Measurement & Verification Load Impact Study for NCPA SB5X Commercial and Industrial HVAC Incentive Programs

Study ID: NCP0001.03

FINAL REPORT

Prepared for
John Berlin, Project Manager
Northern California Power Agency
Roseville, California

Prepared by
Principal Investigators: Robert Mowris and Kathleen Carlson
Robert Mowris & Associates
Olympic Valley, California

June 25, 2005

Funded with California Senate Bill 5X Funds

TABLE OF CONTENTS

Acknowledgements

This measurement and verification load impact study was funded by Senate Bill 5X and administered by Northern California Power Agency under the auspices of 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 Blankenship, B.S., Shelly Coben, B.S., C.E.M., and George Nesbitt performed the onsite inspections. Peter Pressley, Ph.D., developed the NCPA M&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, and wrote the report. John Berlin was the project manager for Northern California Power Agency. Rick Ridge, Ph.D., Ridge Associates, provided review comments and suggestions regarding the statistical analysis and sample design.

1. Executive Summary

This study was conducted at the request of Northern California Power Agency (NCPA) and the California Energy Commission (CEC). The study was managed by NCPA. It was funded by Senate Bill 5X (SB5X) and is available online at www.calmac.org. This report provides Measurement and Verification (M&V) load impact study results for the NCPA SB5X Commercial and Industrial (C&I) Heating, Ventilating, and Air Conditioning (HVAC) Incentive Programs implemented by 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 realized peak kW and kWh savings by paying incentives to C&I customers for installing high efficiency air conditioning measures. The programs provided incentives for 590 projects from 2001 through 2003 with $988,748 of SB5X funds administered by NCPA.

Ex ante program savings are summarized in **Table 1.1**, and ex post savings are summarized in **Table 1.2**. The total ex ante program savings are 5,645,055 kWh/yr and 2,482 kW. The total M&V gross ex post savings are 4,095,475 ± 231,669 kWh/yr and 2,236 ± 159 kW. The total M&V 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 (see **Section 2.3**). The M&V ex post savings are based on billing data, engineering analysis, and computer simulations consistent with the *International Performance Measurement & Verification Protocols* (IPMVP).[1] Ex post energy savings for the MID, Palo Alto, and TDPUD custom air conditioning projects are based on billing data, engineering analysis, measured data, and DOE-2.2 simulations (see Appendices B through G for MID, Palo Alto, and TDPUD custom projects). Ex post energy savings for the Gridley, Lodi, MID, Redding, Roseville, TID, and Ukiah small commercial air conditioning rebate programs and the PSREC Ground Source Heat Pump (GSHP) rebate program are based on billing regression analyses and engineering analyses for 54 sites using the PRInceton Scorekeeping Method (PRISM).[2] Ex post energy and peak demand savings for the Roseville 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. 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 average net-to-gross ratio is 96 percent indicating approximately 4 percent of C&I high air conditioning measures would have been purchased anyway without the program.[3] The net realization rates are 0.70 for kWh savings and 0.86 for kW savings. The M&V savings and realization rates are lower than anticipated due to lower baseline usage, lower or unrealized ex post savings, and lower net-to-gross ratios.

[1] See *International Performance Measurement & Verification Protocols*, DOE/GO-102000-1132, October 2000.
[2] Fels, M., Kissock, K., Marean, M., Reynolds, C. 1995. *PRISM Advanced Version 1.0 User's Guide*. Princeton, New Jersey. Princeton University, Center for Energy and Environmental Studies.
[3] The net-to-gross ratios reflect what customers would have done in the absence of the program (see Section 3).

Table 1.1 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 AC Tune-up ≤5 ton	250	130,000	130.0	1	1	130,000	130.0
Roseville AC Tune-up >5 ton	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 1.2 M&V Ex Post Savings for NCPA SB5X C&I HVAC Incentive Programs

NCPA Utility	Qty.	M&V Gross Ex Post Savings kWh/y	M&V Gross Ex Post Savings kW	Net-to-Gross Ratio kWh/y	Net-to-Gross Ratio kW	M&V Net Ex Post Savings kWh/y	M&V 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
Port of 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
Roseville AC Tune-up <5 ton	250	73,828	44.7	0.96	0.96	70,875	42.9	0.55	0.33
Roseville AC Tune-up >5 ton	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**

The M&V study provides average gross savings per unit and net-to-gross ratios. The M&V gross 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.

Section 2 presents the M&V approach and results, field measurement methodology, findings, and M&V savings. **Section 3** presents participant survey results and the methodology used to develop net-to-gross ratios for kWh and kW savings. **Section 4** presents the M&V methodology used for the sample design, statistical analysis, database, baseline, and program evaluation savings estimates. **Appendix A** provides the Decision-Maker Survey. Appendices **B** through **G** provide M&V reports for 6 large custom air conditioning projects sponsored by MID, Palo Alto, and TDPUD. The 6 large custom projects accounted for 79 percent of total kWh and 71 percent of total kW savings for the C&I Air Conditioner Programs.

2. M&V Approach and Results for C&I HVAC

The measurement and verification approach for the study was based on the *International Performance Measurement & Verification Protocols* (IPMVP) defined **Table 2.1**.[4] Ex post energy and peak demand savings were determined using 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.

Table 2.1 IPMVP M&V Options

M&V Option	How Savings are Calculated	Typical Applications
Option A. Partially Measured Retrofit Isolation Savings are determined by partial field measurement of energy use of system(s) to which a measure was applied, separate from facility energy use. Measurements may be either short-term or continuous. Partial measurement means that some but not all parameters may be stipulated, if total impact of possible stipulation errors is not significant to resultant savings. Careful review of measure design and installation will ensure that stipulated values fairly represent the probable actual value.	Engineering calculations using short term or continuous post-retrofit measurements or stipulations.	Pre- and post-retrofit values are measured with a kW meter and operating hours are based on interviews with occupants or stipulated values.
Option B. Retrofit Isolation Savings are determined by field measurement of the energy use of the systems to which the measure was applied; separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.	Engineering calculations using short term or continuous measurements	AC system electricity use is measured with kW meters. Hours of operation are measured with motor loggers.
Option C. Whole Facility Savings are determined by measuring energy use (and production) at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period. Continuous measurements are based on whole-facility billing data.	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis or conditional demand analysis.	Energy management program affecting many systems in a building. Utility meters measure energy use for 12-month base year and throughout post-retrofit period.
Option D. Calibrated Simulation Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.	Project affecting systems in a building but where pre or post year data are unavailable. Utility billing meters measure pre- or post-retrofit energy use. Savings are determined by simulation using a model calibrated with utility billing data.

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

2.1 Field Measurement Methodology

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.[5] Field measurements, measurement equipment, and measurement tolerances are provided in **Table 2.2**.

Table 2.2 Field Measurements, Measurement Equipment, and Tolerances

Field Measurement	Measurement Equipment	Measurement Tolerances
Temperature in degrees Fahrenheit (°F) of return and supply wetbulb and drybulb and outdoor condenser entering air	4-channel temperature data loggers with 10K thermisters. Calibration of wetbulb and drybulb temperatures were checked using sling psychrometers	Data logger: ± 0.1°F Thermisters: ± 0.2°F Sling psychrometer: ± 0.2°F (wetbulb and drybulb)
Pressure in pounds per square inch (psi) of vapor and suction line	Compound pressure gauge for R22 and R410a	Refrigerant pressure: ± 2 % for R22 and ± 3 percent for R410a
Temperature (°F) of vapor and suction lines	Digital thermometer with clamp-on insulated type K thermocouples	Digital thermometer: ± 0.1°F Type K thermocouple: ± 0.1% °F
Temperature (°F) of actual and required superheat and subcooling	Digital thermometer with clamp-on insulated type K thermocouples	Digital thermometer: ± 0.1°F Type K thermocouple: ± 0.1% °F
Airflow in cubic feet per minute (cfm) across air conditioner evaporator coil	Digital pressure gauge and fan-powered flow hood, flow meter pitot tube array, and electronic balometer	Fan-powered flowhood: ± 3% Flow meter pitot tube array: ± 7% Electronic balometer: ± 4%
Ounces (oz.) of refrigerant charge added or removed	Digital electronic charging scales	Electronic scale: ± 0.5 ounces or ± 0.1% whichever is greater
Total power in kilowatts (kW) of air conditioner compressor and fans	True RMS 4-channel power data loggers and 4-channel power analyzer	Data loggers, CTs, PTs: ± 1% Power analyzer: ± 1%

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.[6] EER was derived 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 any 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 6 to 15.5.[7] Billing data for most sites was collected for a three year period from January 2001 through December 2003. These data were used to develop annual energy savings.

---

[5] EER is the cooling capacity in thousand British Thermal Units per hour (kBtuh) divided by total air conditioner electric power (kW) including indoor fan, outdoor condensing fan, compressor, and controls. The Btu is the energy required to raise one pound of water one degree Fahrenheit. EER values are typically measured under laboratory conditions of 95°F condenser entering air and 80°F drybulb and 67°F wetbulb evaporator entering air.

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

[7] SEER is an adjusted rating based on steady-state EER measured at standard conditions of 82°F outdoor and 80°F drybulb/67°F wetbulb indoor temperature multiplied by the Part Load Factor with a default of 0.875 (ARI 2003).

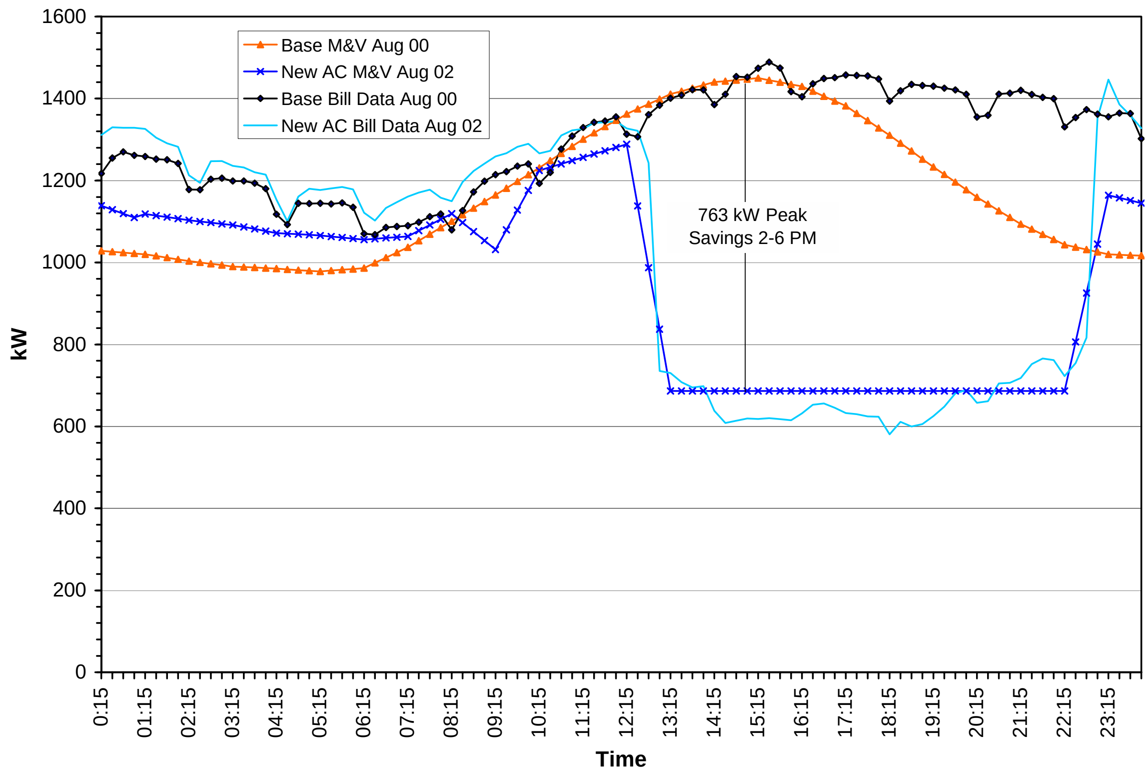
2.2 Findings of Field Measurements

Field measurements were made 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 efficiency air conditioners or GSHP units and chillers. The measurement sample included chillers, cooling towers, controls, large packaged units (greater than 15 tons), small packaged units (less or equal to 15 tons), and GSHP units (from in the 1.5 to 5.5 tons).

