Evaluation results of twelve commercial air-conditioning energy efficiency programs

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Keywords

international performance measurement and verification protocol, monitoring, measurement, evaluation, verification, commercial air conditioners, air conditioning, chillers, cooling towers, energy efficiency, thermal storage, packaged air conditioners, chillers, cooling towers, controls, evaporative pre-coolers, ground source heat pumps

Abstract

Monitoring and evaluation results and costs are provided for twelve commercial air conditioning energy efficiency programs implemented by eleven California public utilities. The programs provided incentives for energy efficient packaged air conditioners, ground-source heat pumps, variable-frequency drive chillers, energy management systems, chiller and cooling tower optimization controls, wine thermal storage, evaporative pre-coolers, and refrigerant charge and airflow tune-ups. Seven large custom projects accounted for 84 % of total kWh savings and 75 % of peak demand savings. Data loggers were installed to monitor pre- and post-retrofit peak demand and energy use for chillers, cooling towers, controls, and packaged units. Peak kW savings are based on 15-minute kW measurements of pre- and post-retrofit conditions. Energy savings are based on engineering analysis, regression analysis, building energy simulations, utility billing data, and short-term field measurements consistent with the International Performance Measurement and Verification Protocols (IPMVP).

The ex-ante gross savings are 5,645,055 kWh/yr and 2,482 kW. The ex-post net savings are 3,944,622 ± 225,177 kWh/yr and 2,142 ± 156 kW. The ex post net lifecycle savings are 58,498,564 ± 3,370,974 kWh. The net-to-gross ratio is 96 % indicating 4 % of the measures would have been purchased without incentives. The net realization rates are 0.70 ± 0.04 for kWh savings and 0.86 ± 0.06 for kW savings. The utilities haven't previously conducted evaluations and were unfamiliar with tracking accomplishments and measuring results. Future evaluations should include the following requirements: tracking database, net savings including precision and error bounds, process evaluation, independent study management, adequate time, and evaluation contractors experienced with IPMVP measurement procedures. Chiller tower optimization is the most cost effective measure followed by EMS, VFD chiller, evaporative pre-cooler, thermal storage, AC tune-up, and high efficiency packaged AC. The average cost of conserved energy is $ 0.022/kWh and $ 619/kW. The program cost is $ 988,748 and the evaluation study cost is $ 46,456.

Introduction

This paper provides evaluation, measurement, and verification (EM&V) results for twelve commercial air conditioning energy efficiency programs implemented by eleven California public utilities. The programs provided incentives for high-efficiency packaged air conditioners, ground-source heat pumps, variable-speed chillers, cooling towers, chiller-tower optimization controls, wine thermal storage, evaporative pre-coolers, and refrigerant charge and airflow tune-ups. The programs were implemented by the following public utilities: Gridley, Lodi, Modesto Irrigation District (MID), Palo Alto, Port of Oakland, Plumas Sierra Electric Cooperative (PSREC), Roseville Electric, Truckee-Donner Public Utility District (TDPUD), Turlock Irrigation District (TID), and Ukiah. The programs provided incentives for 590 projects from 2001 through 2003 with $ 988,748 of Senate Bill 5X taxpayer funds administered

Table 1. Summary of the Commercial Air Conditioning Programs

NCPA Utility	Measures	Qty.	Budget	Ex Ante kWh Savings	Ex Ante kW Savings	Net Ex Post kWh Savings	Net Ex Post kW Savings
Gridley	High Efficiency Packaged Units	2	$9,144	3,995	4.4	972	1.1
Lodi	High Efficiency Packaged Units	6	$5,928	1,200	1.3	3,860	4.4
MID	High Efficiency Packaged Units	79	$31,020	46,479	52.8	38,918	44.5
MID	Thermal Storage, EMS, Pre-Cooler	4	$103,100	1,582,858	789.0	1,603,623	920.7
Palo Alto	High Efficiency VFD Chiller	1	$460,130	2,776,800	960.0	1,456,957	805.9
Port of Oakland	Energy Management System	1	$66,000	250,000	60.0	250,000	60.0
PSREC	Ground Source Heat Pumps	16	$16,000	256,016	63.4	80,396	21.5
Redding	High Efficiency Packaged Units	33	$23,763	38,101	42.5	19,141	21.9
Roseville	High Efficiency Packaged Units	93	$150,613	203,288	205.3	79,681	67.0
Roseville	Small AC Tune-up	250	$34,983	130,000	130.0	70,875	42.9
Roseville	Large AC Tune-up	43	$6,017	44,720	44.7	24,949	13.5
TDPUD	High Efficiency VFD Chiller	1	$10,000	229,166	87.0	290,347	110.2
Turlock	High Efficiency Packaged Units	50	$25,550	29,177	29.8	18,538	21.3
Ukiah	High Efficiency Packaged Units	11	$46,501	53,255	12.2	6,367	7.3
Total	**590**	**590**	**$988,748**	**5,645,055**	**2,482**	**3,944,622**	**2,142**

by Northern California Power Agency (NCPA) and the California Energy Commission (CEC). The evaluation, measurement, and verification budget was $ 46,456. A summary of the twelve commercial air conditioning programs is provided in **Table 1**.

The load impact evaluation ex post energy and peak demand savings are based on short-term or continuous metering, utility billing data, engineering analysis, and building energy computer simulations calibrated to metering data or billing data consistent with the *International Performance Measurement & Verification Protocols* (IPMVP USDOE 2002). Ex post energy savings for the custom air conditioning projects are based on site-specific billing data, engineering analysis, measured data, and DOE-2.2 simulations. Ex post energy savings for the small commercial packaged air conditioning and ground source heat pump (GSHP) rebate programs are based on billing regression analyses and engineering analyses for 54 sites using the PRInceton Scorekeeping Method (PRISM, Fels et al 1995). Ex post energy and peak demand savings for the commercial HVAC tune-up program are based on billing regression and engineering analyses for 11 sites with 20 air conditioners. Ex post peak kW savings are based on field measurements of peak kW for 19 packaged air conditioners, 16 GSHP units, and 6 large custom air conditioning projects. Gross savings and net savings are reported. Participant surveys were used to evaluate net-to-gross ratios and net savings based on the fraction of free riders who would have otherwise implemented energy efficient air conditioning improvements in the absence of the program.[1] The gross kW savings are based on in-situ 15-minute true RMS power measurements. Each unit included in the random sample was measured for several weeks in order to obtain 15-minute average kW measurements during the 2 PM to 6 PM time frame. The peak kW for each unit was taken as the maximum kW that occurs during the 2 PM to 6 PM weekday time frame from the 15-minute data. Participant surveys were used to evaluate net-to-gross ratios. Field measurements of air conditioner efficiencies were made using a three-phase true-RMS electric meters. The on-site data collection efforts analyzed baseline and measure assumptions by taking measurements and collecting billing data at customer sites. Statistical sampling methods were used to analyze the data and extrapolate mean savings estimates from the sample measurements to the population and to evaluate the statistical precision of the results.

The process evaluation included a statistically random sample of 41 participants. The approach for the process evaluation involved designing and implementing surveys to measure free riders, and to obtain suggestions to improve the program's services and procedures. Survey interviews included questions about how and when customers learned about the program, when they installed measures, influence of incentives, and whether or not they would have installed the measures without the incentives. Analysis of participant survey data included a summary of what works, what doesn't work, and the level of need for the program.

