs, relying on the ex ante full-load hours estimate as a proxy for gas billing data to inform the gas consumption normalization factor, and the assumptions inherent in the bin analysis method regarding equipment sizing and building cooling and heating loads being entirely weather-dependent.

### *Measure 4 − Senior Center HVAC*

Sources of uncertainty regarding these HVAC calculations includes the assumed level of degradation of the existing chiller unit, the partial load performance curve developed for the existing chiller from the limited information available, reliance on the ex ante full-load hours estimate as a proxy for gas billing data to inform the gas consumption normalization factor, and the assumptions inherent in the bin analysis method regarding equipment sizing and building cooling and heating loads being entirely weather-dependent.

DNV KEMA's lower ex post savings estimate for boiler therms (51 percent) is primarily due to the fact that the ex ante savings calculations were based on the existing boiler having had a

heating capacity of 696 kBTU/hr existing unit that was replaced with a high-efficiency unit of the same capacity; the site visit revealed that the existing unit had a heating capacity of 408 kBTU/hr and the replacement unit had a capacity of 450 kBTU/hr.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before energy efficiency measure implementation and takes into account the operating efficiency of the equipment, along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the baseline of the measure until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period, and up until the end of the EUL of the installed measure, expected-replacement baseline of the measure is used. This baseline considers either minimally code-compliant conditions or standard practice when no code is applicable.

Table 63 displays the first-year annual kWh, kW, and therm savings values used to calculate the Baseline 1 and Baseline 2 life-cycle savings. Table 63 also lists the effective and remaining useful lives of each measure that were used in conjunction with the first-year energy and power savings values. Table 64 presents the electrical energy, electrical demand, and natural gas energy savings according to Baseline 1 conditions for each year the measure is in place up to the end of the measure's effective useful life.

**Table 63: Values in Ex Post Life-cycle Savings Calculations**

| Measure | Early Replacement | | | Expected Replacement | | | EUL, years | RUL, years |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy, kWh | Electric Demand, kW | Gas Energy, therms | Electric Energy, kWh | Electric Demand, kW | Gas Energy, therms | | |
| EEM1-PC power mgmt. | 66,792 | 0 | 0 | 66,792 | 0 | 0 | 4 | 0 |
| EEM2-Lighting | 697,498 | 100 | 0 | 697,498 | 100 | 0 | 15 | 4 |
| EEM3-PD HVAC | 195,650 | 172 | 1,871 | 19,818 | 18 | 2,620 | 20 | 0 |
| EEM4-SC HVAC | 17,280 | 9 | 511 | 950 | 1 | 577 | 20 | 12 |

Source: DNV KEMA analysis

**Table 64: Baseline 1 Life-cycle Savings**

| Year Number | Calendar Year | Electric Savings, kWh/yr | Electric Demand, kW | Natural Gas Savings, therms/yr |
|---|---|---|---|---|
| 1 | 2011 | 977,220 | 281 | 2,382 |
| 2 | 2012 | 977,220 | 281 | 2,382 |
| 3 | 2013 | 977,220 | 281 | 2,382 |
| 4 | 2014 | 977,220 | 281 | 2,382 |
| 5 | 2015 | 910,427 | 281 | 2,382 |
| 6 | 2016 | 910,427 | 281 | 2,382 |
| 7 | 2017 | 910,427 | 281 | 2,382 |
| 8 | 2018 | 910,427 | 281 | 2,382 |
| 9 | 2019 | 910,427 | 281 | 2,382 |
| 10 | 2020 | 910,427 | 281 | 2,382 |
| 11 | 2021 | 910,427 | 281 | 2,382 |
| 12 | 2022 | 910,427 | 281 | 2,382 |
| 13 | 2023 | 910,427 | 281 | 2,382 |
| 14 | 2024 | 910,427 | 281 | 2,382 |
| 15 | 2025 | 910,427 | 281 | 2,382 |
| 16 | 2026 | 212,930 | 181 | 2,382 |
| 17 | 2027 | 212,930 | 181 | 2,382 |
| 18 | 2028 | 212,930 | 181 | 2,382 |
| 19 | 2029 | 212,930 | 181 | 2,382 |
| 20 | 2030 | 212,930 | 181 | 2,382 |
| Total | | 14,988,227 kWh | 5,120 kW-years | 47,640 therms |

Source: DNV KEMA analysis

Table 65 presents the yearly life-cycle savings values according to Baseline 2 conditions.

**Table 65: Baseline 2 Life-cycle Savings**

| Year Number | Calendar Year | Electric Savings, kWh/yr | Electric Demand, kW | Natural Gas Savings, therms/yr |
|---|---|---|---|---|
| 1 | 2011 | 801,388 | 127 | 3,131 |
| 2 | 2012 | 801,388 | 127 | 3,131 |
| 3 | 2013 | 801,388 | 127 | 3,131 |
| 4 | 2014 | 801,388 | 127 | 3,131 |
| 5 | 2015 | 734,596 | 127 | 3,131 |
| 6 | 2016 | 734,596 | 127 | 3,131 |
| 7 | 2017 | 734,596 | 127 | 3,131 |
| 8 | 2018 | 734,596 | 127 | 3,131 |
| 9 | 2019 | 734,596 | 127 | 3,131 |
| 10 | 2020 | 734,596 | 127 | 3,131 |
| 11 | 2021 | 734,596 | 127 | 3,131 |
| 12 | 2022 | 734,596 | 127 | 3,131 |
| 13 | 2023 | 718,266 | 119 | 3,197 |
| 14 | 2024 | 718,266 | 119 | 3,197 |
| 15 | 2025 | 718,266 | 119 | 3,197 |
| 16 | 2026 | 20,768 | 19 | 3,197 |
| 17 | 2027 | 20,768 | 19 | 3,197 |
| 18 | 2028 | 20,768 | 19 | 3,197 |
| 19 | 2029 | 20,768 | 19 | 3,197 |
| 20 | 2030 | 20,768 | 19 | 3,197 |
| Life-cycle Savings | | 11,340,958 kWh | 1,975 kW-years | 63,148 therms |

Source: DNV KEMA analysis

## Clovis, City of (008-10-ECE-ARRA)

### Site Summary

The city of Clovis applied for Energy Conservation Assistance Act (ECAA-ARRA) loans for electric generating photovoltaic (PV) systems at the City of Clovis Public Safety Building, Fire Station #1 and Fire Station #5. Each of these energy efficiency/generating measures (EEM) consisted of installation of PV arrays on rooftops or carports, DC-AC grid tie inverters, and the balance of the system.

DNV KEMA visited the sites and verified the implementation of these measures. During the site visits, DNV KEMA verified the panel module and inverter manufacturers, model numbers, and quantities, as well as array characteristics such as orientation and tilt angle values. Estimates of annual electrical savings were computed by entering data from the site findings and product specification sheets into the California Solar Initiative Expected Performance Based Buydown (CSI-EPBB) Calculator found at www.csi-epbb.com. This analysis yielded an overall annual electric energy savings of 88.8 percent when compared to ex ante estimates. Estimates of summer on peak demand reduction were calculated to be 20 percent of the AC power output rating of the system. This analysis yielded an overall peak demand reduction of 101 percent when compared to ex ante estimates. The energy and power savings by measure are provided in Table 66.

**Table 66: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Peak Demand Reduction (kW) | Gas Energy (therms) | Electric Energy (kWh) | Peak Demand Reduction (kW) | Gas Energy (therms) | Electric | Gas |
| EEM1- PV Public Safety Building | 585,288 | 65 | N/A | 519,482 | 66 | N/A | 88.8% | N/A |
| EEM2- PV Fire Station #1 | 55,030 | 6 | N/A | 49,160 | 6 | N/A | 89.3% | N/A |
| EEM3- PV Fire Station #5 | 55,030 | 6 | N/A | 48,581 | 6 | N/A | 88.3% | N/A |
| Total | 695,348 | 77 | N/A | 617,223 | 78 | N/A | 88.8% | N/A |

Source: DNV KEMA analysis

Ex post electrical energy savings and demand are similar to ex ante estimates. The ex post electric energy calculation method estimated slightly less annual kWh output than the ex ante calculation method. The ex ante method estimated an energy production factor of 1,800

kWh/kW AC installed, while the results of the ex post calculations were closer to 1,600 kWh/kW AC installed. Details of the orientation of the system arrays that were included in the ex post calculations, but not the ex ante, marginally reduce annual electric energy generation.

Life-cycle savings were calculated relative to Baseline 1: the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures. The installed measures did not replace any existing electricity generating equipment; therefore, the life-cycle savings are calculated as the total electrical energy generation over the EUL of the installation. Results from Table 4 yield life-cycle energy savings of 15,831,770 kWh and 2,001 kW-years, as presented in Table.

**Table: Ex Post Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 15,831,770 | 2,001 | - |

Source: DNV KEMA analysis

## Project Description

### *Measure 1 − PV Public Safety Building*

This project affected the Clovis Public Safety Building. A total of 1,677 solar panel modules were installed atop 19 new carport shading structures in the parking lots of the facility. These modules were wired to either a 260 kW or 100 kW DC-AC grid-tied inverter that was also installed under this project.

### *Measure 2 − PV Fire Station #1*

This project affected the City of Clovis Fire Station #1. Two rooftop arrays totaling 156 solar panel modules were installed at the fire station. The modules were wired to a 35 kW DC-AC grid-tied inverter installed also installed under this project.

### *Measure 3: PV Fire Station #5*

This project affected the City of Clovis Fire Station #5. Two rooftop arrays totaling 156 solar panel modules were installed at the fire station. The modules were wired to a 35 kW DC-AC grid-tied inverter installed also installed under this project.

## Ex Ante Savings

Ex ante energy savings calculations were obtained from Amir Ehyai, the California Energy Commission project manager for this ECAA-ARRA loan. According to the savings spreadsheet that Ehyai provided to DNV KEMA, the DC and AC power output of each system was calculated using the following two equations:

$$DC\ power\ output\ (kW) = \frac{\#_{panels} \times W_{STC}}{1000\frac{W}{kW}}$$

$$AC\ power\ output\ (kW) = \frac{\#_{panels} \times W_{PTC} \times \eta_{inverter} \times \eta_{derate}}{1000\frac{W}{kW}}$$

where,

- $\#_{panels}$ is the quantity of panel modules.
- $W_{STC}$ is the power output (watts) of the panel module under standard test conditions (STC).
- $W_{PTC}$ is the power output (watts) of the panel module under PVUSA test conditions (PTC).
- $_{inverter}$ is the efficiency of the inverter module.
- $_{derate}$ is a system derate factor that accounts for panel mismatch, wiring losses, panel soiling, and so forth. This value is 98 percent (2 percent loss) for all system calculations.

The annual electrical energy output was then calculated using an annual energy production factor of 1,800 kWh/kW AC (1,500 kWh/kW DC). The Energy Commission's *Guide to Photovoltaic (PV) System Design and Installation* states that the annual energy production factor for the city of Fresno is between 1,505 and 1,881 kWh/kW DC. This means that the value of 1,500 kWh/kW DC is very conservative, and thus it represents a low estimate for an optimally oriented system. The annual energy output calculation is represented in the equation below:

$$Annual\ energy\ output\ (kWh) = AC\ power\ output\ (kW) \times 1800\frac{kWh}{kW\ AC}$$

Summer on peak demand reduction was calculated to be 20 percent of the AC power output value, as shown in the equation below:

*Summer On Peak Demand Reduction (kW) = AC power output (kW) x 0.20*

Calculating peak demand reduction from on-site photovoltaic electricity generation is best achieved using building load and PV generation computer simulation, but this process would be complex and time-consuming. In lieu of computer simulation, the Energy Commission's

method of estimating peak demand reduction by way of a peak period capacity factor is acceptable for this program. The *2009 California Solar Initiative (CSI) Impact Evaluation* report claims that the "CSI systems had a peak hour capacity factor of 0.59",[25] at the time of the 2009 California Independent System Operator (California ISO) system peak. Therefore, the peak period capacity factor of 0.20 is a conservative value, likely underestimating the actual PV contribution to peak period demand reduction.

For EEM1, ex ante savings were calculated for a 389.9 kW DC/ 325.1 kW AC system. Equipment for this system included 1,659 Kyocera 235 GX-LPB panels (rated panel output of 235 W DC at STC, 209.4 W DC at PTC) and one 375 kW SatCon Technology Inverter (95.5 percent efficiency).

For EEM2 and EEM3, ex ante savings were calculated as 36.7 kW DC/30.6 kW AC systems for each measure. Equipment for each of these systems included 156 Kyocera 235 GX-LPB panels and six 6 kW SMA America 6000US Inverters (95.5 percent efficiency).

### Project Evaluation

Two DNV KEMA field engineers visited the project sites January 19, 2012, to verify the measure installations and gather data on equipment model numbers and quantity, as well as panel array characteristics. Table 67 summarizes the results of the installation verification.

**Table 67: Verification Summary**

| Site | Equipment | Reported | Verified | Site Notes |
|---|---|---|---|---|
| Public Safety | PV modules | 1659 modules (389.9 kW DC) | 1677 modules (385.7 kW DC) | |
| Public Safety | DC-AC Inverter | 1 (375 kW DC) | 1 (260 kW DC), 1 (100 kW DC) | Verified 328.9 kW AC rated system power output |
| Fire Station #1 | PV modules | 156 modules (36.7 kW DC) | 156 modules (35.88 kW DC) | |
| Fire Station #1 | DC-AC Inverter | 6 (6 kW DC) | 1 (35 kW DC) | Verified 30.6 kW AC rated system power output |
| Fire Station #5 | PV modules | 156 modules (36.7 kW DC) | 156 modules (35.88 kW DC) | |

25 California Public Utility Commission. (2010). *CPUC California Solar Initiative 2009 Impact Evaluation Final Report,* June 2010. Itron, Inc. and KEMA, Inc. Retrieved from http://www.cpuc.ca.gov/NR/rdonlyres/70B3F447-ADF5-48D3-8DF0-5DCE0E9DD09E/0/2009_CSI_Impact_Report.pdf.

| Site | Equipment | Reported | Verified | Site Notes |
|---|---|---|---|---|
| Fire Station #5 | DC-AC Inverter | 6 (6 kW DC) | 1 (35 kW DC) | Verified 30.6 kW AC rated system power output |

Source: DNV KEMA analysis

Ex post DC and AC power output calculations were performed using the ex ante savings calculation method reported in this evaluation to ensure that the reported and verified system sizes are comparable. Ex post summer on peak demand reduction was also calculated in the same manner as the ex ante to ensure that the two values are comparable.

Ex post annual electric energy savings was modeled using the CSI-EPBB online calculator, which is driven by the National Renewable Energy Laboratory (NREL) *PV Watts v.2 calculator*. Pertinent input values for the calculator include postal ZIP code of system location, PV module make and model, quantity of modules, array standoff height, inverter make and model, array shading, array tracking, array tilt, and array azimuth. Results from the calculator include capacity factors, available incentive values, system size, and annual kWh generated. Only the annual kWh generated result was used in this evaluation. Site-specific equipment and array characteristics are presented in the three measure sections below. Table 68 summarizes the verified array characteristics for the three sites.

**Table 68: Array Characteristics**

| Site | Verified Array Characteristics | | | |
|---|---|---|---|---|
| | Array Tilt (degrees) | Array Azimuth (degrees) | Standoff Height (inches) | Shading |
| Public Safety | - | 180 | >6 | Minimal |
| Fire Station #1 | 3 | 180 | >6 | Minimal |
| Fire Station #5 | 1 | 170 | 0-1 | Minimal |

Source: DNV KEMA analysis

### *Measure 1 − PV Public Safety Building*

At the Public Safety Building the DNV KEMA engineering team verified the installation of 1,479 Sharp® ND-230UCJ panel modules on 17 shading structures. The modules are wired to the PV Powered™ PVP260KW-LV 260 kW DC-AC inverter or the PVP100KW-LV 100 kW DC-AC inverter. The panel arrays are all mounted flat—no tilt relative to a horizontal plane—with a standoff height greater than six inches. The additional 198 PV modules were installed after the completion of the two RV shading structures, which were under construction during the time of the site visit. Because the installation was not complete, the system was not commissioned or operating at the time of the site visit. As of March 27, 2012, the array installation was complete,

and the system was awaiting PG&E inspection and grid connection as reported via e-mail between the DNV KEMA engineering team and the city of Clovis site contact.

### *Measure 2 − PV Fire Station #1*

At the Clovis Fire Stations #1 the DNV KEMA engineering team verified the installation two rooftop arrays totaling 156 Sharp® ND-230UCJ panel modules and one PV Powered™ PV35KW-208 35 kW DC-AC grid-tied inverter. The two arrays are mounted with a 3 degree tilt angle and 180 degree azimuth angle—south facing—with a standoff height greater than 6 inches. The PV system was commissioned and generating electricity at the time of the site visit.

### *Measure 3 − PV Fire Station #5*

At the Clovis Fire Stations #5 the DNV KEMA engineering team verified the installation 156 Sharp® ND-230UCJ panel modules in three rooftop arrays and one PV Powered™ PV35KW-208 35 kW DC-AC grid-tied inverter. The three arrays are mounted along a curved roof surface that exhibits an average tile angle of 1 degree and has an azimuth angle of 170 degrees. The standoff height of the arrays is minimal—between zero and 1 inch high. The PV system was commissioned and generating electricity at the time of the site visit.

## Savings Results

The project saved 617,233 kWh of energy in the first year and represents an 88.8 percent realization rate compared to the ex ante electric energy estimates. The project reduced summer on peak demand by 78 kW in the first year and represents a 101percent realization rate compared to the ex ante demand reduction estimates.

## Discussion

Compared to the Energy Commission's estimation method for annual electric energy generation, the CSI-EPBB calculator estimates are around 7 percent lower when modeling an optimally sited and oriented system. Moreover, all three measures have low tilt angles that reduce their total annual kWh output, further reducing the ex post annual electric energy output. The lower tilt angle does increase the system output during the summer production period and so increases the summer on peak demand reduction of the system.

The public safety building PV system that was actually installed is 3.8 kW AC larger, or about 1.1 percent greater, than the ex ante calculated system, and so the ex post peak demand reduction is near 1 kW AC larger than the ex ante estimates. The arrays for this system are mounted flat and so will yield about 10 percent less annual energy output than an array tilted for optimum annual output.

The fire station #1 PV system size installed was the same as was calculated for the ex ante analysis. As a result, the ex post peak demand reduction estimates are 100 percent of the ex ante estimates. The arrays of this system have the greatest tilt—3 degrees—and so have the least reduced annual kWh output due to tilt angle. The lower estimation of the CSI-EPBB calculator and the low tilt angle result in an 89.3 percent realization rate for annual electric energy.

Like the fire station #1 PV system, the fire station #3 PV system size installed was the same as was calculated for the ex ante analysis, and as a result, the ex post peak demand reduction

estimates are 100 percent of the ex ante estimates. The arrays of this system are mounted along a curved roof section that was estimated to have an average tilt angle of 1 degree. The roof on which the arrays are located is also oriented 10 degrees east of south (170° azimuth angle), and so it received slightly less solar insolation than a south-facing surface. The standoff height of this mounting system was the lowest of the three, with a standoff height of less than 1 inch. Lower standoff height reduces convective cooling of the panels when they become hot, and warmer panels convert less energy into electricity. These array orientation characteristics and the lower estimations from the CSI-EPBB calculator result in an 88.3 percent realization rate for annual electric energy.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to an established baseline. Baseline 1 considers the existing conditions found before energy efficiency measure implementation and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. Because these energy efficiency measures are add-ons and do not replace any existing equipment, the life-cycle savings is calculated as the total electrical energy generation over the EUL of the installation.

First-year electric energy savings for all three measures is 617,223 kWh, and first-year electrical demand savings are 78 kW. The individual measure values used in the ex post life-cycle savings calculations are presented in Table 69.

**Table 69: Values Used in Ex Post Life-cycle Savings Calculations**

| Measure | Early Replacement | | EUL (years) |
|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | |
| EEM1- PV Public Safety Building | 519,482 | 0 | 30 |
| EEM2- PV Fire Station #1 | 49,160 | 0 | 30 |
| EEM3- PV Fire Station #5 | 48,581 | 0 | 30 |

Source: DNV KEMA analysis

Power performance degradation due to aging and weathering of the modules and components has been included in the life-cycle savings calculation. Studies suggest that the range of system power performance degradation is between negative 0.2 and 2 percent per year. Taking into consideration during the site visit the system showed signs of soiling due to airborne dust settling and its location in California Climate Zone 13, which typically experiences a hot, sunny, humid summer and a cold, windy winter, a value of negative 1 percent per year of operation has been factored into the annual electric energy savings and electrical demand reduction to

account for the power performance degradation. Table 70 shows the project life-cycle savings over the full 30-year effective useful life of the measures.

**Table 70: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2012 | 617,223 | 78 | - |
| 2 | 2013 | 611,051 | 77 | - |
| 3 | 2014 | 604,879 | 76 | - |
| 4 | 2015 | 598,706 | 76 | - |
| 5 | 2016 | 592,534 | 75 | - |
| 6 | 2017 | 586,362 | 74 | - |
| 7 | 2018 | 580,190 | 73 | - |
| 8 | 2019 | 574,017 | 73 | - |
| 9 | 2020 | 567,845 | 72 | - |
| 10 | 2021 | 561,673 | 71 | - |
| 11 | 2022 | 555,501 | 70 | - |
| 12 | 2023 | 549,328 | 69 | - |
| 13 | 2024 | 543,156 | 69 | - |
| 14 | 2025 | 536,984 | 68 | - |
| 15 | 2026 | 530,812 | 67 | - |
| 16 | 2027 | 524,640 | 66 | - |
| 17 | 2028 | 518,467 | 66 | - |
| 18 | 2029 | 512,295 | 65 | - |
| 19 | 2030 | 506,123 | 64 | - |
| 20 | 2031 | 499,951 | 63 | - |
| 21 | 2032 | 493,778 | 62 | - |
| 22 | 2033 | 487,606 | 62 | - |
| 23 | 2034 | 481,434 | 61 | - |
| 24 | 2035 | 475,262 | 60 | - |
| 25 | 2036 | 469,089 | 59 | - |
| 26 | 2037 | 462,917 | 59 | - |
| 27 | 2038 | 456,745 | 58 | - |
| 28 | 2039 | 450,573 | 57 | - |
| 29 | 2040 | 444,401 | 56 | - |
| 30 | 2041 | 438,228 | 55 | - |
| 31 | 2042 | - | - | - |
| Life-cycle | Total | 15,831,770 kWh | 2001 kW-years | 0 therms |

Source: DNV KEMA analysis

## Del Norte, County of (001-10-ECE-ARRA)

### Site Summary

Del Norte County received an ECAA-ARRA loan to help fund a number of energy efficiency measures at its main jail facility. The measures included the decommissioning of an older diesel boiler that supplied heating hot water to three airside systems. The decommissioning was accomplished by installing high-efficiency propane furnaces, which allowed the removal of the diesel boiler. Nine energy efficiency measures (EEM) were implemented at this site. Specifically, the measures are for converting three air handling systems to propane gas from diesel fuel (EEM 1, 3, and 5), installation of a heat recovery unit (EEM 2), fixing a broken economizer (EEM 4), converting a 100 percent outside air fan system to include an economizer (EEM 6), installation of high-efficiency DHW boilers (EEM 7,9) and installation of high-efficiency rooftop furnaces (EEM 8). Ex post and ex ante energy savings are presented in Table 71 below.