2.2.1 Findings for C&I Custom HVAC Projects

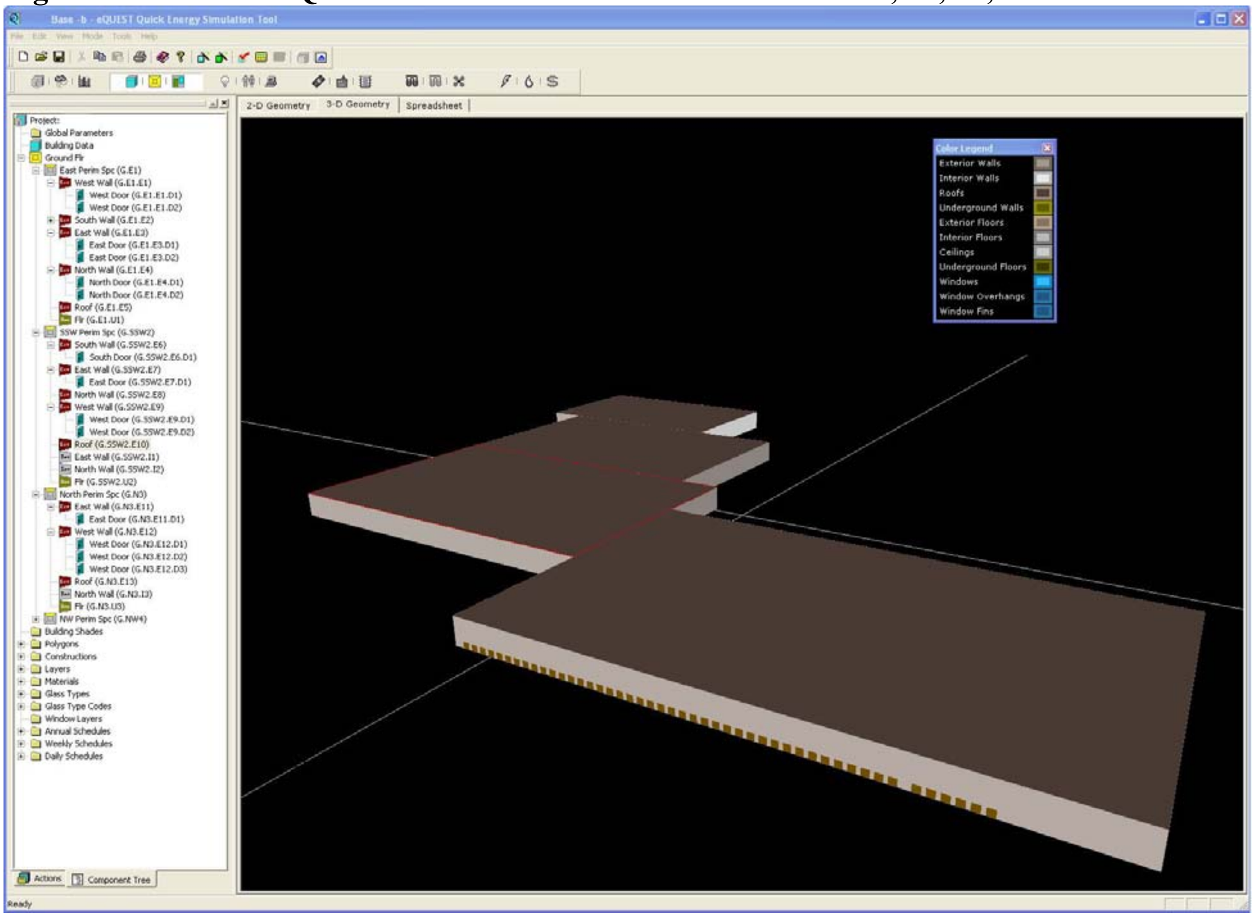
Seven large custom projects accounted for 84 percent of total ex ante kWh savings and 75 percent of peak demand savings for the SB5X C&I HVAC Incentive Programs (see Appendices B through G). This study evaluated 6 out of 7 of the large custom projects. Data loggers were installed at these sites to measure peak demand and energy use for chillers, cooling towers, controls, and 24 large packaged units (greater than 15 tons). Peak kW savings are based on 15-minute kW measurements of pre- and post-retrofit conditions as shown in **Figure 2.1** for the thermal storage project at Site #2. This site provided 33 percent of the total M&V savings.

Figure 2.1 Measurements of Thermal Storage Peak kW Savings for Custom Site #2



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. The DOE-2,2/eQuest 3-D model for site #2 is shown in **Figure 2.2**.

Figure 2.2 DOE-2.2/eQuest 3-D Model for Site #2 Warehouses #1, #2, #3, and #4



Baseline cooling and M&V savings values for MID custom projects are summarized in **Table 2.3**. Baseline cooling and M&V savings for custom projects in Palo Alto and TDPUD are summarized in **Tables 2.4** and **2.5**. The measure effective useful life (EUL) is 15 years for high efficiency chillers, evaporative pre-coolers, thermal storage, and chiller tower optimization.[8]

Table 2.3 MID Baseline Cooling and M&V Savings for C&I Custom HVAC Projects

Site	Base Cooling (kWh/yr)	Tons	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option or Report
1	21,278,898	425	Evaporative Pre-cooler	531,250	130	453,792	60	Appendix B
2	4,035,000	1,000	Thermal Storage	730,276	514	747,600	763	Appendix C
3	18,524,071	1,900	CTO Optimization	221,037	90	201,453	51	Appendix D
4	16,075,501	2,400	CTO Optimization	100,295	55	270,915	87	Appendix E
Total	**59,913,470**			**1,582,858**	**789**	**1,673,760**	**961**	
90% CI						108,198	75.98	

[8] See *Energy Efficiency Policy Manual*, Chapter 4, page 21-22, prepared by the California Public Utilities Commission, 2001.

Table 2.4 Palo Alto Baseline Cooling and M&V Savings for C&I Custom HVAC Project

Site	Base Cooling (kWh/yr)	Tons	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option or Report
56	5,345,061	3,200	High Eff. VFD Chillers	2,776,800	960	1,473,327	815	Appendix F
90% CI						177,678	137.56	

Table 2.5 TDPUD Baseline Cooling and M&V Savings for C&I Custom HVAC Project

Site	Base Cooling (kWh/yr)	Tons	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option or Report
57	3,188,738	370	High Eff. VFD Chiller	229,166	87	305,628	116	Appendix G
90% CI						87,481	2.62	

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 M&V evaluation verified the Port of Oakland ex ante savings of 250,000 kWh/yr and 60 kW, and these values were accepted as the ex post savings.

2.2.2 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 2.6**.

Table 2.6 Measured kW Values for Packaged Air Conditioners

Site	Cooling Capacity Tons	SEER or EER	Baseline kW	Average Measured kW	kW Savings	Indoor Dry/Wetbulb & Outdoor Temperature °F
16	2	15.5 GSHP	2.8	1.77	1.03	80/67/95
35	2	12	2.82	2.26	0.56	80/67/95
36	2	12	2.82	2.14	0.68	80/67/95
15	2.5	15.5 GSHP	3.5	2.21	1.29	80/67/95
40	3	13	4.14	3.21	0.93	80/67/95
17	3	15.5 GSHP	4.1	2.67	1.43	80/67/95
37	4	11	5.4	5.14	0.26	80/67/95
54	4	12	5.4	4.96	0.44	80/67/95
55	4	13	5.4	4.25	1.15	80/67/95
21	4	15.5 GSHP	5.38	3.72	1.66	80/67/95
38	5	11	6.82	6.2	0.62	80/67/95
39	5	12	6.82	5.885	0.935	80/67/95
33	5	12	7.26	6.47	0.79	80/67/103
34	5	12	6.673	5.785	0.888	80/67/92
33	5	13	6.82	5.76	1.06	80/67/95
34	5	13	6.8	5.69	1.11	80/67/95

Table 2.6 Measured kW Values for Packaged Air Conditioners

Site	Cooling Capacity Tons	SEER or EER	Baseline kW	Average Measured kW	kW Savings	Indoor Dry/Wetbulb & Outdoor Temperature °F
35	5	13	6.82	5.55	1.27	80/67/95
36	5	13	6.82	5.538	1.282	80/67/95
37	5	13	6.82	5.571	1.249	80/67/95
27	5	15.5 GSHP	6.8	4.74	2.06	80/67/95
32	7	10.3	8.90	8.02	0.87607	80/67/95
32	10	10.3	13	11.68	1.32	80/67/95
32	10	10.3	13	11.779	1.221	80/67/95
31	10	10.3	13	11.44	1.56	80/67/95
32	15	9.7	20.4	18.67	1.73	80/67/95
47	15	9.7	20.4	18.89	1.51	80/67/95
72	5	10	6.33	5.93	Non-part.	80/67/85
72	5	10	6.655	6.335	Non-part.	80/67/92
73	10	8.9	13	14.57	Non-part.	80/67/103
73	10	8.9	13.3	15.132	Non-part.	80/67/105

Average measured versus calculated kW savings from manufacturer data are shown in **Table 2.7**. Savings range from 0.32 kW for a 2 ton 11-SEER unit to 1.26 kW for a 5 ton 15-SEER conventional unit with maximum savings of 2.1 kW for GSHP units.

Table 2.7 Measured versus Calculated kW Savings for Packaged Units ≤ 5 tons

	Measured kW Baselines and Savings					Calculated kW from Manufacturer Data				
Tons	Baseline 10 SEER kW	11 SEER ΔkW	12 SEER ΔkW	13 SEER ΔkW	GSHP 15.5 EER ΔkW	Baseline 10 SEER kW	11 SEER ΔkW	12 SEER ΔkW	13 SEER ΔkW	GSHP 15.5 EER ΔkW
2	2.8		0.62		1.03	2.82	0.32	0.61	0.79	1.03
2.5	3.8				1.29	3.32	0.25	0.48	0.7	1.29
3	4.1			0.92	1.43	4.14	0.33	0.64	0.93	1.55
3.5	n/a					4.77	0.38	0.74	1.04	1.61
4	5.1	0.26	0.44	1.12	1.66	5.4	0.23	0.45	1.15	1.66
5	6.8	0.62	0.87	1.23	2.06	6.82	0.44	0.85	1.26	2.1

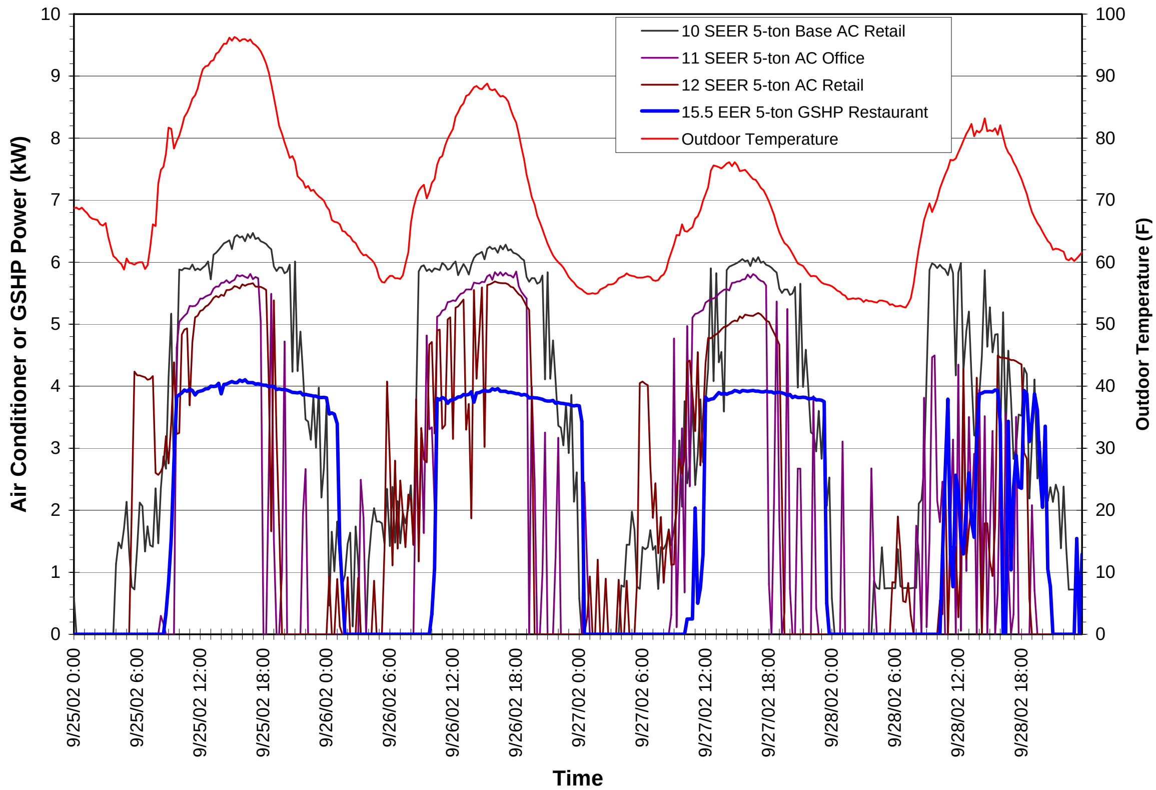
Average estimated peak kW savings for 7, 10, and 15 ton properly installed packaged AC units are shown in **Table 2.8**. Savings range from 0.88 kW for a 7 ton 10.3 EER unit to 4.34 kW for a 15 ton 10.8 EER unit.

Table 2.8 Measured versus Calculated kW Savings for Packaged Units >5 tons

	Measured kW Baselines and Savings			Calculated kW from Manufacturer Data		
Tons	Baseline 8.9 EER kW	10.3 EER ΔkW	11.0 EER ΔkW	Baseline 8.9 EER kW	10.3 EER ΔkW	11.0 EER ΔkW
7	8.65	0.88		8.7	1.26	1.73
10	13	1.37		3.32	1.77	2.09
Tons	Baseline 8.5 EER kW	9.7 EER ΔkW	10.8 EER ΔkW	Baseline 8.5 EER kW	9.7 EER ΔkW	10.8 EER ΔkW
15	20.4	1.62		20.7	2.52	4.34

Average measured savings are based on short-term measurements of standard and energy efficient air conditioners and GSHP units as shown in **Figure 2.3**. These measurements were made on units with proper refrigerant charge and airflow within manufacturers' specifications.

Figure 2.3 Measurements of 5-ton Packaged AC and Ground Source Heat Pump Units



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 calibration 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 M&V savings values for MID are summarized in **Table 2.9**. Baseline cooling and M&V savings for GSHP units in PSREC are summarized in **Table 2.10**. Baseline cooling and M&V savings values for Roseville are summarized in **Table 2.11**. The ex ante effective useful life for high efficiency packaged air conditioners is 15 years.[9]

[9] See *Energy Efficiency Policy Manual*, Chapter 4, page 21-22, prepared by the California Public Utilities Commission, 2001.