Measurement and Evaluation Approach

The measurement and verification approach for the study is based on the *International Performance Measurement & Verification Protocols* (IPMVP) defined **Table 2**.[2] Ex post energy and peak demand savings were determined using IPMVP Option A (i.e., partially measured retrofit isolation), IPMVP Option B (i.e., retrofit isolation), IPMVP Option C (whole facility billing regression analysis), and IPMVP Option D (calibrated simulations). PRISM and engineering analyses were used to baseline kWh energy use for packaged units. DOE-2.2 simulations calibrated to billing data were used to estimate gross kWh/yr savings for custom sites. Field measurements were used to estimate gross kW savings.

Field Measurement Methodology

Field measurements were used to determine in-situ energy and peak demand savings. Multiple data loggers were installed at six large custom sites and more than 20 small commercial sites to measure peak demand and energy use for standard and high ef-

1. The net-to-gross ratios reflect what customers would have done in the absence of the program.

2. See *International Performance Measurement & Verification Protocols*, DOE/GO-102000-1132, October 2000.

Table 2. IPMVP Options

IPMVP Option	Savings Calculation	Typical Applications
Option A. Partial Measured Retrofit Isolation Savings are determined by short-term or continuous field measurements of energy use. Partial measurement means some parameters may be stipulated.	Engineering calculations using short term or continuous measurements and stipulations.	Air conditioner power draw is measured periodically. Operating hours are measured with data loggers.
Option B. Retrofit Isolation Savings are determined by short-term or continuous measurements of energy use.	Engineering calculations using short term or continuous measurements.	Air conditioners or chillers where electricity use is measured and compared to labeled energy use.
Option C. Whole Facility Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken during post-retrofit period.	Analysis of whole facility utility meter or sub-meter data using comparison or regression analyses.	Energy management program affecting many systems in a building. Pre- and post-retrofit energy use is measured with utility meters.
Option D. Calibrated Simulation Savings are determined through simulation of components or whole facility. Simulation models actual energy performance measured in the facility.	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.	Weather-sensitive measures in a building. Savings based on simulations calibrated with pre- or post-retrofit utility data.

Source: USDOE 2002

ficiency air conditioners and chillers. The measurement sample included chillers, cooling towers, controls, packaged units, and GSHP units. Field measurements of the Energy Efficiency Ratio (EER) were made to determine in-situ efficiency on a sample of 34 small commercial air conditioners and 16 GSHP units.[3] Return and supply temperatures were measured inside the return and supply plenums. Temperature and power were measured at one minute intervals. Airflow was measured before and after making any changes to the supply/return ducts, opening vents, or installing new air filters that would affect airflow. Return and supply enthalpies were derived from the temperature measurements using standard psychrometric algorithms (Kelsey 2004). EER was calculated from the combination of enthalpy, airflow, and power measurements. Measurements were made to evaluate the relative change in efficiency not the absolute efficiency. All measurements of air conditioner performance were made within minutes of efficiency improvements, but at least 15 minutes after any refrigerant charge adjustments. Measurement tolerances are less important than the relative performance change. New and old systems were examined with labeled Seasonal Energy Efficiency Ratios (SEER) or EER ranging from 1.75 to 4.5 (ARI 2003).[4] Billing data for most sites was collected for a three year period to develop annual energy savings.

Findings for Commercial and Industrial Custom HVAC Projects

Seven large custom projects accounted for 84 percent of total ex ante kWh savings and 75 percent of peak demand savings for the SB5X C&I HVAC Incentive Programs. This study evaluated 6 out of 7 of the large custom projects. Data loggers were installed at these sites to measure peak demand and energy use for chillers, cooling towers, controls, and 24 large packaged units (greater than 52.7 kW). Peak kW savings are based on 15-minute kW measurements of pre- and post-retrofit conditions as shown in **Figure 1** for the thermal storage project at Site #2. This site provided 33 percent of the total ex post savings.

The kWh savings for custom sites are based on DOE-2.2 simulations calibrated using utility meter data, average monthly kW profiles, monthly kWh usage, and short-term measurements.

Baseline cooling and ex post savings values for MID custom projects are summarized in **Table 3**. Baseline cooling and ex post savings for custom projects in Palo Alto and TDPUD are summarized in **Tables 4** and **5**. The measure effective useful life (EUL) is 15 years for high efficiency chillers, evaporative pre-coolers, thermal storage, and chiller tower optimization (CPUC 2003). EM&V studies for custom sites adhered to IPMVP Options B, C, and D.

The Port of Oakland installed an energy efficient cooling tower and energy management system (EMS) at the Oakland Airport involving seven buildings and 430,000 square feet. An on-site inspection was conducted in October 2002 to verify the installed equipment and review the ex ante energy and peak demand savings developed by a third-party engineering consulting firm. The Port of Oakland ex ante savings of 250,000 kWh/yr and 60 kW were verified and accepted as ex post savings based on site visits, measurements, and review of engineering reports.

3. EER is the cooling capacity (kW) divided by total air conditioner electric power input (kW) including evaporator fan, condenser fan, compressor, and controls. In the United States, the labeled EER is measured at standard conditions with condenser entering air temperature of 35°C and evaporator entering air of 26.7°C drybulb and 19.4°C wetbulb (ARI 2003). EER field measurements are made at non-standard temperature conditions and are not directly comparable to laboratory measurements at standard conditions where airflow, return air, and condenser air temperatures are controlled. EER is derived from simultaneous enthalpy, airflow, and power measurements.

4. In the United States the SEER and EER are defined as the cooling capacity in British thermal units (Btu) per hour divided by total air conditioner electric power input (kW) including evaporator fan, condenser fan, compressor, and controls. The Btu is the energy required to raise one pound of water one degree Fahrenheit. This paper converts SEER and EER to SI units (i.e., kW/kW) through division by 3.413 Btu/kW. SEER is defined as the cooling capacity divided by the electric power input and is an adjusted rating based on a specified EER measurement multiplied by a 0.875 Part Load Factor where the EER is measured at condenser entering air temperature of 27.8°C and evaporator return temperatures of 26.7°C drybulb and 19.4°C wet bulb (ARI 2003).