**Table 71: Energy Savings Summary**

| Measure | Ex Ante | | | | | Ex Post | | | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Electric energy (kWh) | Demand (kW) | Fuel Oil Savings (Gallons) | Liquid Propane Savings (Gallons) | Fuel Oil/ Propane Energy (equivalent therms) | Electric energy (kWh) | Demand (kW) | Fuel Oil Savings (Gallons) | Liquid Propane Savings (Gallons) | Fuel Oil/Propane Energy (equivalent therms) | Electric | therms |
| EEM 1 - New LP gas condensing furnaces, MZ-4 | 5,639 | Not reported | 6,758 | -8,469 | 2,774 | -17,133 | 0.00 | 0.00 | 1,673 | 1,348 | -304% | 49% |
| EEM 2 - MZ-4 heat recovery unit | -15,505 | Not reported | 470 | 0 | 794 | -10,797 | 0.00 | 0.00 | 687 | 653 | N/A | 82% |
| EEM 3 - New LP gas condensing furnaces, MZ-6 | -4,083 | Not reported | 7,259 | -11,960 | 2,968 | -8,108 | 0.00 | 0.00 | 2,392 | -1,273 | N/A | -43% |
| EEM 4 - Repair MZ-6 economizer | 1,153 | Not reported | 1,104 | 0 | 360 | 1153.49 | 0.13 | 0.00 | 1,616 | 1,535 | 100% | 426% |
| EEM 5 - New LP gas condensing furnace at AHU-54 zones | 10,500 | Not reported | 2,650 | -4,829 | 1,152 | 7,177 | 0.00 | 0.00 | 966 | -903 | 68% | -78% |
| EEM 6 - Install new economizer at AHU-54 zones | 0 | Not reported | 923 | 0 | 401 | 0 | 0.00 | 0.00 | 1,350 | 1,283 | N/A | 320% |

| Measure | Ex Ante | | | | | Ex Post | | | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Electric energy (kWh) | Demand (kW) | Fuel Oil Savings (Gallons) | Liquid Propane Savings (Gallons) | Fuel Oil/ Propane Energy (equivalent therms) | Electric energy (kWh) | Demand (kW) | Fuel Oil Savings (Gallons) | Liquid Propane Savings (Gallons) | Fuel Oil/Propane Energy (equivalent therms) | Electric | therms |
| EEM 7 - New LP gas condensing DHW heater, old jail | 0 | Not reported | 604 | 0 | 1,160 | 0 | 0.00 | 0.00 | 884 | 840 | N/A | 72% |
| EEM 8 - Replace H&V units with higher efficiency LP gas condensing furnaces | 0 | Not reported | - | -291 | 303 | 0 | 0.00 | 0.00 | 582 | -277 | N/A | -91% |
| EEM 9 - New LP gas condensing DHW heater, new jail | 0 | Not reported | - | 835 | 1,301 | 0 | 0.00 | 0.00 | 835 | 793 | N/A | 61% |
| Total | -2,296 | 0 | 19,768 | 24,714 | 11,213 | -27,708 | 0.13 | 0.00 | 10,985 | 3,999 | N/A | 36% |

Note: Ex ante values were in either gallons of propane or gallons of fuel oil #2 and converted to therms. The conversion factor was 139,000 BTU/gallon for fuel oil #2 and 95,000 BTU/gallon for liquid propane gas. To get therms, these values are divided by 100,000. For EEM9, there is a mismatch in units reported, rendering the values in the database invalid. This value was corrected by going into the ex ante calculations and directly converting the BTU's saved for this measure into therms (divide by 100,000) to provide a more relevant value for comparison.Source: DNV KEMA analysis

As reflected in the ex ante savings estimates, some of these measures were expected to increase electrical usage while saving fuel therms. Additionally, some of these measures represent an improvement in the living conditions and were not individually expected to result in savings. While the project was installed as described, electric energy consumption increased because the new equipment operated at higher building load relative to preretrofit conditions. Fuel savings were realized, but to a lesser extent than expected. It was likely the facility was underheated, and the conversion of the heating system to propane allowed the building to maintain set points better. A discussion by measure is included toward the end of this report. The lower realization rate is also due in part to calculation missteps in the ex ante algorithms, which were corrected with the results presented here.

The analysis uses billing data after the first commissioning effort was completed. The performance of the system was unsatisfactory, so the site contact requested a second commissioning effort. Results of the second commissioning effort are not reflected in this analysis since billing data is not available for that relevant time frame. It is possible more energy savings are realized due to the second commissioning effort, but at least one more year must elapse before this can be seen in the billing data. The results presented in this report are the result of the first commissioning effort.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally *code-compliant* conditions or *standard practice* as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

For this site, Baseline 2 shows more savings than Baseline 1 because the same postretrofit heating loads were used under the Baseline 2 definition. Under Baseline 1, which by definition uses the pre-existing condition to determine energy consumption, the heating load is actually less and results in an energy penalty for some measures.

For Baseline 1, life-cycle energy savings is 45,744 therms with an electric energy penalty of 416,362 kWh. Under Baseline 2 the life-cycle savings is 135,853 therms with an electric energy penalty of 165,641 kWh (Table 72).

**Table 72: Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Fuel oil/ Propane Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | (416,362) | 0.7 | 45,744 |
| Baseline 2 | (165,641) | 0.4 | 135,853 |

Source: DNV KEMA analysis

## Project Description

The county of Del Norte operates the County Jail and Sheriff's Office facility located in Crescent City. The jail facility was built in the 1960s with a new addition about 29 years ago. Before the retrofit, the facility operated on propane gas and #2 diesel fuel. The main heating was supplied by a 200 MMBtu/h boiler and hot water heating coils. According to the feasibility report, much of the HVAC system had deteriorated and was not in good operating condition. The project was for various energy efficiency upgrades performed throughout the facility. The retrofit involved the replacement of the 200 MMBtu/h boiler with a propane furnace system, fixing and installing new economizers, and replacing a number of DHW boilers. The measures are described in more details below.

***EEM 1: High-efficiency propane furnaces replacing diesel boiler, MZ4*** **–** Replace the MZ4 heating system with high-efficiency propane furnaces. Prior to the retrofit, this system served four zones using one air handling unit. Heating hot water was supplied by a diesel boiler.

***EEM 2: Install a heat recovery unit at MZ4 system*** **–** The MZ4 system uses 100 percent outside air. This measure is to install a heat recovery unit to temper the outside air.

***EEM 3: High efficiency propane furnaces replacing diesel boiler, MZ6*** **–** Replace the MZ6 heating system with high-efficiency propane furnaces. Before the retrofit, this system served six zones using one air handling unit. Heating hot water was supplied by a diesel boiler.

***EEM 4: Repair MZ6 economizer*** **–** The MZ6 economizer is broken and stuck in the open position. This measure is to repair the economizer. A premium efficiency motor for the return air fan is also included as part of this measure.

***EEM 5: High-efficiency propane furnaces replacing diesel boiler, AHU54*** **–** Replace the AHU54 heating system with high-efficiency propane furnaces. Before the retrofit, this system served three zones using one air handling unit. Heating hot water was supplied by a diesel boiler.

***EEM 6: Add economizer to AHU54 system*** **–** The AHU54 system was previously on 100 percent outside air. This measure is to add a return air fan and economizer to this system to reduce the heating load.

***EEM 7: New propane DHW boilers, old jail*** **–** The old jail DHW water is supplied by the large 200 MMBtu/h boiler. As part of the decommissioning of this boiler, new propane-condensing boilers will be installed to supply the DHW needs for the old jail section.

***EEM 8: Replace two heating and ventilation (H&V) units with high efficiency propane furnaces*** **–** Two rooftop propane H&V units with standard efficiency are to be replaced with high-efficiency propane furnaces.

***EEM 9: New propane DHW boilers, new jail*** **–** The new jail facility DHW water is supplied by propane boilers. The boilers are 16 years old with inferior thermal efficiencies. New high-efficiency propane-condensing boilers will be installed to supply the DHW needs for the new jail section.

## Ex Ante Savings

Ex ante energy savings were calculated using a spreadsheet approach employing bin analyses and best estimates of operation parameters.[26]

***EEM 1, 3, 5: High-efficiency propane furnaces replacing diesel boiler*** **–** Energy savings were determined by first using bin analysis. The bin analysis was used to estimate the total annual heating energy required for each system. Energy savings were assumed as 15 percent of the total annual energy required after applying a 0.75 factor. The 15 percent was for an efficiency improvement from 80 percent to 94 percent thermal efficiency.

***EEM 2: Install a heat recovery unit at MZ4 system*** **–** The same bin analysis was used to determine energy savings for this measure. In the preretrofit case, the entering outside air was used to determine the heating requirements of the system. In the postretrofit case, outside air was assumed to be tempered at 65°F for all temperature bins in the analysis. The analysis assumes that this measure is applied after EEM 1 is implemented.

***EEM 4: Repair MZ6 economizer*** **–** The analysis for the heating energy savings is similar to EEM 2. In the preretrofit case, the mixed air is assumed to range from 43-65°F as a result of a broken economizer. In the post-retrofit case, the mixed air is assumed to be improved to 60-65°F at various temperature bins. To determine electric energy savings from the premium efficiency motor at the return air fan, a standard energy calculation for the motor using the nameplate information is performed, and then a 5 percent energy savings factor is applied to determine the energy savings.

***EEM 6: Add economizer to AHU54 system*** **–** The analysis is the same as EEM 2 except that the mixed air is assumed to range from 60-65°F in the postretrofit case.

***EEM 7: New propane DHW heaters, old jail*** **–** The analysis uses the input boiler capacity and an estimate on the DHW annual load to determine an output DHW capacity for the old boiler. The output DHW capacity is matched using the same calculation algorithm for the new boiler. The algorithm can be described using the following equation.

$$Input_1 L_1 \eta_2 \text{ X } 8{,}760 = Input_2 L_2 \eta_2 \text{ X } 8{,}760$$

26 Johnson Controls performed the calculations.

Where *Input* is the input capacity of the old and new boilers (subscript *1* and *2*, respectively), η is the rated thermal efficiency, and *L* is an estimate on the percent loading of the boiler. $L_1$ is initially assumed at 25 percent. Energy savings are the difference between the two boiler input capacities multiplied by 8,760 hours and respective percent loading *L*.

***EEM 8: Replace two heating and ventilation (H&V) units with high efficiency propane furnaces*** – The analysis for this measure also uses a bin analysis similar to EEM 1. However, after determining the total annual heating energy required for the system, this value was divided by the pre-existing furnace efficiency to determine the baseline energy usage. In the efficient case, this value was divided by the new efficiency of the furnaces. Energy savings are the difference between these two values. The algorithm used to determine energy savings in this case uses the proper approach as opposed to the approach used in EEM 1 through EEM 6.

***EEM 9: New propane DHW boilers, new jail*** – The algorithms assumed both pre- and postretrofit boilers operate with the same number of hours. Ultimately, energy savings come from a difference in boiler input capacities. The correct algorithm was performed in EEM 7 but not used here. There is also a mismatch in the unit of energy consumed in the pre- and postretrofit cases. The reported savings are invalid due to an incorrect algorithm used and an error from a unit calculation mismatch.

## Project Evaluation

A DNV KEMA field engineer visited the project's site on September 29, 2011, to verify measure installation. Nameplate data for the boilers and furnaces were collected. DNV KEMA installed one temperature sensor each at the MZ4, MZ6, and AHU54 airside systems along with an outside air temperature sensor at the facility rooftop. These sensors were retrieved on November 17, 2011. The data were extracted and used to inform the bin analysis calculations.

The boilers were factory equipped with technology that recorded burner on time and total elapsed time. This information was extracted for all DHW boilers and were used in the ex post calculations for their respective measures. DNV KEMA also requested billing data from the site contact and was able to obtain 7 months of post retrofit data. The site contact stated that after implementation of the measures, the cost to run the equipment increased significantly. A check on the billing data at the time showed cost increased by 43 percent over a four month period post implementation confirming the site contact's assertion.[27]

Table 73 lists a summary of the site findings with further details for each measure provided in the section immediately after.

27 The seven months of billing data applied only to propane. There were four full months of bills for propane, diesel, and electric. The check was relative to previous year costs.

**Table 73: Site Findings**

| Measure | Ex Ante Quantity | Ex Post Quantity | Notes |
|---|---|---|---|
| EEM 1 - High Efficiency Propane Furnaces Replacing Diesel Boiler, MZ-4 | 4 units at 94% thermal efficiency | 4 units at 95.8% thermal efficiency | All units rated at 120 kBtu/h input. Total airflow (8,000 CFM) slightly higher than previously assumed (7,800 CFM). |
| EEM 2 - MZ-4 heat recovery unit | 1 | 1 | Pump motor is 1.5 HP, 77% η, 2.8 amps, 460 volts. |
| EEM 3 - High Efficiency Propane Furnaces Replacing Diesel Boiler, MZ-6 | 6 units at 94% thermal efficiency | 8 units at 96% thermal efficiency | Units rated at (2) 60, (2) 100, and (4) 120 kBtu/h input. Total airflow (15,000 CFM) higher than previously assumed (11,100 CFM). |
| EEM 4 - Repair MZ-6 economizer | 1 | 1 | Found to be operating as proposed; not able to access return air fan motor for nameplate. |
| EEM 5 - High Efficiency Propane Furnaces Replacing Diesel Boiler, AHU-54 | 3 units at 94% thermal efficiency | 3 units at 96% thermal efficiency | Units rated at (1) 60 and (2) 100 kBtu/h input. Total airflow (5,200 CFM) higher than previously assumed (3,480 CFM). |
| EEM 6 - Install new economizer at AHU-54 zones | 1 | 1 | Economizer found operating as proposed. |
| EEM 7 - New propane gas condensing DHW boiler, old jail | 1 at 300 kBtu/h input and 96% thermal efficiency | 1 at 300 kBtu/h input and 96% thermal efficiency | Data from new boiler shows it's been operating for 281 days and 9 hours. Of that time, the burner is on 44 days and 23 hours |
| EEM 8 - Replace H&V units with higher efficiency propane gas condensing furnaces | 2 units at 95.5% thermal efficiency | 2 units at 95.8% thermal efficiency | Both units rated at 120 kBtu/h input. Total airflow is (4,000 CFM) higher than previously assumed (3,000 CFM). |
| EEM 9 - New propane gas condensing DHW boiler, new jail | 2 units at 300 kBtu/h input and 96% thermal efficiency | 2 units at 250 kBtu/h input and 95% thermal efficiency | Data from the two boilers show that the burners are on 9.66% of the total time. |

Source: DNV KEMA analysis

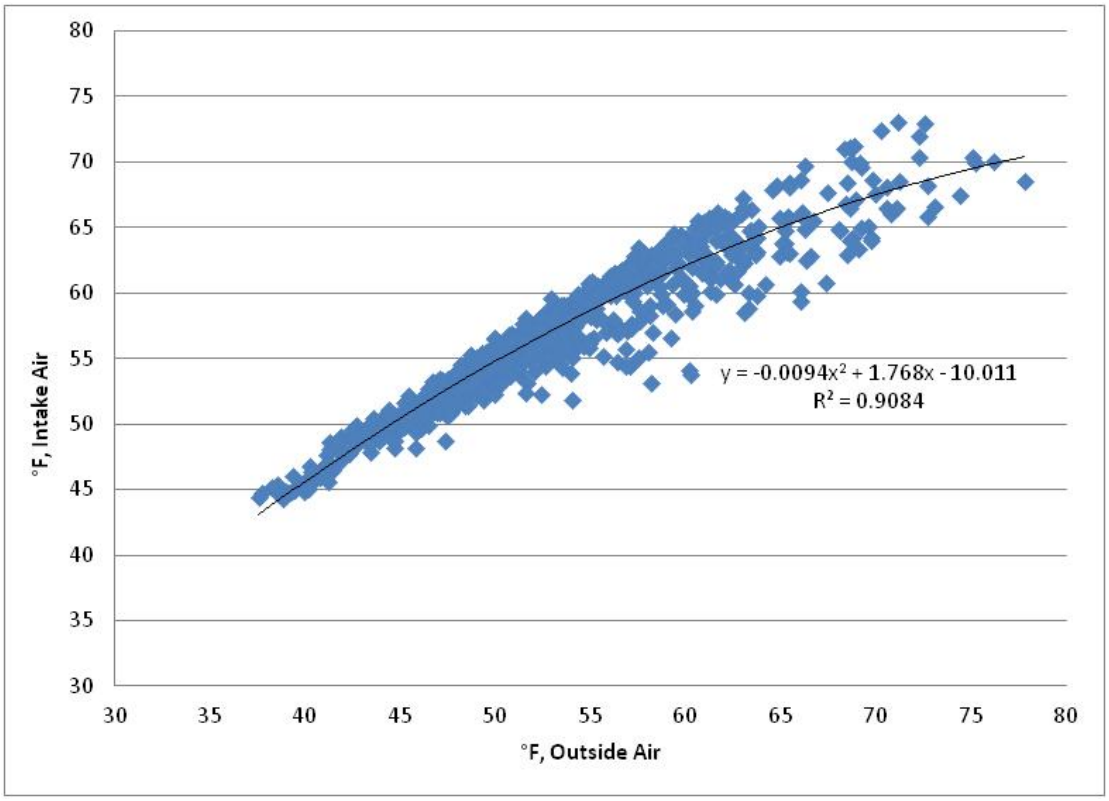
***EEM 1, 3, 5: High efficiency propane furnaces replacing diesel boiler*** – For these three measures a total of 15 high-efficiency propane furnaces averaging 96 percent thermal efficiency were found. The total airflow from the furnaces based on the nameplate data was 28,200 CFM. This total is in contrast to the ex ante assumptions of 13 furnaces at 94 percent thermal efficiency delivering a composite airflow of 22,380 CFM.

The bin analysis was updated with these values. Ex post energy savings were calculated with a similar bin analysis approach as the ex ante, except that the diversity factor of 0.75 was eliminated from the algorithm and the total annual heating energy requirements were corrected using the thermal efficiency of the systems in the pre- and postretrofit cases. The diversity factor was eliminated as there was no explanation of what it was or why it was needed. The results for all (EEM 1 – EEM 9) the major diesel and propane gas uses were compiled using this analysis to see if the values were in reason with the billing data. The results show that in the preretrofit case, when there were two fuels used at the facility, the estimated usage predicted by the bin analysis was within 3.5 percent of diesel fuel usage and 7.9 percent of propane gas usage. In the postretrofit case, where space heating and DHW usage is supplied by propane gas only, annual energy usage predicted by the bin analysis was within 2 percent of the estimated annual usage using the seven months of postretrofit billing data.[28] The close match using both pre- and postbilling data suggests the ex post bin analysis algorithms are a good predictor of energy consumption. EEM 1, 3, and 5 altogether resulted in a net energy *penalty* of 18,065 kWh and 828 therms and is relative to pre-existing conditions that are reflected in the bills and bin analysis.

***EEM 2: Install a heat recovery unit at MZ4 system*** **–** Data collected from the outside air intake compartment and located after the heat exchanger yielded the following intake air versus outside air profile.

28 Since only seven months was available, KEMA took the percentage difference between the propane bills seven months postimplementation and compared that to the same seven months preimplementation. The resulting ratio is multiplied by the annual usage in the preperiod to estimate annual usage in the postperiod.

**Figure 20: Intake Air Chamber Temperature at MZ4 System Relative to Outside Air**

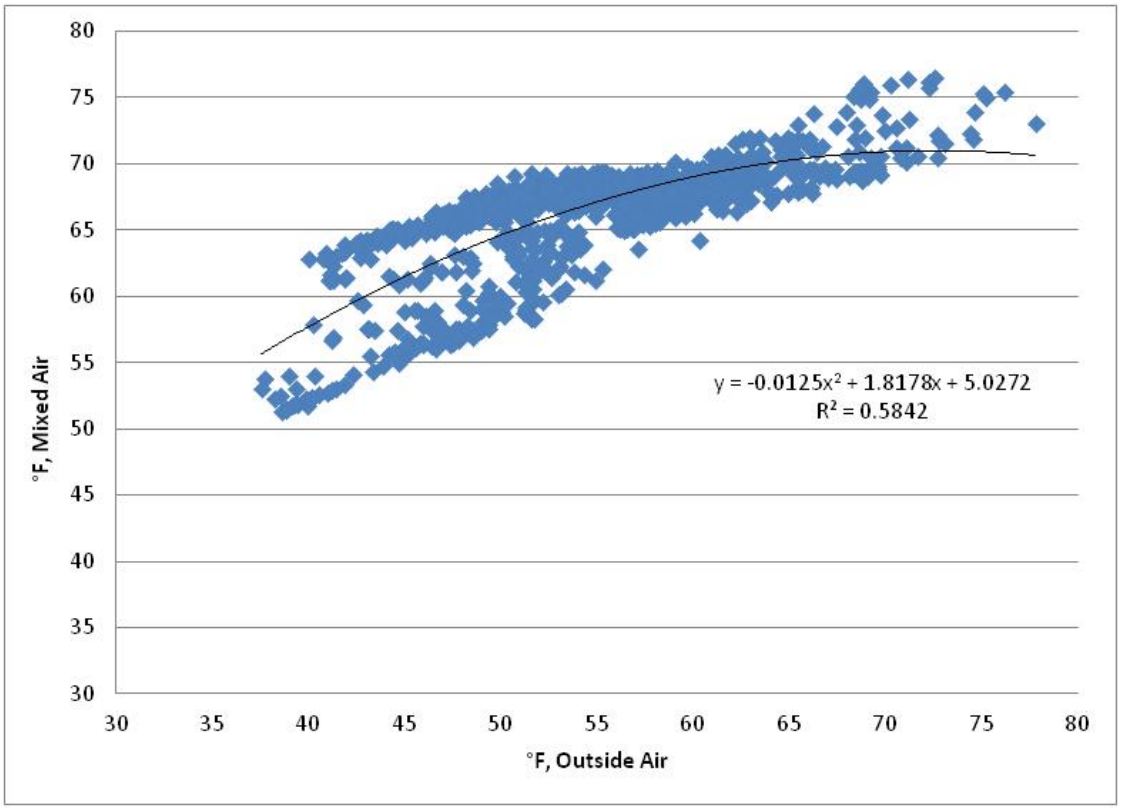



Source: DNV KEMA analysis

A regression was performed using a quadratic curve fit. Using the curve fit, the intake air temperatures were modified in the efficient case bin analysis. The higher intake air due to the heat exchanger resulted in energy savings for this measure of 653 therms but also resulted in an electric energy penalty of 10,797 kWh due to the heat exchanger pump.

***EEM 4: Repair MZ6 economizer –*** Data collected from the mixed air compartment in one of the MZ6 units yielded the following mixed air versus outside air temperature profile.