Table 2.9 MID Baseline Cooling and M&V Savings for Packaged HVAC Units

Site	Base Cooling (kWh/yr)	Tons	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option
5	1,620	2.5	12 SEER Pkg. AC	348	0.4	336	0.48	B, C, D
6	2,571	5	13 SEER Pkg. AC	1071	1.22	593	1.26	B, C, D
7	1,493	3	12 SEER Pkg. AC	418	0.47	249	0.64	B, C, D
98	2,684	2	12 SEER Pkg. AC	278	0.32	447	0.61	B, C, D
9	2,617	5	12 SEER Pkg. AC	696	0.79	436	0.85	B, C, D
10	4,212	5	12 SEER Pkg. AC	676	0.79	702	0.85	B, C, D
11	4,774	3	12 SEER Pkg. AC	418	0.47	796	0.64	B, C, D
12	7,264	5	12.5 SEER Pkg. AC	891	1.01	1,453	0.85	B, C, D
13	3,218	4	12 SEER Pkg. AC	557	0.63	536	0.45	B, C, D
14	3,977	2.5	12 SEER Pkg. AC	348	0.4	663	0.48	B, C, D
Average	**3,443**			**570**	**0.65**	**621**	**0.71**	
90% CI	940			143	0.16	185	0.14	

Table 2.10 PSREC Baseline Cooling and M&V Savings for GSHP Units

Site	Base Cooling (kWh/yr)	Tons	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option
15	15,260	2.5	15.5 SEER GSHP	16,001	3.96	6,012	1.29	B, C, D
16	12,208	2	15.5 SEER GSHP	16,001	3.96	4,809	1.03	B, C, D
17	18,312	3	15.5 SEER GSHP	16,001	3.96	7,214	1.55	B, C, D
18	9,156	1.5	15.5 SEER GSHP	16,001	3.96	3,607	0.77	B, C, D
19	9,156	1.5	15.5 SEER GSHP	16,001	3.96	3,607	0.77	B, C, D
20	18,312	3	15.5 SEER GSHP	16,001	3.96	7,214	1.55	B, C, D
21	24,416	4	15.5 SEER GSHP	16,001	3.96	9,618	1.66	B, C, D
22	18,312	3	15.5 SEER GSHP	16,001	3.96	7,214	1.55	B, C, D
23	18,312	3	15.5 SEER GSHP	16,001	3.96	7,214	1.55	B, C, D
24	24,416	4	15.5 SEER GSHP	16,001	3.96	9,618	1.66	B, C, D
25	18,312	3	15.5 SEER GSHP	16,001	3.96	7,214	1.55	B, C, D
26	11,191	1.83	15.5 SEER GSHP	16,001	3.96	4,408	0.95	B, C, D
27	29,503	5	15.5 SEER GSHP	16,001	3.96	11,622	2.10	B, C, D
28	2,236	5.5	15.5 SEER GSHP	16,001	3.96	881	2.31	B, C, D
29	1,898	4.67	15.5 SEER GSHP	16,001	3.96	748	1.95	B, C, D
30	2,236	5.5	15.5 SEER GSHP	16,001	3.96	881	2.31	B, C, D
Average	**14,577**			**16,001**	**3.96**	**5,743**	**1.53**	
90% CI	3,516					1,385	0.21	

Table 2.11 Roseville Baseline Cooling and M&V Savings for Packaged HVAC Units

Site	Base Cooling (kWh/yr)	Tons	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option
31	95,864	10	10.3 EER Pkg. AC	3,970	3.97	3,284	0.47	B, C, D
32	20,496	10	10.3 EER Pkg. AC	4,339	3.34	1,254	0.47	B, C, D
33	17,050	5	13 SEER Pkg. AC	2,698	3.36	1,616	0.61	B, C, D
34	19,837	3	13 SEER Pkg. AC	2,698	3.36	763	0.93	B, C, D
35	2,805	2	12 SEER Pkg. AC	1,060	1.06	468	0.93	B, C, D
36	2,805	2	12 SEER Pkg. AC	1,060	1.06	468	0.93	B, C, D
37	3,726	5	11 SEER Pkg. AC	2,650	2.65	339	0.93	B, C, D
38	2,981	4	11 SEER Pkg. AC	2,650	2.12	271	0.93	B, C, D
39	20,906	5	12 SEER Pkg. AC	2,128	2.65	3,484	0.64	B, C, D
40	3,737	3	13 SEER Pkg. AC	1,950	1.63	652	0.23	B, C, D
41	4,983	4	13 SEER Pkg. AC	2,600	2.17	869	1.15	B, C, D
42	6,229	5	13 SEER Pkg. AC	3,250	2.71	1,086	0.45	B, C, D
43	6,229	5	13 SEER Pkg. AC	3,250	2.71	1,086	1.26	B, C, D
44	6,229	5	13 SEER Pkg. AC	3,250	2.71	1,086	0.44	B, C, D
45	6,229	5	13 SEER Pkg. AC	3,250	2.71	1,086	0.85	B, C, D
46	18,686	15	9.7 EER Pkg. AC	9,749	8.14	3,259	1.26	B, C, D
47	18,686	15	9.7 EER Pkg. AC	9,749	8.14	3,259	1.26	B, C, D
48	2,317	3	13 SEER Pkg. AC	740	0.74	535	1.26	B, C, D
49	26,153	3	13 SEER Pkg. AC	2,020	2.02	6,035	1.26	B, C, D
50	4,146	3	13 SEER Pkg. AC	1,480	1.48	957	1.26	B, C, D
51	1,221	2	12 SEER Pkg. AC	838	0.70	203	1.77	B, C, D
52	2,944	3	12 SEER Pkg. AC	1,590	1.59	491	1.77	B, C, D
53	6,667	5	13 SEER Pkg. AC	3,360	3.36	1,539	2.52	B, C, D
54	5,526	4	12 SEER Pkg. AC	4,024	2.12	921	2.52	B, C, D
Average	**12,769**			**3,098**	**2.77**	**1,459**	**1.09**	
90% CI	6,610			784	0.64	482	0.20	

2.2.3 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 pre- and post-retrofit Normalized Annual Consumption (NAC) and Normalized Annual Cooling Consumption (NACC). The average NAC savings are negative as shown in **Table 2.12**. According to IPMVP Option C, the estimated annual energy savings must be greater than or equal to 10 percent of the total building annual consumption to be separated from the noise. Only site 70 met this requirement. Therefore, a combination of billing analyses, field measurements, and engineering analyses were used to evaluate energy savings for HVAC tune-ups.

Table 2.12 NAC and Ex Ante Savings for 11 Sites with HVAC Tune-up Measures

Site	Pre NAC kWh/yr	Post NAC kWh/yr	NAC Savings kWh/yr	Ex Ante Savings kWh/yr	Savings as % of Base NAC	Savings >10% of NAC per IPMVP Option C?
61	305,703	323,116	-17,413	2,080	0.7%	No
62	76,469	81,062	-4,594	2,600	3.4%	No
63	15,537	14,255	1,282	1,040	6.7%	No
64	22,668	19,447	3,221	520	2.3%	No
65	10,071	10,051	20	520	5.2%	
66	648,545	693,052	-44,507	5,200	0.8%	No
67	35,913	35,787	126	520	1.4%	No
68	57,818	59,443	-1,625	1,560	2.7%	No
69	12,666	16,119	-3,452	520	4.1%	No
70	3,884	3,610	274	520	13.4%	
71	32,065	30,806	1,260	1,040	3.2%	No
Ave.	**186,910**	**196,278**	**-9,367**	**1,473**	**0.8%**	**No**

An engineering estimate of the percentage savings for 22 HVAC tune-up measures at 11 sites are provided in **Table 2.13**. The estimated savings for refrigerant charge adjustments are based on the ratio of the absolute value of the refrigerant charge adjustment in ounces divided by the factory charge in ounces according to the following equation.

Eq. 1 $$\%_{\text{Charge Savings}} = \frac{\text{ABS}[\Delta \text{ Oz.}]}{\text{Factory Oz.}}$$

The estimated ex ante savings for airflow adjustments were assumed to be 5%, if the airflow adjustment was recorded and zero if no airflow adjustment was recorded in the tracking database.[10] The HVAC tune-up savings per unit were calculated using the following equation.

Eq. 2 $$\%_{\text{Tune-up Savings}} = 1 - \{(1 - \%_{\text{Charge Savings}}) \times (1 - \%_{\text{Airflow Savings}})\}$$

These values were multiplied times the normalized annual cooling consumption at each site to develop ex post kWh savings for the sample according to the following equation.

Eq. 3 $$\text{kWh Savings}_{unit} = \text{NACC} \times \frac{\text{CAP}_i}{\sum_{i=1}^{n} \text{CAP}_i} \times \%_{\text{Tune-up Savings}_i}$$

Where,

i = i^{th} air conditioning unit at the site
N = Number of air conditioning units at the site
NACC = Normalized annual cooling consumption for the site
CAP_i = Cooling capacity of each air conditioning unit at the site.

[10] The 5% savings for airflow adjustments is based on multiplicative difference of the ex ante savings per measure of 17% minus the ex ante savings of 12.5% for refrigerant charge adjustments. Note that the airflow adjustments are less likely to deliver persistent savings due to filters getting dirty and registers being adjusted or closed. Ex post savings of 5% are assumed for any reported airflow adjustment in the database in spite of these potential problems.

Table 2.13 Engineering Estimate of Percentage Savings for HVAC Tune-up Measures

Site #	Capacity (tons)	Refrigerant Charge Adjustment Oz.	Airflow Adjustment	Refrigerant Charge Savings	Airflow Savings	HVAC Tune-up Savings
61	4	0		0.0%		0.0%
61	5	-9		5.9%		5.9%
61	10	-36		13.5%		13.5%
62	AC < 5T	-6	Open registers	5.9%	5.0%	10.6%
62	6	-18	Open registers	11.3%	5.0%	15.7%
62	6	2		1.3%		1.3%
63	6.25	12	Open registers	8.3%	5.0%	12.9%
64	5	-7	Open Registers, clean filter	4.0%	5.0%	8.8%
65	2.5	-2	Increase blower	2.5%	5.0%	7.4%
66	7.5	3	Open Registers	3.1%	5.0%	8.0%
66	10	-3		1.1%	5.0%	6.0%
66	7.5	-2		2.1%		2.1%
66	7.5	10		10.4%		10.4%
66	10	-10		4.3%		4.3%
67	5	-8	Increase blower, no filter	8.0%	5.0%	12.6%
68	AC < 5T	-6		6.3%		6.3%
68	AC < 5T	6		6.3%		6.3%
68	AC < 5T	0		0.0%		0.0%
69	3	-10		13.9%		13.9%
70	2.5	-16		26.7%		26.7%
71	2	2	Open Registers	2.3%	5.0%	7.2%
71	3.5	-10	Open Registers	10.0%	5.0%	14.5%
Ave.				**6.7%**		**8.8%**

Peak cooling savings estimates were calculated based on the minimum of the following two equations.

1) Peak demand-to-energy ratio (i.e., PDER) times the estimated kWh savings.[11]
2) Average peak demand for the air conditioner times a coincident diversity factor (i.e., CDF) times the refrigerant charge savings.[12]

Eq. 4

$$\text{kW Savings}_{unit} = \text{MIN}\left|\begin{array}{l} \dfrac{0.000647\ \text{kW}}{\text{kWh}} \times \text{kWh Savings}_{\text{unit}} \\ \\ \dfrac{\text{CAP}_{\text{i}}}{1{,}000 \times \text{EER}_{\text{i}}} \times \text{CDF} \times \%_{\text{Charge Savings}_{i}} \end{array}\right.$$

Where,

$PDER_i$ = Peak demand-to-energy ratio assumed to be 0.000647 kW/kWh for this study.
CDF_i = Coincident Diversity Factor assumed to be 0.85 for this study.
EER_i = Energy Efficiency Ratio at 95°F outdoor air temperature and 80°F return drybulb and 67°F return wetbulb temperature for each air conditioning unit.

[11] SCE Energy-Efficiency Potential Study, prepared by XENERGY, Inc., Oakland, CA, prepared for Southern California Edison Company, 1992.

[12] The field measurements generally found airflow adjustments improved capacity and EER and reduced run time (see Section 2.2.3.2). Airflow adjustments were not found to reduce peak kW unless low airflow caused icy evaporator coils. Therefore, only refrigerant charge savings were used to estimate peak kW savings.

Baseline cooling and M&V savings values are summarized in **Table 2.14**. Ex ante energy and peak demand savings are based on the average estimated efficiency improvement times the baseline values.[13] The ex post efficiency improvement was verified by conducting detailed on-site inspections at ten sites (see **Section 2.2.3.2)**. The average ex ante unit savings are 0.52 kW and 520 kWh/yr for air conditioners less than or equal to 5 tons, and 1.04 kW and 1,040 kWh/yr for air conditioners greater than 5 tons. The average M&V ex post unit engineering estimate of savings are 277 ± 79 kWh/yr and 0.17 ± 0.04 kW for air conditioners less than or equal to 5 tons, and 588 ± 194 kWh/yr and 0.32 ± 0.13 kW for units greater than 5 tons.

Table 2.14 NACC, Ex Ante, and M&V Savings for Roseville HVAC Tune-up Sites

Site	Base NACC kWh/yr	≤ 5 tons	> 5 tons	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option
61	7,966	1	1	1,560	1.56	690	0.45	B, C, D
62	17,100	1	2	2,600	2.6	1,523	0.99	B, C, D
63	2,905		1	1,040	1.04	375	0.24	B, C, D
64	6,071	1		520	0.52	534	0.35	B, C, D
65	1,584	1		520	0.52	117	0.08	B, C, D
66	52,579		5	5,200	5.2	3,176	2.06	B, C, D
67	3,797	1		520	0.52	478	0.31	B, C, D
68	8,278	2		1,040	1.04	348	0.22	B, C, D
69	2,578	1		520	0.52	358	0.23	B, C, D
70	1,297	1		520	0.52	346	0.22	B, C, D
71	3,223	2		1,040	1.04	384	0.25	B, C, D
≤ 5 tons	**2,609**	**11**		**520**	**0.52**	**277**	**0.17**	
90% CI	617					79	0.04	
> 5 tons	**8,162**		**9**	**1,040**	**1.04**	**588**	**0.32**	
90% CI	1905					194	0.13	

Note: Average savings for ≤ 5 tons excludes two units with zero savings at sites #61 and #68 (i.e., no adjustments).

2.2.3.1 Evaluation of Commercial HVAC Tune-up Program Database

The commercial HVAC tune-up program database was evaluated to: 1) determine how many refrigerant charge and airflow tune-up adjustments were made, and 2) verify the cooling capacity and factory refrigerant charge from manufacturers' data.[14] The findings of the program database evaluation are provided in **Tables 2.15** and **2.16**. The program reported 250 tune-ups on air conditioners less than or equal to 5 tons (or 60,000 Btu/hr of cooling capacity), and 43 tune-ups greater than 5 tons. The database contained 225 documented tune-ups where an adjustment was reported for either refrigerant charge, airflow, or both (i.e., 197 tune-ups ≤ 5 tons and 28 tune-ups > 5 tons). An engineering estimate of percentage savings for each of these types of adjustments were evaluated using equations provided earlier.

[13] The Roseville HVAC Tune-up program assumed a 17 percent average ex ante efficiency improvement based on Neme, C., Nadel, S., and Proctor, J. 1998. *National Energy Savings Potential from Addressing HVAC Installation Problems*, Vermont Energy Investment Corporation, prepared for US Environmental Protection Agency.