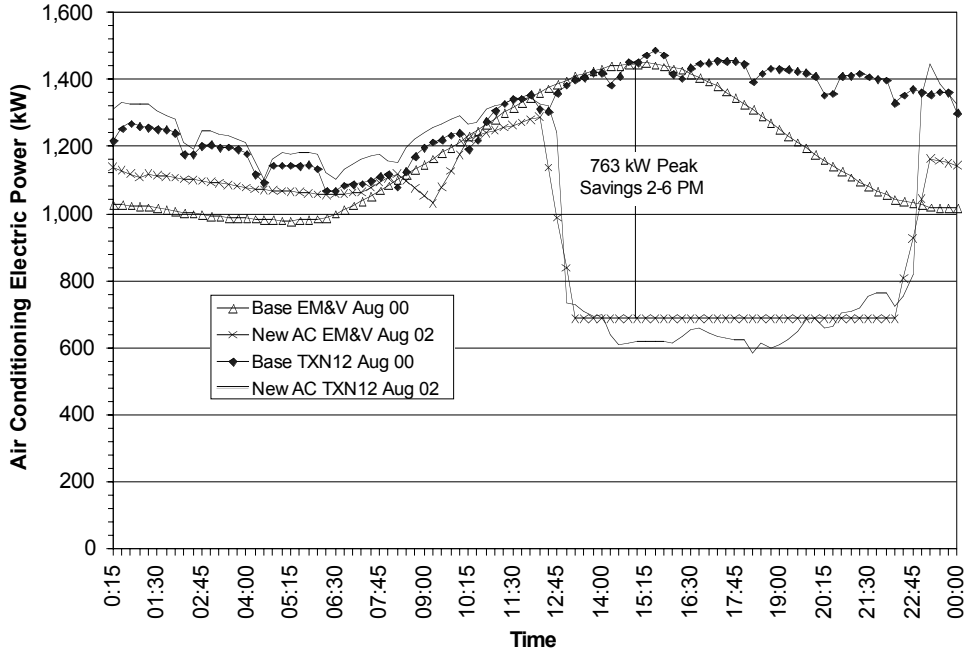

Figure 1. Measurements of Thermal Storage Peak kW Savings for Custom Site #2

Table 3. MID Baseline Cooling and Ex Post Savings for C&I Custom HVAC Projects

Site	Base Cooling (kWh/y)	Cooling Cap. kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Post Savings kWh/yr	Ex Post Savings kW
1	21,278,898	1,494	Evaporative Pre-cooler	531,250	130	453,792	60
2	4,035,000	3,516	Thermal Storage	730,276	514	747,600	763
3	18.524,071	6,680	CTO Optimization	221,037	90	201,453	51
4	16,075,501	8,438	CTO Optimization	100,295	55	270,915	87
Total	**59,913,470**			**1,582,858**	**789**	**1,673,760**	**961**
90% Confidence						108,198	76

Table 4. Palo Alto Baseline Cooling and Ex Post Savings for C&I Custom HVAC Project

Site	Base Cooling (kWh/y)	Cooling Cap. kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Post Savings kWh/yr	Ex Post Savings kW
56	5,345,061	14,064	High Eff, VFD Chillers	2,776,800	960	1,473,327	815
90% Confidence						177,678	137.6

Table 5. TDPUD Baseline Cooling and Ex Post Savings for C&I Custom HVAC Project

Site	Base Cooling (kWh/y)	Cooling Cap. kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Post Savings kWh/yr	Ex Post Savings kW
57	3,188,738	1,301	High Eff, VFD Chillers	229,166	87	305,628	116
90% Confidence						87,481	2.6

Table 6. Measured kW Values for Packaged Air Conditioners

Site	Cooling Capacity kW	EER	Baseline kW	Average Measured kW	kW Savings	Indoor Dry/Wetbulb & Outdoor Temperature °C
16	7	4.5 GSHP	2.8	1.77	1.03	27/19/35
35	7	3.5	2.82	2.26	0.56	27/19/35
36	7	3.5	2.82	2.14	0.68	27/19/35
15	8.8	4.5 GSHP	3.5	2.21	1.29	27/19/35
40	10.5	3.8	4.14	3.21	0.93	27/19/35
17	10.5	4.5 GSHP	4.1	2.67	1.43	27/19/35
37	14	3.2	5.4	5.14	0.26	27/19/35
54	14	3.5	5.4	4.96	0.44	27/19/35
55	14	3.8	5.4	4.25	1.15	27/19/35
21	14	4.5 GSHP	5.38	3.72	1.66	27/19/35
38	17.6	3.2	6.82	6.2	0.62	27/19/35
39	17.6	3.5	6.82	5.885	0.935	27/19/35
33	17.6	3.5	7.26	6.47	0.79	27/19/39
34	17.6	3.5	6.673	5.785	0.888	27/19/33
33	17.6	3.8	6.82	5.76	1.06	27/19/35
34	17.6	3.8	6.8	5.69	1.11	27/19/35
35	17.6	3.8	6.82	5.55	1.27	27/19/35
36	17.6	3.8	6.82	5.538	1.282	27/19/35
37	17.6	3.8	6.82	5.571	1.249	27/19/35
27	17.6	4.5 GSHP	6.8	4.74	2.06	27/19/35
32	24.6	3.0	8.9	8.02	0.87607	27/19/35
32	35.2	3.0	13	11.68	1.32	27/19/35
32	35.2	3.0	13	11.779	1.221	27/19/35
31	35.2	3.0	13	11.44	1.56	27/19/35
32	52.7	2.8	20.4	18.67	1.73	27/19/35
47	52.7	2.8	20.4	18.89	1.51	27/19/35
72	17.6	2.9	6.33	5.93	Non-part.	27/19/29
72	17.6	2.9	6.655	6.335	Non-part.	27/19/33
73	35.2	2.6	13	14.57	Non-part.	27/19/39
73	35.2	2.6	13.3	15.132	Non-part.	27/19/41

Table 7. Measured versus Calculated kW Savings for Small Packaged Units ≤ 17.6 kW Cooling Capacity

	Measured kW Baseline and kW Savings					Calculated kW from Manufacturer Data				
Cool Cap. kW	Baseline 2.9 SEER kW	3.2 SEER ΔkW	3.5 SEER ΔkW	3.8 SEER ΔkW	GSHP 4.5 EER ΔkW	Baseline 2.9SEER kW	3.2 SEER ΔkW	3.5 SEER ΔkW	3.8 SEER ΔkW	GSHP 4.5 EER ΔkW
7	2.8		0.62		1.03	2.82	0.32	0.61	0.79	1.03
8.8	3.8				1.29	3.32	0.25	0.48	0.7	1.29
10.5	4.1			0.92	1.43	4.14	0.33	0.64	0.93	1.55
12.3	n/a					4.77	0.38	0.74	1.04	1.61
14	5.1	0.26	0.44	1.12	1.66	5.4	0.23	0.45	1.15	1.66
17.6	6.8	0.62	0.87	1.23	2.06	6.82	0.44	0.85	1.26	2.1

Findings for C&I High Efficiency Air Conditioners

The 290 C&I high efficiency air conditioner measures accounted for 13 percent of total ex ante kWh savings and 18 percent of total ex ante peak demand savings for the SB5X C&I HVAC Incentive Programs. Data loggers were installed at 20 sites on 19 packaged units and 16 GSHP units to measure peak demand and energy use for standard and high efficiency air conditioners. Measured kW values for packaged air conditioners are shown in **Table 6**.

Average measured versus calculated kW savings from manufacturer data are shown in **Table 7**. Savings range from 0.32 kW for a 7 kW 2.9-SEER unit to 1.26 kW for a 17.6 kW 4.4-SEER conventional unit with maximum savings of 2.1 kW for GSHP units.

Average estimated peak kW savings for 24.6, 35.2, and 52.7 kW properly installed packaged AC units are shown in **Table 8**. Savings range from 0.88 kW for a 24.6 kW 3 EER unit to 4.34 kW for a 52.7 kW 3.2 EER unit.

Average measured savings are based on short-term measurements of standard and energy efficient air conditioners and GSHP units as shown in **Figure 2**. These measurements were made on units with proper refrigerant charge and airflow within manufacturers' specifications.