**Figure 21: Mixed Air Compartment Temperature at MZ6 System Relative to Outside Air**

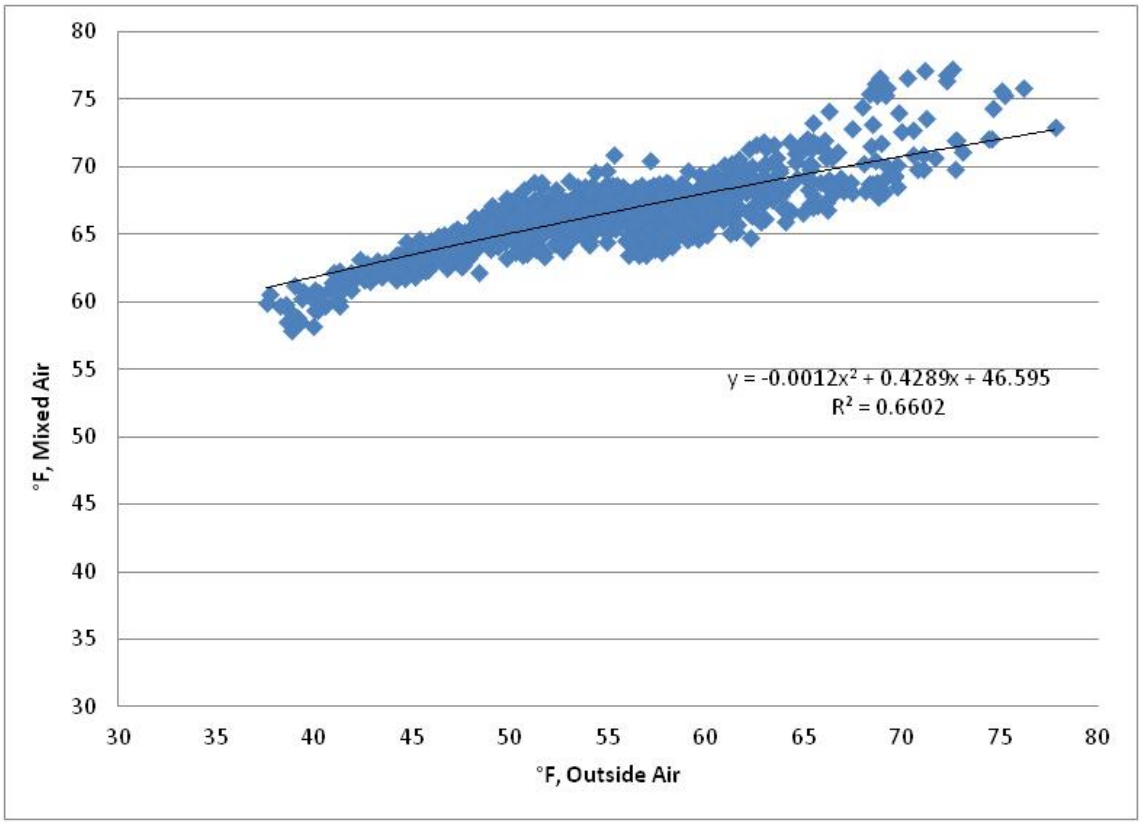



Source: DNV KEMA analysis

A regression was performed using a quadratic curve fit. Using the curve fit, the mixed air temperatures were modified in the efficient case bin analysis. The higher mixed air due to the heat exchanger resulted in energy savings for this measure of 1,535 therms. Electric energy savings for this measure is unchanged at 1,153 kWh due to the premium efficiency motor upgrade.

***EEM 6: Add economizer to AHU54 system*** **–** Data collected from the mixed air compartment in one of the AHU54 units yielded the following mixed air versus outside air temperature profile:

**Figure 22: Mixed Air Compartment Temperature at AHU54 System Relative to Outside Air**




Source: DNV KEMA analysis

A regression was performed using a quadratic curve fit. Using the curve fit, the intake air temperatures were modified in the efficient case bin analysis. The higher intake air due to the heat exchanger resulted in energy savings for this measure of 1,283 therms.

***EEM 7 & 9: New propane DHW heaters, old jail –*** The ex post analysis is similar to the ex ante analysis algorithms for EEM 7 except DNV KEMA used data from the boilers to eliminate uncertainty. The following equation, which was used in the ex ante analysis for EEM 7, is also used here:

$$Input_1 L_1 \eta_2 \text{ X } 8{,}760 = Input_2 L_2 \eta_2 \text{ X } 8{,}760$$

The only unknown in this equation is $L_1$, the percentage loading of the old boiler, which can be solved. Energy savings are the difference between the two boiler input capacities multiplied by 8,760 hours and respective percentage loading $L$. Energy savings for EEM 7 and EEM 9 are 840 and 793 therms, respectively.

***EEM 8: Replace two H&V units with high efficiency propane furnaces –*** The analysis for this measure also uses a bin analysis similar to EEM 1. The new units are actually rated at a higher input capacity (120 kBtu/h) than the original (75 kBtu/h). Correspondingly, the airflow is also

rated higher as well (2000 CFM versus 1500 CFM). After adjusting for site findings, the energy penalty for this measure was estimated at 277 therms due to the increase in heating load.

## Savings Results

Considering the implementation of all nine EEMS, this site received an electric energy *penalty* of 27,708 kWh and a natural gas energy savings of 4,000 therms of energy in its first year. Table 74 breaks down the ex post energy savings by measure. The ex ante energy savings are also provided for comparison.

## Discussion

### *EEM 1, 3, 5 – High-Efficiency Propane Furnaces Replacing Diesel Boiler*

Combined, these measures resulted in a penalty for both electric energy and gas energy (-18,065 kWh and -828 therms). EEM 1, 3, and 5 are for the propane furnace replacements at the rooftop MZ-4, basement MZ-6, and basement AHU 53 systems, respectively. In the preretrofit case, these systems collectively delivered 22,380 CFM of airflow throughout the various zones they serve. These CFM airflow rates were reasonable based on a comparison of the estimated annual preretrofit diesel energy consumption to the billing data. In contrast, the new propane furnace units that were found on-site had a collective airflow delivery of 28,200 CFM, 26 percent higher than preretrofit conditions. The higher airflow delivery meant that the units were delivering a higher amount of heating than before and is partly responsible for the lower energy savings. Indeed, this is reflected in the postretrofit propane bills, which showed a threefold rise in propane usage relative to preretrofit conditions.

While a modest increase in the propane bills was expected since these measures represented a fuel switch from diesel to propane, the amount was much more than anticipated. Based on hard copies of the billing data provided, costs to heat the facility were actually higher after measure implementation even when considering the elimination of the diesel fuel. Part of the reason is differences in the volume of airflow delivery as mentioned, which resulted in a higher building load and contributes significantly to the negative energy savings for these measures. The results suggest that the building was underheated before measure implementation and is now able to meet space temperature set points but at a significant cost.

Another major source of discrepancy can be found when examining the energy savings algorithm in the spreadsheet calculations. The following equations were used to determine energy consumption and savings in the ex ante analysis after the bin analysis was completed:

$$EC_2 = EC_1 \times D$$

$$EC_3 = EC_2 \times SF$$

Where $EC_1$ is the total energy required for heating the building (from the bin analysis), $EC_2$ is the baseline energy consumption, and $EC_3$ is the efficient case energy consumption. The constant $D$ is an assumed diversity factor of 0.75[29] and $SF$ is a savings factor at 15 percent.

29 It is not stated why this constant was used or how this was determined.

Energy savings were determined by subtracting $EC_3$ from $EC_1$, which is not correct. This is analogous to saying the heat output from the high-efficiency furnaces is actually less than the total required energy to heat the building. This analogy suggests that the new furnaces are undersized and cannot meet building load. The correct approach would be to divide the estimated required heating load $EC_1$ by the thermal efficiency of the pre-existing equipment, repeat for the efficient case, and take the difference of the two. By overlooking this point, the ex ante calculations compute energy savings that do not exist.

The higher penalty in electric energy savings are because there were more fans required to deliver air to the building zones in the postretrofit case. These fans drew more power and consumed more energy than what was presumed.

### *EEM 2 –MZ4 Heat Recovery Unit*

Ex post electric energy penalty was only 10,797 kWh versus ex ante estimates of 15,505 kWh. The lower penalty comes from findings from the site visit showing the heat recovery unit motor responsible for delivering heated water to the MZ4 units was smaller than previously assumed. The installed motor is rated at 1.5 horsepower, not 2.0 horsepower. This revision resulted in a lower electric energy penalty.

Gas energy savings were lower because the heat exchanger functioned much less efficiently than assumed. In the ex ante calculations, the entering air temperature was modeled with a low limit of 65°F, regardless of outside air conditions due to the heat exchanger. However, data collected at the mixing box showed that no such limit exists. The heat exchangers increased the outside air modestly, but the relationship was linear and without a low limit. While gas energy savings do exist because of the heat exchanger, this value is slightly less than what is claimed.

### *EEM 4 – Repair MZ-6 Economizer*

Ex post gas energy savings are 426 percent of ex ante estimates for this measure. This is chiefly due to differences in the estimation of the mixed air temperature for the MZ-6 system in the postretrofit case. Temperature loggers placed at the mixing box for one of the MZ-6 furnace showed that the mixed air temperatures ranged between 63-68°F when outside air was between 45-59°F. In comparison, ex ante calculations assumed that the mixed air remained at 60°F under these same conditions suggesting that the effect of fixing the economizer was underestimated. The corresponding temperature bins make up a large chunk of the bin hours and results in a much higher energy savings in the ex post analysis.

### *EEM 6 – Install New Economizer at AHU-54 System*

Ex post gas energy savings are 320 percent of ex ante estimates for this measure. Reasons for the discrepancy are similar to the one described in EEM 4. Temperature loggers placed at the mixing box for one of the AHU-54 furnaces showed that the mixed air temperatures ranged between 64-67°F when outside air was between 45-59°F. In comparison, ex ante calculations assumed that the mixed air remained at 60°F under these same conditions suggesting that the effect of adding the economizer was underestimated. Similar to EEM 4, the corresponding bin hours make up a large portion of the analysis and results in a much higher energy savings in the ex post analysis.

### *EEM 7 – New Propane Condensing Boilers to Replace Diesel Boiler, Old Jail*

Ex post gas energy savings (840 therms) are less than ex ante estimates (1,160 therms) because the typical boiler load was much less than previously thought. The new boilers are equipped with technology that records the total elapsed time, and the total amount of time the boiler is active. Data collected from the boiler computer system show that the typical new boiler load at the old jail facility is only 16 percent of the input capacity over 8,760 hours. Compare this to the 22 percent estimated in the ex ante algorithms. When this value was updated in the energy savings calculation, the ex post energy savings was reduced by the same proportion.

### *EEM 8 – High-Efficiency Propane Furnaces, Heating and Ventilation Units*

Energy savings for this measure is negative. The pre-existing furnaces were rated at 75 kBtu/h and delivered an estimated 1,500 CFM to the zones it served. However, the new units were rated at 120 kBtu/h and delivered 2,000 CFM to the zones it served. The higher-rated capacity and airflows result in delivering more heat to the building in the postretrofit case and results in negative energy savings for this measure.

### *EEM 9 – New Propane Condensing Boilers, New Jail*

The actual load of the new boiler was found to be 9.66 percent of input capacity. The input capacity was rated at 250 kBtu/h as opposed to 300 kBtu/h in the ex ante calculations. From these values, a total heating output due to DHW needs was estimated at about 402 MMBtu/h and was very similar to the ex ante estimate of 394 MMBtu/h. Yet ex post energy savings yielded only 61 percent of ex ante estimates.

One reason for this discrepancy come from inconsistent treatments of the pre- and postretrofit conditions in the ex ante calculations. To properly compare pre- and post-energy consumption, the same DHW load should be used to assess total energy consumption from this end use. This assessment provides an apples-to-apples comparison for the DHW end use. While this was properly done in EEM 7, it was overlooked for EEM 9. The preretrofit DHW load, calculated as the total output of the boilers, is actually 11 percent higher than postretrofit conditions.

The realization rate for this measure is actually irrelevant because the ex ante estimate for this measure is invalid due to a calculation error. The measure is for a standard propane boiler that is converted to high-efficiency propane boiler. In both cases, the boiler uses propane. However, the baseline is calculated using gallons of propane gas and compares this to the efficient case, which is reported in gallons of fuel oil. These two values were subtracted from each other to determine savings. The result is invalid because the units are not the same.

## Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the energy efficiency measure implementation and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the remaining useful life (RUL) of the

existing equipment. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the expected-replacement baseline for the measure is used. This baseline considers either minimally code-compliant conditions or standard practice when no code is applicable.

The diesel boilers and propane furnaces at this site were more than 20 years old and past their useful lives. However, the efficiencies for these units were already assumed at 80 percent thermal efficiency, which is code-compliant. Therefore, Baseline 1 and Baseline 2 are the same for these measures (EEM 1, 3, 5, 7, 8, and 9).

The other three measures are add-on measures, so the replacement baselines are not applicable. The standard baseline is unit operation without the new controls

Table 74 summarizes the energy savings and life-cycle parameters by measure used in the life-cycle savings calculations. EUL values come from the DEER.

For EEM 1, 3, 5, and 8, the energy savings were higher under the Baseline 2 definition, even though the same equipment efficiencies were used. This result is because conditions of the building in the preretrofit case showed a lower heating load than that found in the postretrofit case. In compliance with the Energy Commission's request to compare energy usage to preretrofit conditions, these loads were preserved and compared with the higher loads observed in the postretrofit conditions (Baseline 1). Because of this, Baseline 1 in some cases result in negative energy savings.

Under the Baseline 2 definition, the same building loads were used for pre- and postretrofit conditions regardless of the actual pre retrofit heating loads for the building. This method is the standard practice when estimating energy savings and is captured in Baseline 2.

**Table 74: Values Used in Life-cycle Savings Calculations by Measure**

| Measure | Baseline 1 | | Baseline 2 | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| EEM 1 - New LP gas condensing furnaces, MZ-4 | -17,133 | 1,348 | 0 | 1,589 | 15 | 0 |
| EEM 2 - MZ-4 heat recovery unit | -10,797 | 653 | -10,797 | 653 | 14 | 0 |
| EEM 3 - New LP gas condensing furnaces, MZ-6 | -8,108 | -1,273 | 0 | 2,272 | 15 | 0 |

| Measure | Baseline 1 | | Baseline 2 | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| EEM 4 - Repair MZ-6 economizer | 1,153 | 1,535 | 608 | 1,535 | 5 | 0 |
| EEM 5 - New LP gas condensing furnace at AHU-54 zones | 7,177 | -903 | 0 | 918 | 15 | 0 |
| EEM 6 - Install new economizer at AHU-54 zones | 0 | 1,283 | 0 | 1,283 | 10 | 0 |
| EEM 7 - New LP gas condensing DHW heater, old jail | 0 | 840 | 0 | 840 | 20 | 0 |
| EEM 8 - Replace H&V units with higher efficiency LP gas condensing furnaces | 0 | -277 | 0 | 553 | 15 | 0 |
| EEM 9 - New LP gas condensing DHW heater, new jail | 0 | 793 | 0 | 793 | 20 | 0 |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 45,744 therms (Table 75). There is an electrical energy penalty of 416,362 kWh. However, if Baseline 2 is used, the life-cycle savings comes to 135,853 therms with an electric energy penalty of 165,641.

**Table 75: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | -27,708 | 0 | 4,000 |
| 2 | 2012 | -27,708 | 0 | 4,000 |
| 3 | 2013 | -27,708 | 0 | 4,000 |
| 4 | 2014 | -27,708 | 0 | 4,000 |
| 5 | 2015 | -27,708 | 0 | 4,000 |
| 6 | 2016 | -28,862 | 0 | 2,465 |
| 7 | 2017 | -28,862 | 0 | 2,465 |
| 8 | 2018 | -28,862 | 0 | 2,465 |
| 9 | 2019 | -28,862 | 0 | 2,465 |
| 10 | 2020 | -28,862 | 0 | 2,465 |
| 11 | 2021 | -28,862 | 0 | 1,182 |
| 12 | 2022 | -28,862 | 0 | 1,182 |
| 13 | 2023 | -28,862 | 0 | 1,182 |
| 14 | 2024 | -28,862 | 0 | 1,182 |
| 15 | 2025 | -18,065 | 0 | 529 |
| 16 | 2026 | 0 | 0 | 1,633 |
| 17 | 2027 | 0 | 0 | 1,633 |
| 18 | 2028 | 0 | 0 | 1,633 |
| 19 | 2029 | 0 | 0 | 1,633 |
| 20 | 2030 | 0 | 0 | 1,633 |
| 21 | 2031 | 0 | 0 | 0 |
| Life-cycle | Total | (416,363) | 0.7 | 45,747 |

Source: DNV KEMA analysis

**Table 76: Baseline 2 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | -27,708 | 0 | 4,000 |
| 2 | 2012 | -10,189 | 0 | 10,436 |
| 3 | 2013 | -10,189 | 0 | 10,436 |
| 4 | 2014 | -10,189 | 0 | 10,436 |

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 5 | 2015 | -10,189 | 0 | 10,436 |
| 6 | 2016 | -10,797 | 0 | 8,901 |
| 7 | 2017 | -10,797 | 0 | 8,901 |
| 8 | 2018 | -10,797 | 0 | 8,901 |
| 9 | 2019 | -10,797 | 0 | 8,901 |
| 10 | 2020 | -10,797 | 0 | 8,901 |
| 11 | 2021 | -10,797 | 0 | 7,618 |
| 12 | 2022 | -10,797 | 0 | 7,618 |
| 13 | 2023 | -10,797 | 0 | 7,618 |
| 14 | 2024 | -10,797 | 0 | 7,618 |
| 15 | 2025 | 0 | 0 | 6,965 |
| 16 | 2026 | 0 | 0 | 1,633 |
| 17 | 2027 | 0 | 0 | 1,633 |
| 18 | 2028 | 0 | 0 | 1,633 |
| 19 | 2029 | 0 | 0 | 1,633 |
| 20 | 2030 | 0 | 0 | 1,633 |
| 21 | 2031 | 0 | 0 | 0 |
| Life-cycle | Total | (165,637) | 0.0 | 135,851 |

Source: DNV KEMA analysis

## Duarte, City of (003-10-ECE-ARRA)

### Site Summary

The city of Duarte applied for Energy Conservation Assistance Act (ECAA-ARRA) loans for various energy efficiency projects throughout the city. The projects consisted of three total energy efficiency measures (EEM). These measures included retrofitting several buildings with new heating, ventilation, and air-conditioning (HVAC) units, replacing existing analog thermostats with programmable thermostats, and upgrading the interior and exterior lighting system.

DNV KEMA visited the site and verified the implementation of these measures. During the site visit, the interior lighting fixtures were monitored to determine hours of use. Spreadsheet analysis was used to estimate energy savings for all measures, using a combination of site findings and data from the lighting loggers. The analysis yielded an overall electric energy savings of 111 percent and 39 percent for gas when compared to the ex ante estimates. The energy savings by measure are provided in Table 77.

**Table 77: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM1-Lighting Retrofit | 102,243 | Not reported | 0 | 124,937 | 46.46 | 0 | 122% | N/A |
| EEM2-High Efficiency HVAC | 25,039 | Not reported | 88 | 23,758 | 17.46 | 54 | 95% | 62 % |
| EEM3-Building Controls, programmable thermostats | 22,508 | Not reported | 260 | 18,223 | 0.00 | 81 | 81% | 31 % |
| Total | 149,790 | Not Reported | 348 | 166,918 | 63.92 | 135 | 111% | 39 |

Source: DNV KEMA analysis

At the measure level, EEM 1 saved more energy as a result of a higher estimate in hours of use for various halogen and high-intensity discharge (HID) lights that were found to be on photocell controls. EEM 2 saved less energy because there had been a reduction in scope that was not reflected in the ex ante numbers. For EEM 3, lower energy savings were calculated due

to a lack of control optimization on a number of the units. A full discussion for these differences by measure is provided toward the end of this report.

Table 78 below shows the life-cycle energy savings for this site. Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

Results from Table 78 yield a life-cycle energy savings of 2,430,874 kWh and 1,707 therms when considering only the Baseline 1, whereas the life-cycle savings comes to 2,113,619 kWh and 1,180 therms when using Baseline 2.

**Table 78: Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 2,430,874 | 958.8 | 1,707 |
| Baseline 2 | 2,113,619 | 724.7 | 1,180 |

Source: DNV KEMA analysis

## Project Description

This project was implemented at various buildings throughout Duarte. The measures affected energy consumption at several locations: City Center, Duarte Park, North Yard, South Yard, Royal Oaks Park, and Senior Center. Cooling and heating are supplied by a mix of split and package system air conditioners (AC), gas furnaces, and heat pumps. There were three measures implemented throughout the city, which consisted of the following.

**EEM 1: Lighting Retrofit** — This measure was a fixture-for-fixture replacement of the pre-existing T-12 and first-generation T-8 linear fluorescent lighting system with next-generation T8 lamps and electronic ballasts. Sensor controls for some of the spaces were also included as part of this measure. A number of exterior lights were retrofitted with induction-type fixtures.

**EEM 2: High-Efficiency HVAC**—This measure was for the replacement of the existing HVAC equipment with higher efficiency units. The ex ante analysis shows that seven units were replaced. A total heat pump capacity of 15 tons and a package unit AC capacity of 50 tons were shown as replaced in the analysis spreadsheet. There is no entry for furnace units, although that

may be implicitly implied in the package unit category. Details are not provided as to the actual efficiency of each unit or analysis method used.

**EEM 3: Building Controls, Programmable Thermostats**—This measure was for installation of seven-day programmable thermostats for select HVAC units throughout the city. There are 13 units included in the analysis. Similar to EEM 2, details of the analysis were not provided for review.

### Ex Ante Savings

Ex ante energy savings were derived by the implementers using standard spreadsheet analysis for EEM 1. Pacific West Energy Solutions provided a summary sheet for EEM 2 and EEM 3. The summary contained only hard entered values for the measure and lacked detail on how those values were calculated. The following lists how energy savings for each measure were calculated under the implementer's algorithms when this information was available.

**EEM 1: Lighting** — Spreadsheet analysis using pre- and postinstallation fixture quantities and wattages was used to determine the demand savings. Next, hours of operations were applied to the space types using an estimate of annual hours of operation for both pre and post cases. Similar lighting hours of use were assumed for most of the buildings. Values for hours of use were later reduced by 14 percent across the board to match logged values from lighting sensors employed after the retrofit.

**EEM 2: High-Efficiency HVAC**—The actual spreadsheet analysis details is not available for review. The only summary that was provided lacked details on which efficiencies were used to determine the energy savings. From what can be extracted from this summary, 15 tons of heat pump capacity at the Senior Center and 50 tons of package DX cooling capacity at the City Center were replaced.

**EEM 3: Building Controls, Programmable Thermostats**—Similar to EEM 2, the spreadsheet analysis details is not available for review. From what can be extracted from the summary, 13 thermostats were replaced, which controlled 540 MBH of furnace capacity, 60 tons of DX cooling capacity, and 10 tons of heat pump capacity. The analysis used seven-day operation from 6 a.m. to 6 p.m. in the existing case and Monday through Friday operation from 7 a.m. to 5 p.m. in the post-retrofit case.