[14] Based on reported model numbers versus manufacturer model numbers for units greater than 5 tons, the factory charge was incorrectly reported for 18 units and the capacity was misreported for 16 units where 8 units were actually less than or equal to 5 tons.

Table 2.15 Evaluation of HVAC Tune-ups for Air Conditioners ≤ 5 tons

Description	Qty.	% Savings	Tons	Factory Charge Oz.	Charge Adjustment Oz.
Total Reported in Database	**250**	17.0%			
No Adjustments Reported in Database	61	0.0%	4.3	81.0	0.0
Refrigerant Charge Adjustment Only	48	9.2%	4.1	103.2	8.8
Air Flow Adjustment Only	35	5.0%	4.3	107.3	0.0
Refrigerant Charge and Airflow Adj.	114	14.8%	4.3	111.7	10.9
Total Adjusted Units	**197**	**11.7 ± 0.9%**	**4.2**	**108.9**	**10.2**

Table 2.16 Evaluation of HVAC Tune-ups for Air Conditioners > 5 tons

Description	Qty.	% Savings	Tons	Factory Charge Oz.	Charge Adjustment Oz.
Total Reported in Database	**43**	17.0%			
No Adjustments Reported in Database	7	0.0%	9.3	313.3	0.0
Refrigerant Charge Adjustment Only	13	4.6%	8.2	217.2	9.5
Air Flow Adjustment Only	3	5.0%	9.7	290.3	0.0
Refrigerant Charge and Airflow Adj.	12	9.6%	7.7	215.0	8.6
Total Adjusted Units	**28**	**6.8 ± 1.4%**	**8.1**	**224.1**	**9.0**

The average percent savings for units less than 5 tons is 11.7 ± 0.9%, and the average percentage savings for units greater than 5 tons is 6.8 ± 1.4%. The average annual cooling consumption for units less than or equal to 5 tons is 2,609 ± 617 kWh/yr and the average unit energy consumption for units greater than 5 tons was 8,162 ± 1,905 kWh/yr. These values can be used to develop another M&V estimate of average unit energy savings using the following equation.

Eq. 5 $$\text{kWh Savings}_{unit} = \text{NACC}_{\text{average}} \times \%_{\text{Tune-up Savings}_{\text{average}}}$$

Where,

$\text{NACC}_{\text{average}}$= Average normalized annual cooling consumption

Using equation 5, the average unit energy savings are 287 ± 68 kWh/yr for units less than or equal to 5 tons, and 555 ± 42 kWh/yr for units greater than 5 tons. These values are within 3 to 6 percent of the ex post unit savings shown in **Table 2.14** (i.e., of 277 ± 79 kWh/yr for units less than or equal to 5 tons, and 588 ± 194 kWh/yr for units greater than 5 tons. The savings values from **Table 2.14** are normalized on a per unit basis (e.g., kWh/ton or kW/ton) to allow clearer interpretation of the data and develop ex post program savings. Normalized ex ante and M&V ex post cooling savings are summarized in **Table 2.17**.

Table 2.17 Normalized Ex Ante and M&V Savings for Roseville HVAC Tune-ups

Site	Base NACC kWh/yr-ton	≤ 5 tons	> 5 tons	Ex Ante Savings kWh/yr-ton	Ex Ante Savings kW/ton	M&V Savings kWh/yr-ton	M&V Savings kW/ton	IPMVP Option
61	531.1	5.0	10.0	104.0	0.104	46.0	0.030	B, C, D
62	830.8	4.0	16.6	126.3	0.126	74.0	0.048	B, C, D
63	464.8		6.3	166.4	0.166	60.0	0.038	B, C, D
64	1,214.2	5.0		104.0	0.104	106.8	0.070	B, C, D
65	633.6	2.5		208.0	0.208	46.8	0.032	B, C, D
66	1,237.2		42.5	122.4	0.122	74.7	0.048	B, C, D
67	759.4	5.0		104.0	0.104	95.6	0.062	B, C, D
68	1,034.8	8.0		130.0	0.130	43.5	0.028	B, C, D
69	859.3	3.0		173.3	0.173	119.3	0.077	B, C, D
70	518.8	2.5		208.0	0.208	138.4	0.088	B, C, D
71	586.0	5.5		189.1	0.189	69.8	0.045	B, C, D
≤ 5 tons	**809.95**	**3.7**		**141.2**	**0.141**	**80.2**	**0.049**	
90% CI	116.77					16.7	0.011	
> 5 tons	**989.93**		**8.4**	**124.2**	**0.124**	**72.2**	**0.039**	
90% CI	177.94					22.7	0.015	

The average gross realization rates for the HVAC tune-up sites are shown in **Table 2.18**, and the M&V gross ex post savings are shown in **Table 2.19**.

Table 2.18 Average Gross Realization Rates for HVAC Tune-up Sites

NCPA Utility	Qty. tons	Ex Ante kWh/yr-ton	Ex Ante kW/ton	M&V kWh/yr-ton	M&V kW/ton	AGRR kWh/yr-ton	AGRR kW/ton
Roseville AC Tune-up ≤5 tons	40.5	141.23	0.141	80.21	0.049	0.567911	0.344005
Roseville AC Tune-up >5 tons	75.35	124.22	0.124	72.19	0.039	0.581133	0.313942

Table 2.19 M&V Gross Ex Post Savings for Roseville HVAC Tune-up Sites

NCPA Utility	Qty.	Ex Ante Savings kWh/y	Ex Ante Savings kW	AGRR kWh/yr-ton	AGRR kW/ton	M&V Gross Ex Post Savings kWh/y	M&V Gross Ex Post Savings kW
Roseville AC Tune-up <5 ton	1,096.1	130,000	130.0	0.567911	0.344005	73,828	44.7
Roseville AC Tune-up >5 ton	292.6	44,720	44.7	0.581133	0.313942	25,988	14.0
Total	**1,388.7**	**174,720**	**174.7**	**0.571291**	**0.336005**	**99,816**	**58.7**

The M&V ex post program savings are 99,816 ± 22,623 kWh/yr and 58.7 ± 14.7 kW. 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 0.33 ± 0.08 for kW savings. 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 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.

2.2.3.2 Evaluation of Efficiency Improvement for Commercial HVAC Tune-ups

The Roseville commercial HVAC tune-up program assumed an average efficiency improvement of 17 percent based previous studies.[15] This assumption was evaluated using billing analysis, refrigerant charge and airflow adjustments in program tracking database, and detailed on-site

[15] Ibid.

inspections at ten sites. Several studies indicate approximately 50 to 67 percent of air conditioners have improper refrigerant charge and airflow (RCA), and found this reduces efficiency by roughly 10 to 20 percent.[16] Finding from the on-site inspections found 80 percent of units had improper RCA consistent with the program database showing 77 percent of units required an adjustment (i.e., 225 out of 293 units). Measurements of refrigerant charge and airflow, kW, capacity, and EER were made on ten packaged units to evaluate HVAC tune-ups. The relative efficiency gains due to proper refrigerant charge and airflow for a random sample of ten packaged air conditioners are shown in **Table 2.20**. Sites labeled "n/c" were not checked due to insufficient time or customer refusal. Site #33 had an efficiency gain of 90.7% due to 7.1 percent overcharge and dirty/icy evaporator coil. Excluding this outlier site, yields an average efficiency gain of 8.6 ± 3.5 percent for the sample. This is consistent with the average ex post efficiency improvement of 8.8 ± 2.2 percent shown in **Table 2.13**.

Measurements of EER were made at non-standard temperature conditions (i.e., not at 95°F outdoor temperature or 80°F dry-bulb/67°F wet-bulb inlet conditions). The absolute EER measurements are not directly comparable to laboratory measurements of EER at standard conditions where airflow, return air temperatures, and condenser entering air temperatures are carefully controlled. The relative efficiency gains shown in **Table 2.20** are applicable to normal operating conditions since laboratory studies indicate the change in EER (as a function of airflow and charge) is independent of operating conditions.

Table 2.20 EER Measurements and Efficiency Gain for Packaged Air Conditioners

Site	Tons	Factory Charge oz.	Charge Adjust +Add -Remove	Rated SEER/ EER	Pre-EER	Post-EER	Relative Efficiency Gain	Average Outdoor Temp °F	Airflow cfm/ton	Notes
32	10	323	Okay	11	10.4	n/a	n/a	74	280	New Unit
33	10	200	-7.1%	10.3	5.4	10.3	90.7%	83	383	New Iced Coil
34	5	192	13.8%	13	9	10.1	12.2%	98	296	New Unit
37	2	85	-3.5%	12	9.1	9.4	3.3%	95	409	New Unit
44	5	156	3.8%	13	10.7	11	2.8%	70	366	New Unit
45	5	156	4.9%	13	10.6	11	3.8%	70	327	New Unit
47	15	n/a	Okay	10.8	n/a	n/a	n/a	70	n/a	New Unit
55	4	166	-9.4%	11	8.6	9.3	8.1%	70	255	New Unit
59	5	126	13.7%	n/a	6.2	7	12.9%	72	289	Old Unit
60	10	250	13.8%	n/a	5.6	6.5	16.1%	72	366	Old Unit
Ave	**7.1**	**184**	**8.8%**	**11.8**	**8.4**	**9.3**	**8.6%**	**77.4**	**330**	Excl. Site 33

The uncertainty associated with field measurements of capacity and EER was evaluated using the propagation of error technique including the following factors: sensor accuracy; recording system accuracy; data display or recording resolution; and sampling error.[17] The uncertainty

[16] Downey, T., Proctor, J. 2002. "What Can 13,000 Air Conditioners Tell Us?" In the *Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings*. 1:53-67. Washington, D.C.: American Council for an Energy-Efficient Economy. Rodriguez, A. 1995. *The Effect of Refrigerant Charge, Duct Leakage, and Evaporator Air Flow on the High Temperature Performance of Air Conditioners and Heat Pumps*, Palo Alto, Calif.: Electric Power Research Institute.

[17] American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE). 2002. *ASHRAE Guideline 14-2002 – Measurement of Energy and Demand Savings*. Atlanta, Ga.: American Society of Heating Refrigerating and Air-Conditioning Engineers. Hall, N., Barata, S., Chernick, P., Jacobs, P., Keating, K., Kushler, M., Migdal, L., Nadel, S., Prahl, R., Reed, J., Vine, E., Waterbury, S., Wright, R. 2004. *The California Evaluation*

associated with instrument error is ± 3.7 percent, and the measurement error is ± 4.6 percent. Therefore, the total uncertainty error is ± 5.9 percent and this is close to uncertainty errors reported in laboratory studies.[18]

Measurements of a 10-ton packaged rooftop air conditioner at site #33 are shown in **Figure 2.4** before and after an HVAC tune-up. The 10-ton unit had a dirty/icy evaporator coil and dirty air filters and was overcharged by 14.2 ounces or 7.1 percent of the factory charge of 200 ounces. The evaporator coil was cleaned/de-iced and new air filters were installed. Prior to performing the HVAC tune-up, the average efficiency was 5.7 EER, and average power usage was 13 kW. After performing the HVAC tune-up the efficiency improved to 10.3 EER, and the average power usage was reduced to 9.5 kW. This is consistent with the ARI rating of 10.3 EER.

Figure 2.4 Measurements of 10-ton Packaged Rooftop Air Conditioner at Site #33

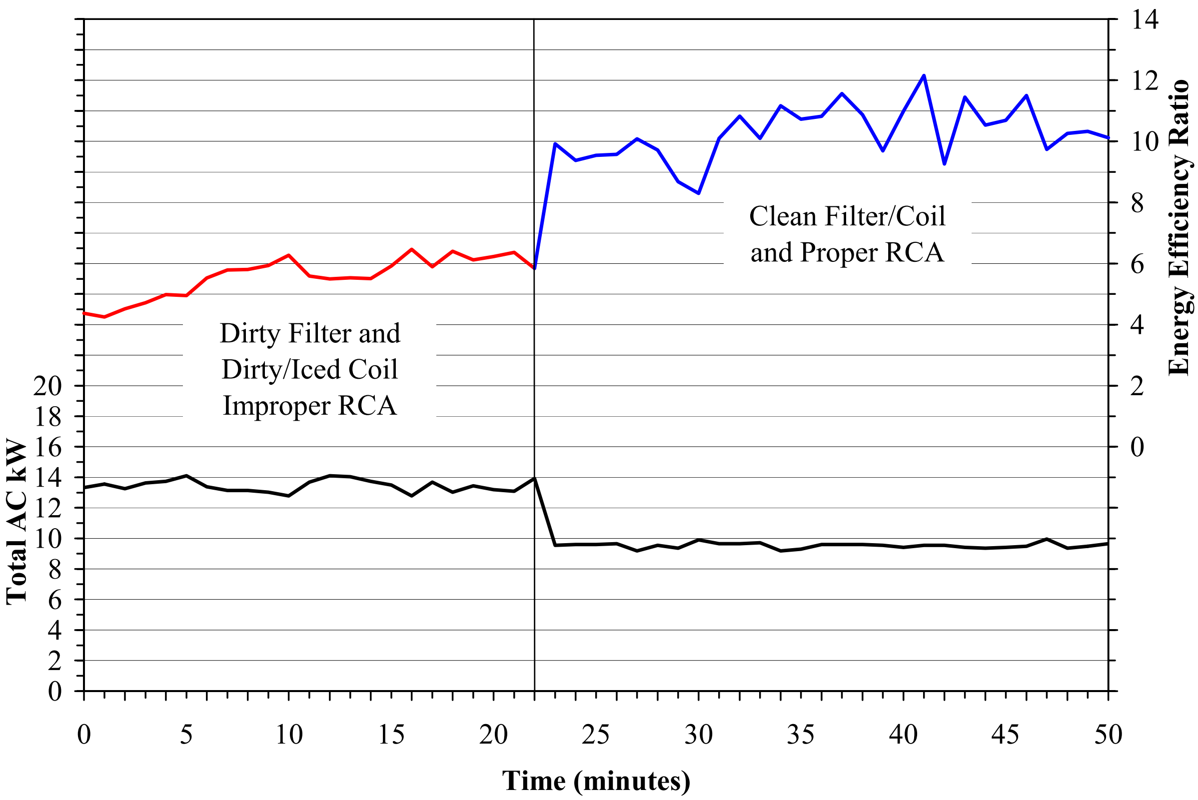


Figure 2.5 shows the technician measuring airflow and **Figure 2.6** shows the technician measuring temperature across the coil, kW, and EER. **Figure 2.7** shows the clean and dirty evaporator coil, and **Figure 2.8** shows the clean and dirty air filters.