Billing data were collected from 54 sites in MID, PSREC, Roseville, Palo Alto, and TDPUD. These data were used as inputs for the PRInceton Scorekeeping Method (PRISM) or for cali-

Table 8. Measured versus Calculated kW Savings for Large Packaged Units > 17.6 kW Cooling Capacity

	Measured kW Baseline and kW Savings			Calculated kW from Manufacturer Data		
Cool Cap. kW	**Baseline 2.6 EER kW**	**3 EER ΔkW**	**3.2 EER ΔkW**	**Baseline 2.,6 EER kW**	**3 EER ΔkW**	**3.2 EER ΔkW**
24.6	8.65	0.88		8.7	1.26	1.73
35.2	13	1.37		3.32	1.77	2.09
Cool Cap. kW	**Baseline 2.5 EER kW**	**2.8 EER ΔkW**	**3.2 EER ΔkW**	**Baseline 2.5 EER kW**	**2.8 EER ΔkW**	**3.2 EER ΔkW**
52.7	20.4	1.62		20.7	2.52	4.34

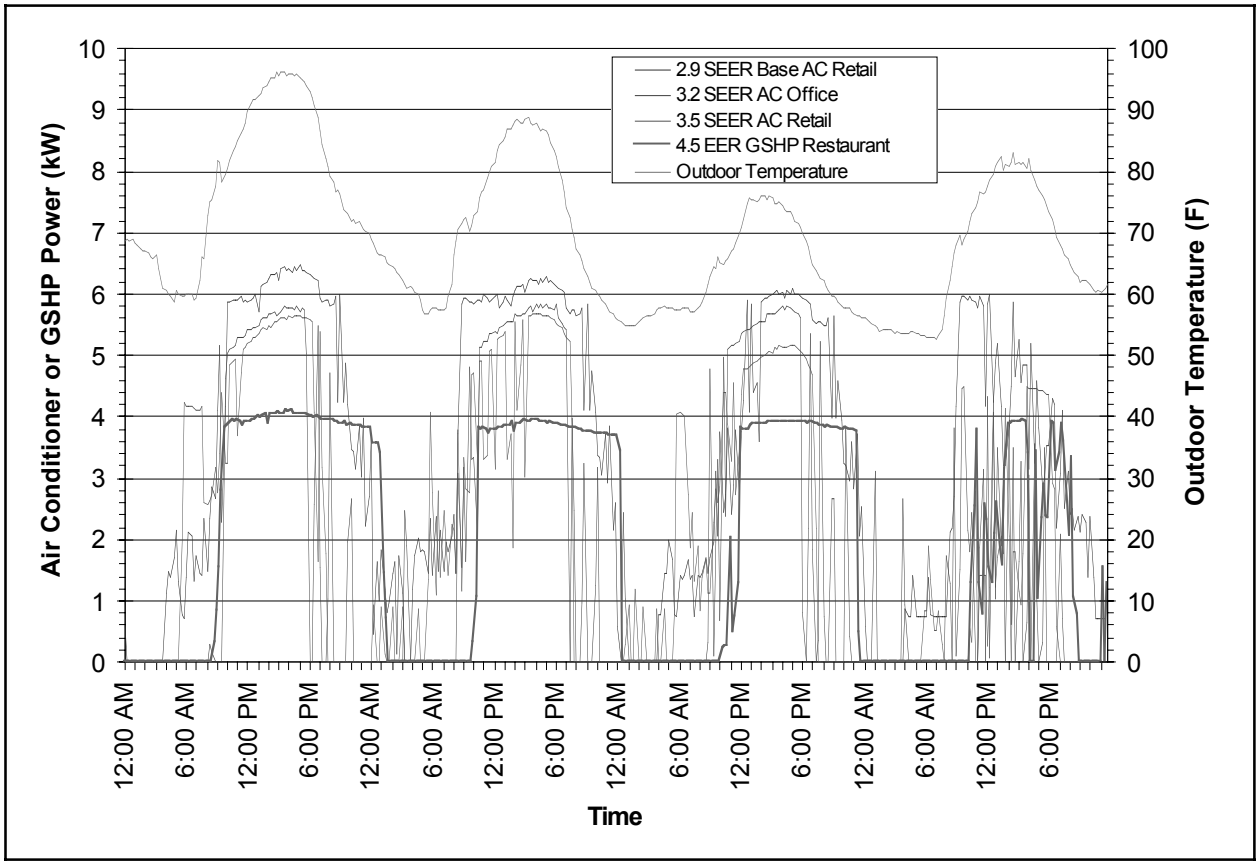

Figure 2. Measurements of 17.6 kW Packaged AC and Ground Source Heat Pump Units

bration with DOE-2.2 to develop base cooling values. The cooling savings for packaged units are based on the average SEER or EER improvement with respect to the baselines. Peak kW savings are based on 15-minute data collected for 19 packaged units. Baseline cooling and ex post savings values for MID are summarized in **Table 9**. Baseline cooling and ex post savings for GSHP units in PSREC are summarized in **Table 10**. Baseline cooling and ex post savings values for Roseville are summarized in **Table 11**. The ex ante effective useful life for high efficiency packaged air conditioners is 15 years (CPUC 2003).

Findings for Commercial HVAC Tune-ups

The 293 commercial HVAC tune-up measures accounted for 3 percent of the total ex ante kWh savings and 7 percent of the total ex ante peak demand savings for the SB5X C&I HVAC Incentive Programs. Billing data were obtained for 20 participating sites, but pre- and post-retrofit billing data were only available for 11 sites with 22 participating HVAC tune-ups. These data were used as inputs for PRISM to develop Normalized Annual Cooling Consumption (NACC). Billing analyses, field measurements, and engineering analyses were used to evaluate energy savings for HVAC tune-ups. Normalized ex ante and ex post cooling savings are summarized in **Table 12**.

The Average Gross Realization Rates (AGRR) for the HVAC tune-up sites are shown in **Table 13**, and the gross ex post savings are shown in **Table 14**.[5]<

The ex ante program savings are 174,720 kWh/yr and 174.7 kW and the average gross realization rates for the program are 0.57 ± 0.13 for kWh savings and 0.34 ± 0.08 for kW savings. The ex post program savings are 99,816 ± 22,623 kWh/yr and 58.7 ± 14.7 kW. The effective useful life for HVAC tune-ups is assumed to be 8 years. Therefore, the lifecycle savings are 766,593 ± 180,980 kWh. The gross realization rates are lower

5. Average Gross Realization Rate (AGRR) is defined as gross ex post savings divided by gross ex ante savings.

Table 9. MID Baseline Cooling and Ex Post Savings for Packaged HVAC Units

Site	Base Cooling (kWh/y)	Cool Cap. kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Post Savings kWh/yr	Ex Post Savings kW
5	1,620	8.8	3.5 SEER Pkg. AC	348	0.4	336	0.48
6	2,571	17.6	3.8 SEER Pkg. AC	1071	1.22	593	1.26
7	1,493	10.5	3.5 SEER Pkg. AC	418	0.47	249	0.64
98	2,684	7.0	3.5 SEER Pkg. AC	278	0.32	447	0.61
9	2,617	17.6	3.5 SEER Pkg. AC	696	0.79	436	0.85
10	4,212	17.6	3.5 SEER Pkg. AC	676	0.79	702	0.85
11	4,774	10.5	3.5 SEER Pkg. AC	418	0.47	796	0.64
12	7,264	17.6	3.5.5 SEER Pkg. AC	891	1.01	1,453	0.85
13	3,218	14.1	3.5 SEER Pkg. AC	557	0.63	536	0.45
14	3,977	8.8	3.5 SEER Pkg. AC	348	0.4	663	0.48
Average	**3,443**			**570**	**0.65**	**621**	**0.71**
90% Confidence	940			143	0.16	185	0.14