### Project Evaluation

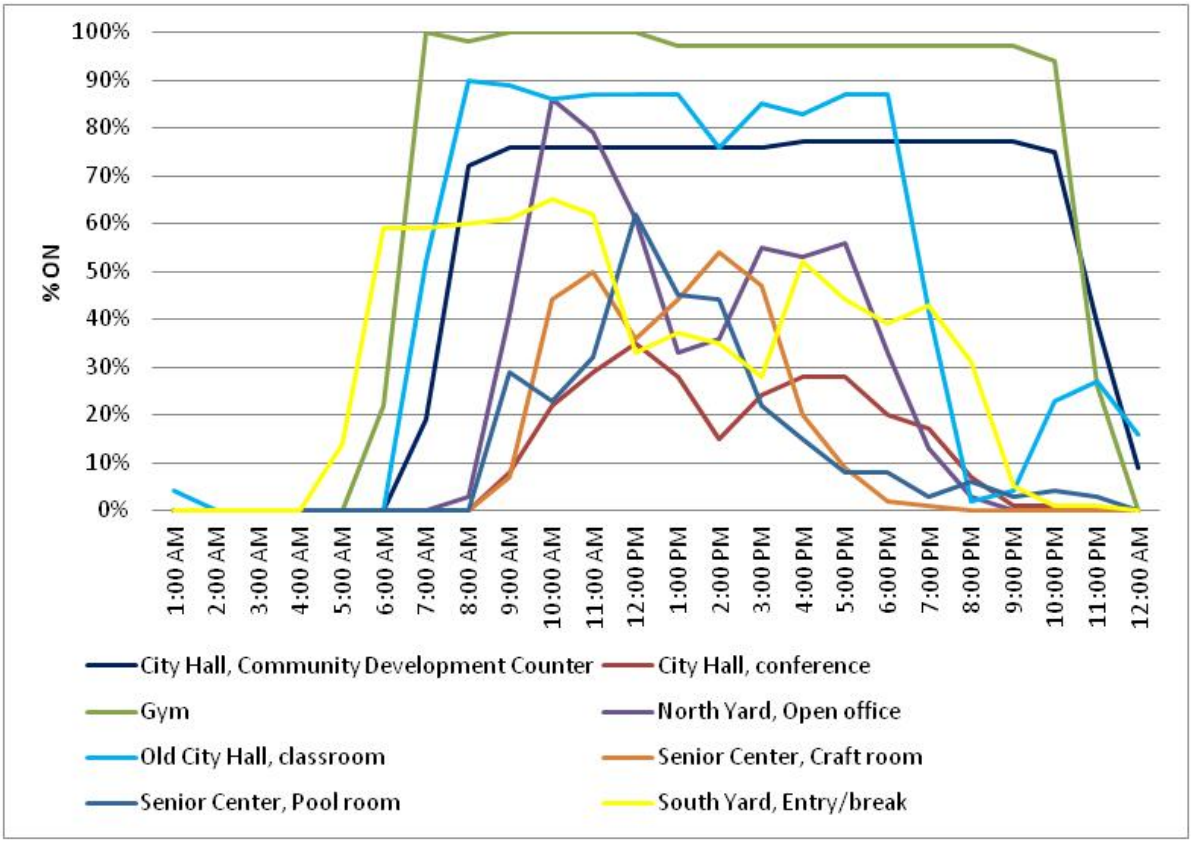
A DNV KEMA field engineer visited the project site October 27, 2011, to verify the measure installation and install time-of-use photocell data loggers for determining lighting hours of operation. The engineer returned December 8, 2011, to retrieve the lighting loggers. Since the site visit occurred during the winter season, no monitoring of the condenser units were done because it is not expected to yield useful data for analysis. For heat pumps, it is still possible to monitor the units during the winter to establish a heating load profile. However, it was found on-site that the monitoring equipment could not be confined safely inside the heat pump units and was therefore not performed. (If left on, the units were accessible to the public and posed electrical shock hazards if tampered with.)

*EEM 1- Lighting Retrofit*

Lighting loggers were placed at fixtures throughout various buildings. DNV KEMA sampled fixtures that were expected to represent the majority of the energy savings for the project. The sampling accounted for building and space types when possible, but more focus was placed at fixtures where energy savings were expected to be highest.

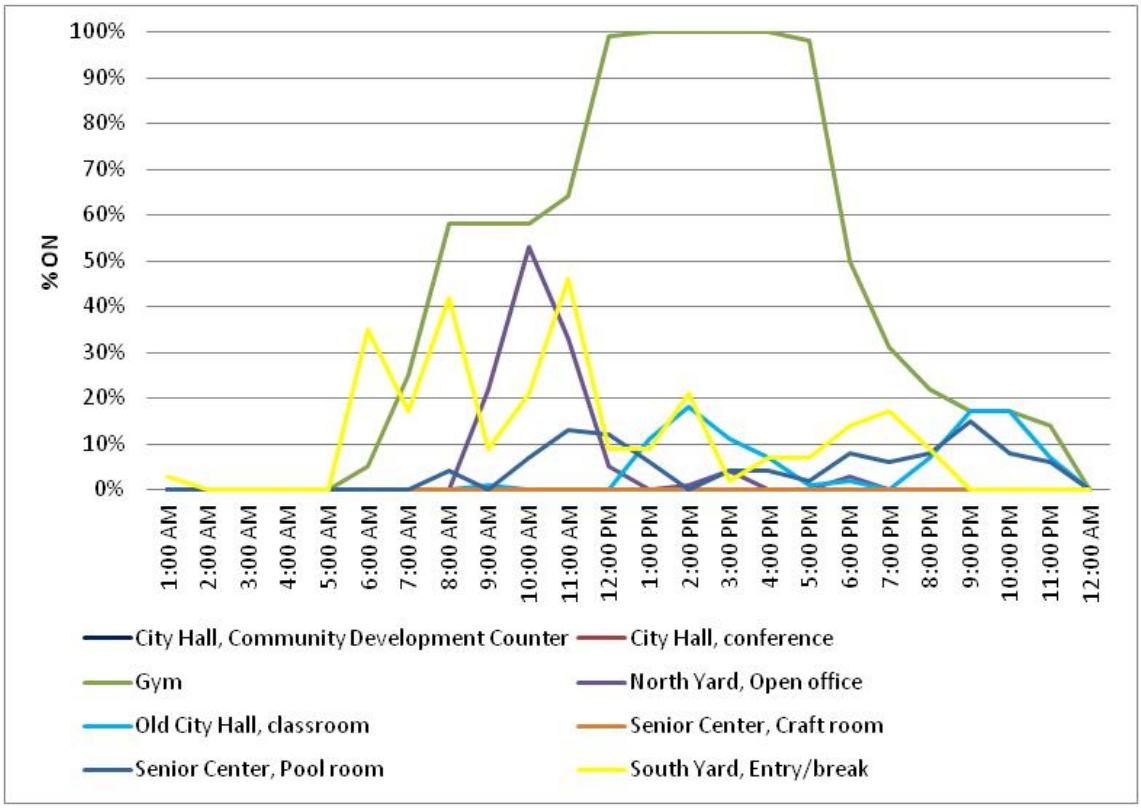
The ex post savings estimate for the lighting retrofit was generated with a spreadsheet analysis using time-of-use data from the photocell data loggers. Data from the lighting loggers were processed into weekend day and weekday time-of-use profiles. These profiles are shown in Figure 24and Figure 25below. The high variability from space to space reflects the space diversity across building types. Fixture types were verified and found to be consistent with what was recorded in the spreadsheet from the project files.

**Figure 23: Typical 24-hour Weekday Lighting Usage Profile at Various Locations**




Source: DNV KEMA analysis

**Figure 24: Typical 24-hour Weekend Day Lighting Usage Profile at Various Locations**




Source: DNV KEMA analysis

Extrapolated hours of use based on the logger data are shown in Table 79 below. One of the logger data showed zero hours of use (North Yard Conference Room) and were not used in the analysis because the hours are not likely reflective of the space over the entire year. DNV KEMA reverted to the minimal value assumed in the ex ante calculations for this space. This adjustment had negligible impact on the overall energy savings for this project since it affected only eight fixtures.

The hours of use for some fixtures were adjusted based on site findings. In particular, exit lights were given 8,760 hours of annual operation, and some exterior lights had their hours of operations revised upward. For example, the exterior lights in the South Yard were photocell-controlled and were therefore given 4,380 hours of annual operation. Hours of use for the remaining spaces were employed in the analysis. Energy savings were calculated using the following equation supplemented with the hours from the data loggers:

$$\textit{Energy Savings} = \textit{Quantity} \times \textit{Annual Hours} \times (kW_{Pre} - kW_{Post})$$

where,

- *Energy Savings* is the annual energy savings for all fixtures covered by the measure in kWh.

- *Quantity* is the total number of affected fixtures.
- *kW* is the pre- and postinstallation fixture wattages in kW.
- *Annual Hours* are the estimated hours using data from the loggers.

The total ex post savings for this measure using this analysis method is 124,937 kWh of electric energy and 46.5 kW of demand savings. The higher realization rate of 122 percent shown in Table 77 reflects adjustments in hours of use for the exterior lights in the South Yard that were controlled by photocell sensors. Without this adjustment, ex ante and ex post energy savings differed by only 5 percent.

**Table 79: Annual Lighting Hours of Operation by Fixture Location**

| Fixture Location | Ex ante Annual Hours | Ex post Annual Hours |
|---|---|---|
| City Hall, Community Development Counter | 2460 | 3141 |
| City Hall, conference | 1290 | 684 |
| City Hall, Human Resources Office | 2460 | 1820 |
| City Hall, Office | 2460 | 2125 |
| City Hall, Reception | 2460 | 3183 |
| City Hall, Restroom | 2460 | 2581 |
| Gym | 3756 | 5261 |
| North Yard, conference room | 1032 | 0 |
| North Yard, Open office | 2460 | 1562 |
| North Yard, shower room | 1968 | 566 |
| Old City Hall, classroom | 2460 | 3000 |
| Old City Hall, hallway | 2460 | 2923 |
| Senior Center, Craft room | 1968 | 816 |
| Senior Center, Office | 1968 | 781 |
| Senior Center, Pool room | 2460 | 906 |
| Senior Center, Activity Room | 2236 | 861 |
| Senior Center, TV room | 2460 | 1591 |
| South Yard, Entry/break | 2460 | 2177 |
| Teen Center, TV room | 2012 | 733 |

Source: DNV KEMA analysis

*EEM 2 – High-Efficiency HVAC*

DNV KEMA verified the installation of the seven new HVAC units at two buildings. There were four new units found at the City Center and three at the Senior Center. The units were either heat pumps or large packaged DX units. The efficiencies of the cooling units ranged from an EER of 10 to a SEER of 13. The packaged gas units had a thermal efficiency between 80 percent and 81.2 percent. Details for each unit are provided in Table 80 below.

The old units had already been removed but were assumed to provide the same capacity of heating and cooling to the spaces they served. The site contact indicated that the age of the units were around 17.5 years and were functional at the time of the replacement but had some operation problems. Since the old units had already been removed, DNV KEMA cannot provide an assessment of the condition of those units. However, based on the age, DNV KEMA assumed the units met Title 24 minimum efficiency standards post-1992. The efficiency for the baseline case was, thus, SEER 9.7, HSPF 6.8 (heat pump units), and 78 AFUE (for units with a gas furnace). No efficiency degradation was assumed in the analysis.

**Table 80: New High-Efficiency HVAC Unit Capacities Verified On-site**

| Location | Quantity | Cooling Tons | SEER/EER | Furnace, Input Capacity (MBH) | Furnace Efficiency | Heat Pump (HSPF) |
|---|---|---|---|---|---|---|
| Senior Center | 3 | 5 | 13 SEER | | | 7.8 |
| City Center | 1 | 20 | 10 EER | 250 | 81.2% | |
| City Center | 1 | 15 | 11 EER | 250 | 81.2% | |
| City Center | 1 | 10 | 11.3 EER | 150 | 80% | |
| City Center | 1 | 5 | 13 SEER | | | 8 |

Source: DNV KEMA analysis

Ex post energy savings were estimated using 5°F weather bins and assuming linear building loads. Building loads begin at the 65-70°F bin and are maximum at the 90-95°F bin. For heating the start point is at the 60-65°F bin and is maximum at the "below 30°F" bin. The closest TMY 3 weather data were used to establish the load profile for the site (Riverside station). The spreadsheet model considers the hours of operation along with flags for the heating/cooling months. The latter was necessary so that hours during the summer are not erroneously used in the heating application when cooling is expected. Actual efficiencies of the HVAC units were used in the analysis. This analysis yielded 23,758 kWh and 54 therms of energy savings.

*EEM 3 – Building Controls, Programmable Thermostats*

Findings for this measure are summarized in **Table 81**, DNV KEMA observed that there were indeed programmable thermostats installed throughout all the buildings at the facility. The site contact confirmed the thermostats are set so that the units turned off during the weekends at the City Center and Senior Center. Further discussions with the site contact indicated that the settings in the preretrofit case were the same as postretrofit conditions for the City Center. Hence, this measure did not achieve energy savings for the thermostats that controlled the HVAC units supplying the City Center.

**Table 81: Thermostats HVAC Unit Capacities Verified On-site**

| Location | Ex ante, Total Capacity HVAC Control | Ex post, Total Capacity HVAC Control | Comments |
|---|---|---|---|
| City Center | 30 tons, packaged units | Same as ex ante | There are no savings for this location because the programming of the thermostats did not change from the preretrofit conditions |
| North Yard | 4 tons, heat pump | Same as ex ante | |
| Senior Center | 20 tons split DX, 360 MBH furnace heating | 25 tons heat pump capacity, | The senior center is heated using heat pumps not furnace heating |
| South Yard | 6 tons, heat pump | Same as ex ante | |
| Teen Center | 10 tons split DX cooling, 180 MBH furnace heating | 4 tons split DX cooling, 120 MBH furnace heating | No energy savings for the other units because the preretrofit conditions are the same |

Source: DNV KEMA analysis

For the units supplying the Senior Center, the current operation schedule is Monday through Friday from 7 a.m. to 8 p.m. Schedules at the Teen Center, North Yard and South Yards were assumed as similar to the City Center. Project files mention that a number of units had analog thermostats before the building retrofit. and so energy savings are estimated for these units.

Ex post energy savings were calculated using a similar binning approach as in EEM 2. For the baseline case, all hours between 7 a.m. to 7 p.m. for all days of the week were used in the baseline analysis. In the postretrofit case, only hours from Monday through Friday at 7 a.m. to 7

p.m. were included in the analysis. No adjustments to the weekday hours were made since current hours of operation for the weekdays are identical to baseline conditions. Total savings for this measure are calculated at 18,223 kWh and 81 therms.

Both ex post and ex ante analyses assume the base case as HVAC operation during all weekends. However, the occupants along with the maintenance staff had the power to turn the units off before the beginning of the weekends. Since the researchers have no direct information about actual HVAC operations on the weekend, DNV KEMA maintained the assumption of HVAC operation on the weekend, although this may overstate energy savings for this measure.

## Savings Results

Considering the implementation of all three EEMS, this site saved 166,918 kWh and 135 therms of energy in the first year. Table 82 breaks down the ex post energy savings by measure. The ex ante energy savings are also provided for comparison.

## Discussion

### *EEM 1 –Lighting*

For this measure, ex post analysis yielded 122 percent of ex ante estimates. The line item entries for the exterior halogen and high intensity (HID) fixtures in the South Yard garage areas are responsible for the higher ex post energy savings estimates. In the ex ante calculation spreadsheet, these exterior fixtures hours of use were assumed at 1,118 hours a year. Site findings indicate that these fixtures were photocell-controlled and operated for more hours than originally thought. The hours were adjusted to 4,380 to reflect actual operating times.

Indeed, if these fixtures were omitted from the project, ex post energy savings for the lighting come to within 5 percent of ex ante estimates despite independent verification of the time-of-use lighting hours.

### *EEM 2 – High-Efficiency HVAC*

The ex post analysis yielded 95 percent and 62 percent of the ex ante electric and gas energy savings claims, respectively. Details of the analysis method for this site were not available for DNV KEMA's review; therefore, it is not possible to provide a full discussion for why there is a discrepancy in electric or gas energy savings for this measure. DNV KEMA was provided only with the hard entered energy savings values for each HVAC unit type (packaged, split, heat pump, or gas furnace) replaced, along with the total nominal capacities. However, there is no report or additional spreadsheets that show how these values were derived.

DNV KEMA's analysis used site data, when possible. For the postretrofit case, an average DX capacity of 65 tons with a composite SEER value of 12.39 was used in the analysis. For heating, the units were either heat pumps with an HSPF of 7.85 or gas furnace with an AFUE of 81 percent. Since there is no information available on the preretrofit units, DNV KEMA assumed similar cooling capacities and reduced the efficiency of the units in the baseline case to match minimum Title 24 standards at the time the units were expected to be installed (SEER 9.7/HSPF 6.8 and 78 AFUE for post 1992 year units). The weather file used in the analysis comes from a weather station closest to the site. For this site, TMY3 (typical meteorological year) weather for Riverside was used as opposed to climate zone data since this is expected to yield more accurate

results. It is likely a combination of these factors resulted in the lower gas energy savings estimate.

### *EEM 3 – Building Controls, Programmable Thermostats*

Ex post analysis yielded 81 percent and 31 percent of the electrical and gas energy savings claimed in the project files. Conversations with the site contact indicated that the HVAC units supplying City Hall were already on programmed schedules before installation of the thermostats, and after installation was completed, no schedule adjustments were made to the controls. These units account for the majority of the gas energy savings. They are also responsible for a large part of the electric energy savings as well, and removing them from the analysis significantly reduced the energy savings for this measure.

There were likely other differences between ex post and ex ante methods and assumptions used in determining energy savings as well, but without the ex ante analysis details, it is not possible for DNV KEMA to provide a full discussion. However, in examining the summary that was provided, DNV KEMA notes that gas energy savings were not based on actual site data but relied on the assumption that if the cooling units were DX (non-heat pump) then the gas input capacity was 1½ times the cooling capacity. The units at the Senior Center were also erroneously classified as DX cooling with gas heating. All units found on-site at the Senior Center were heat pumps. These differences likely contributed to ex post and ex ante energy savings estimates.

## Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the energy efficiency measure implementation and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have operated for the full effective useful life (EUL) of the new equipment, regardless if the existing equipment was at the end of its useful life. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the existing equipment's remaining useful life (RUL). After the remaining useful-life period and up until the end of the EUL of the installed measure, an expected replacement baseline is used. This baseline considers minimally code-compliant conditions or standard practice when no code is applicable.

According to the site contact, HVAC equipment at the facility is used generally for 15-20 years, and the pre-existing units had exceeded this mark. In cases where the units are past their useful lives, Baseline 1 is not used except for in the first-year energy savings calculations. Baseline 2 uses an HVAC cooling efficiency between EER 11 to SEER 13 (depending on unit capacity) and an AFUE of 80 percent for gas. This is in line with federal minimum standards.

In the case of interior lighting, the existing conditions are used for both baselines since the existing conditions are already code-compliant.

The controls measure is an add-on measure, so the replacement baselines are not applicable. The standard baseline is unit operation without the new controls.

Table 82 summarizes the energy savings and life-cycle parameters by measure used in the life-cycle savings calculations.

**Table 82: Values Used in Life-cycle Savings Calculations by Measure**

| Measure | Early Replacement | | Expected Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| EEM1-Lighting | 124,937 | 0 | 124,937 | 0 | 15 | 0 |
| EEM2-High Efficiency HVAC | 23,758 | 54 | 1,097 | 17 | 14 | 0 |
| EEM3-Building Controls | 18,223 | 81 | 18,223 | 81 | 11 | 0 |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields estimated energy savings of 2,430,874 kWh and 1,707 therms (Table 83) whereas the life-cycle savings come to 2,113,619 kWh and 1,180 therms when using Baseline 2. Table 84 tabulates the energy savings by year starting with 2011 using the Baseline 2.

**Table 83: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 166,918 | 64 | 135 |
| 2 | 2012 | 166,918 | 64 | 135 |
| 3 | 2013 | 166,918 | 64 | 135 |
| 4 | 2014 | 166,918 | 64 | 135 |
| 5 | 2015 | 166,918 | 64 | 135 |
| 6 | 2016 | 166,918 | 64 | 135 |
| 7 | 2017 | 166,918 | 64 | 135 |
| 8 | 2018 | 166,918 | 64 | 135 |
| 9 | 2019 | 166,918 | 64 | 135 |
| 10 | 2020 | 166,918 | 64 | 135 |
| 11 | 2021 | 166,918 | 64 | 135 |
| 12 | 2022 | 148,695 | 64 | 54 |
| 13 | 2023 | 148,695 | 64 | 54 |
| 14 | 2024 | 148,695 | 64 | 54 |
| 15 | 2025 | 148,695 | 64 | 54 |
| 16 | 2026 | 0 | 0 | 0 |
| Total | | 2,430,878 | 960 | 1,701 |

Source: DNV KEMA analysis

**Table 84: Baseline 2 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 166,918 | 64 | 135 |
| 2 | 2012 | 144,257 | 47 | 98 |
| 3 | 2013 | 144,257 | 47 | 98 |
| 4 | 2014 | 144,257 | 47 | 98 |
| 5 | 2015 | 144,257 | 47 | 98 |
| 6 | 2016 | 144,257 | 47 | 98 |
| 7 | 2017 | 144,257 | 47 | 98 |
| 8 | 2018 | 144,257 | 47 | 98 |
| 9 | 2019 | 144,257 | 47 | 98 |
| 10 | 2020 | 144,257 | 47 | 98 |
| 11 | 2021 | 144,257 | 47 | 98 |
| 12 | 2022 | 126,034 | 47 | 17 |
| 13 | 2023 | 126,034 | 47 | 17 |
| 14 | 2024 | 126,034 | 47 | 17 |
| 15 | 2025 | 126,034 | 47 | 17 |
| 16 | 2026 | 0 | 0 | 0 |
| Life-cycle | Total | 2,113,624 | 722 | 1,183 |

Source: DNV KEMA analysis

## Grover Beach, City of (010-09-ECE-ARRA)

### Site Summary

The city of Grover Beach applied for Energy Conservation Assistance Act (ECAA-ARRA) loans for various energy efficiency projects throughout the city. The projects consisted of seven energy efficiency measures (EEM) of which six were eventually implemented. These six measures included retrofitting several buildings with new heating, ventilation, and air-conditioning (HVAC) units, replacing existing analog thermostats with programmable digital thermostats, upgrading the interior lighting system, retrofitting the traffic lights, and installing vending machine and computer power management controls.

DNV KEMA visited the site and verified implementation of these measures. During the site visit, the interior lighting fixtures were monitored to determine hours of use. Spreadsheet analysis were used to estimate energy savings for all measures using a combination of site findings, data from the lighting loggers, spot power measurements, and literature reviews. The energy savings by measure are provided in Table 85.

**Table 85: Energy Savings Summary**

| Measure | Ex Post | | | Ex Ante | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| EEM1-Interior Lighting | 75,856 | 26.15 | 0 | 71,452 | 25 | 0 | 106% | N/A |
| EEM2-Computer Power Management | 10,011 | 0.00 | 0 | 13,052 | Not reported | | 77% | N/A |
| EEM3-Traffic Lights | 71,234 | 8.58 | 0 | 57,816 | 7 | | 123% | N/A |
| EEM4-High Efficiency HVAC | 5,392 | 12.95 | 336 | 10,110 | 12 | 513 | 53% | 66% |
| EEM5-Building Controls, programmable thermostats | 5,034 | 0.00 | 1375 | 16,812 | Not reported | 1,324 | 30% | 104% |
| EEM6-Vending Machines | 1,112 | 0.00 | 0 | 1,778 | Not reported | | 63% | N/A |
| Total | 168,639 | 47.68 | 1711 | 171,020 | Not Reported | 1,837 | 99% | 93% |

Source: DNV KEMA analysis

The analysis yielded an overall electric energy savings of 99 percent and 93 percent for gas when compared to the ex ante estimates.

While the ex post electric energy savings for the entire project are in line with ex ante values, energy savings by measure varied significantly. Variations in energy savings for non-HVAC measures (EEM 2, EEM 3, and EEM 6) are chiefly the result of the differences in calculation approaches.

In contrast, variation in energy savings for the high-efficiency HVAC measure (EEM 4) come from site findings showing that the total tonnage of the installed equipment was less than what was initially assumed, the equipment efficiencies were overestimated, and a possible spreadsheet error in the ex ante bin analysis eliminates the lowest cooling bin in the efficient case analysis. For EEM 5, ex post energy savings are lower because the fan energy is treated as cycling versus continuous and reflects the typical field operation of these units.

A full discussion of these differences by measure is provided toward the end of this report.

**Table 86**: Life-cycle Savings Summary below shows the life-cycle energy savings for this site. Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

Table 86 shows a life-cycle energy savings of 2,032,024 kWh and 20,165 therms when considering only the Baseline 1 where as the life-cycle savings comes to 1,978,910 kWh and 19,084 therms when using Baseline 2.