Framework, Appendix to Chapter 7: 191-195. Uncertainty Calculation. San Francisco, Calif.: California Public Utilities Commission.

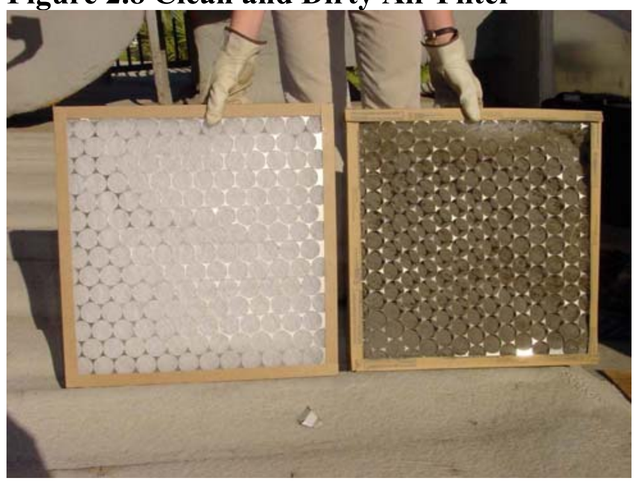
[18] Ibid.

Figure 2.5 Measuring Airflow

Figure 2.6 Measuring EER

Figure 2.7 Clean and Dirty Evaporator Coil

Figure 2.8 Clean and Dirty Air Filter



3. Participant Survey Results

This study used participant surveys to estimate the net-to-gross ratios for kWh and peak kW savings. Participant surveys were completed for 27 participants in nine NCPA utility service areas. This sample size exceeded the M&V plan of 20 sites, and included all of the custom sites accounting for more than 85 percent of the total M&V savings.

3.1 Participant Survey Methodology

Participant surveys were used to develop net-to-gross ratios (NTGRs) for calculating net kW and kWh savings. The net-to-gross ratio is used to estimate the fraction of free riders who would have otherwise implemented commercial or industrial air conditioning improvements in the absence of the program. Ten participant survey questions were used to assess net-to-gross ratios as shown in **Table 3.1**. The NTGR score for each completed participant survey is the average score based on answers to questions 2 through 10. No score was assigned to responses of "don't know", "refused to answer," or "other."

Table 3.1 Net-to-Gross Ratio Participant Survey Questions and Scoring

#	Question	Answer	Score
2	Did you understand the value of the program BEFORE or AFTER you installed the efficiency upgrades?	Before	1
		After	0
3	Did you install the high efficiency AC units BEFORE or AFTER you heard about the Rebate Program?	Before	0
		After	1
4	On a scale from 0 to 10, with 0 being no influence at all and 10 being very influential, how much influence did the Utility or Rebate have on your decision to install the efficiency upgrades?	0 to 10	0=0, 10=1
5	If the rebates had not been available, how likely is it you would have done exactly the *same* thing. Please use a scale from 0 to 10, with 0 being not at all likely and 10 being very likely.	0 to 10	0=1, 10=0
6	What role did the Utility Program play in your decision to install the upgrades?	1 = Reminded	0.25
		2 = Speeded Up (i.e., early replacement)	0.5
		3 = Showed Benefits Didn't Know Before	1
		4 = Clarified Benefits	0.75
		5 = No role	0
7	The Utility Program was nice but it was unnecessary to get the efficiency upgrades installed.	0 to 10	0=1, 10=0
8	The Utility Program was a critical factor in installing the efficiency upgrades.	0 to 10	0=0, 10=1
9	We would not have installed the efficiency upgrades without the Utility Program.	0 to 10	0=0, 10=1
10	If you had not received the [rebate or service] from the Utility, would you have installed upgrades?	Within 6 months	0
		< 1 year	0.125
		1 to 2 years	0.25
		2 to 3 years	0.5
		3 to 4 years	0.75
		4 or more years	1
		Never	1

3.2 Findings of the Participant Surveys

Findings of the participant surveys for each program are presented in **Table 3.2**. 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 statewide nonresidential Express Efficiency program that offers rebates for high efficiency air conditioners for commercial and industrial customers.[19]

Table 3.2 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 HVAC Tune-up ≤5 ton	250		44.72	0.019996	0.96			0.019196
Roseville HVAC Tune-up >5 ton	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**

A census was performed for Gridley, MID (Custom), Palo Alto, Port of Oakland, PSREC, TDPUD, and Ukiah. For the C&I high efficiency air conditioner programs a random participant sample was selected. The coefficient of variation was used to measure the sample size required to satisfy the 90 percent confidence level criteria for estimating mean net-to-gross ratios for the population (see Equations 9, 10, and 11, Section 4, below). For MID a survey sample of 5 yielded a 0.77 ± 0.09 NTGR with a Cv of 0.17 indicating a finite population corrected (FPC) sample of 7 to achieve 90% confidence and 10% relative precision (i.e., 90/10 criteria). For Roseville a survey sample of 14 yielded a 0.83 ± 0.07 NTGR with a Cv of 0.18 indicating a FPC sample of 8 to achieve 90/10 criteria. For TID a survey sample of 10 yielded a 0.79 ± 0.10 NTGR with a Cv of 0.24 indicating a FPC sample of 11 to achieve 90/10 criteria. The sample size for Roseville exceeded the 90/10 criteria, and the sample size for MID and TID exceeded the 85/15 criteria.

4. M&V Methodology

The M&V methodology for the metering and participant survey tasks are discussed above in **Sections 2** and **3**. The M&V methodology for sample design, statistical analysis, database tracking, baseline, and program evaluation savings estimates are discussed below.

[19] See *Energy Efficiency Policy Manual*, Chapter 4, page 23, prepared by the California Public Utilities Commission, 2001.

4.1 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.[20] Selecting participants for the sample was guided by the statistical sampling plan as well as input from NCPA 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/ton). Normalizing the savings allows clearer interpretation of the savings data. Considering each NCPA utility program within a program category as a stratum, the sample mean within a program was calculated using **Equation 6**.

Eq. 6 $$\text{Mean Savings} = \bar{y}_h = \frac{1}{N_h}\sum_{k=1}^{n} y_k$$

Where,

$\bar{y}_h$ = Mean savings, y, for stratum h.

N_h = Number of measures in stratum h.

y_k = M&V savings estimate for measure k.

The mean savings for each program category is based on the sample mean savings estimate across NCPA utility programs strata in the program category. The program category sample mean savings were calculated using **Equation 7**.

Eq. 7 $$\text{Program Category Sample Mean} = \bar{y}_p = \sum_{h=1}^{L} W_h \bar{y}_h$$

Where,

$\bar{y}_p$ = Program category sample mean savings estimate.

$W_h = \frac{N_h}{N_p}$ = Weighting factor across all strata.

N_p = Total number of measures across all strata in program category.

The variance, s_h^2, of the sample mean for a utility program stratum within a program category was calculated using **Equation 8**.

Eq. 8 $$s_h^2 = \frac{\sum_{k=1}^{n}\left(y_k - \bar{y}_h\right)^2}{N_h - 1}$$

The coefficient of variation (Cv) provides a relative measure of the sample size required to satisfy the 90/10 criteria (or 80/20 criteria) for estimating the mean of the population. The sample Cv for the utility program stratum was calculated using **Equation 9**.

[20] Cochran, William G. *Sampling Techniques*. New York: John Wiley & Sons, 1977, Kish, Leslie. *Survey Sampling*. New York: John Wiley & Sons, 1965. Thompson, Steven K. *Sampling*. New York: John Wiley & Sons, 1992.

Eq. 9 Sample Coefficient of Variation $= Cv_h = \dfrac{s_h}{\bar{y}_h}$

Where,

$s_h = \sqrt{s_h^2}$ = Standard deviation of the sample mean savings in stratum h.

The sample size necessary to obtain a desired level of relative precision for the utility program stratum mean savings estimate was calculated using **Equation 10**.

Eq. 10 Utility Program Stratum Sample Size $= n_h = \dfrac{t_o Cv_h^2}{r_h^2}$

Where,

$n_h =$ Sample size of the utility program stratum.

$r_h =$ Desired relative precision for the utility program stratum.

For small populations, the sample size was corrected using the finite population correction (FPC) equation as follows.[21]

Eq. 11 FPC Sample Size $= n_{FPC\,h} = \dfrac{n_h}{1 + (n_h - 1)/N_h}$

Where,

$n_{FPC\,h} =$ Sample size for stratum with finite population correction.

The utility program stratum error bound of $\bar{y}_h$ as an estimator of the mean value at the 90% level of confidence was calculated using **Equation 12**.

Eq. 12 Stratum Error Bound $= Eb(\bar{y}_h) = t_o \dfrac{s_h}{\sqrt{n_h}}$

Where,

$t_o =$ 1.645 at 90 percent level of confidence (1.28 at 80 percent confidence).

$n_h =$ Number of units in sample in stratum h.

An unbiased estimate of the program category variance was calculated using **Equation 13**.

Eq. 13 $s_p^2 = \sum_{h=1}^{L} \dfrac{W_h^2 s_h^2}{n_h} - \sum_{h=1}^{L} \dfrac{W_h s_h^2}{N_p}$

Where,

$s_p^2 =$ Variance of the program category mean savings estimate, $\bar{y}_p$.

The Cv for the program category was calculated using **Equation 14**.

[21] Cochran, William G. *Sampling Techniques*. New York: John Wiley & Sons, 1977, Kish, Leslie. *Survey Sampling*. New York: John Wiley & Sons, 1965. Thompson, Steven K. *Sampling*. New York: John Wiley & Sons, 1992.

Eq. 14 Program Category Coefficient of Variation $= Cv_p = \frac{s_p}{\bar{y}_p}$

Where,

$s_p = \sqrt{s_p^2}$ = Standard deviation of the mean savings in the program category.

Statistical analysis was used to extrapolate M&V ex post kW and kWh savings at the sample level for a utility program (stratum) 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 M&V samples or sites were summed and compared to ex ante savings to develop M&V Average Gross Realization Rates (AGRR) for kW and kWh savings. The M&V AGRR for kW and kWh savings were calculated using **Equations 15** and **16**.

Eq. 15 $$AGRR_{kW} = \frac{\sum_{j=1}^{n} kW\ Savings_{M\&V}}{\sum_{j=1}^{n} kW\ Savings_{Ex\ Ante}}$$

Where,

$AGRR_{kW}$ = Average Gross Realization Rate for kW savings defined as the sum of M&V kW savings for measures or sites in the random sample divided by the ex ante kW savings for measures or sites in the random sample.

Eq. 16 $$AGRR_{kWh} = \frac{\sum_{j=1}^{n} kWh\ Savings_{M\&V}}{\sum_{j=1}^{n} kWh\ Savings_{Ex\ Ante}}$$

Where,

$AGRR_{kWh}$ = Average Gross Realization Rate for kWh savings defined as the sum of M&V kWh savings for measures or sites in the random sample divided by the ex ante kWh savings for measures or sites in the random sample.

The gross M&V ex post program category savings were calculated as the sum of the ex ante program stratum savings times the respective M&V average gross realization rate (AGRR) as shown in **Equation 17**.

Eq. 17 $$\hat{Y}_p = \text{M\&V Gross Ex Post Program Category Savings} = \sum_{i=1}^{m} \left[\hat{X}_{p_i} \times AGRR_{p_i}\right]$$

Where,

$\hat{Y}_p$ = M&V gross ex post program category savings (kW or kWh).

$\hat{X}_{p_i}$ = Ex ante program stratum "i" savings (kW or kWh).

$AGRR_{p_i}$ = M&V average gross realization rate for program stratum "i." Defined as the sum of M&V savings for measures or sites in the random sample divided by ex ante savings for measures or sites in the random sample (kW or kWh).

The error bound for the program category is the square root of the sum of the squared error bounds for each of the utility program stratums and was calculated using **Equation 18**.[22]

Eq. 18 $$\hat{E}b(\bar{y}_p) = \sqrt{\sum_{i=1}^{m}\left[Eb\left(\bar{y}_{h_i}\right)\right]^2}$$

Where,

$\bar{y}_{h\,i}$ = M&V ex post sample mean savings for utility program stratum "i" within the program category.

The AGRR is combined with the Net-to-Gross Ratio (NTGR) to develop the Net Realization Rate (NRR) relative to planning. The net realization rates for kW and kWh savings were calculated using **Equations 19** and **20**.

Eq. 19 $$NRR_{kW} = NTGR \times AGRR_{kW}$$

Where,

NRR_{kW} = Net Realization Rate for kW savings.

NTGR = Net to Gross Ratio defined as the number of units that would not have been installed without the program divided by the total number of units installed through the program (kW or kWh).

Eq. 20 $$NRR_{kWh} = NTGR \times AGRR_{kWh}$$

Where,

NRR_{kWh} = Net Realization Rate for kWh savings.

Some statistics were calculated using other equations.[23]

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. 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.

---

[22] This result is a consequence of (a) the fact that the standard deviation of the difference between two statistically independent random variables (e.g., the standard savings of each program) is the square root of the sum of the squares of the standard deviations of each of the random variables, and (b) the error bound at the 90 percent level of confidence is 1.645 times the standard deviation. See Hall, N., Barata, S., Chernick, P., Jacobs, P., Keating, K., Kushler, M., Migdal, L., Nadel, S., Prahl, R., Reed, J., Vine, E., Waterbury, S., Wright, R. 2004. *The California Evaluation Framework*, Chapter 12: Uncertainty, pp. 280-306. San Francisco, Calif.: California Public Utilities Commission.

[23] Hall, N., Barata, S., Chernick, P., Jacobs, P., Keating, K., Kushler, M., Migdal, L., Nadel, S., Prahl, R., Reed, J., Vine, E., Waterbury, S., Wright, R. 2004. *The California Evaluation Framework*, San Francisco, Calif.: California Public Utilities Commission. Cochran, William G. *Sampling Techniques*. New York: John Wiley & Sons, 1977, Kish, Leslie. *Survey Sampling*. New York: John Wiley & Sons, 1965. Thompson, Steven K. *Sampling*. New York: John Wiley & Sons, 1992.