Table 10. PSREC Baseline Cooling and Ex Post Savings for GSHP Units

Site	Base Cooling (kWh/y)	Cool Cap. kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Post Savings kWh/yr	Ex Post Savings kW
15	15,260	8.8	4.5 EER GSHP	16,001	3.96	6,012	1.29
16	12,208	7.0	4.5 EER GSHP	16,001	3.96	4,809	1.03
17	18,312	10.5	4.5 EER GSHP	16,001	3.96	7,214	1.55
18	9,156	5.3	4.5 EER GSHP	16,001	3.96	3,607	0.77
19	9,156	5.3	4.5 EER GSHP	16,001	3.96	3,607	0.77
20	18,312	10.5	4.5 EER GSHP	16,001	3.96	7,214	1.55
21	24,416	14.1	4.5 EER GSHP	16,001	3.96	9,618	1.66
22	18,312	10.5	4.5 EER GSHP	16,001	3.96	7,214	1.55
23	18,312	10.5	4.5 EER GSHP	16,001	3.96	7,214	1.55
24	24,416	14.1	4.5 EER GSHP	16,001	3.96	9,618	1.66
25	18,312	10.5	4.5 EER GSHP	16,001	3.96	7,214	1.55
26	11,191	6.4	4.5 EER GSHP	16,001	3.96	4,408	0.95
27	29,503	17.6	4.5 EER GSHP	16,001	3.96	11,622	2.10
28	2,236	19.3	4.5 EER GSHP	16,001	3.96	881	2.31
29	1,898	16.4	4.5 EER GSHP	16,001	3.96	748	1.95
30	2,236	19.3	4.5 EER GSHP	16,001	3.96	881	2.31
Average	**14,577**			**16,001**	**3.96**	**5,743**	**1.53**
90% Confidence	3,516					1,385	0.21

than expected due to 23 percent of sites not requiring tune-up adjustments, lower baseline usage, and smaller refrigerant charge and airflow adjustments than assumed in ex ante program plans.

Findings of the Participant Surveys

Findings of the participant surveys for each program are presented in **Table 15**. The weighted average net-to-gross ratio is 0.96 based on average participant survey results multiplied times savings for each program divided by total savings for all programs. The average net to gross ratio of 0.96 is consistent with the California Express Efficiency program that offers rebates for high efficiency air conditioners for commercial customers (CPUC 2003).

Sample Design and Statistical Analysis

Statistical survey sampling methods were used to select a sample of customers or projects from each program population in order to evaluate load impacts (Cochran 1997, Kish 1965, Thompson 1992). Selecting participants for the sample was guided by the statistical sampling plan as well as input from the utilities. Statistical analysis methods were used to analyze the data and extrapolate mean savings estimates from the sample sites to the population of all program participants and to evaluate the statistical precision of the results. Savings were normalized on a per unit basis in the statistical analyses (e.g., kW of savings per kW of cooling capacity). Normalizing the savings allows clearer interpretation of the savings data.

Statistical analysis was used to extrapolate the ex post kW and kWh savings at the sample level for a utility program (stra-

Table 11. Roseville Baseline Cooling and Ex Post Savings for Packaged HVAC Units

Site	Base Cooling (kWh/y)	Cool Cap. kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Post Savings kWh/yr	Ex Post Savings kW
31	95,864	35.2	3 EER Pkg. AC	3,970	3.97	3,284	0.47
32	20,496	35.2	3 EER Pkg. AC	4,339	3.34	1,254	0.47
33	17,050	17.6	3.8 SEER Pkg. AC	2,698	3.36	1,616	0.61
34	19,837	10.5	3.8 SEER Pkg. AC	2,698	3.36	763	0.93
35	2,805	7.0	2.5 SEER Pkg. AC	1,060	1.06	468	0.93
36	2,805	7.0	3.5 SEER Pkg. AC	1,060	1.06	468	0.93
37	3,726	17.6	3.2 SEER Pkg. AC	2,650	2.65	339	0.93
38	2,981	14.1	3.2 SEER Pkg. AC	2,650	2.12	271	0.93
39	20,906	17.6	3.5 SEER Pkg. AC	2,128	2.65	3,484	0.64
40	3,737	10.5	3.8 SEER Pkg. AC	1,950	1.63	652	0.23
41	4,983	14.1	3.8 SEER Pkg. AC	2,600	2.17	869	1.15
42	6,229	17.6	3.8 SEER Pkg. AC	3,250	2.71	1,086	0.45
43	6,229	17.6	3.8 SEER Pkg. AC	3,250	2.71	1,086	1.26
44	6,229	17.6	3.8 SEER Pkg. AC	3,250	2.71	1,086	0.44
45	6,229	17.6	3.8 SEER Pkg. AC	3,250	2.71	1,086	0.85
46	18,686	52.7	2.8 EER Pkg. AC	9,749	8.14	3,259	1.26
47	18,686	52.7	2.8 EER Pkg. AC	9,749	8.14	3,259	1.26
48	2,317	10.5	3.8 SEER Pkg. AC	740	0.74	535	1.26
49	26,153	10.5	3.8 SEER Pkg. AC	2,020	2.02	6,035	1.26
50	4,146	10.5	3.8 SEER Pkg. AC	1,480	1.48	957	1.26
51	1,221	7.0	3.5 SEER Pkg. AC	838	0.70	203	1.77
52	2,944	10.5	3.5 SEER Pkg. AC	1,590	1.59	491	1.77
53	6,667	17.6	3.8 SEER Pkg. AC	3,360	3.36	1,539	2.52
54	5,526	14.1	3.5 SEER Pkg. AC	4,024	2.12	921	2.52
Average	**12,769**			**3,098**	**2.77**	**1,459**	**1.09**
90% Confidence	6,610			784	0.64	482	0.20

Table 12. Normalized Ex Ante and Ex Post Savings for Roseville HVAC Tune-ups

Site	Base NACC kWh/yr-kW	≤ 17.6 kW	> 17.6 kW	Ex Ante Savings kWh/yr-kW	Ex Ante Savings kW/kW	Ex Post Savings kWh/yr-kW	Ex Post Savings kW/kW
61	151.1	17.6	35.2	365.7	0.366	161.7	0.105
62	236.3	14.1	58.4	444.1	0.443	260.2	0.169
63	132.2		22.2	585.1	0.584	211.0	0.134
64	345.3	17.6		365.7	0.366	375.5	0.246
65	180.2	8.8		731.3	0.731	164.5	0.113
66	351.9		149.4	430.4	0.429	262.6	0.169
67	216.0	17.6		365.7	0.366	336.1	0.218
68	294.3	28.1		457.1	0.457	152.9	0.098
69	244.4	10.5		609.3	0.608	419.5	0.271
70	147.6	8.8		731.3	0.731	486.6	0.309
71	166.7	19.3		664.9	0.665	245.4	0.158
Small Tune-up	**230.4**	**13.0**		**496.5**	**0.496**	**282.0**	**0.172**
90% CI	33.2					58.7	0.039
Large Tune-up	**281.6**		**29.5**	**436.7**	**0.436**	**253.9**	**0.137**
90% CI	50.6					79.8	0.053