**Table 86: Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 2,032,024 | 672.3 | 20,165 |
| Baseline 2 | 1,978,910 | 544.7 | 19,084 |

Source: DNV KEMA analysis

## Project Description

This project was implemented at various buildings throughout Grover Beach. The measures affected energy consumption at several locations: Trouville Center, Police Station, City Hall, Fire Station, Ramona Center, and Corporate Yard buildings. Cooling and heating are supplied

by a mix of split and package system air conditioners (AC), gas furnaces, and unitary gas heaters. There were six measures implemented throughout the city, and they consisted of the following.

**EEM 1: Lighting Retrofit** — This measure was a fixture-for-fixture replacement of the pre-existing T-12 and first-generation T-8 linear fluorescent lighting system with next-generation T8 lamps and electronic ballasts.

**EEM 2: Computer power management**—This measure was for installing control software on computers and monitors to manage computer power settings from a centralized source. The measure affected 75 computers.

**EEM 3: LED Traffic Lights**—This measure was for converting the existing traffic lights from incandescent to LED.

**EEM 4: High-Efficiency HVAC**—This measure was for replacing the existing HVAC equipment with higher-efficiency units. The ex ante analysis shows that a total of 47.5 tons of direct expansion (DX) air-conditioning capacity and 855 MBH of heating (output) capacity were replaced throughout the city with higher-efficiency units. Details are not provided as to the actual efficiency of each unit, but the feasibility study shows the average efficiency for the new units are estimated at SEER 19 for cooling and 95 percent thermal efficiency for heating.

**EEM 5: Building Controls, Programmable Thermostats**—This measure was for installing seven-day programmable thermostats for all HVAC units throughout the city. The number of affected HVAC units is the same as those mentioned in EEM 4.

**EEM 6: Vending Machine Controls**—This measure was for installing control software on one vending machine. The software allows the vending machine to power down during times when there is no occupancy.

### Ex Ante Savings

Ex ante energy savings were derived by Pacific West Energy Solutions using standard spreadsheet analysis for all measures. The following lists how energy savings for each measure were calculated under Pacific West Energy Solution's algorithms.

**EEM 1: Lighting** — Spreadsheet analysis using pre- and postinstallation fixture quantities and wattages was used to determine the demand savings. Next, hours of operations were applied to the space types using an estimate of annual hours of operation for both pre and post cases. Similar lighting hours of use were assumed for most of the buildings.

**EEM 2: Computer Power Management**—A general algorithm taking into account the number of computers, power requirements of the computers at various operation modes (on, off, suspend), and changes in hours of operation at each mode due to the power management software are used to determine savings. The algorithm also assumes that for every 3 kWh that is saved from the measure during times when the air conditioner is running, 1 kWh of energy of HVAC is saved as a result of interactive effects.

All values are assumed without source citations. For measures involving energy management software, the savings are highly uncertain due to various unknown factors such as typical power draws at various operational states and fraction of hours at each operational state with or without energy management software. Savings can be easily overestimated or underestimated due to this.

**EEM 3: LED Traffic Lights**—The feasibility study lists the quantities of units replaced along with pre- and postretrofit fixture wattages and hours of use. However, the final values do not match when employing the energy savings algorithm. There is no information in the project files to determine how the final savings value was established.

**EEM 4: High-Efficiency HVAC**—The actual spreadsheet analysis is not available for review, but based on the feasibility study available, the analysis uses 5 degree weather bins and assumes a linear load profile to predict energy consumption for the baseline and efficient cases. The baseline uses a SEER 13 equivalent, while the efficient case uses a SEER 19 equivalent for cooling. Baseline heating efficiency is assumed at 80 percent while the efficient case is 95 percent.

**EEM 5: Building Controls, Programmable Thermostats**—The analysis is similar to EEM 4 except weekend hours of use were eliminated in the efficient case. In addition, the HVAC units were predicted to start one hour later and end one hour earlier than the baseline case. Most of the savings come from avoided fan energy. The supply fans are assumed to operate for all hours when the building is expected to be occupied.

**EEM 6: Vending Machine Controls**—The analysis takes into account the power requirement of the vending machine and hours of operation with and without the controls. Hours of operation before and after the application of the controls were assumed. It is unknown how the power draw of the unit was determined.

## Project Evaluation

A DNV KEMA field engineer visited the project site September 27, 2011, to verify measure installation and install time-of-use photocell data loggers for determining lighting hours of operation. The engineer returned October 25, 2011, to retrieve the lighting loggers. Since the site visit occurred during the winter season, no monitoring of the condenser units was done because it is not expected to yield useful data for analysis. A spot power measurement was taken for the vending machine for use in the analysis. Table 87 summarizes the monitoring equipment details.

**Table 87: Monitoring Details**

| Monitored Equipment | Logger Type | Measurement Type | Measurement Interval | Duration |
|---|---|---|---|---|
| (18) Light fixtures | DENT TOU lighting loggers | On/Off (time-of-use) | Continuous | 6 weeks |
| Vending Machine | WattsUp Power Meter | Spot Power | Once | N/A |

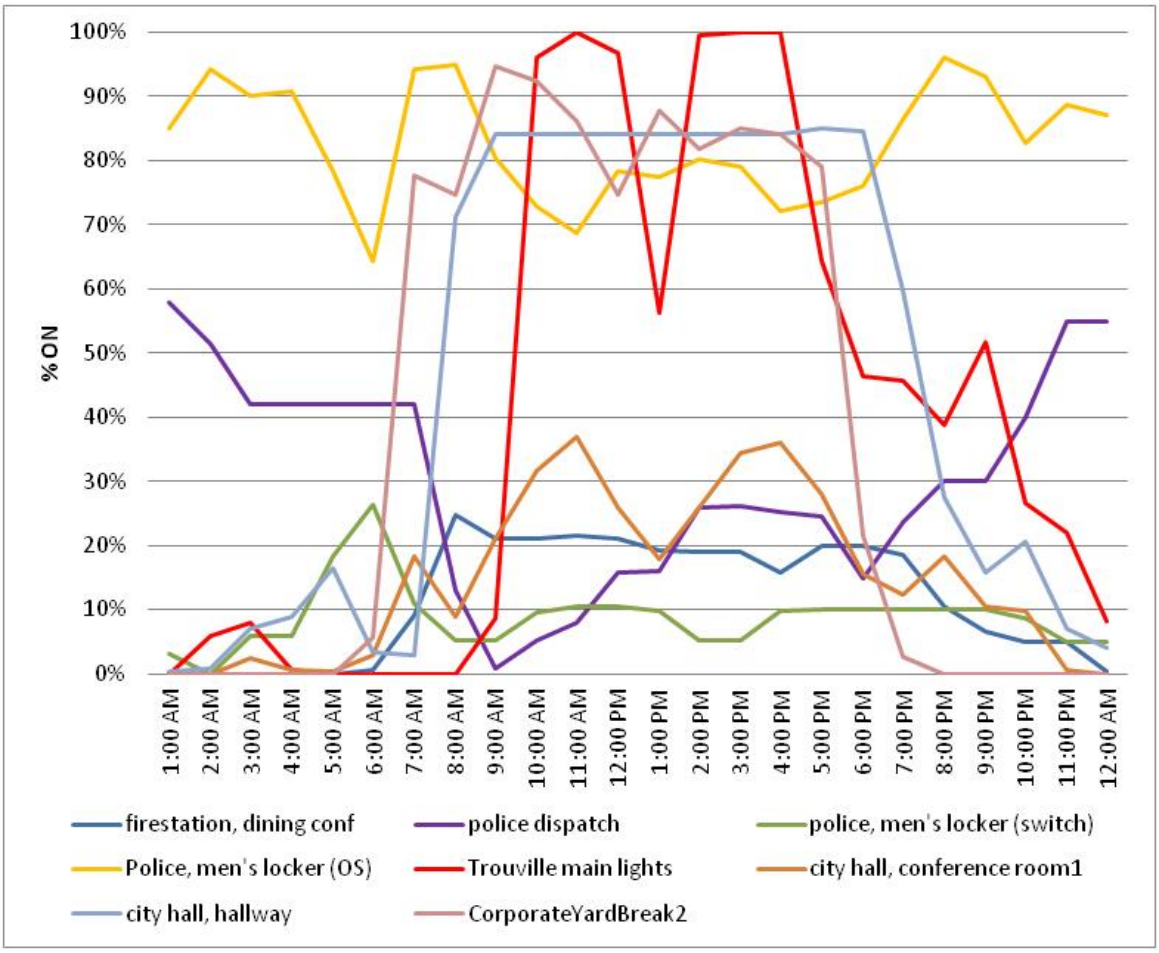
Source: DNV KEMA analysis

*EEM 1- Lighting*

Lighting loggers were placed at fixtures throughout various buildings. DNV KEMA sampled fixtures that were expected to represent the majority of the energy savings for the project. The sampling accounted for building and space types, when possible, but more focus was placed at fixtures where energy savings were expected to be highest.

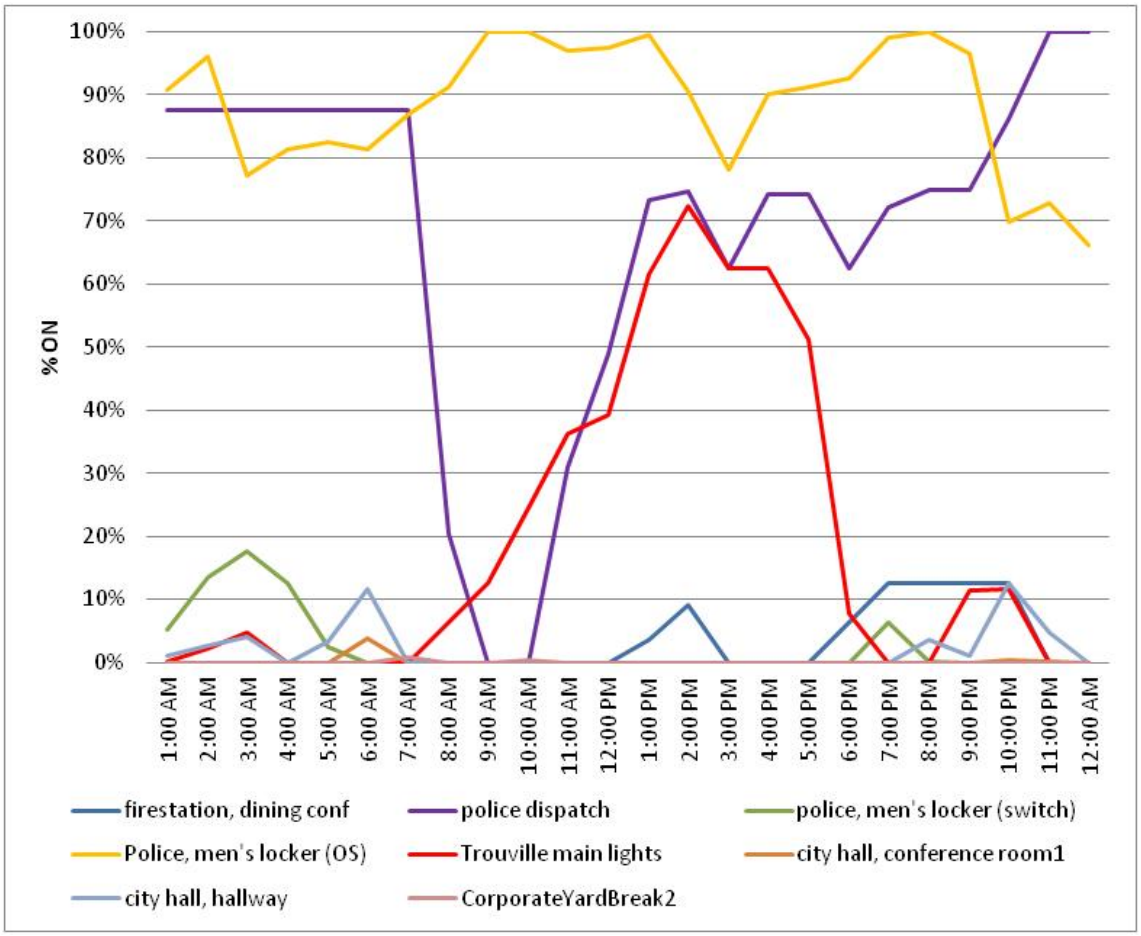
The ex post savings estimate for the lighting retrofit was generated with a spreadsheet analysis using time-of-use data from the photocell data loggers. Data from the lighting loggers were processed into weekend day and weekday time-of-use profiles. These profiles are shown in Figure 25 and Figure 26 below. Fixture types were also verified and found to be consistent with what was recorded in the spreadsheet from the project files.

**Figure 25: Typical 24-hour Weekday Lighting Usage Profile at Various Locations**




Source: DNV KEMA analysis

**Figure 26: Typical 24-hour Weekend Day Lighting Usage Profile at Various Locations**




Source: DNV KEMA analysis

Extrapolated hours of use based on the logger data are shown in Table 88 below. Two of the logger data showed near zero hours of use (Fire station office/storage and City Hall Conference Room 2) and were not used because the hours are not likely reflective of the space over the entire year. For these spaces, DNV KEMA reverted to the ex ante assumptions for hours of use. Hours of use for the remaining spaces were employed in the analysis. The high variability from space to space reflect the space diversity across building types. Energy savings were calculated using the following equation supplemented with the hours from the data loggers:

$$Energy\ Savings = Quantity \times Annual\ Hours \times (kW_{Pre} - kW_{Post})$$

where,

- *Energy Savings* is the annual energy savings for all fixtures covered by the measure in kWh.
- *Quantity* is the total number of affected fixtures.

- *kW* is the pre- and postinstallation fixture wattages in kW.
- *Annual Hours* are the estimated hours using data from the loggers.

The total ex post savings for this measure using this analysis method are 75,856 kWh of electric energy and 26.2 kW of demand savings. The ex post estimate differed from the updated ex ante value by only 1 percent. The higher realization rate of 106 percent shown in Table 85 reflects the expanded scope that was not accounted for in the ex ante values reported to DNV KEMA.

**Table 88: Annual Lighting Hours of Operation by Fixture Location**

| Fixture Location | Annual Hours |
|---|---|
| Fire station reception | 79 |
| Fire station, dining conf | 796 |
| Fire station office (used as storage) | 2 |
| Police dispatch | 3,619 |
| Police WEAPS room | 1,601 |
| Police office | 1,910 |
| Police, men's locker (switch) | 607 |
| Police, men's locker (OS) | 7,397 |
| Police, hallway | 8,760 |
| Police, conference room break | 8,602 |
| Trouville dining | 1,218 |
| Trouville main lights | 3,026 |
| City hall, conference room 1 | 935 |
| City Hall open office area | 2,130 |
| City hall, conference room 2 | 0 |

Source: DNV KEMA analysis

### *EEM 2 – Computer Power Management*

Installation of the computer power management software was verified with the site contact via invoices. A total of 75 licenses were purchased and installed, according to the information technology personnel responsible for the setup.

Ex post analysis for this measure used the following equation to determine energy consumption for the preretrofit case.

$$Energy = 8{,}760 \text{ X } (Hours_{on} \text{ X } Power_{on} + Hours_{sleep} \text{ X } Power_{sleep} Hours_{off} \text{ X } Power_{off})$$

where,

- *Energy* is the annual energy consumption in kWh.
- *Hours* is the estimated number of hours the computer is in *on, sleep*, or *off* modes.
- *Power* is the respective power draws at those modes.

Hours of operation at these different modes are based on established studies for office equipment[30] while the power draws at the different modes come from compiled ENERGY STAR data on computers.[31]

For the postretrofit case, the power draws were unchanged, but the hours of use were augmented to reflect power management software settings. DNV KEMA assumed that the power management software will decrease the initial "on" time hours by 46 percent resulting in more hours in the standby mode.[32] Using this analysis, total energy savings for this measure were calculated at 10,011 kWh.

### *EEM 3 – LED Traffic Lights*

The DNV KEMA engineer visited nine intersections within the city limits and visually verified the installation of LED traffic lights. All pedestrian walkways used LED technology. Each intersection to some extent was retrofitted with LED traffic lights. The total count exceeded what was claimed in the documentation. However, only the quantities claimed in the project files were used in the ex post analysis since some of the intersections were known to have LED traffic lights before measure implementation.

Energy savings were calculated similar to the lighting calculations in EEM 1. For the 12-inch ball traffic signals, 8,760 hours were used in the analysis. For the pedestrian lights, the hours of use was derated to 6,421 to account for the "flashing" portion of the lights. Ex post energy savings for this measure are 71,234 kWh.

### *EEM 4 – High-Efficiency HVAC*

DNV KEMA verified the installation of the new HVAC units at six buildings. These units were either packaged or split systems. There was one new unitary heater, but the efficiency of the unit did not exceed the existing units found and therefore was not counted in the analysis. Cooling efficiencies ranged from SEER 13 up to SEER 18, while heating efficiencies ranged from 80 percent to 96.7 percent thermal efficiency. Details for each the unit is provided in Table 89 below.

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30 *After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment,* Roberson et al., 2004.

31 ENERGY STAR 5.0 Dataset for Computers, using Category B computers.

32 "Enterprise PC Power Management Tools: Greening IT from the Top Down," Barr et al, 2010.

**Table 89: New High-Efficiency HVAC Unit Capacities Verified On-site**

| Location | Quantity | Cooling Tons | SEER | Furnace, Input Capacity (MBH) | Furnace efficiency |
|---|---|---|---|---|---|
| Police Station | 3 | 4 | 15 | 108 | 83% |
| Police Station | 1 | 3 | 15.1 | | |
| City Hall | 1 | 3 | 16.5 | 80 | 81% |
| City Hall | 1 | 3 | 13 | 50 | 80% |
| City Hall | 1 | 5 | 13 | 100 | 80% |
| Fire Station | 1 | 5 | 14 | 108 | 83% |
| Fire Station | 1 | 3.5 | 14 | 80 | 81% |
| Ramona | 1 | 5 | 18 | | |
| Ramona | 1 | | | 100 | 97% |
| Ramona | 1 | | | 60 | 96.7% |
| Trouville | 1 | | | 100 | 97% |
| Corporate Yard | 1 | | | 60 | 96.7% |

Source: DNV KEMA analysis

Ex post energy savings were estimated using 5°F weather bins and assuming linear building loads. Building loads begin at the 65-70°F bin and are maximum at the 90-95°F bin. For heating the start point is at the 60-65°F bin and is maximum at the "below 30°F" bin. The closest TMY 3 weather data was used to establish the load profile for the site (Santa Maria Airport ). The spreadsheet model considers the hours of operation along with flags for the heating/cooling months. The latter was necessary so that hours during the summer are not erroneously used in the heating application when cooling is expected. Actual efficiencies of the HVAC units were used in the analysis. This analysis yielded 5,392 kWh and 336 therms of energy savings.

*EEM 5 – Building Controls, Programmable Thermostats*

DNV KEMA observed that there were indeed programmable thermostats installed throughout all buildings at the facility. The site contact confirmed the thermostats are set so that the units turned off during the weekends.

Ex post energy savings were calculated using a similar binning approach as in EEM 4. For the baseline case, all hours between 6 a.m. to 6 p.m. for all days of the week were used in the baseline analysis. In the postretrofit case, only hours from Monday through Friday at 7 a.m. to 5 p.m. were used consistent with the expected settings of the thermostat. Total savings for this measure are calculated at 5,034 kWh and 1,375 therms.

### *EEM 6 – Vending Machine Controls*

DNV KEMA verified the installation of occupancy controls on the vending machine. A spot power measurement of 276 watts was recorded using a WattsUp Pro plug in power meter. The analysis used this value and assumed the unit ran for all hours throughout the year in the pre retrofit case. Vending machine controls were assumed to reduce annual consumption by 46 percent[33] in the post retrofit case. Energy savings for this measure is calculated at 1,112 kWh for the one vending machine control installed.

## Savings Results

Considering the implementation of all six EEMS, this site saved 172,642 kWh and 1,711 therms of energy in the first year.  breaks down the ex post energy savings by measure. The ex ante energy savings are also provided for comparison.

## Discussion

### *EEM 1 – Interior Lighting*

Ex post and ex ante energy savings are nearly identical since the majority of the lighting fixtures were found installed as specified in the final spreadsheet provided to DNV KEMA.[34] There had been some changes in scope since the feasibility study, which is reflected in DNV KEMA's final energy savings value for this measure. While there were some discrepancies in the hours of use employed in the calculations, it did not affect the final savings estimates for this measure because the higher estimates tend to balance the lower estimates when applied to the entire site.

### *EEM 2 – Computer Power Management*

DNV KEMA employed a set of values for power draws and hours of use at different computer operation states (on, sleep, off) using findings from the literature. For this measure, deemed savings from the literature are typically used when pre and post data are not available due to the potential for high variability in savings estimates. A great deal of uncertainty is introduced when the calculations are based on generalized estimates, as is the case for the ex ante energy savings claim. DNV KEMA's lower ex post savings estimate (77 percent) is a reflection of eliminating this uncertainty inherent in the ex ante algorithm.

Ex ante analysis also considers an HVAC interaction factor. Typically, reduction in plug loads will result in some small savings due to interaction with the HVAC units. However, considering the mild climate zone, and the fact that the majority of the energy savings are generated when the HVAC units are not operating, this value is negligible and should not be factored into this measure. HVAC interaction is much more complex and cannot be accurately captured in a spreadsheet model. Savings reported in the literature and reported here do not consider this effect chiefly due to the uncertainty.

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33 Claimed by manufacturer and supported by various independent case studies. This value is also used in multiple technical resource manuals to estimate vending machine control savings.

34 Spreadsheet provided by Pacific West.

### *EEM 3 – LED Traffic Lights*

Ex ante calculation details are not available for review, and, therefore, it is not possible to identify the cause for differences in energy savings for this measure.

### *EEM 4 – High-Efficiency HVAC*

The ex post analysis yielded 53 percent and 66 percent of the ex ante electric and gas energy savings claim, respectively, despite using similar analysis methods. Examination of the feasibility report shows that the values used in the ex ante calculations for this measure were inconsistent with what was found on site. For example, a total nominal cooling capacity of 39.5 tons were found installed, but the ex ante calculations used 47.5 instead. In addition, efficiencies of the new units were assumed in the ex ante calculations at 19 SEER and 95 percent AFUE, while actual efficiencies averaged 14.9 SEER and 87 percent AFUE.

A main source for the HVAC discrepancy comes from the treatment of the efficient (or "proposed") case analysis. In the efficient case analysis, the lowest cooling HVAC bin (67.5 °F) is eliminated from the analysis for unknown reasons. This was not treated the same in the baseline case. By doing this any energy consumed when the HVAC is predicted to operate between 65-70°F is excluded and becomes energy saved. Elimination of this bin is unlikely related to the HVAC efficiency, and by excluding it, the energy savings will be overstated.

In addition, fan cooling energy is double-counted in the bin analysis. The compressor calculations uses a SEER efficiency rating to determine the power draw for the compressor and by definition already includes fan energy. However, fan energy is calculated again in an adjacent section. Typically, even if the fan power is double counted, this would cancel out when the total proposed case energy consumption is subtracted from the baseline case. Because the bottom HVAC bin is eliminated from the calculation, however, extra fan energy savings result. Taken together, the ex ante removal of the bottom HVAC bin in the proposed case results in 37 percent energy savings from the baseline and is likely overstated.

### *EEM 5 – Building Controls, Programmable Thermostats*

Ex post analysis yielded only 30 percent of the electrical energy savings claimed in the project files. A portion can be attributed to double counting fan energy for the cooling application in the ex ante analysis as mentioned above, but the majority comes from how the fan energy calculations are treated overall in the ex ante analysis.

As shown in the feasibility study, the fan is assumed as running continuously for all hours, included in the bin analysis. The fan energy is not derated in any way. This is generally true for large buildings that have their climate control via a central HVAC system or large, big box package-type systems with dedicated air handling units that must remain on to satisfy outside air requirements. However, this is not the case for this site. Rather, the site is composed largely of very small buildings that are served by residential type split HVAC units. The indoor fan cycles on when there is a need for cooling or heating, and, therefore, the fans do not operate the full hour. Operation of the fans must be derated to account for this.