4.2 Database

Data for the C&I HVAC incentive programs were tracked and archived in the NCPA Tracking Database. Data for all programs of this type are summarized within the database for M&V sampling and reporting purposes. The tracking system data is based on reports provided by the respective utilities. The database includes general customer information, quantity and type of measures installed, make and model number, SEER/EER value, kW/ton, capacity (tons), and NCPA account number (if available). The database was updated on a quarterly basis with program activity sent electronically by utility program staff.

4.3 Baseline

The baseline kWh values are based on billing data and PRISM analyses. For custom HVAC measures the baseline was taken from monthly billing data normalized using DOE-2.2 analyses (see Appendices B through G). The baseline kW values are based on metering results for a random sample of new high efficiency air conditioners, chillers and custom measures (monthly kW from billing data), and old standard air conditioners or the appropriate baseline prior to retrofit of the custom measures (see **Section 2**). The sample mean baseline full-year unit energy consumption for the standard efficiency commercial packaged air conditioners was 4,366 ± 440 kWh/yr at the 90 percent confidence level. The sample mean baseline full-year unit energy consumption for the Roseville HVAC Tune-up program was 4,881 ± 1,287 kWh/yr at the 90 percent confidence level. The sample mean baseline kW varied from 3.01 ± 0.3 kW for 2 ton standard air conditioner to 6.4 ± 0.6 kW for 5-ton standard units. The baseline efficiency level for each measure was within the requirements of the Energy Policy Act of 1992 (EPACT). EPACT mandated minimum energy efficiency levels of cooling equipment manufactured for sale in the US. EPACT required states adopt codes at least as strict as ASHRAE /IES Standard 90.1-1989. These standards govern the minimum efficiency of packaged and split-system central air conditioners, packaged terminal air conditioners, and water and air-cooled chillers. Recent revisions to these standards and 2001 California Title 24 building codes were used to establish the baseline for each measure and/or site.

4.4 Program Evaluation Savings Estimates

Gross M&V program evaluation savings (i.e., kWh/yr and kW) are based on the Average Gross Realization Rates (AGRR) from the M&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 M&V 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 M&V 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. Methods used to develop net-to-gross ratios are described above in **Section 3**. The gross and net savings estimates obtained at the participant level are extrapolated to the population of program participants using the methods described above in **Section 4**. The weighted average gross realization rates for M&V custom, packaged AC, and GSHP and Tune-up sites are provided in **Tables 4.1**, **4.2**, and **4.3**.

Table 4.1 Average Gross Realization Rates for M&V Custom Sites

NCPA Utility	Qty. tons	Ex Ante kWh/yr-ton	Ex Ante kW/ton	M&V kWh/yr-ton	M&V kW/ton	AGRR kWh/yr-ton	AGRR kW/ton
MID Custom #1	425	1,250.00	0.306	1,067.75	0.141	0.854197	0.461538
MID Custom #2	1,000	730.28	0.514	747.60	0.763	1.023723	1.484436
MID Custom #3	1,900	116.34	0.047	106.03	0.027	0.911399	0.566667
MID Custom #4	2,400	41.79	0.023	112.88	0.036	2.701182	1.581818
Palo Alto Custom #56	2000	1,388.40	0.480	736.66	0.408	0.530584	0.848958
TDPUD Custom #57	370	619.37	0.235	826.02	0.314	1.333653	1.333333

Table 4.2 Average Gross Realization Rates for M&V Packaged AC Sites

NCPA Utility	Qty. tons	Ex Ante kWh/yr-ton	Ex Ante kW/ton	M&V kWh/yr-ton	M&V kW/ton	AGRR kWh/yr-ton	AGRR kW/ton
MID Packaged AC	37	154.08	0.176	167.55	0.192	1.087426	1.093846
Roseville Packaged AC	128	580.87	0.520	273.54	0.204	0.470913	0.392352

Table 4.3 Average Gross Realization Rates for M&V GSHP and HVAC Tune-up Sites

NCPA Utility	Qty. tons	Ex Ante kWh/yr-ton	Ex Ante kW/ton	M&V kWh/yr-ton	M&V kW/ton	AGRR kWh/yr-ton	AGRR kW/ton
PSREC GSHP	53	4,830.49	1.195	1,733.60	0.463	0.358887	0.387622
Roseville AC Tune-up ≤5 tons	40.5	141.23	0.141	80.21	0.049	0.567911	0.344005
Roseville AC Tune-up >5 tons	75.35	124.22	0.124	72.19	0.039	0.581133	0.313942

The MID savings per ton were used to develop engineering estimates of AGRR values for packaged AC incentive programs implemented by Gridley, Lodi, Redding, TID and Ukiah since these utilities are located in similar climate zones to MID (see **Table 4.4**).

Table 4.4 Average Gross Realization Rates for Other Packaged HVAC Programs

NCPA Utility	Qty. tons	Ex Ante kWh/yr-ton	Ex Ante kW/ton	M&V kWh/yr-ton	M&V kW/ton	AGRR kWh/yr-ton	AGRR kW/ton
Gridley	6	665.8	0.733	167.6	0.192	0.251642	0.262039
Lodi	24	50.0	0.054	167.6	0.192	3.351035	3.547609
Redding	119	320.2	0.357	167.6	0.192	0.523307	0.537838
TID	140	208.4	0.213	167.6	0.192	0.803964	0.902775
Ukiah	38	1,401.4	0.321	167.6	0.192	0.119556	0.598538

M&V gross ex post savings and realization rates for all utilities in the C&I HVAC program category are provided in **Table 4.5**.

Table 4.5 M&V Gross Savings and Realization Rates for C&I HVAC Programs

NCPA Utility	Qty. tons	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Gross Ex Post Savings kWh/yr	M&V Gross Ex Post Savings kW	AGRR kWh/yr	AGRR kW
Gridley	6	3,995	4.4	1,005	1.2	0.251642	0.262039
Lodi	24	1,200	1.3	4,021	4.6	3.351035	3.547609
MID	342	46,479	52.8	50,542	57.8	1.087426	1.093846
MID-Custom	5,725	1,582,858	789	1,673,760	961.0	1.057429	1.217997
Palo Alto-Custom	3,200	2,776,800	960	1,473,327	815.0	0.530584	0.848958
Port of Oakland-Custom	600	250,000	60	250,000	60.0	1.000000	1.000000
PSREC-GSHP	80	256,016	63.4	91,881	24.6	0.358887	0.387622
Redding	119	38,101	42.5	19,939	22.9	0.523307	0.537838
Roseville	456	203,288	205.3	95,731	80.5	0.470913	0.392352
Roseville AC Tune-up ≤5 tons	1,096	130,000	130	73,828	44.7	0.567911	0.344005
Roseville AC Tune-up >5 tons	293	44,720	44.7	25,988	14.0	0.581133	0.313942
TDPUD-Custom	370	229,166	87	305,628	116.0	1.333653	1.333333
TID	140	29,177	29.8	23,457	26.9	0.803964	0.902775
Ukiah	38	53,255	12.2	6,367	7.3	0.119556	0.598538
Total	12,488	5,645,055	2,482.40	4,095,475	2,236.46	0.725498	0.900927

Ex ante program savings are summarized in **Table 4.6**, and ex post savings are summarized in **Table 4.7**. 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 4.8**. 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 (see **Section 3.2**). The realization rates are 0.70 for kWh savings and 0.86 for kW savings. The M&V 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.

Table 4.6 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 AC Tune-up ≤5 ton	250	130,000	130.0	1	1	130,000	130.0
Roseville AC Tune-up >5 ton	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 4.7 M&V Ex Post Savings for NCPA SB5X C&I HVAC Incentive Programs

NCPA Utility	Qty.	M&V Gross Ex Post Savings kWh/y	M&V Gross Ex Post Savings kW	Net-to-Gross Ratio kWh/y	Net-to-Gross Ratio kW	M&V Net Ex Post Savings kWh/y	M&V 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
Port of 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
Roseville AC Tune-up <5 ton	250	73,828	44.7	0.96	0.96	70,875	42.9	0.55	0.33
Roseville AC Tune-up >5 ton	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 4.8 Ex Post Lifecycle Savings for NCPA SB5X C&I HVAC Incentive Programs

NCPA Utility	Qty.	M&V Net Ex Post Annual Savings kWh/yr	Effective Useful Lifetime	M&V 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 AC Tune-up <5 ton	250	70,875	8	567,003	118,245
Roseville AC Tune-up >5 ton	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.

Appendix A: NCPA C&I AC Decision-Maker Survey

Interview Instructions for Decision-Maker Survey

1. Purpose

The purpose of the Decision-Maker Survey is to obtain sufficient information to estimate the Net-to-Gross Ratio (NTGR).

2. Selection of Respondent

The **decision-maker** must be the person who decided to install or implement rebated measures.

3. Two Types of Sites

This survey will be used for two types of sites:

1. **On-Site M&V Only**. Sites that receive an on-site inspection for the M&V evaluation.
2. **Telephone Only**. Sites that only receive a telephone survey.

4. How to Start a Survey

Complete the following steps to start one of these surveys:

1. Review file information for the site (if available).
2. Make sure you understand what was installed prior to initiating the call or visit.
3. Contact the person and explain the purpose of the Survey. Tell them that the data provided by them will be kept strictly confidential and will not be shared with anyone.

C&I AC DECISION-MAKER SURVEY

Customer Name: ______________________	Date: ______________________
Business Name: ______________________	Contact: ______________________
Phone Number: ______________________	City: ______________________
Start Call Time: ______________________	End Call time: ______________________
Surveyor Initials: ______________________	Survey Completed: Y NA R WB BN
	Y = yes, NA = no answer, R = refused, WB = wrong business, BN = bad number

The purpose of the decision-maker survey is to obtain information necessary to calculate a net-to-gross ratio. You will need to interview the customer who was responsible for the decision to implement measures at the site. If this person is not available attempt to locate someone who is at least familiar with how that decision was made.

Introduction

Say: "Hello. My name is [**Anne**] and I am conducting a survey regarding the your participating in the energy efficiency programs funded with SB5X funds. Would you mind spending 5 minutes to answer a few questions?"

Begin Survey

1. When and how did you first learn about the Utility Program? [**Only ask this question <u>once,</u> for the first recommendation for each site.**]

   ____

   1 Didn't know there was a program (**Go to Q.3**)

2. Keeping that in mind, did you understand the value of the program BEFORE or AFTER you installed the efficiency upgrades? (**Circle One**)

   1 Before **2** After (**Go to Q.4**) **98** Don't Know **99** Refused to Answer

3. Did you install the high efficiency AC unit BEFORE or AFTER you heard about the Utility Rebate Program? (**Circle One**)

   1 Before **2** After **98** Don't Know **99** Refused to Answer

4. On a scale from 0 to 10, with 0 being no influence at all and 10 being very influential, how much influence did the Utility or Rebate have on your decision to install the efficiency upgrades?

   ___ Response (**0-10**) **98** Don't Know **99** Refused to Answer

5. If the rebates had not been available, how likely is it you would have done exactly the *same* thing. Please use a scale from 0 to 10, with 0 being not at all likely and 10 being very likely.

   ___ Response (**0-10**) **98** Don't Know **99** Refused to Answer

   Notes: ____

C&I AC DECISION-MAKER SURVEY (Continued)

Special Instruction for Contradictory Responses: If [**Q.4 is 0,1,2** *and* **Q.5 is 0,1,2**] *or* [**Q.4 is 8,9,10** *and* **Q.5 is 8,9,10**]. Probe for the reason. However, it is important not to communicate a challenging attitude when posing the question. For example, say,

When you answered "8" for the question about the influence of the rebate or service, I interpreted that to mean that the Utility Program was important to your decision. Then, when you answered "8" for how likely you would be to take the same action *without* the rebate or service, it sounds like the Utility was *not* very important. I want to check to see if I understand your answers or if the questions may have been unclear.

If they volunteer a helpful answer at this point, respond by changing the appropriate answer. If not, follow up with something like: "Would you explain in your own words, the role the Utility Program played in your decision to take this action?

If possible translate their answer into responses for **Questions 4** and **5** and check these responses with the respondent for accuracy. If the answer doesn't allow you to decide what answer should be changed, write the answer down and continue the interview.

Answer: ____

6. What role did the Utility Program play in your decision to install the upgrades [**describe implemented recommendation**]? [Prompt by reading list if the respondent has trouble answering.]

   1 Reminded us of something we already knew
   2 Speeded up process of what we would have done anyway (i.e., early replacement)
   3 Showed us the benefits of this action that we didn't know before
   4 Clarified benefits that we were *somewhat* aware of before
   5 Recommendation had no role
   6 Other ____
   98 Don't Know
   99 Refused to Answer

Say: Here are some statements that may be more or less applicable for your home about the Utility Program [**or recommendation**]. Please assign a number between 0 and 10 to register how applicable it is. A 10 indicates that you fully agree, and 0 indicates that you completely disagree.

7. The Utility Program was nice but it was unnecessary to get the efficiency upgrades installed.

   ___ Response (**0-10**) **98** Don't Know **99** Refused to Answer

8. The Utility Program was a critical factor in installing the efficiency upgrades.

   ___ Response (**0-10**) **98** Don't Know **99** Refused to Answer

C&I AC DECISION-MAKER SURVEY (Continued)

9. We would not have installed the efficiency upgrades without the Utility Program.

   ___ Response (**0-10**) **98** Don't Know **99** Refused to Answer

10. If you had not received the [rebate or service] from the Utility, would you have installed upgrades [**or other measures**]...

    1 ..within 6 months?

    2 ..6 months to 1 year?

    3 ..one to two years later?

    4 ..two to three years later?

    5 ..three to four years later?

    6 ..four or more years later?

    7 ..Never

    98 ..Don't Know - **Try less precise response, if still "don't know" use 98**

    8 ...less than one year?

    9 ...one year or more?

    99 ...Refused to Answer

    <u>Time relative to the installation date</u>. For customers with more than one measure ask if their response is the same. If not, obtain a response for each measure. Write answers in margins and enter answers on a new line in the Excel spreadsheet.