Table 13. Average Gross Realization Rates for HVAC Tune-up Sites

NCPA Utility	Qty. Cool Cap. kW	Ex Ante kWh/yr-kW	Ex Ante kW/kW	Ex Post kWh/yr-kW	Ex Post kW/kW	AGRR kWh/yr	AGRR kW
Roseville Small Tune-up	142.4	40.20	0.040	22.81	0.014	0.567911	0.344005
Roseville Large Tune-up	264.9	35.30	0.035	20.53	0.011	0.581133	0.313942

Table 14. Gross Ex Post Savings for Roseville HVAC Tune-up Sites

NCPA Utility	Qty. Cool Cap. kW	Ex Ante Savings kWh/yr	Ex Ante Savings kW	AGRR kWh/yr	AGRR kW	Gross Ex Post Savings kWh/y	Gross Ex Post Savings kW
Roseville Small Tune-up	3853.9	130,000	130.0	0.567911	0.344005	73,828	44.7
Roseville Large Tune-up	1028.8	44,720	44.7	0.581133	0.313942	25,988	14.0
Total	**4882.6**	**174,720**	**174.7**	**0.571291**	**0.336005**	**99,816**	**58.7**

Table 15. Findings of Participant Surveys

NCPA Utility	Ex Post Measure Qty.	Completed Surveys	Ex Post Program Savings kW	Weighting Factor	Actual Net-to-Gross Ratio	Coefficient of Variation Cv	Required Sample to Meet 90/10 Criteria	Weighted Net-to-Gross Ratio
Gridley	2	2 (Census)	1.15	0.000516	0.97	n/a	n/a	0.000500
Lodi	6		4.61	0.002062				0.000000
MID	79	5	57.76	0.025824	0.77	0.17	7	0.019885
MID-Custom	4	4 (Census)	961.00	0.429697	0.96	n/a	n/a	0.412509
Palo Alto	1	1 (Census)	815.00	0.364415	0.99	n/a	n/a	0.360771
Port of Oakland	1	1 (Census)	60.00	0.026828	1	n/a	n/a	0.026828
PSREC-GSHP	16	2 (Census)	24.58	0.010988	0.88	n/a	n/a	0.009670
Redding	33		22.86	0.010221	0.96			0.009812
Roseville	93	14	80.55	0.036017	0.83	0.18	8	0.029894
Roseville Small Tune-up	250		44.72	0.019996	0.96			0.019196
Roseville Large Tune-up	43		14.03	0.006275	0.96			0.006024
TDPUD	1	1 (Census)	116.00	0.051868	0.95	n/a	n/a	0.049274
TID	50	10	26.90	0.012029	0.79	0.24	11	0.009503
Ukiah	11	1 (Census)	7.30	0.003265	1	n/a	n/a	0.003265
Total	**590**	**41**	**2,236**	**1**				**0.96**

tum) to the program category level and finally for the NCPA SB5X portfolio. This step included an assessment of the error bounds and relative precision of program-level kW and kWh savings as discussed above. Savings for the sample sites were summed and compared to ex ante savings to develop Average Gross Realization Rates for kW and kWh savings.

The weighted sample coefficient of variation for kWh savings is 0.47, the weighted Cv for kW savings is 0.42, and the weighted participant survey coefficient of variation is 0.09.[6] The Cv values are relatively small because 84 percent of program savings are from 6 custom sites where the savings are based on monthly billing data, detailed site audits, 15-minute kW measurement data, and calibrated DOE-2.2 simulations. The kWh and kW billing and metered data sample included 45 packaged AC units, 16 GSHP units, and 6 custom sites. All results in this report are presented at the 90/10 confidence level.

Load Impact Evaluation Findings

Gross ex post program evaluation savings (i.e., kWh/yr and kW) are based on the Average Gross Realization Rates (AGRR) from the EM&V on-site audits. Gross ex post kWh savings are based on billing data analysis of 76 packaged air conditioners and 6 custom sites accounting for 84 percent of the total savings. Gross ex post peak kW savings are based on field measurements of peak kW of 19 packaged air conditioners, 16 GSHP units, and 6 large custom air conditioning projects. Gross ex post savings for the sampled units were compared to ARI ratings and other sources. Net program evaluation savings are based on the participant decision-maker survey results that were analyzed to develop net-to-gross ratios for kWh and kW savings. The gross and net savings estimates obtained at the participant level are extrapolated to the population of program participants using statistical methods. The weighted average gross realization rates for EM&V custom, packaged AC, and GSHP and Tune-up sites are provided in **Tables 16**, **17**, and **18**.

The MID savings per kW of cooling capacity were used to develop engineering estimates of AGRR values for packaged AC incentive programs implemented by Gridley, Lodi, Red-

6. The coefficient of variation is defined as the ratio of the standard deviation divided by the mean savings.

Table 16. Average Gross Realization Rates for EM&V Custom Sites

NCPA Utility	Qty. Cool Cap. kW	Ex Ante kWh/yr-kW	Ex Ante kW/kW	Ex Post kWh/yr-kW	Ex Post kW/kW	AGRR kWh/yr	AGRR kW
MID Custom #1	1494	355.52	0.090	303.69	0.040	0.854197	0.461538
MID Custom #2	3516	207.7	0.150	212.63	0.220	1.023723	1.484436
MID Custom #3	6680	33.09	0.010	30.16	0.010	0.911399	0.566667
MID Custom #4	8438	11.89	0.010	32.1	0.010	2.701182	1.581818
Palo Alto Custom #56	7032	394.88	0.140	209.52	0.120	0.530584	0.848958
TDPUD Custom #57	1301	176.16	0.070	234.93	0.090	1.333653	1.333333

Table 17. Average Gross Realization Rates for EM&V Packaged AC Sites

NCPA Utility	Qty. Cool Cap. kW	Ex Ante kWh/yr-kW	Ex Ante kW/kW	Ex Post kWh/yr-kW	Ex Post kW/kW	AGRR kWh/yr	AGRR kW
MID Packaged AC	130	43.82	0.050	47.65	0.050	1.087426	1.093846
Roseville Packaged AC	450	165.21	0.150	77.8	0.060	0.470913	0.392352

Table 18. Average Gross Realization Rates for EM&V GSHP and HVAC Tune-up Sites

NCPA Utility	Qty. Cool Cap. kW	Ex Ante kWh/yr-kW	Ex Ante kW/kW	Ex Post kWh/yr-kW	Ex Post kW/kW	AGRR kWh/yr	AGRR kW
PSREC GSHP	186	1373.87	0.340	493.06	0.130	0.358887	0.387622
Roseville Small AC Tune-up	142	40.17	0.040	22.81	0.010	0.567911	0.344005
Roseville Large AC Tune-up	265	35.33	0.040	20.53	0.010	0.581133	0.313942

Table 19. Average Gross Realization Rates for Other Packaged HVAC Programs

NCPA Utility	Qty. Cool Cap. kW	Ex Ante kWh/yr-kW	Ex Ante kW/kW	Ex Post kWh/yr-kW	Ex Post kW/kW	AGRR kWh/yr	AGRR kW
Gridley	21	189.36	0.210	47.67	0.050	0.251642	0.262039
Lodi	84	14.22	0.020	47.67	0.050	3.351035	3.547609
Redding	418	91.07	0.100	47.67	0.050	0.523307	0.537838
TID	492	59.27	0.060	47.67	0.050	0.803964	0.902775
Ukiah	134	398.58	0.090	47.67	0.050	0.119556	0.598538