Much of the discrepancy comes from the fan savings for the heating application. The ex ante claims an energy savings of 13,634 kWh in fan savings during the heating season, while ex post

values are estimated at 1,147 kWh. The values determined in the ex post are much more realistic when considering fan energy as a total of building energy usage. Using preimplementation billing data as a quality check for the Ramona building, which has two HVAC units, energy consumption from fan energy would come out to 45 percent of total building energy consumption if the ex ante algorithms are used, a phenomenally high value considering that fan energy only takes up roughly 3-10 percent of a similarly occupied building's energy use.[35] Using DNV KEMA's method, the fan power is around 5 percent, which is in line with expectations. The same is true for the other building, where preimplementation billing data is available.

#### *EEM 6 – Vending Machine Controls*

Ex post and ex ante analysis methods are essentially the same for this measure. The only differences are the two parameters used for the analysis. DNV KEMA used a typical power draw of 276 watts and an energy reduction savings factor of 46 percent in contrast to ex ante assumptions of 380 watts and 54 percent, respectively. DNV KEMA's power draw value comes from a spot power measurement of the unit, while the energy reduction savings factor come from literature searches in addition to claims by the technology manufacturer. There is no similar supporting material for claims provided in the ex ante analysis.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the energy efficiency measure implementation and takes into account the operating efficiency of the equipment, along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the baseline of the measure until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the expected-replacement baseline of the measure is used. This baseline considers either minimally code-compliant conditions or standard practice when no code is applicable.

According to the feasibility study for Grover Beach, the HVAC equipment had exceeded its useful life, so Baseline 1 is not used except in the first-year energy savings calculations. Baseline 2 uses an HVAC efficiency of SEER 13 and 80 percent AFUE, in line with federal minimum standards.

In the case of interior lighting, the existing conditions are used for both baselines since the existing conditions are already code-compliant. For traffic lights, there is no industry standard practice that addresses LED lights, so the existing conditions are used as the baseline for both the cases.

35 CBECS data by end use.

The rest of the measures are add-on measures, so Baselines 1 and 2 are the same, which is the unit operation without the new controls.

Table 90 summarizes the energy savings and life-cycle parameters by measure used in the life-cycle savings calculations.

**Table 90: Values Used in Life-cycle Savings Calculations by Measure**

| Measure | Early Replacement | | Expected Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| EEM1-Interior Lighting | 75,856 | 0 | 75,856 | 0 | 15 | 0 |
| EEM2-Computer Power Management | 10,011 | 0 | 10,011 | 0 | 4 | 0 |
| EEM3-Traffic Lights | 71,234 | 0 | 71,234 | 0 | 10 | 0 |
| EEM4-High Efficiency HVAC | 5,392 | 336 | 1,598 | 259 | 15 | 0 |
| EEM5-Building Controls, programmable thermostats | 5,034 | 1375 | 5,034 | 1,375 | 11 | 0 |
| EEM6-Vending Machines | 1,112 | 0 | 1,112 | 0 | 5 | 0 |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 2,032,024 kWh and 20,165 therms (Table 91). However, if the Baseline 2 is used, the life-cycle savings comes to 1,978,910 kWh and 19,084 therms. Table 91 tabulates the energy savings by year starting with 2011 using Baseline 2.

**Table 91: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 168,638 | 48 | 1,711 |
| 2 | 2012 | 168,638 | 48 | 1,711 |
| 3 | 2013 | 168,638 | 48 | 1,711 |
| 4 | 2014 | 168,638 | 48 | 1,711 |
| 5 | 2015 | 158,627 | 48 | 1,711 |
| 6 | 2016 | 157,515 | 48 | 1,711 |
| 7 | 2017 | 157,515 | 48 | 1,711 |
| 8 | 2018 | 157,515 | 48 | 1,711 |
| 9 | 2019 | 157,515 | 48 | 1,711 |
| 10 | 2020 | 157,515 | 48 | 1,711 |
| 11 | 2021 | 86,281 | 39 | 1,711 |
| 12 | 2022 | 81,248 | 39 | 336 |
| 13 | 2023 | 81,248 | 39 | 336 |
| 14 | 2024 | 81,248 | 39 | 336 |
| 15 | 2025 | 81,248 | 39 | 336 |
| 16 | 2026 | 0 | 0 | 0 |
| Life Cycle | Total | 2,032,027 | 675 | 20,165 |

Source: DNV KEMA analysis

**Table 92: Baseline 2 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 168,638 | 48 | 1,711 |
| 2 | 2012 | 164,844 | 39 | 1,634 |
| 3 | 2013 | 164,844 | 39 | 1,634 |
| 4 | 2014 | 164,844 | 39 | 1,634 |
| 5 | 2015 | 154,833 | 39 | 1,634 |
| 6 | 2016 | 153,721 | 39 | 1,634 |
| 7 | 2017 | 153,721 | 39 | 1,634 |
| 8 | 2018 | 153,721 | 39 | 1,634 |
| 9 | 2019 | 153,721 | 39 | 1,634 |
| 10 | 2020 | 153,721 | 39 | 1,634 |
| 11 | 2021 | 82,487 | 30 | 1,634 |
| 12 | 2022 | 77,454 | 30 | 259 |
| 13 | 2023 | 77,454 | 30 | 259 |
| 14 | 2024 | 77,454 | 30 | 259 |
| 15 | 2025 | 77,454 | 30 | 259 |
| 16 | 2026 | 0 | 0 | 0 |
| Life Cycle | Total | 1,978,911 | 549 | 19,087 |

Source: DNV KEMA analysis

## Hollister, City of - (027-09-ECE-ARRA)

### Site Summary

The Hollister Community Center is an office building used by local residents year round for recreational activities in Hollister, California. The original 6,780-square-foot community center constructed in 1980 is heated and cooled by three rooftop packaged air-conditioning units with gas-fired furnaces. In 1990, an additional 1,800-square-foot annex has been added that is heated and cooled with two rooftop air-conditioning units with gas-fired furnaces. Thus, there are a total of five packaged rooftop air conditioners operating at the Hollister Community Center. Typical operating hours for the community center are 8 a.m. to 8 p.m. Monday through Friday, with occasional events occurring on Saturdays between 1 p.m. and 11 p.m.. There is an average of one special Saturday event per month. As stated by the site contact, the rooftop units are expected to be operating from 8 a.m. to 8 p.m. Monday through Friday and during the occasional Saturday events.

The only energy efficiency measure implemented at this site was the replacement of the three original rooftop packaged air conditioners. The two newer packaged units for the additional annex were not changed for this project. The original ducting and temperature controls were also unchanged.

A DNV KEMA engineer visited the site to verify installation and operation of the mentioned packaged HVAC units. Nameplate data, operating schedules, and billing data were analyzed to yield an overall electric energy savings of 89 percent and natural gas savings of 323 percent when compared to the Baseline 1 ex ante savings. Table 93 below summarizes the ex post and ex ante savings estimates.

**Table 93: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| HVAC Retrofit | 14,840 | Not Reported | 229 | 13,160 | 8.04 | 740 | 89% | 323% |

Source: DNV KEMA analysis

Lower electric energy savings are estimated compared to the ex ante estimate due to shorter operating hours. The site contact reported shorter annual operating hours (3,240 hours) than the annual hours used in the ex ante report (3,645 hours). The higher natural gas savings is mainly due to incorrect assumptions in the ex ante savings calculation methodology, along with the new operating hours.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

**Table 94: Life-cycle Savings Summary**

| Baseline Type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 197,398 | 120.7 | 11,100 |
| Baseline 2 | 37,958 | 23.2 | 740 |

Source: DNV KEMA analysis

## Project Description

This project was implemented at the Hollister Community Center in Hollister. The building is a one-story office building with roughly 8,580 square feet of conditioned space that is served by rooftop packaged air-conditioning units with gas-fired furnaces. The project consists of one measure, which affects only 6,780 square feet of the premise.

**Measure 1:** HVAC Retrofit – This measure was for replacing pre-existing rooftop packaged air-conditioning units with new, more efficient packaged HVAC units. Three new units (two 7.5-ton units and one 10-ton unit) replaced the pre-existing units (one 15-ton unit, one 12.5-ton unit, and one 10-ton unit). The pre-existing equipment had a total capacity of 37.5 tons, which was deemed to be oversized by the initial site report conducted by Aircon Energy, so the new efficient equipment was sized at 25 tons. A summary of the pre-existing equipment compared to the new equipment can be found in Table 95.

**Table 95: Summary of Pre- and Postinstalled Equipment Efficiencies**

| | Pre-existing | | | | | | Newly Installed | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Manuf** | **Model No** | **Manuf Yr** | **Tons** | **EER** | **AFUE** | **Manuf** | **Model No** | **Manuf Yr** | **Tons** | **EER** | **AFUE** |
| **AC1** | Trane | SFCA-1253-LB | 1979 | 12.5 | 6.6 | 75 | Trane | YHC092F | 2011 | 7.5 | 12.6 | 80.0 |
| **AC2** | Trane | SFCA-1003-LD | 1979 | 10 | 6.8 | 75 | Trane | YHC092F | 2011 | 7.5 | 12.6 | 80.0 |
| **AC3** | Trane | SFCA-1503-LB | 1979 | 15 | 6.3 | 74.6 | Trane | YHC120E | 2011 | 10.0 | 12.5 | 80.0 |
| Totals | | | | 37.5 | | | | | | 25.0 | | |

Source: DNV KEMA analysis

## Ex Ante Savings

Aircon Energy derived ex ante savings using eQuest, a building energy modeling application that uses the DOE 2.2 simulation engine. The savings estimate uses preretrofit minus postretrofit modeled energy usage based on the retrofitted HVAC equipment. Energy consumption printouts that were included in the initial site report showed an annual savings of 14,840 kWh, which matched the Energy Commission claimed savings. However, the eQuest printouts showed an annual gas savings of 342.7 therms, while the Energy Commission claimed an annual savings of 229 therms. It is not known where the final gas energy savings reported to the Energy Commission came from. The eQuest models that were used in the calculations were requested from the site contact, but not available for review, so DNV KEMA could not verify the baseline assumptions and energy savings method. The preretrofit and postretrofit installation equipment summary can be found in Table 13. However, it is not clear whether these values were actually used in the final analysis since the eQuest models were not confirmed.

## Project Evaluation

A DNV KEMA field engineer visited the project site January 24, 2012, to verify measure installation, acquire specific nameplate information, and gather facility operating data to help assess energy savings. During the verification, the proposed installation of the three new HVAC units was confirmed. The capacity and specifications for all three units matched those described in the project files. Economizers were also verified on the new HVAC units, but they were closed during inspection. The economizers were confirmed to be working by the city engineer on site. Since the site visit occurred during the winter season, no monitoring of the air-conditioning unit was done since it is not expected to yield useful data for analysis. All visible measure components were verified as summarized in Table 96 below.

**Table 96: Verification Summary**

| | Reported | Verified | A/C Unit (tons) | EER | Furnace Input (kBTUh) | Furnace Output (kBTUh) | AFUE |
|---|---|---|---|---|---|---|---|
| AC1 | 1 | 1 | 7.5 | 12.6 | 150 | 120 | 80 |
| AC2 | 1 | 1 | 7.5 | 12.6 | 150 | 120 | 80 |
| AC2 | 1 | 1 | 10 | 12.5 | 200 | 160 | 80 |

Source: DNV KEMA analysis

The ex post savings used a bin analysis approach with 5 degree weather bins and assumed a linear load profile. Building cooling loads begin at the 65-70°F and are maximum at the 90-95°F bin. For heating, the start point is at the 60-65°F bin and is maximum at the "below 30°F" bin. The closest TMY 3 weather data within the same weather region was used to establish the load profile for the site. The spreadsheet model considered the hours of operation, unit sizes, and unit efficiencies, along with flags for the heating/cooling months. The latter was necessary so that hours during the summer are not erroneously used in the heating application when cooling is expected, such as during a cold summer morning. Actual efficiencies of the HVAC units were used in the analysis.

The bin analysis was calibrated based on monthly billing data provided by the site contact. Only the billing data from March 2011 – November 2011 were available, so the remaining months (December – February) were assumed to have the same heating load as November. The monthly kWh usage was extracted from the billing data, and the plug loads from lighting and other miscellaneous equipment were removed to get the kWh used only for cooling loads. Similarly, the monthly therms usage was extracted from the billing data, and the therms usage for hot water and other miscellaneous end uses were subtracted to get the therms used only for space heating. Electricity usage (kWh) was minimal in the winter months because there was minimal space cooling, while gas usage (therms) was minimal in the summer months because there was minimal space heating. The energy usage of the two smaller 4-ton HVAC units that were not replaced under this program was subtracted from the monthly billing data to better define the usage from the three HVAC units that were retrofitted. Energy usage directly from billing data is the most accurate source of information because it corresponds to actual building loads. Conversely, the ex ante savings assumed heating and cooling loads in the eQuest models that did not match the billing data. The filtered electricity and gas usage from the billing data was then used as a baseline to adjust the research team's bin analysis.

According to the billing data, the annual kWh and therms usage for the building preretrofit was approximately 30,769 kWh and 2,759 therms respectively. The preretrofit energy usage according to the bin analysis was calibrated to match the billing data by adjusting temperature bins and heating/cooling load percentages, and by applying a load factor. The load factor was necessary because the bin analysis assumed that the preretrofit rooftop units were properly sized for the building, when they actually were not. Thus, the load factor helped account for the oversizing factor in the bin analysis.

The original 37.5-ton HVAC system was not operating at its full capacity because it was oversized for the building. Based on the analysis done by Aircon Energy, the HVAC system for this building should be properly sized at 25 tons. Since the original HVAC for the building was oversized at 37.5 tons compared to the properly sized 25 tons, a load factor of 67 percent (25/37.5) was applied to the pre-existing conditions. This load factor accounted for the reduced load and operating hours that the oversized system operated compared to a properly sized system operating at full load. Since the equipment was oversized, the original HVAC units operated for reduced hours because the larger units did not have to operate as long to cool the building. After applying the load factor to the bin analysis, the adjusted preretrofit kWh usage was 32,113 kWh compared to the billing data suggested 30,769 kWh.

### Savings Results

The annual energy savings (kWh and therms) are the sum of hourly savings over all hours of the year. Based on the calibrated bin analysis, this project saved a total 13,160 kWh and 740 therms of energy. Table 93 provides a breakdown of the ex post energy savings along with the ex ante energy savings for comparison.

### Discussion

The ex post analysis yielded 89 percent of the ex ante electric claim and 323 percent of the ex ante claimed gas savings. Unfortunately, the details of the ex ante analysis were not available to the DNV KEMA team for review, so the analysis methods couldn't be compared. The operating hours claimed in the ex ante were not verified due to the lack of the eQuest models, but the ex post analysis used the operating hours as stated by the site contact. The difference in operating hours played a role in the electric and gas savings difference. However, without the ex ante analysis details, differences in the energy savings methods remain unknown.

The annual cooling and heating energy usage collected by the billing data was 30,769 kWh and 2,759 therms respectively. Comparably, the cooling and heating loads estimated by the bin analysis were 32,113 kWh and 2,603 therms. The difference in cooling and heating load is small and can be attributed to actual weather conditions differing from the assumed TMY3 weather data. Also, the bin analysis assumes that the heating/cooling load is weather-dependent and can be described using linear regression or approximated with a linear relationship. However, this relationship may not be exactly linear, leading to this minor uncertainty.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before implementing the energy efficiency measure and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assume the pre-existing equipment would have continued to operate indefinitely, up to the effective useful life (EUL) of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the baseline of the measure until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the expected-replacement baseline of the measure is used.

This baseline considers either minimally code-compliant conditions or standard practice when no code is applicable.

According to the feasibility study for Hollister, the HVAC equipment was installed 33 years ago in 1979 and was used past its EUL of 15 years as stated by DEER 2008. Baseline 1 uses an average of EER 6.6 for cooling and 75 AFUE for heating in accordance with what was specified in the feasibility report for the existing HVAC efficiency. Baseline 2 uses efficiencies rated at EER 11.2 and 80 AFUE, based on 2008 Title 24 and federal standards. Calibrating the energy usage using the billing data accounted for the degradation that likely played a role in the 33-year-old HVAC equipment, as the billing data reflected the actual energy usage of the pre-existing HVAC units. Table 97 summarizes the energy savings and life-cycle parameters used in the life-cycle savings calculations.

**Table 97: Values Used in Life-cycle Savings Calculations**

| Measure | Early Replacement | | Expected Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric Energy (kWh) | Gas Energy (therms) | | |
| HVAC Retrofit | 13,160 | 740 | 1,771 | 0 | 15 | 1 |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 197,398 kWh and 11,100 therms. However, if Baseline 2 is used, the life-cycle savings become 37,958 kWh and 740 therms. Table 98 and

Table 99 tabulates the energy savings by year starting with 2011, using this dual baseline.

**Table 98: Baseline 1 Life-cycle Savings**

| Life-cycle | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 13,160 | 8.04 | 740 |
| 2 | 2012 | 13,160 | 8.04 | 740 |
| 3 | 2013 | 13,160 | 8.04 | 740 |
| 4 | 2014 | 13,160 | 8.04 | 740 |
| 5 | 2015 | 13,160 | 8.04 | 740 |
| 6 | 2016 | 13,160 | 8.04 | 740 |
| 7 | 2017 | 13,160 | 8.04 | 740 |
| 8 | 2018 | 13,160 | 8.04 | 740 |
| 9 | 2019 | 13,160 | 8.04 | 740 |
| 10 | 2020 | 13,160 | 8.04 | 740 |
| 11 | 2021 | 13,160 | 8.04 | 740 |
| 12 | 2022 | 13,160 | 8.04 | 740 |
| 13 | 2023 | 13,160 | 8.04 | 740 |
| 14 | 2024 | 13,160 | 8.04 | 740 |
| 15 | 2025 | 13,160 | 8.04 | 740 |
| 16 | 2026 | 0 | 0 | 0 |
| Total | | 197,400 kWh | 120.6kW-years | 11,100 therms |

Source: DNV KEMA analysis

**Table 99: Baseline 2 Life-cycle Savings**

| Life-cycle | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 13,160 | 8.04 | 740 |
| 2 | 2012 | 1,771 | 1.08 | 0 |
| 3 | 2013 | 1,771 | 1.08 | 0 |
| 4 | 2014 | 1,771 | 1.08 | 0 |
| 5 | 2015 | 1,771 | 1.08 | 0 |
| 6 | 2016 | 1,771 | 1.08 | 0 |
| 7 | 2017 | 1,771 | 1.08 | 0 |
| 8 | 2018 | 1,771 | 1.08 | 0 |
| 9 | 2019 | 1,771 | 1.08 | 0 |
| 10 | 2020 | 1,771 | 1.08 | 0 |
| 11 | 2021 | 1,771 | 1.08 | 0 |
| 12 | 2022 | 1,771 | 1.08 | 0 |
| 13 | 2023 | 1,771 | 1.08 | 0 |
| 14 | 2024 | 1,771 | 1.08 | 0 |
| 15 | 2025 | 1,771 | 1.08 | 0 |
| 16 | 2026 | 0 | 0 | 0 |
| Total | | 37,954 kWh | 23.2 kW-years | 740 therms |

Source: DNV KEMA analysis

## Marin, County of (001-09-ECE-ARRA)

### Site Summary

Marin County applied for an Energy Conservation Assistance Act (ECAA-ARRA) loan for various energy efficiency projects at the Civic Center Auditorium. The majority of the auditorium space is dedicated to the theater and backstage areas, although there are a few offices in the building as well. The center hosts events about 70 days a year. On nonevent days, only the back of auditorium areas are occupied. The projects consisted of four energy efficiency measures (EEM). These measures included upgrading interior and exterior lighting; replacing one 153-ton dual-compressor, reciprocating, water-cooled chiller with a 150-ton dual compressor, screw, water-cooled chiller; repairing air handling units; and installing economizer controls.

DNV KEMA visited the 2,000 seat Marin County Auditorium in San Rafael and verified implementation of the measures on August 26, 2010. Spreadsheet analysis was used to estimate energy savings for lighting measures. Both an eQuest model and spreadsheet analysis were used for the energy savings calculations for the chiller and air handlers.

**Table 100: Energy Savings Summary**

| Measure | Ex Ante | | | Ex Post | | | Realization Rate | |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) | Electric | Gas |
| Interior Lighting | 84,418 | 69.34 | N/A | 84,418 | 69.34 | N/A | 100% | N/A |
| Exterior Lighting | 11,602 | 23.20 | N/A | 11,602 | 23.20 | N/A | 100% | N/A |
| Chiller Replacement | 85,439 | Not reported | N/A | 113,185 | 22.61 | N/A | 132% | N/A |
| Air Handler Control System & Repairs | 13,389 | Not reported | N/A | 51,834 | 0.00 | N/A | 387% | N/A |
| Total | 194,848 | 92.54 | - | 261,039 | 115.15 | - | 134% | - |

Source: DNV KEMA analysis

The chiller and air handler measures saved more energy than was originally projected by the ex ante calculations, while the savings due to the lighting measures were equal to the ex ante estimates. The savings discrepancy was based on assumptions made in the ex ante calculation due to lack of available data on cooling load. The ex ante savings values for the chiller and air handler measures were based on a bin analysis where the demand was based solely on weather data, where the ex post analysis used eQuest to simulate demand based on information recorded while on-site in addition to weather data.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1, which uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures
- Baseline 2, the dual baseline, which uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

**Table 101: Ex Post Life- Savings Summary**

| Baseline Type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 3,963,171 | 1,840.3 | 0 |
| Baseline 2 | 2,308,005 | 1,491.7 | 0 |

Source: DNV KEMA analysis

## Project Description

### *EEM 1− Interior Lighting*

This measure replaced both the house and stage lights with more efficient lighting:

- Replaced 196 300W house lights with 100W halogen flood lights
- Replaced 44 1,000W stage lights with 575W ellipsoidal spot lights
- Replaced 36 1,000W stage lights with 750W Fresnel spot lights
- Replaced 91 75W foyer lights with 10 14W LEDs, 16 19W CFLs, 10 50W incandescent and 55 60W incandescent bulbs

No office lights were replaced.

Initial savings calculations for the ellipsoidal spot lights had the existing wattage as 2,000W. Upon replacement, existing wattage identified as 1,000W. The final ex ante savings referenced in this report reflect the correct existing value of 1,000W.

The 75W foyer lights were replaced with a variety of lighting types to accommodate ushers reading tickets, dimming needs, and brightness and color concerns.