Repeat **Questions 2** through **10** for each installed measure or service.

Appendix B: MID C&I Custom HVAC Site #1

M&V REPORT FOR C&I CUSTOM AC SITE #1

Prepared for the Modesto Irrigation District and the Northern California Power Agency

Prepared by Robert Mowris & Associates

January 15, 2003

SITE SUMMARY INFORMATION

Company Name:	**N/A**		
Site Name:	**Site #1 – Modesto**		
Site Address:	**Modesto, CA 95357**		
Principal Site Contact:	**N/A**	**Telephone:**	**N/A**
MID Contact:	**Peter Govea**	**Telephone:**	**(209) 526-7344**
Assigned Lead Engineer:	**Robert Mowris, P.E.**	**Telephone:**	**(800) 786-4130**

Site: **Site #1, Modesto, CA**

PROJECTS PAID BY SB5X FUNDS

Project	Account Number	End Use	NCPA Utility	Program	Project Type
Site #1	N/A	Air Conditioning	MID	SB5X Priority Project	HVAC

MEASURES FOR EACH PROJECT

		Ex Ante Savings Estimate			
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)	Rebate ($)
1	DualCool Evaporative Pre-Coolers	130	531,250	n/a	$26,038

PROGRAM MEASUREMENT AND VERIFICATION SAVINGS ESTIMATE

		M&V Evaluation Savings		
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)
1	DualCool Evaporative Pre-Coolers	60	453,792	n/a

Evaluation of Spillover

No evidence of spillover was found.

Impact Evaluation Report: MID **End Use: HVAC**

Introduction

On August 2, 2002 Robert Mowris, P.E., of Robert Mowris & Associates (RMA), conducted an M&V site visit to install data loggers on five packaged Roof Top Unit air conditioners at Site #1 located in Modesto, California. Peter Govea, Senior Energy Services Engineer for Modesto Irrigation District (MID) arranged and attended the site visits with the Site #1 Facilities & Maintenance Resource Engineer. On September 11, 2002, Robert Mowris, P.E., and George Nesbitt of RMA conducted a second M&V site visit to download data. On November 1, 2002, Robert Mowris and Anne Blankenship of RMA conducted a third M&V site visit to download data, remove data loggers, and verify installation of DualCool evaporative pre-coolers on RTUs 4, 5, 6, 7, 8, and 10. Peter Govea arranged and attended all site visits with the Site #1 Facilities & Maintenance Resource Engineer.

MID provides electricity to the facility and PG&E provides natural gas. Electricity use for the facility is metered by MID. The electrical panel readings indicated electrical demand consistent with design specifications and historical billing data provided by Site #1 and MID. Pre-retrofit equipment and post-retrofit equipment that received incentives from MID's SB5X funds was examined and verified during the M&V site visits.

Readings of the electric utility meters were obtained from MID and readings of sub-panels, various gauges, equipment, and controls were made during the site visits. In addition, run-time and short-term power measurements were made to assess equipment operation and energy consumption for the cooling towers and chillers. Electric poly-phase data loggers were installed on five RTUs (4, 5, 6, 7, and 8) to measure true RMS electric power usage. Temperature data loggers were installed on the roof to measure outdoor temperatures and in the office area (served by RTU 6, 7, and 8) and the product packaging area (served by RTU 4, 5, and 10). Data loggers were installed from 8-02-02 through 11-01-02. Model numbers and performance data were obtained for RTUs and DualCool Units. Historical utility billing data for the facility was also reviewed both before and after installation. Historical billing data are provided in **Attachment 1**.

Business Description

Site #1 has been located in Modesto for 13 years. The facility is used during the entire year, but peak cooling occurs from May through September.

Scope of Project

Site #1's Custom Rebate Application was for 130 kW and 531,250 kWh for the new DualCool RTU Evaporative Pre-Cool Units. The total incentive is $26,038 based on 2.5% of their annual electric bill.[24]

Schedule of Key Dates

Full implementation of project was completed on October 22, 2002.

[24] MID's Commercial Power Saver Custom Rebate is based on the minimum of three incentive caps: 1) $500 per kW of peak savings from 2-6PM; 2) 2.5% of account's annual electric bill; or 3) 50% of total cost of project.

Measure Description

Efficiency Improvement: Site #1 installed DualCool evaporative pre-cool units on the following six packaged air conditioners: RTUs 6, 7, and 8 are 25 tons; RTUs 4 and 5 are 110 tons; and RTU 10 is 130 tons (425 tons total). The DualCool is a cooling load reduction product targeting commercial packaged RTU air conditioners. It uses evaporative cooling, which is water evaporation combined with an air moving device and is designed to pre-cool condenser and ventilation air. The RTU condenser fan provides air movement and the DualCool pump and media allow for evaporation. DualCool saves energy and peak demand by improving compressor operating efficiency and increasing capacity. The DualCool indirectly pre-cools ventilation air without adding moisture. In most cases, higher capacity allows blower speed to be reduced further reducing blower motor energy use. Since blower heat is added to the supply air stream, reducing blower speed also reduces the cooling load and increases effective capacity. The DualCool units were installed by Trane Company and manufactured by Integrated Comfort, Inc. (ICI).

Pre-installation Equipment and Operation: *The pre-installation RTU equipment did not have the ICI DualCool units. The pre-installation RTUs are 8.5 EER units.*

As-Built Equipment and Operation: The as-built equipment had DualCool RTU evaporative pre-cool units installed. All RTUs were inspected and found to be operating as specified by Trane and Site #1.

Variability in Schedule and Production: The facility operates twelve months per year with most space cooling from May through September.

Square Footage of Affected Area: The affected area is 50,370 square feet including 20,740 square feet for the office area (RTUs 6, 7, and 8) and 29,630 square feet for the packaging area (RTUs 4, 5, and 10). Total facility area is 322,660 square feet.

Algorithms for Estimating Energy Savings for Paid Measure

Site #1 Savings:

Site #1 provided estimated ex ante savings of 130 kW and 531,250 kWh/yr for the DualCool RTU pre-coolers (from Trane). Site #1 kW savings are based on assumed average kW savings of 21.66% and average 8.5 Energy Efficiency Ratio (EER) for all RTUs.

$$\text{Ex Ante kW Savings} = \frac{\sum_{i=1}^{n} \text{Tons}_{\text{RTU}_i} \times \frac{12{,}000 \times \text{Btu - kW}}{\text{hr - ton - 1,000W}} \times 0.2166}{8.5 \frac{\text{Btu}}{\text{hr - W}}} = \frac{425 \times 12 \times 0.2166}{8.5} = 130\ kW$$

Ex Ante kWh savings are based on assumed average savings of 1,250 kWh/ton.

$$\text{Ex Ante kWh Savings} = 1{,}250\ \text{kWh/ton/yr} \times 425\ \text{tons} = 531{,}250\ kWh/yr$$

M&V Savings:
The M&V savings are 60 kW and 453,792 kWh/yr or 0.141 kW/ton and 1,068 kWh/yr-ton (based on 425 tons). M&V savings are based on calibrated eQuest simulations with and without the DualCool installed using normalized TMY weather data. The calibration is based on historical 2001 billing data (shown in **Attachment 1**) and short-term measurements of the RTUs with and without the DualCool installed. Short-term measurements were made during the months of August, September, and October using poly-phase data loggers.[25] Short-term measurements for the three 25-ton units (i.e., RTU 6, 7, and 8 serving the office area) indicate savings of 10 kW. These measurements were made on similar days in terms of maximum rooftop temperatures and office temperatures as shown in **Table 1** and **Figure 1**. Short-term measurements for all five RTUs that were monitored indicate savings of 67 kW as shown in **Figure 2**.[26]

October Peak kW Savings (RTU 6, 7, 8) = 57.2 *kW* – 47.2 *kW* = 10 *kW*

October Peak kW Savings (RTU 4, 5, 6, 7, 8, 10) = 317 *kW* – 250 *kW* = 67 *kW*

Table 1. Measured kW Savings for the DualCool for RTU 6, 7, and 8

Description	Date	Rooftop Maximum Outdoor Temperature	2-6 PM kW	% Savings
Baseline peak load	9-30-02	95.4 F	57.2 kW	
DualCool peak load	10-27-02	95.2 F	47.2 kW	
Measured Savings			**10 kW**	**17.4%**

Savings in October should be less than savings during the hotter months of July and August which are the peak cooling months. During hotter months the DualCool evaporative pre-cooler can produce greater wetbulb temperature depressions (i.e., lower effective condenser entering air temperatures) and this will lower RTU compressor lift conditions, which reduces electrical use.

The M&V savings are based on calibrated eQuest simulations that are normalized to account for weather and building operational differences. The DualCool eQuest simulation assumptions are as follows: 1) DualCool direct evaporative pre-cooled condenser with 85% effectiveness; 2) DualCool indirect evaporative cooler on entering outdoor air with 55% effectiveness; and 3) DualCool circulating pump power of 200 W each for the three 25-ton units and 300 W each for the two 110-ton and one 130-ton unit. The eQuest simulation results are shown in **Table 2**, and the M&V kW and kWh savings are as follows. The eQuest 3-D model is shown in **Figure 3**.

[25] Continuous measurements of peak kW demand were made by Robert Mowris, P.E., from 8-01-02 through 11-01-02 using true RMS poly-phase ElitePro data loggers manufactured by Dent Instruments, Inc. RMA verified these measurements on 9-11-02 and 11-02-02 using a true RMS poly-phase PowerSight data logger manufactured by Summit Technologies and calibrated on 8-05-02.

[26] Monitored savings of 67 kW are based on peak demand measurements of 317 kW on 9-23-02 and 250 kW on 10-29-02 for the three 25-ton units (i.e., RTU 6, 7, and 8) and the two 110-ton units (i.e., RTU 4 and 5). These savings are based on five of six RTUs that received DualCool retrofits and do not include savings for the largest 130-ton unit (i.e., RTU 10).

$$\text{M\&V kW Savings} = \frac{\sum_{i=May}^{Sep} \text{Baseline kW}_i - \text{DualCool kW}_i}{5} = 60\ kW$$

$$\text{M\&V kWh Savings} = 21{,}278{,}898\ kWh/yr - 20{,}825{,}106\ kWh/yr = 453{,}792\ kWh/yr$$

Figure 1. Baseline versus DualCool (RTU 6, 7, 8)