Table 20. Gross Ex Post Savings and Realization Rates for C&I HVAC Programs

NCPA Utility	Qty. Cooling Cap. kW	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Post Savings kWh/yr	Ex Post Savings kW	AGRR kWh/yr	AGRR kW
Gridley	21	3,995	4.4	1,005	1.2	0.251642	0.262039
Lodi	84	1,200	1.3	4,021	4.6	3.351035	3.547609
MID	1,202	46,479	52.8	50,542	57.8	1.087426	1.093846
MID-Custom	20,129	1,582,858	789	1,673,760	961.0	1.057429	1.217997
Palo Alto-Custom	11,251	2,776,800	960	1,473,327	815.0	0.530584	0.848958
Port of Oakland-Custom	2,110	250,000	60	250,000	60.0	1.000000	1.000000
PSREC-GSHP	281	256,016	63.4	91,881	24.6	0.358887	0.387622
Redding	418	38,101	42.5	19,939	22.9	0.523307	0.537838
Roseville	1,603	203,288	205.3	95,731	80.5	0.470913	0.392352
Roseville Small AC Tune-up	3,854	130,000	130	73,828	44.7	0.567911	0.344005
Roseville Large AC Tune-up	1,030	44,720	44.7	25,988	14.0	0.581133	0.313942
TDPUD-Custom	1,301	229,166	87	305,628	116.0	1.333653	1.333333
TID	492	29,177	29.8	23,457	26.9	0.803964	0.902775
Ukiah	134	53,255	12.2	6,367	7.3	0.119556	0.598538
Total	**43,907**	**5,645,055**	**2,482.40**	**4,095,475**	**2,236.46**	**0.725498**	**0.900927**

Table 21. Ex Ante Savings for NCPA SB5X C&I HVAC Incentive Programs

NCPA Utility	Qty.	Ex Ante Savings kWh/yr	Ex Ante Savings kW	Ex Ante Net-to-Gross Ratio kWh/y	Ex Ante Net-to-Gross Ratio kW	Ex Ante Savings kWh/y	Ex Ante Savings kW
Gridley	2	3,995	4.4	1	1	3,995	4.4
Lodi	6	1,200	1.3	1	1	1,200	1.3
MID	79	46,479	52.8	1	1	46,479	52.8
MID-Custom	4	1,582,858	789.0	1	1	1,582,858	789.0
Palo Alto-Custom	1	2,776,800	960.0	1	1	2,776,800	960.0
Port of Oakland-Custom	1	250,000	60.0	1	1	250,000	60.0
PSREC-GSHP	16	256,016	63.4	1	1	256,016	63.4
Redding	33	38,101	42.5	1	1	38,101	42.5
Roseville	93	203,288	205.3	1	1	203,288	205.3
Roseville Small Tune-up	250	130,000	130.0	1	1	130,000	130.0
Roseville Large Tune-up	43	44,720	44.7	1	1	44,720	44.7
TDPUD-Custom	1	229,166	87.0	1	1	229,166	87.0
TID	50	29,177	29.8	1	1	29,177	29.8
Ukiah	11	53,255	12.2	1	1	53,255	12.2
Total	**590**	**5,645,055**	**2,482.4**	**1.00**	**1.00**	**5,645,055**	**2,482**

Table 22. Ex Post Savings for NCPA SB5X C&I HVAC Incentive Programs

NCPA Utility	Qty.	Gross Ex Post Savings kWh/y	Gross Ex Post Savings kW	Net-to-Gross Ratio kWh/y	Net-to-Gross Ratio kW	Net Ex Post Savings kWh/y	Net Ex Post Savings kW	Net Realization Rate kWh/y	Net Realization Rate kW
Gridley	2	1,005	1.2	0.97	0.97	972	1.1	0.24	0.25
Lodi	6	4,021	4.6	0.96	0.96	3,860	4.4	3.22	3.41
MID	79	50,542	57.8	0.77	0.77	38,918	44.5	0.84	0.84
MID-Custom	4	1,673,760	961.0	0.96	0.96	1,603,623	920.7	1.01	1.17
Palo Alto-Custom	1	1,473,327	815.0	0.99	0.99	1,456,957	805.9	0.52	0.84
Oakland-Custom	1	250,000	60.0	1.00	1.00	250,000	60.0	1.00	1.00
PSREC-GSHP	16	91,881	24.6	0.88	0.88	80,396	21.5	0.31	0.34
Redding	33	19,939	22.9	0.96	0.96	19,141	21.9	0.50	0.52
Roseville	93	95,731	80.5	0.83	0.83	79,681	67.0	0.39	0.33
Rosvle Sm Tune-up	250	73,828	44.7	0.96	0.96	70,875	42.9	0.55	0.33
Rosvle Lg Tune-up	43	25,988	14.0	0.96	0.96	24,949	13.5	0.56	0.30
TDPUD-Custom	1	305,628	116.0	0.95	0.95	290,347	110.2	1.27	1.27
TID	50	23,457	26.9	0.79	0.79	18,538	21.3	0.64	0.71
Ukiah	11	6,367	7.3	1.00	1.00	6,367	7.3	0.12	0.60
Total	**590**	**4,095,475**	**2,236.46**	**0.96**	**0.96**	**3,944,622**	**2,142.35**	**0.70**	**0.86**

Table 23. Ex Post Lifecycle Savings for NCPA SB5X C&I HVAC Incentive Programs

NCPA Utility	Qty.	Net Ex Post Annual Savings kWh/yr	Effective Useful Lifetime	Net Ex Post Lifecycle Savings kWh	90% CI kWh
Gridley	2	972	15	14,577	4,361
Lodi	6	3,860	15	57,906	17,324
MID	79	38,918	15	583,766	174,651
MID-Custom	4	1,603,623	15	24,054,340	1,554,968
Palo Alto-Custom	1	1,456,957	15	21,854,351	2,635,563
Port of Oakland-Custom	1	250,000	15	3,750,000	375,000
PSREC-GSHP	16	80,396	15	1,205,935	290,858
Redding	33	19,141	15	287,114	85,899
Roseville	93	79,681	15	1,195,214	395,294
Roseville Small AC Tune-up	250	70,875	8	567,003	118,245
Roseville Large AC Tune-up	43	24,949	8	199,590	62,735
TDPUD-Custom	1	290,347	15	4,355,199	1,246,600
TID	50	18,538	15	278,066	83,192
Ukiah	11	6,367	15	95,505	28,573
Total	**590**	**3,944,622**	**15**	**58,498,564**	**3,370,974**

Note: The total 90% confidence interval (CI) kWh is the square root of the sum of the squares of the 90% CI for each program.

Table 24. Average Energy Savings and Cost of Conserved Energy for Each Measure

Measure	Cool Cap kW	Incremental Measure Cost $	Life	Net Ex Post Savings kWh	Net Ex Post Savings kW	CCE $/kWh	CCE $/kW
Chiller Tower Optimization	15,118	$67,919	15	452,574	132	0.010	$514
Energy Management System	2,110	$66,000	15	250,000	60	0.018	$1,100
Variable Frequency Drive Chiller	8,333	$461,130	15	1,747,302	916	0.018	$504
Evaporative Pre-cooler	1,494	$124,230	15	434,776	57	0.019	$2,161
Thermal Storage	3,516	$257,000	15	716,273	731	0.024	$352
AC Tune-up	4,883	$41,000	8	95,824	56	0.054	$727
High Efficiency Packaged AC	1,915	$308,519	15	247,873	189	0.083	$1,632
Total	**37,368**	**$1,325,798**	**15**	**3,944,622**	**2,142**	**0.022**	**$619**

ding, TID, and Ukiah since these utilities are located in similar climate zones to MID (see **Table 19**).