**Figure 27: Photos of Old and New Stage Lights (left) and an Installed New Stage Light (right)**

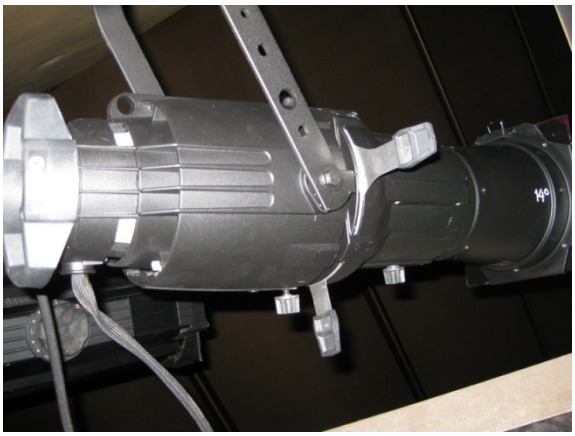


Photo Credit: DNV KEMA

### *EEM 2 –Exterior Lighting*

The grounds of the property are lit by decorative pole fixtures with multiple bulbs on each pole. The lights are turned on only for events and are off when the theater is not being used. The exterior lighting retrofit consisted of the following:

- Replaced 362 60W incandescent lights with 14W CFLs
- Replaced 312 25W incandescent lights with 4W CFLs

**Figure 28: Exterior Light Pole**

Photo Credit: DNV KEMA

### *EEM 3 – Chiller Replacement*

The original cooling strategy involved using two chillers: one as a primary unit and the other as backup. One of the existing chillers was no longer functional, while the other was fully functional but very old (more than 30 years). Before the retrofit, the site was using the functional chiller as the primary, with no backup. It was not possible to obtain data on the oldest (removed) chiller, but the existing primary chiller was a 153-ton dual-compressor, reciprocating, water-cooled chiller. The retrofit replaced the nonfunctional chiller with a 150-ton dual-compressor, screw, water-cooled chiller (Trane, MN: RTWD 150F 2B02 A1A1 AA1A 1A1X), which was installed in April or May 2010. The older chiller is now used a backup unit, although the site contact says they have not ran it since the new chiller was installed. Both chillers and the cooling towers are controlled by an EMS system.

**Figure 29: New Chiller**

Photo Credit: DNV KEMA

### *EEM 4 –Air Handler Repairs and Controls*

Before this retrofit, the economizers were manually controlled and typically were fully closed. Repairs were completed on any broken economizers, and controls were installed so that the economizers could be regulated by the EMS system.

## Ex Ante Savings

Ex ante energy savings were derived using standard spreadsheet analysis for all measures.

**Table 102: Ex Ante Savings by Measure**

| Measure | Ex Ante | | |
|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) |
| Interior Lighting | 84,418 | 69.34 | N/A |
| Exterior Lighting | 11,602 | 23.20 | N/A |
| Chiller Replacement | 85,439 | Not reported | N/A |
| Air Handler Control System & Repairs | 13,389 | Not reported | N/A |
| Total | 194,848 | 92.54 | - |

Source: DNV KEMA analysis

The following described how ex ante energy savings were calculated for each measure:

*EEM 1- Interior Lighting*

A spreadsheet analysis was conducted using pre- and postinstallation fixture quantities and wattages to determine the demand savings. Next, hours of operations were applied to the fixtures for both pre and post cases to determine kWh savings. The lobby and foyer areas all used similar hours of operation, where the stage lights had lower hours per year as they are only on during shows.

*EEM 2 –Exterior Lighting*

Just as in the interior lighting measure, a spreadsheet analysis was conducted using pre- and postinstallation fixture quantities and wattages to determine the demand savings. Hours of operations were then applied to the fixtures for both pre and post cases to determine kWh savings. All exterior lighting had the same hours of operation.

*EEM 3 – Chiller Replacement*

The chiller measure also used a spreadsheet analysis that used 5 degree weather bins and a part-load profile based on a typical carrier 5H series compressor (for the existing case) and a TurboCor Compressor TT300 data Sheet (proposed) to predict energy consumption for the baseline and efficient cases.

*EEM 4 –Air Handler Repairs and Controls*

The air handler repairs measure used a modified version of the chiller savings spreadsheet, where the base case was a typical carrier 5H series compressor and the measure reduced the load for the cooler temperature bins. No savings were claimed for bins with average temperature above 82 °F. The economizers were assumed to have a linear effect (with respect to temperature) on chiller use.

## Project Evaluation

A DNV KEMA field engineer visited the project site August 26, 2010, to verify measure installation. Since the chiller operates specifically during performances, it was determined that monitoring would represent only short-term operation that would not necessarily represent a fraction of the annual savings. Instead, the site contact provided an estimated number of performances throughout the year as a schedule. Similarly, lighting loggers were not used to understand time-of-use; the time-of-use is based on the performance schedule.

### *EEM 1− Interior Lighting*

The ex post savings estimate was generated with a spreadsheet analysis that used the wattages of the fixtures and operating hours as recorded in the project files, which were verified while on-site. Energy savings were calculated using the following equation:

$$Energy\ Savings = Quantity \times Annual\ Hours \times (kW_{Pre} - kW_{Post})$$

where,

- *Energy Savings* is the annual energy savings for all fixtures covered by the measure in kWh
- *Quantity* is the total number of affected fixtures.
- *kW* is the pre- and postinstallation fixture wattages in kW.
- *Annual Hours* are the estimated hours from the site contact and project files.

**Table 103: Annual Lighting Hours of Operation by Fixture Location**

| Fixture Location | Annual Hours |
|---|---|
| Auditorium House Lighting | 1,100 |
| Stage Lighting | 500 |
| Stage Lighting | 500 |
| South Foyer | 1,300 |
| North Foyer | 1,300 |
| Toyon Room | 1,300 |

Source: DNV KEMA analysis

### *EEM 2 –Exterior Lighting*

Like the interior lighting measure, the ex post savings estimate was generated with a spreadsheet analysis that used the wattages of the fixtures and operating hours as recorded in

the project files, which were verified while on-site. The outdoor lights are on only during performances. Energy savings were calculated using the following equation:

$$Energy\ Savings = Quantity \times Annual\ Hours \times (kW_{Pre} - kW_{Post})$$

where,

- *Energy Savings* is the annual energy savings for all fixtures covered by the measure in kWh.
- *Quantity* is the total number of affected fixtures.
- *kW* is the pre- and postinstallation fixture wattages in kW.
- *Annual Hours* are the estimated hours from the site contact and project files.

**Table 104: Annual Lighting Hours of Operation by Fixture Location**

| Fixture Location | Annual Hours |
|---|---|
| Exterior Exhibit Hall | 500 |
| Exterior VMA Auditorium | 500 |
| Exterior Lagoon Park | 500 |

Source: DNV KEMA analysis

### *EEM 3 – Chiller Replacement*

DNV KEMA verified the installation of one new chiller. The model number and capacity of the unit matched what was described in the project files. Energy management system and billing data were requested from Marin County but were not made available for review. Ex post energy savings were estimated using an 8760 analysis where the building load was modeled in eQUEST. DNV KEMA chose to use eQUEST to model the load as the HVAC use of the site was not heavily dependent on weather, and, therefore, a binned spreadsheet analysis was not the ideal approach. Input parameters to eQUEST included building vintage, square footage, lighting density and schedules, and occupancy schedules. Because eQUEST was used only to model load (and not consumption), it was not necessary to input chiller specifics.

Once a load profile of the building was created, an 8760 analysis was conducted. The replacement case used a part load performance curve from Trane literature specific to the chiller installed, while the base case used a general performance curve for a reciprocating compressor chiller from eQUEST, which was modified to fit the full load performance as indicated in Trane's literature. It was necessary to fit a general curve for the base case as the manufacturer's literature only includes part load performance for newer models.

### *EEM 4 –Air Handler Repairs and Controls*

The savings estimates for the air handler repairs also used an 8760 spreadsheet analysis based on building load data from eQUEST. The turndown effect of the economizers was assumed to be the same linear profile used in the ex ante calculations. The main difference between the calculation methods was that that chiller consumption in the ex ante was calculated using a binned, heavily weather-dependent method, while the ex post estimate calculated consumption using a load profile that took lighting and occupancy into account in addition to weather (as explained in above in Measure 3). All other assumptions remained the same.

## Savings Results

Overall, the site saved 261,039 kWh, 115.15 kW, and 0 therms. The savings are broken down by measure in Table 105 below:

**Table 105: Ex Post Savings by Measure**

| Measure | Ex Post | | |
|---|---|---|---|
| | Electric Energy (kWh) | Demand (kW) | Gas Energy (therms) |
| Interior Lighting | 84,418 | 69.34 | N/A |
| Exterior Lighting | 11,602 | 23.20 | N/A |
| Chiller Replacement | 113,185 | 22.61 | N/A |
| Air Handler Control System & Repairs | 51,834 | 0.00 | N/A |
| Total | 261,039 | 115.15 | - |

Source: DNV KEMA analysis

## Discussion

### *EEM 1 − Interior Lighting*

While on-site, it was confirmed that all lighting was installed as reported, with the exception of 18 of the Fresnel spot lights. These lights had been purchased but not yet installed. Because the site was already in possession of the lights, it was assumed they would be installed, so they were still included in the savings calculations. The site contact confirmed that the lights would be installed shortly. The ex ante and ex post savings were the same for this measure.

### *EEM 2 – Exterior Lighting*

Lights were installed as reported. The ex ante and ex post savings were the same for this measure.

### *EEM 3 – Chiller Replacement*

Discrepancies in savings estimates are due to DNV KEMA using a different calculation method than what was performed for the ex ante calculations. DNV KEMA assessed that a binned

spreadsheet analysis was not an accurate method to estimate savings as it uses weather as the primary variable, and the chiller is more likely to be affected by occupancy and lighting since the venue capacity is more than 2,000 people and has a high lighting density (due to the high wattage stage lights). Using eQUEST to model demand takes into account occupancy, lighting, and building vintage as well as weather. This resulted in a higher savings estimate (realization rate was 132 percent).

#### *EEM 4 –Air Handler Repairs and Controls*

Again, these discrepancies stem mainly from DNV KEMA estimating building cooling load using a different method than the ex ante calculations, as described above. This resulted in a higher savings estimate (realization rate was 387 percent). It's likely the ex post savings were much higher as the highest load on the chiller routinely occurs during off-peak periods. Most of the shows (and therefore load) occur during the fall, winter, or evenings, when the economizers can meet much of the load using outside air.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before energy efficiency measure implementation and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have operated for the full effective useful life (EUL) of the new equipment regardless if the existing equipment was at the end of its useful life. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period and up until the end of the EUL of the installed measure, an expected replacement baseline is used. This baseline considers minimally code-compliant conditions or standard practice when no code is applicable.

In the case of lighting, the existing conditions were used for both baselines since the existing conditions are already code-compliant. For the chiller, the Baseline 1 calculations used the existing equipment as a baseline. For Baseline 2, the expected replacement assumed a COP of 4.9 (from Title 24, as this is the minimum COP allowable for a water-cooled, electronically operated, screw compressor chiller). For the air handler measure, the baselines are the same, as the existing conditions are already code-complaint.

Both the inside and outside lighting was in relatively good shape, with the stage lights scheduled for donation to CSU, Sonoma. Because of this, DNV KEMA estimated that the light fixtures had an RUL of five years. The chiller was old and had definitely exceeded its EUL but was still functional, likely due to the lower than average use. The old chiller was still installed when the on-site visit was conducted but had been relegated to backup use only. The site contact confirmed that officials had not needed to use the old chiller at all since installing the new one. Because of this, DNV KEMA conservatively estimated the chiller had a RUL of 1 year.

Table 106 summarizes the energy savings and other parameters used in the life-cycle calculations.

**Table 106: Values Used in Ex Post Life-cycle Savings Calculations**

| Measure | Early Replacement | | | Expected Replacement | | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Demand kW | Gas Energy (therms) | Electric Energy (kWh) | Demand kW | Gas Energy (therms) | | |
| Interior Lighting | 84,418 | 69.34 | 0 | 84,418 | 69.34 | 0 | 15 | 5 |
| Exterior Lighting | 11,602 | 23.20 | 0 | 11,602 | 23.20 | 0 | 15 | 5 |
| Chiller Replacement | 113,185 | 22.61 | 0 | 26,071 | 4.26 | 0 | 20 | 1 |
| Air Handler Controls & Repairs | 51,834 | 0 | 0 | 51,834 | 0 | 0 | 5 | NA |

Source: DNV KEMA analysis

When considering only Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 3,963,171 kWh and 1,840.3 kW-years (Table 107).

**Table 107: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 261,039 | 115.15 | 0 |
| 2 | 2012 | 261,039 | 115.15 | 0 |
| 3 | 2013 | 261,039 | 115.15 | 0 |
| 4 | 2014 | 261,039 | 115.15 | 0 |
| 5 | 2015 | 261,039 | 115.15 | 0 |
| 6 | 2016 | 209,205 | 115.15 | 0 |
| 7 | 2017 | 209,205 | 115.15 | 0 |
| 8 | 2018 | 209,205 | 115.15 | 0 |
| 9 | 2019 | 209,205 | 115.15 | 0 |
| 10 | 2020 | 209,205 | 115.15 | 0 |
| 11 | 2021 | 209,205 | 115.15 | 0 |
| 12 | 2022 | 209,205 | 115.15 | 0 |
| 13 | 2023 | 209,205 | 115.15 | 0 |
| 14 | 2024 | 209,205 | 115.15 | 0 |
| 15 | 2025 | 209,205 | 115.15 | 0 |
| 16 | 2026 | 113,185 | 22.61 | 0 |
| 17 | 2027 | 113,185 | 22.61 | 0 |
| 18 | 2028 | 113,185 | 22.61 | 0 |
| 19 | 2029 | 113,185 | 22.61 | 0 |

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 20 | 2030 | 113,185 | 22.61 | 0 |
| Total | | 3,963,170 kWh | 1,840.3 kW-years | 0 therms |

Source: DNV KEMA analysis

However, if the dual baseline is used, the life-cycle savings are 2,308,005 kWh and 1,491.7 kW-years. Table 108 shows the energy savings by year starting with 2011 using this dual baseline.

**Table 108: Baseline 2 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 261,039 | 115.15 | 0 |
| 2 | 2012 | 173,925 | 96.80 | 0 |
| 3 | 2013 | 173,925 | 96.80 | 0 |
| 4 | 2014 | 173,925 | 96.80 | 0 |
| 5 | 2015 | 173,925 | 96.80 | 0 |
| 6 | 2016 | 122,091 | 96.80 | 0 |
| 7 | 2017 | 122,091 | 96.80 | 0 |
| 8 | 2018 | 122,091 | 96.80 | 0 |
| 9 | 2019 | 122,091 | 96.80 | 0 |
| 10 | 2020 | 122,091 | 96.80 | 0 |
| 11 | 2021 | 122,091 | 96.80 | 0 |
| 12 | 2022 | 122,091 | 96.80 | 0 |
| 13 | 2023 | 122,091 | 96.80 | 0 |
| 14 | 2024 | 122,091 | 96.80 | 0 |
| 15 | 2025 | 122,091 | 96.80 | 0 |
| 16 | 2026 | 26,071 | 4.26 | 0 |
| 17 | 2027 | 26,071 | 4.26 | 0 |
| 18 | 2028 | 26,071 | 4.26 | 0 |
| 19 | 2029 | 26,071 | 4.26 | 0 |
| 20 | 2030 | 26,071 | 4.26 | 0 |
| Total | | 2,308,004 kWh | 1,491.7 kW-years | 0 therms |

Source: DNV KEMA analysis

## McKinleyville Community Services District (013-09-ECE-ARRA)

### Site Summary

The Ramey Pump Station is part of the McKinleyville Community Services District (MCSD). The pump station is responsible for pumping water from the city's main water tank on Essex Hill into the city's primary pressure zone, which serves the McKinleyville communities via two hilltop reservoirs, Cochran Tank and Norton Tank. Potable water is then gravity-fed from the hilltop reservoirs into homes.

The Ramey Pump Station uses numerous pumps to drive an average of 1,200,000 gallons of water daily. The retrofit consisted of replacing five smaller water pumps (four at 20 horsepower and one at 40 horsepower) with two larger high-efficiency water pumps (2 at 262 horsepower) controlled by variable-frequency drives (VFDs). The new equipment was installed around August 1, 2011. DNV KEMA visited the site on November 10, 2011. At the time of the site visit, it was determined that the commissioning of the VFDs had not occurred. Commissioning did not occur until June 2012. In the draft report, the savings calculation performed was based on the information collected from the site visit, as well as data provided by the plant personnel. DNV KEMA received a new set of commissioned data (flow and energy consumption) for a six-week period. This report has been updated to include the results based on the data following commissioning of the VFDs.

Based on the commissioned data provided to DNV KEMA, the project yielded energy savings. Also, the pumps are now used during the nighttime, resulting in peak demand reduction. Demand reduction is based on the fact that the new pumps are not operating from 12 p.m. to 7 p.m.; therefore, the demand savings are based on the power consumed by the earlier pumps at 40 percent efficiency. The energy savings on the commissioned data received for four weeks (08/30/2012 to 09/30/2012), the flow is expected to be low during July, but due to unavailability of the annual data, the savings are annually. The pump retrofit might save more or less, based on the actual data.

Ex ante and ex post savings for the motor retrofits are provided in Table 109 below.

**Table 109: Energy Savings Summary**

| Measure | Ex Ante | | Ex Post | | Realization Rate |
|---|---|---|---|---|---|
| | Electric Energy (kWh) | Electric Energy (kWh) | Electric Energy (kWh) | Demand (kW) | Electric |
| EEM 1 - Pump Retrofit | 56,900 | 14.5 | 13,743 | 179.4 | 24% |

Source: DNV KEMA analysis

A baseline measurement of an energy measure is critical for savings calculations because energy savings cannot be calculated without comparing it to a control group. In short, the savings

forecast is the difference between the baseline condition and the new condition. There are two types of baselines that DNV KEMA will be using, Baseline 1 and Baseline 2. Baseline 1 refers to the existing conditions found before implementing the efficiency measure and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have operated for the full effective useful life (EUL) of the new equipment, regardless if the existing equipment was at the end of its useful life. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the remaining useful life (RUL) of the existing equipment. After that, an expected conditions replacement baseline (for example, standard practice or code minimum) is used until the EUL is reached. EUL and RUL values are usually determined from California's Database for Energy Efficiency Resources (DEER), or if not in DEER, then from another source of specifying industry standard practice. According to DEER 2008, the EUL for the pump motors was 15 years. Table 110 summarizes the life-cycle savings relative to each of these baselines. In this case, both baselines are equal.

**Table 110: Ex Post Life-cycle Savings Summary**

| Baseline type | Electrical Energy Savings (kWh) | Electrical Demand Savings (kW-years) | Natural Gas Energy Savings (therms) |
|---|---|---|---|
| Baseline 1 | 206,145 | 179.4 | 0 |
| Baseline 2 | 206,145 | 179.4 | 0 |

Source: DNV KEMA analysis

## Project Description

*Measure 1:*

The Ramey Pump Station retrofitted its five horizontal centrifugal potable water distribution pumps with two vertical five-stage centrifugal pumps with high-efficiency 262 horsepower (Hp) motors and variable-frequency drives (VFD). Two variable-speed units (two 262 hp motors) replaced the pre-existing five fixed-speed units (four 20hp motors and one 40hp motor). The pre-existing motors did not have VFDs. Pictures of the pre-existing and newly installed pumps and VFDS can be provided as backup information.

## Ex Ante Savings

The total for the ex ante savings from the ECAA-ARRA monthly status report was 56,900 kWh. The feasibility study estimated energy savings by analyzing coincident electricity consumption and pumping flow rates for the pre-existing system as a baseline. The energy use of the new system was estimated assuming similar head and flow rates and the manufacturer's data for the purchased pumps.

## Project Evaluation

A Katin Engineering Consulting engineer visited the project site on November 10, 2011, to verify the installation of each new fixture, acquire specific nameplate information, and gather facility scheduling data to help assess energy savings. During the verification, the proposed installation of two new pumps was confirmed. The Ramey Pump Station project installed two new pumps; however, only one operates at a time, the other is an installed spare. Operation of the pumps is alternated for maintenance and pump longevity. The Ramey Pump Station transfers potable water to two Cochran Tanks and two Norton Tanks, which gravity feed the community. The four existing tanks have a combined capacity of 2,500,000 gallons.

The Ramey Pump Station equipment was specified and designed by Winzler and Kelly (W&K), a Santa Rosa, California engineering firm. W&K recommended each new pump be operated at a minimum speed of 70 percent and a maximum speed of 85 percent. Therefore, these 1,185 revolution-per-minute (rpm) motors were operated at between 830 rpm/42 Hertz (Hz) and 1,007 rpm/51 Hz using the variable frequency drive.

Pacific Gas and Electric (PG&E) charges a different rate based on the time of day. Therefore, to save money, the pumps are not run (unless there is a fire, and water demand requires its operation) between noon and 7 p.m. The facility has advised that the PG&E meter on the Ramey pump station powers the pump, an area light, and Supervisory Control and Data Acquisition (SCADA) system. The PG&E meter shows the daily kWh draw of the entire pump station. The pump motor is a three-phase, 460 VAC, 262 horsepower motor. Area lighting is not energized, since this is an unmanned pump station. The only additional power requirements are for a 24 VDC SCADA system. Since more than 99 percent of the power indicated on the PG&E meter is supplying the pump motor, the PG&E meter was considered an accurate measure of the power drawn by the pump motor. Total volume pumped and pump operating hours were recorded automatically by the SCADA system at midnight each day. Power consumption is recorded by the Ramey pump station operator manually, reading the PG&E meter every weekday between 8 a.m. and 10 a.m. On weekends or holidays, the data are not collected. Therefore, on the following normal work day, the meter reading is recorded, and the power consumed is evenly attributed to each day. In other words, if the PG&E meter is read Friday at 8 a.m. and again on Monday at 8 a.m., the difference between the two readings is divided by three and attributed equally to Friday, Saturday, and Sunday.

Daily flow rating (gallons/day), pump operating schedules (hours/day), and energy consumption (kWh/day) were gathered for one year before the project (2010) using the SCADA software and commissioned data after the project (July 2012) provided by the California Energy Commission. The amount of water pumped during July 2012 was 50,123,000 gallons and during July 2010 was 62,945,000 gallons. The volume of water pumped is different; therefore, the energy savings are calculated based on the energy consumed to pump the flow in July 2010 by the new pumps. Scaling the savings for one month (31 days) to get the annual savings for the entire years (365 days) uses the following equation:

$$\frac{kWh_1}{31\ Days} = \frac{kWh_2}{365\ Days}$$

where,

- $kWh_1$ = kWh saved during the tracked 3 month period (92 days).
- $kWh_2$ = kWh saved during the entire year (365 days).

## Savings Results

Table 111 shows a summary of the energy consumed before the project (July 2010) versus after the project (July 2012), based on the data provided by the Energy Commission. The raw data for the measured three months can be provided as backup data.

**Table 111: Three-Month Energy Use Summary for Preinstallation and Postinstallation**

| Time | Water Pumped (Gallons) | Energy Consumed (kWh) |
|---|---|---|
| July 2010 | 62,945,000 | 32,080 |
| July 2012 | 50,123,000 | 24,400 |

Source: DNV KEMA analysis

The savings have been scaled to the same flow in July 2012, total for the 31-day span, and the ex post energy savings are 1,1145 kWh/month. Scaling this up for the entire year becomes negative 17,256 kWh. Overall, the project did not save energy.

Before the project, the five small pumps, including four motors were 20 Hp and one was 40 Hp, collectively ran an average of 53.7 hrs per day. Now the new 262 Hp motors running one pump per day are running only on average 4.6 hrs per day. The new pumps have a larger capacity and are significantly oversized for the current operation. Furthermore, when the pump curve is reviewed, it appears that the new pumps may not be operated at the best efficiency point. It appears that the new pumps are designed for future expansion, and are oversized for the current population.

## Discussion

The water pumped in July 2010 and July 2012 is different; therefore, the savings have been scaled for the water pumped in July 2012. As the pumps are not operated during the daytime (12 p.m. to 7 p.m.), demand savings are observed. Demand savings are based on the power drawn by the pumps before the retrofit was done.

## Ex Post Life-cycle Savings

Life-cycle savings account for the total energy savings achieved by the installed measures over their effective useful lives (EUL). Life-cycle savings are, therefore, predicated on a number of

factors, included the effective useful life of the installed equipment, the remaining useful life (RUL) of the pre-existing equipment, and the standard practice baseline for the measure. Table 5 below provides the annual energy savings estimates, EULs, and RULs that fed into the life-cycle savings calculations.