The gross ex post savings and realization rates for all utilities are provided in **Table 20**.

Ex ante program savings are summarized in **Table 21**, and ex post savings are summarized in **Table 22**. The total ex ante program savings are 5,645,055 kWh/yr and 2,482 kW. The total gross ex post savings are 4,095,475 ± 231,669 kWh/yr and 2,236 ± 159 kW. The total net ex post savings for the program are 3,944,622 ± 225,177 kWh/yr and 2,142 ± 156 kW. The total net ex post lifecycle savings are 58,498,564 ± 3,370,974 kWh as shown in **Table 23**. The net-to-gross ratio is calculated based on decision maker surveys regarding whether or not the unit would have been installed without rebates from the programs. The realization rates are 0.70 for kWh savings and 0.86 for kW savings. The ex post savings and net realization rates are lower than anticipated primarily due to lower baseline usage, unrealized or lower ex post savings, and lower net-to-gross ratios.

The average energy savings and cost of conserved electricity (CCE) for each measure are provided in **Table 24**. The average CCE for all measures is $ 0.022/kWh and $ 619/kW. The cost of conserved energy is 83 % less than the cost of supplying electricity and the cost of conserved electric power is 58 % less than the cost of new coal power plants.[7]

Conclusions

Monitoring and evaluation results are provided for twelve commercial air conditioning energy efficiency programs implemented by twelve public utilities located in California. The programs provided incentives for high-efficiency packaged air conditioners, ground-source heat pumps, variable-speed chillers, cooling towers, chiller-tower optimization controls, wine thermal storage, evaporative pre-coolers, and refrigerant charge and airflow tune-ups. Seven large custom projects accounted for 84 % of total kWh savings and 75 % of peak demand savings. Data loggers were installed to monitor pre- and post-retrofit peak demand and energy use for chillers, cooling towers, controls, and packaged units. Peak kW savings are based on 15-minute kW measurements of pre- and post-retrofit conditions. The load impact evaluation savings are based on short-term or continuous metering, utility billing data, engineering analysis, and building energy computer simulations calibrated to metering data or billing data consistent with the *International Performance Measurement & Verification Protocols.*

Load impact evaluation findings indicate the program met 70 % of its kWh savings goals and 86 % of its kW savings goals. The ex-post net savings are 3,944,622 ± 225,177 kWh/yr and 2,142 ± 156 kW. The ex post net lifecycle savings are 58,498,564 ± 3,370,974 kWh. The net-to-gross ratio is 96 % indicating 4 % of the measures would have been purchased without incentives. The net realization rates are 0.70 ± 0.04 for kWh savings and 0.86 ± 0.06 for kW savings. The net realization rates are lower than anticipated due to lower baseline usage, lower or unrealized ex post savings, and lower net-to-gross ratios. The utilities haven't previously conducted evaluations and were unfamiliar with tracking accomplishments and measuring results. Future evaluations should include the following requirements: tracking database, net savings including precision and error bounds, process evaluation, independent study management, adequate time, and evaluation contractors experienced with IPMVP measurement procedures. Chiller tower optimization is the most cost effective measure followed by EMS, VFD chiller, evaporative pre-cooler, thermal storage, AC tune-up, and high efficiency packaged air conditioners. The average cost of conserved energy for all measures is $ 0.022/kWh and $ 619/kW. The cost of conserved energy is 83 % less than the cost of supplying electricity and the cost of conserved electric power is 58 % less than the cost of new coal power plants. The program cost is $ 988,748 and the evaluation study cost is $ 46,456.

References

American Refrigeration Institute (ARI). 2003. *2003 Standard for Unitary Air Conditioning and Air-Source Heat Pump Equipment.* DOE Test Method as specified in 10 CFR. 1995. Section 430.23(b). ARI 210/240-2003. Arlington, Va.: American Refrigeration Institute.

California Public Utilities Commission (CPUC), 2003. Energy Efficiency Policy Manual, Version 3. San Francisco, Calif: Available online: www.cpuc.ca.gov/.

Cochran, William G. 1977. *Sampling Techniques*. New York: John Wiley & Sons.

Fels, M., Kissock, K., Marean, M., and Reynolds, C. 1995. *PRISM Advanced Version 1.0 User's Guide*. Princeton, N.J.: Princeton University, Center for Energy and Environmental Studies.

Kish, Leslie. 1965. *Survey Sampling*. New York: John Wiley & Sons.

7. Based on a 5 % discount rate and $ 0.1313/kWh average commercial electricity price in California (USEIA 2006). The cost of 159 new coal power plants in the US is $ 141 billion for 96 GW or $ 1,468/kW (USNETL 2007).

Kelsey, J. 2004. Get Psyched™ Psychrometric Software for MS Excel, Available online: www.kw-engineering.com. Oakland, Calif. kW Engineering.

Mowris, R., Blankenship, A., Jones, E., Noack, R. 2005. *Measurement & Verification Report for NCPA SB5X Commercial and Industrial HVAC Incentive Programs*, prepared for Northern California Power Agency and the California Energy Commission. Olympic Valley, Calif.: Robert Mowris & Associates. Available online: http://www.calmac.org.

Thompson, Steven K. *Sampling*. 1992. New York: John Wiley & Sons.

United States Department of Energy (USDOE). 2002. International Performance Measurement & Verification Protocols: Concepts and Options for Determining Energy and Water Savings. Volume I. DOE/GO-102000-1132. Washington, D.C.: United States Department of Energy. Available online: www.ipmvp.org.

United States Energy Information Administration (USEIA). 2006. Average Retail Price of Electricity to Ultimate Customers by End-Use Sector by State. Washington, D.C.: United States Energy Information Administration. Available online: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html

United States National Energy Technology Laboratory (USNETL). 2007. Coal's Resurgence in Electric Power Generation. Pittsburgh, Penn.: National Energy Technology Laboratory. Available online: http://www.netl.doe.gov/coal/refshelf/ncp.pdf.

Acknowledgements

Funding for the study was provided by Northern California Power Agency through a joint contract with the California Energy Commission. Field research at customer sites was made possible with the cooperation of the following individuals, utilities, and companies: Kris Blair, Roseville Electric Company; Peter Govea, Modesto Irrigation District; Jay James, Port of Oakland; Nell Thomas, Plumas-Sierra Rural Electric Utility; and Scott Terrell, Truckee Donner Public Utilities District. Robert Mowris, P.E., Principal Consultant, and Kathleen Carlson, Esq., Principal Consultant, were responsible for project management, EM&V plans, database design, survey instrument, analyses, and writing the reports. Robert Mowris, Ean Jones, B.S., Anne Jones, B.S., Shelly Coben, B.S., C.E.M., and George Nesbitt performed the onsite inspections. Peter Pressley, Ph.D., developed the EM&V tracking database and Rachel Noack, B.S., managed and revised the database. Robert Mowris performed the DOE-2/eQuest simulations, statistical analyses, developed the figures and tables. John Berlin was the study manager for Northern California Power Agency. Rick Ridge, Ph.D., Ridge Associates, provided review comments and suggestions regarding the statistical analysis and sample design.