**Table 112: Values Used in Ex Post Life-cycle Savings Calculations**

| Measure | Early Replacement | | Normal Replacement | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric Energy (kWh) | Gas Energy (therms) | | |
| EEM1 - Pump Motor Retrofits | 17,256 | 0 | 17,256 | 0 | 15 | 0 |

Source: DNV KEMA analysis

Table 113 below provides life-cycle savings for the project relative to Baseline 1 on a year-by-year basis through the EUL of the longest-lived measure. Under this baseline, energy savings were presumed to occur relative to the pre-existing equipment for the duration of the life of each measure. For this project, the life-cycle savings estimates relative to Baseline 2 (dual baseline) are the same as the life-cycle savings relative to Baseline 1.

**Table 113: Baseline 1 Life-cycle Savings**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Electrical Demand (kW) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|---|
| 1 | 2011 | 13,743 | 179.4 | 0 |
| 2 | 2012 | 13,743 | 179.4 | 0 |
| 3 | 2013 | 13,743 | 179.4 | 0 |
| 4 | 2014 | 13,743 | 179.4 | 0 |
| 5 | 2015 | 13,743 | 179.4 | 0 |
| 6 | 2016 | 13,743 | 179.4 | 0 |
| 7 | 2017 | 13,743 | 179.4 | 0 |
| 8 | 2018 | 13,743 | 179.4 | 0 |
| 9 | 2019 | 13,743 | 179.4 | 0 |
| 10 | 2020 | 13,743 | 179.4 | 0 |
| 11 | 2021 | 13,743 | 179.4 | 0 |
| 12 | 2022 | 13,743 | 179.4 | 0 |
| 13 | 2023 | 13,743 | 179.4 | 0 |
| 14 | 2024 | 13,743 | 179.4 | 0 |
| 15 | 2025 | 13,743 | 179.4 | 0 |
| 16 | 2026 | 0 | 0 | 0 |
| Life-cycle | Total | 206,145 kWh | 2,691 kW-years | 0 therms |

Source: DNV KEMA analysis

## Rancho Mirage, City of (009-09-ECE-ARRA)

### Site Summary

The Rancho Mirage Public Library is a state-of-the-art community facility located in Rancho Mirage, California. This facility contains library space, as well as a large event room used for lecturers, speeches, concerts, and movie showings throughout the year. To reduce energy consumption at the library, city officials completed a central plant retrofit, wherein a 7- year-old, 150-ton, single-compressor centrifugal chiller was replaced with a 150-ton SMARDT chiller with two 75-ton frictionless Turbocor compressors. Additionally, Kiltech CPECS controls were installed to optimize plant operations. Ex ante and ex post savings for the plant retrofit are presented in Table 114.

**Table 114: Energy Savings Summary**

| Measure | Ex Ante | | Ex Post | | Realization Rate | |
|---|---|---|---|---|---|---|
| | Electric Energy (kWh) | Gas Energy (therms) | Electric Energy (kWh) | Gas Energy (therms) | Electric | Gas |
| Central Plant Retrofit | 162,593 | 0 | 103,049 | 0 | 63.4% | N/A |
| Total | 162,593 | 0 | 103,049 | 0 | 63.4% | N/A |

Source: DNV KEMA analysis

The project saved less energy than projected in the ex ante analysis. The savings discrepancy exists largely because the ex ante analysis underestimated the efficiency of the pre-existing plant.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1, which uses the pre-existing condition as the baseline for the full estimated useful life (EUL) of the installed measures
- Baseline 2, the dual baseline, which uses minimally code-compliant conditions or standard practice as the baseline once the remaining useful life (RUL) of the pre-existing equipment is exceeded.

**Table 115: Life-cycle Savings Summary**

| Baseline | Electrical Energy Savings (kWh) | Natural Gas Energy Savings (therms) |
|---|---|---|
| Baseline 1 | 2,060,972 | 0.0 |
| Baseline 2 | 1,930,278 | 0.0 |

Source: DNV KEMA analysis

## Project Description

Before the retrofit, the Rancho Mirage Public Library's central plant consisted of a 150-ton McQuay WSC-050 fixed-speed, single-compressor centrifugal chiller. This chiller was operated in the context of a variable primary pumping configuration. The plant contains two redundant, 10-hp variable-speed chilled water pumps and two redundant, 10-hp variable-speed condenser water pumps. The condenser water pumps were piped to an open-cell cooling tower with two fans.

The pre-existing McQuay chiller was replaced with a 150-ton SMARDT chiller with two variable-speed controlled 75-hp frictionless centrifugal compressors. Additionally, the plant was upgraded from McQuay's onboard controls to full DDC control with a Kiltech CPECS control system. The CPECS control system theoretically optimizes all variable-speed plants to yield the best possible plant operating efficiency at any time.

## Ex Ante Savings

Ex ante savings were calculated using Trane's System Analyzer (ver. 6.1.1) building simulation software. Only the results printouts,[36] not the measure specific inputs, were provided for review. It was therefore impossible to assess whether the pre- and post-retrofit mechanical systems were modeled correctly, or whether the analysis was conducted using a representative building model. The System Analyzer program has very few inputs and limited flexibility compared to other building simulation tools. According to Trane's website, the software is advertised as "a comparative analysis tool for preliminary evaluations of HVAC systems based on energy…" and a software that allows "an HVAC novice to create a comprehensive, accurate analysis in as little as ten minutes".[37]

Using the available outputs, the evaluation team determined that on an annualized basis, the preretrofit plant modeled efficiency was 1.63 kW/ton, while the modeled efficiency of the installed plant was 0.34 kW/ton. These plants were each estimated to serve a gross annual load of 231,251 ton-hours.

36 See the provided project documentation titled "City of Rancho Mirage.pdf".

37 "www.trane.com/commercial/dna/view.aspx?i=1135.

## Project Evaluation

DNV KEMA visited the Rancho Mirage Public Library on January 3, 2012, to verify installation of the SMARDT chiller as well as the CPECS controls. Both the chiller and the controls were found installed as proposed. Additionally, the plant equipment (for example, chilled water pumps, condenser water pumps, cooling towers) was surveyed to verify the configuration and equipment types previously discussed over the phone with the site contact. The site contact was asked to explain how the plant operated before the retrofit. He stated that the preretrofit plant operated in an all-variable-speed configuration just like the new plant, but the controls had recurring issues. In particular, even though the condenser water pumps were intended to modulate based on load, they always operated at 100 percent speed. This issue was resolved during the retrofit.

Another issue with the preretrofit plant controls involved improper low load operation. Under low load conditions, the chiller would not throttle down adequately, causing the chilled water loop supply temperature to plummet to 40 F or below. This, in turn, would yield a fault condition, causing the chiller to cycle off as a protection mechanism. As plant load built up, the loop temperature would increase. The chiller would then come back on-line and ramp up to near full load because of the high chilled water temperatures. Chilled water temperatures would again fall, and the chiller would not throttle down quickly enough to prevent the chilled water temperature from returning to the fault range. The chiller would then again turn off, and the cycle would then repeat until the plant load increased sufficiently to maintain constant chiller operation.

The cycling issue was particularly prevalent during summer morning start up (5 a.m. to 8 a.m.) and evenings between 6 and 10 p.m. when only the library community room was in use. To prevent recurrent cycling, the library mechanical staff would generate artificial loads by running air handlers in zones that were not scheduled to operate. The site contact put the DNV KEMA evaluator in contact with the controls technician responsible for the project. This technician was kind enough to FTP into the Rancho Mirage plant and download 15-minute interval data spanning the 11 months since project implementation. The interval data provided by the controls contractor included:

- BTU meter readings (tons).
- Chilled water loop flow (GPM).
- Chilled water loop supply and return temperatures (F).
- Chiller power draw (kW).
- Chilled water pump, condenser water pump, and cooling tower fan power draws (kW).
- VFD drive speed readings for the chilled water pumps, condenser water pumps and cooling tower fans.
- Plant kW/ton efficiency readings.

Given the comprehensiveness and time span of the plant data provided by the controls contractor, it was unnecessary to install additional data logging equipment at the site.

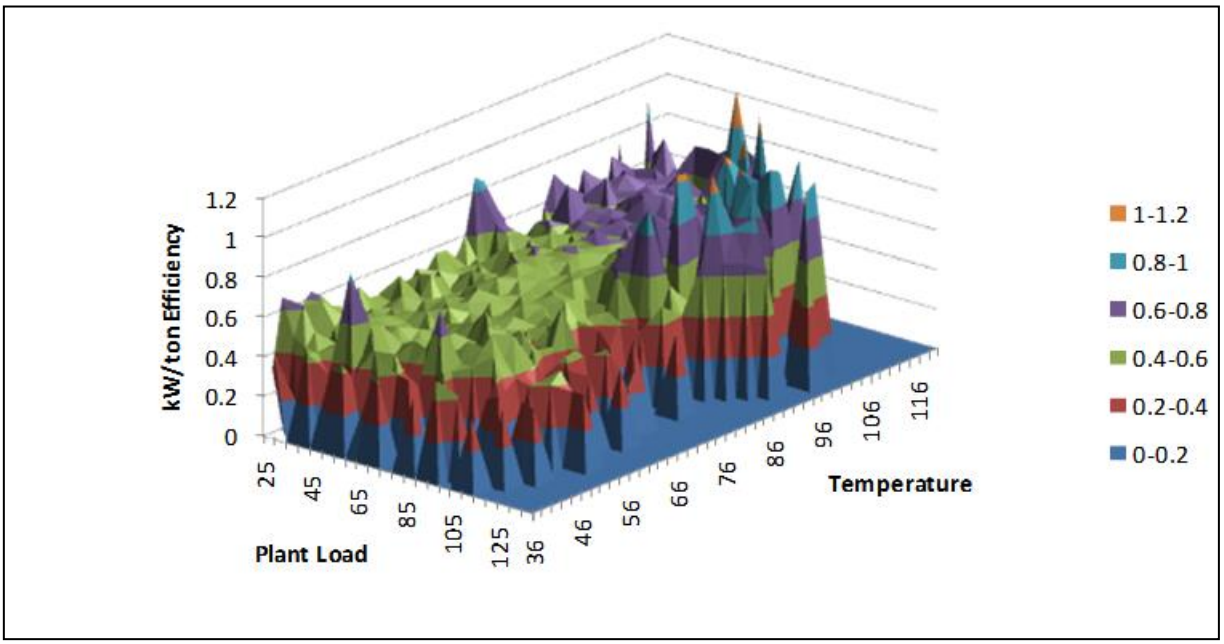
The first step in the savings analysis was developing an annualized plant load profile. The depth and breadth of the plant data available for this analysis allowed daytime-specific load regressions. For each two-hour period of the day, *i*, ( for example, 12:00 a.m. to 1:59 a.m.), a unique quadratic regression between temperature and load (tons) was developed from the metered data: $Load_i = a_i + b_iT + c_iT^2$. This process was carried out using data from all days during which the library was open. Additionally, a single quadratic regression was carried out for all periods when the library was closed (generally Sundays and holidays). The benefit of using time of day-specific regression curves (as opposed to a single regression curve encompassing all hours) is that they account for time-dependent load variations. For instance, the plant load at 4 p.m. on a summer day when the ambient temperature is 96° F is undoubtedly different than the load at 9 p.m. at the same temperature. Differences in radiant load, building occupancy, building temperature set points, and zonal schedules, among other factors, dictate that the load varies based on variables other than temperature alone.

The regression was formulated such that all of the quadratic curves were aggregated into a single regression curve with 39 coefficients (three for each two hour weekday period, and three total for weekends). In this structure, 36 of the coefficients were dummy values (zeroed out) during the hours in which they were not needed. (For example, only the three coefficient specific to 4 a.m. to 5:59 a.m. were used for that period). The overall fit of the 39 coefficient regression to the available data was validated on the basis of the coefficient of multiple determination ($R^2$ value), which was 0.837 for the available data set.

Using the time of day-specific load profiles developed for this analysis, an annual 8,760 load profile was developed using TMY3 weather data from the nearest local weather station, Palm Springs, California.

The next step in the analysis was determining the performance of the installed and base case plants in meeting those loads. The metered data provided by the controls contractor again provided a wealth of data for the postinstallation period. The postinstallation kW/ton plant efficiency data was first cross-referenced with ambient temperature and plant load data. These data were plotted to observe any discernible trends. As Figure 30: below demonstrates, plant efficiency generally decreased as temperature and plant load increased.

**Figure 30: Metered Plant Efficiency as a Function of Load and Temperature**



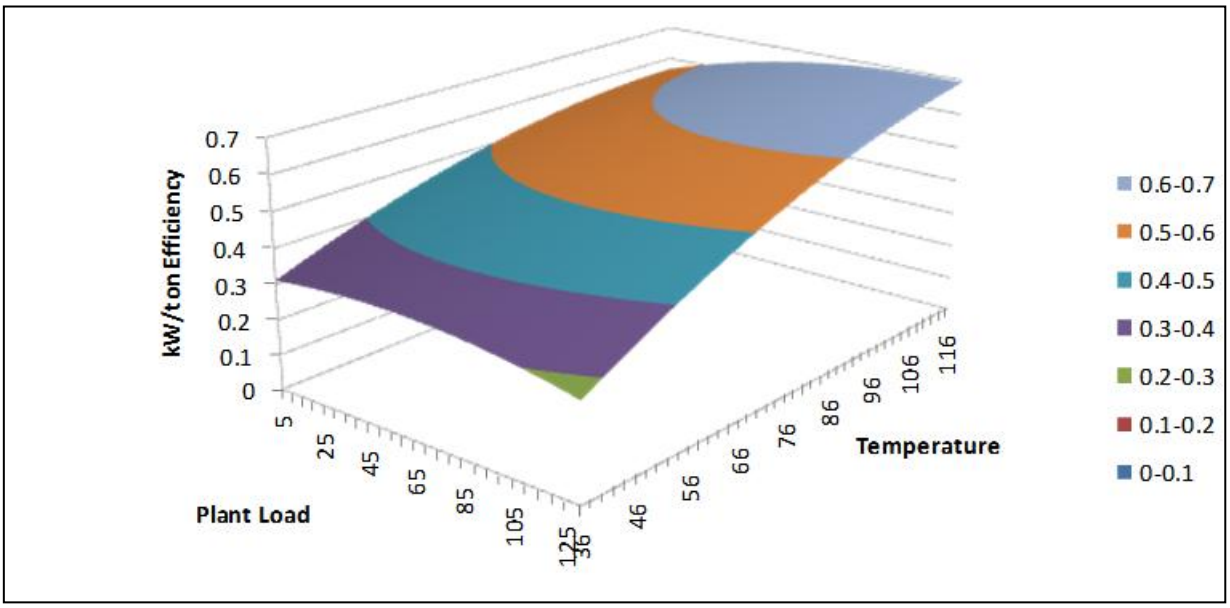

Source: DNV KEMA analysis

A biquadratic equation of the form

$$\frac{kW}{ton} = a + bT + cT^2 + dLoad + eLoad^2 + fTLoad,$$

was fit to the data, yielding the performance map in Figure 31 below. Notice that the map fits the behavior of the actual plant well, excluding peaked outliers at the extremities of the range. Many of these outlying values correspond to temperature and load regions with very few sample points. These outlying values and the generally varied shape of the plant load map made it difficult to get a tight regression fit, yielding an $R^2$ value of 0.37. In spite of the relatively low $R^2$ value, it was clear that statistically estimating the plant performance from actual data was a better option than projecting plant performance based on spreadsheet-calculated operating strategy estimates.

**Figure 31: Modeled Plant Efficiency as a Function of Load and Temperature**




Source: DNV KEMA analysis

Using the performance map above, plant efficiency was determined for each hour of the 8,760 analysis based on ambient temperature and plant load. Subsequently, plant power draw was calculated for the installed case plant based on the hourly plant load and efficiency.

With the installed case defined, the last step in the analysis was estimating how the pre-existing plant would perform while meeting the same loads. To begin, the part load performance curve of the removed chiller was obtained from McQuay. This curve was derated by 10 percent to account for age and wear related degradation. While the pre-existing chiller was only 7 years old and in good working order according to the maintenance contractor, the site contact stated that the issues with the chiller expansion valve negatively affected performance.

The hourly plant load data from the installed case were modified to account for the cycling issues of the pre-existing chiller. Based on the loads typical of the periods (summer mornings between 5 and 8 a.m.) when the pre-existing chiller most commonly into short-cycling issues, the average minimum load below which short cycling accorded was estimated. During all hours when the pre-existing chiller would have short cycled, the plant load was modeled as a minimum of 49 tons to represent the artificial load that would theoretically have been imposed on the plant to prevent the short-cycling. The plant load profile was otherwise left unmodified since the building loads would not have changed as a result of the retrofit.

Based on the site contact's statements about preretrofit condenser water pump operations, a condenser water pump was modeled to operate at full speed whenever the plant was loaded.

Chilled water pump power was modeled as a function of plant load using metered data collected from the postretrofit period. Since chilled water flow was already load-dependent before the retrofit, this approximation of functional dependence remained valid.

Constant operation of a single cooling tower fan was modeled irrespective of load. The metered data from the postretrofit period indicate that only one tower fan is required under full-load conditions. Furthermore, tower fan speed modulated minimally during the postretrofit period, so there is no reason to believe that fan speed modulated more liberally in the preretrofit period.

After modeling all preretrofit plant equipment, postretrofit savings were calculated on an hourly basis by taking the difference between the preretrofit and postretrofit plant demand. Hourly energy savings were summed to develop annual energy savings.

Expected replacement savings were calculated using an identical approach for the RUL of the preretrofit chiller. After the RUL, a Title 24 efficiency centrifugal chiller was used. Plant operations were assumed to remain unchanged from the pre-existing equipment case, but the chiller short-cycling issue was assumed to have been resolved.

### Savings Results

Relative to the pre-existing equipment, the project saved 103,049 kWh. Relative to expected replacement equipment, the project saved 84,378 kWh. The project did not result in any therm savings. The central plant retrofit achieved a kWh realization rate of 63.4 percent relative to the pre-existing equipment baseline. Relative to the expected replacement baseline, the project achieved a realization rate of 51.9 percent.

### Discussion

The project ultimately saved less energy than projected in the ex ante analysis because the pre-existing plant was not as inefficient as estimated. In fact, it is a simple matter to isolate the issue to plant efficiency because the ex ante and ex post analyses both projected nearly identical annual loads for the plant. In the ex ante analysis, the plant served an annual load of 231,251 ton-hrs; in the ex post analysis, the plant served an annual load of 231,211 ton-hrs.

Table 116 below compares the ex ante and ex post annualized average central plant efficiencies.

**Table 116: Ex Ante and Ex Post Plant Efficiencies**

| | Ex Ante | Ex Post |
|---|---|---|
| **Pre-existing Plant Efficiency** | 1.633 kW/ton | .968 kW/ton |
| **Postretrofit Plant Efficiency** | Unknown | 0.586 kW/ton |

Source: DNV KEMA analysis

The postretrofit plant efficiency used in the ex ante analysis is unknown. The ex ante savings estimates for this project were revised based on project scope changes that occurred midstream.

Revised savings calculations were not provided to the evaluation team to allow investigation of the postretrofit plant efficiency used in the updated analysis. The ex post verified postretrofit plant efficiency is based on 11 months of actual plant data.

To investigate the discrepancy between the ex ante and ex post *pre-existing* plant efficiency estimates, DNV KEMA mocked up a scenario under which the pre-existing plant operated as inefficiently as possible. This scenario included assuming that the chilled water pump and cooling tower fans operated at full speed whenever the central plant was running. Since the condenser water pump was already pegged at full speed in the actual ex post analysis, making these modifications was tantamount to stating that the pre-existing plant operated in a constant flow configuration without any variable speed equipment. Even in this least efficient configuration, the annualized plant efficiency decreased only to 1.170 kW/ton, much less than the 1.633 kW/ton projected in the ex ante analysis. Based on this additional analysis, DNV KEMA concluded that the realization rate was low at least in part because the ex ante analysis failed to accurately estimate the efficiency of the pre-existing plant. Whether the ex ante analysis also overstated the postretrofit plant efficiency is unclear because the revised ex ante analysis was not provided.

### Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before implementing the energy efficiency measure and takes into account the operating efficiency of the equipment along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have operated for the full effective useful life (EUL) of the new equipment regardless if the existing equipment was at the end of its useful life. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the remaining useful life (RUL) of the existing equipment. After the remaining useful-life period and up until the end of the EUL of the installed measure, an expected replacement baseline is used. This baseline considers minimally code-compliant conditions or standard practice when no code is applicable.

Table 117 below provides the annual energy savings estimates that fed into the life-cycle savings calculations, as well as the EUL for the installed measure.

**Table 117: Values Used in Life-cycle Savings Calculations**

| Measure | Pre-existing Equipment Baseline | | Expected Replacement Baseline | | EUL (years) | RUL (years) |
|---|---|---|---|---|---|---|
| | Electric energy (kWh) | Gas Energy (therms) | Electric energy (kWh) | Gas Energy (therms) | | |
| Central Plant Retrofit | 103,049 | 0 | 84,378 | 0 | 20 | 13 |

Source: DNV KEMA analysis

Table 118 provides life-cycle savings for the project relative to Baseline 1.

**Table 118: Life-cycle Savings Relative to Baseline 1**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|
| 1 | 2011 | 103,049 | - |
| 2 | 2012 | 103,049 | - |
| 3 | 2013 | 103,049 | - |
| 4 | 2014 | 103,049 | - |
| 5 | 2015 | 103,049 | - |
| 6 | 2016 | 103,049 | - |
| 7 | 2017 | 103,049 | - |
| 8 | 2018 | 103,049 | - |
| 9 | 2019 | 103,049 | - |
| 10 | 2020 | 103,049 | - |
| 11 | 2021 | 103,049 | - |
| 12 | 2022 | 103,049 | - |
| 13 | 2023 | 103,049 | - |
| 14 | 2024 | 103,049 | - |
| 15 | 2025 | 103,049 | - |
| 16 | 2026 | 103,049 | - |
| 17 | 2027 | 103,049 | - |
| 18 | 2028 | 103,049 | - |
| 19 | 2029 | 103,049 | - |
| 20 | 2030 | 103,049 | - |
| 21 | 2031 | - | - |
| Life-cycle | Total | 2,060,980 kWh | 0 therms |

Source: DNV KEMA analysis

Table 119 provides life-cycle savings for the project relative to Baseline 2.

**Table 119: Life-cycle Savings Relative to Baseline 2**

| EUL Year | Year | Electric Energy Savings (kWh/yr) | Natural Gas Energy Savings (therms/yr) |
|---|---|---|---|
| 1 | 2011 | 103,049 | - |
| 2 | 2012 | 103,049 | - |
| 3 | 2013 | 103,049 | - |
| 4 | 2014 | 103,049 | - |
| 5 | 2015 | 103,049 | - |
| 6 | 2016 | 103,049 | - |
| 7 | 2017 | 103,049 | - |
| 8 | 2018 | 103,049 | - |
| 9 | 2019 | 103,049 | - |
| 10 | 2020 | 103,049 | - |
| 11 | 2021 | 103,049 | - |
| 12 | 2022 | 103,049 | - |
| 13 | 2023 | 103,049 | - |
| 14 | 2024 | 84,378 | - |
| 15 | 2025 | 84,378 | - |
| 16 | 2026 | 84,378 | - |
| 17 | 2027 | 84,378 | - |
| 18 | 2028 | 84,378 | - |
| 19 | 2029 | 84,378 | - |
| 20 | 2030 | 84,378 | - |
| 21 | 2031 | - | - |
| Life-cycle | Total | 1,930,283 kWh | 0 therms |

Source: DNV KEMA analysis