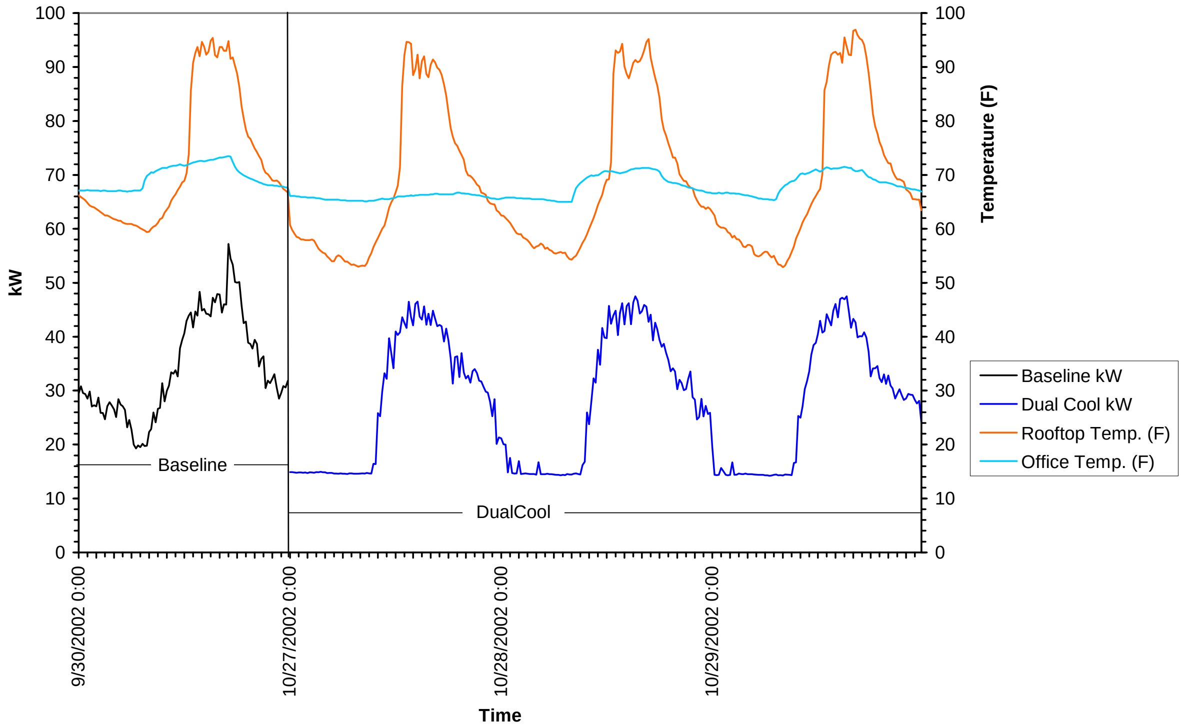


Figure 2. Baseline versus DualCool for RTU 4, 5, 6, 7, and 8

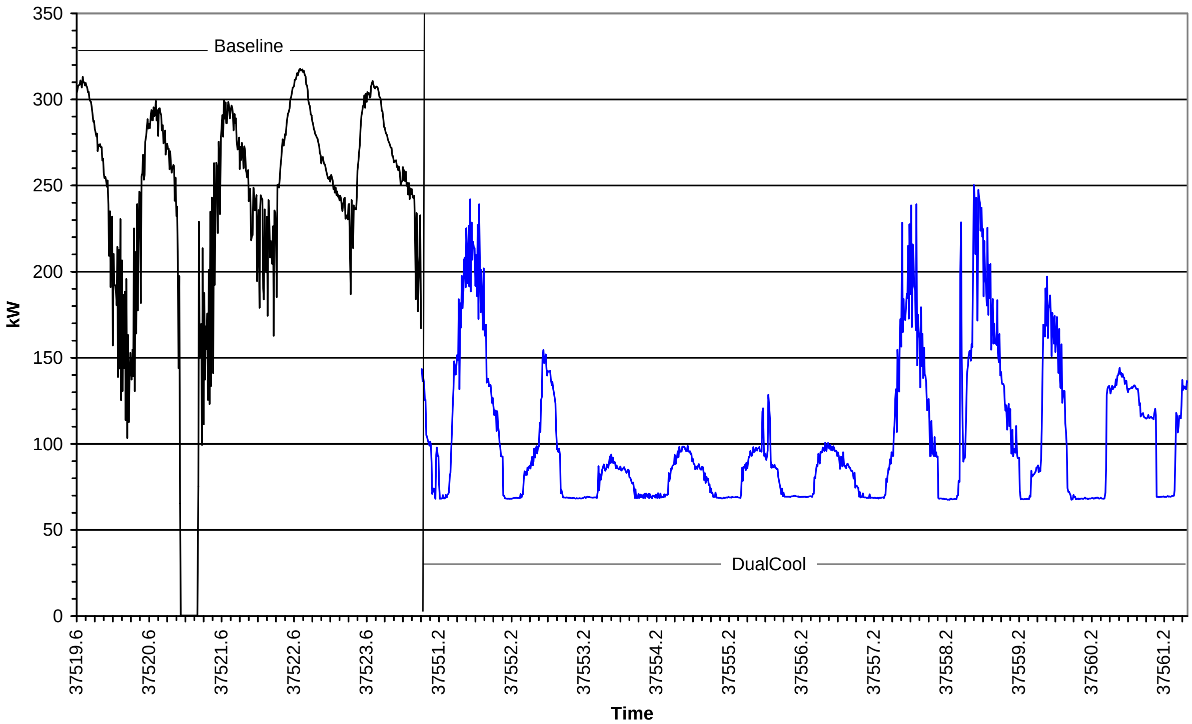
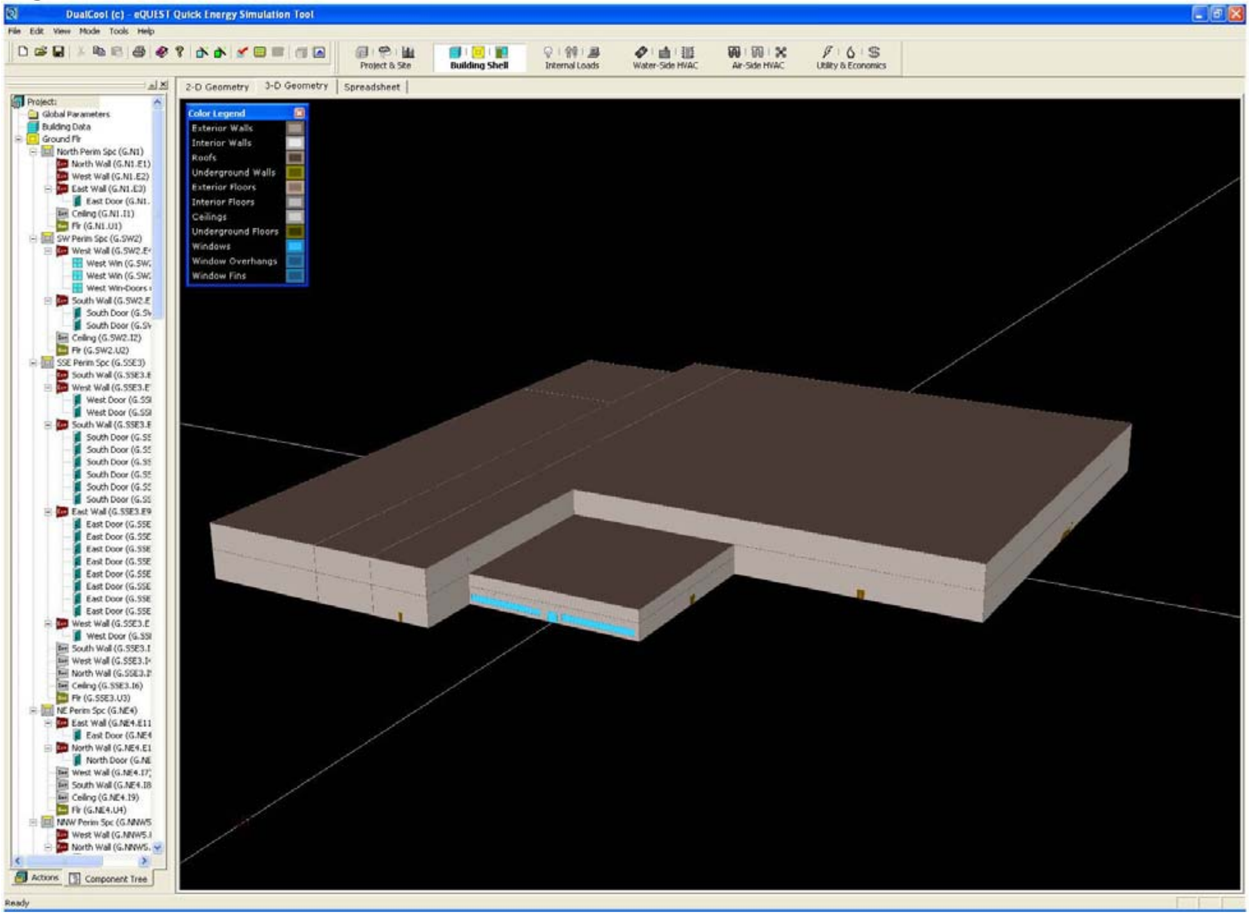


Table 2. Normalized eQuest Simulation Results for Site #1

Month	Baseline kW	Baseline 2-6 PM Peak kW	Baseline kWh	DualCool kW	DualCool 2-6 PM Peak kW	DualCool kWh	Savings kW	Savings kWh
Jan	3,443		1,651,888	3,352		1,649,442		2,446
Feb	3,794		1,532,830	3,455		1,510,454		22,376
Mar	3,799		1,721,826	3,467		1,685,598		36,228
Apr	3,852		1,827,433	3,652		1,780,557		46,876
May	3,942	3,672	1,895,889	3,941	3,616	1,843,607	56	52,282
Jun	3,945	3,686	1,798,968	3,932	3,620	1,750,220	66	48,748
Jul	3,994	3,713	1,983,642	3,972	3,650	1,935,203	63	48,439
Aug	3,975	3,715	1,978,828	3,969	3,655	1,925,516	60	53,312
Sep	3,921	3,695	1,785,341	3,874	3,641	1,734,624	54	50,717
Oct	3,878		1,882,179	3,726		1,823,674		58,505
Nov	3,802		1,564,591	3,526		1,534,728		29,863
Dec	3,451		1,655,483	3,451		1,651,483		4,000
Total		3,715	21,278,898		3,655	20,825,106	60	453,792

Note: M&V peak kW savings are averaged over the summer peak period (i.e., May through September).

Figure 3. eQuest 3-D Model of Site #1



Data Collection

Site Specific Input Parameters: Data were collected during the on-site survey to support the M&V analyses. Make and model numbers of rebated equipment were verified (i.e., RTUs and DualCool pre-coolers). Equipment efficiency and relevant performance were also verified.

Data Collection Method: Electric power and temperature data loggers were installed to measure kW and kWh usage for all relevant equipment. Data loggers were installed from 8-02-02 through 11-01-02 to obtain short-term measurements. Measurements and observations during the on-site survey were used to verify rebated equipment. Inventories by type and schedules of internal lighting and equipment were collected during the on-site survey to estimate internal loads. Capacities of cooling systems are based on manufacturer's data. Seasonal variations in operating schedules were obtained from building operations staff during the survey. Operational characteristics of the cooling system, such as the baseline control strategy, on/off schedule, and thermostats setpoints were obtained from a combination of direct observations and an interview with operations personnel during the survey. Operational characteristics for the DualCool were obtained from Trane.

Customer Cost/Benefit Analysis

Cost and Payback: No payback analysis was performed by Site #1 or MID. Based on information provided in the file, the total installed cost for the DualCool was $124,230.[27] The MID incentive was $26,038. The total annual electricity savings are $22,050 (see **Table 5**). The simple payback is 4.45 years including the incentive (based on estimated M&V savings).[28]

Table 5. M&V Evaluation of Monetary Savings for DualCool

Description	Annual Savings	$/unit	Annual Savings
kWh	453,792	0.0418	$18,969
kW	60	10.27	$3,081
Maintenance			n/a
Total			$22,050

Note: kW savings are multiplied times 5 months over the summer peak period (i.e., May through September).

Non-Energy Costs and Benefits: Annual labor and maintenance benefits were not provided by Site #1.

Energy Savings

Comparison of MID and Evaluation Estimates:

The M&V evaluation estimate of gross savings for the DualCool is 60 kW and 453,792 kWh/yr. Peak demand savings are 54 percent lower and annual electric savings are 15 percent lower than the Site #1 custom application estimate of 130 kW and 531,250 kWh/yr. The estimated savings were calculated without the benefit of as-built measurements. Savings would be greater if Site #1 were to take full advantage of the DualCool as follows: 1) DualCool direct evaporative pre-cooling typically allows for one or more condenser fans to be turned off on each RTU; and 2) Dual Cool typically provides a 20% increase in capacity and this allows the evaporator blower speed to be reduced on each RTU. Including these additional efficiency improvements would yeild savings closer to the application savings estimate.

Savings Persistence: The expected lifetime for the new DualCool is 15 years provided that the DualCool units are properly cleaned and maintained.[29] DualCool is manufactured using 20 gauge and 18 gauge 316 stainless steel.

[27] Installed cost of $124,230 is from Trane DualCool Evaporative Pre-Cooling cost proposal prepared by Scott Frechette, Trane, October 20, 2001.
[28] Electricity savings are based on MID rate schedule IC-1. The $/unit kWh rate is averaged based on the summer peak-, partial-, and off-peak rates and winter peak- and off-peak rates.
[29] DualCool maintenance should be performed twice per year and involves: 1) cleaning the sump; 2) cleaning media screen; and 3) cleaning the media with a brush. DualCool cleaning maintenance is comparable to condenser coil cleaning maintenance.

ATTACHMENT

1. Historical Billing Data for Site #1

Month	2001 Peak kW	2001 kWh	2002 Peak kW	2002 kWh
Jan	3,313	1,894,327	3,482	2,050,036
Feb	3,461	1,668,132	3,418	1,726,442
Mar	3,697	2,081,905	3,292	1,849,751
Apr	3,738	2,020,069	3,767	1,817,985
May	3,965	2,440,347	3,743	2,038,891
Jun	3,917	2,342,098	3,824	2,077,958
Jul	3,934	2,260,590	3,994	2,264,181
Aug	3,844	2,436,315	3,930	2,242,800
Sep	3,822	1,988,117	3,939	1,960,092
Oct	3,825	2,089,151	3,651	1,908,579
Nov	3,559	1,905,702	3,505	1,683,078
Dec	3,482	1,947,503	3,464	1,921,587
Total	3,965	25,074,256	3,994	23,541,380

Note: DualCool installation was completed on October 22, 2002.

Appendix C: MID C&I Custom HVAC Site #2

M&V REPORT FOR C&I CUSTOM AC SITE #2

**Prepared for the Modesto Irrigation District
and the Northern California Power Agency**

Prepared by Robert Mowris & Associates

SITE SUMMARY INFORMATION

Company Name:	**Site #2**		
Site Name:	**Site #2 - Modesto**		
Site Address:	**Modesto, CA 95353**		
Principal Site Contact:	**N/A**	**Telephone:**	**N/A**
MID Contact:	**Peter Govea**	**Telephone:**	**(209) 526-7344**
Assigned Lead Engineer:	**Robert Mowris, P.E.**	**Telephone:**	**(800) 786-4130**

Site: Site #2, Modesto, CA

PROJECTS PAID BY SB5X FUNDS

Project	Account Number	End Use	NCPA Utility	Program	Project Type
Site #2	N/A	Process Cooling	MID	SB5X Priority Project	HVAC

MEASURES FOR EACH PROJECT

		Ex Ante Savings Estimate			
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)	Rebate ($)
1	Efficient AC Load Control	514	730,276	n/a	$257,000

PROGRAM MEASUREMENT AND VERIFICATION SAVINGS ESTIMATE

		M&V Evaluation Savings		
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)
1	Efficient AC Load Control	763	747,600	106,100

Evaluation of Spillover

No evidence of spillover was found.

Impact Evaluation Report: MID **End Use: HVAC**

Introduction

On August 28, 2002 Robert Mowris, P.E., of Robert Mowris & Associates (RMA), conducted a Measurement and Verification (M&V) site visit to evaluate the new high-efficiency air conditioning (AC) and Energy Management System (EMS) installed at Site #2 located in Modesto, California. Peter Govea, Senior Energy Services Engineer for Modesto Irrigation District (MID) arranged and attended the site visits with the Site #2 project manager. Also in attendance were the Site #2 electrician and facilities maintenance personnel. On September 11, 2002 Robert Mowris, P.E., and George Nesbitt of RMA conducted a second M&V site visit. Peter Govea arranged and attended the second site visit with Site #2 project manager.

MID provides electricity to the facility and PG&E provides natural gas. Electricity use for the facility is metered at multiple panels. Site #2 Meter serves the affected area of Warehouses #4, #2, and #3. The electrical panel readings indicated electrical demand consistent with design specifications and historical utility meter data provided by Site #2 and MID. Equipment that received incentives from MID's SB5X funds was examined and verified during the M&V site visits.

Readings of the electric utility meters were obtained from the utility and readings of sub-panels, various gauges, equipment, and controls were made during the site visits. In addition, run-time and short-term power measurements were made to assess equipment operation and energy consumption for the fans, pumps, cooling tower, and chillers. Electric poly-phase data loggers were installed on the fans, pumps, cooling tower, and chillers to measure true RMS electric power usage. Temperature data loggers were installed inside warehouse #4 and on the roof of warehouse #4 to measure outdoor, indoor, and beverage case temperatures. Data loggers were installed from 8-28-02 through 9-11-02. Model numbers and performance data were obtained for air handling equipment, fans, pumps, cooling tower, and chillers. Historical utility meter data for the facility was also reviewed both before and after installation. Historical utility meter data for warehouses #2, #3, and #4 are provided in **Attachment 1**.

Business Description

Site #2 has been located in Modesto for more than 50 years and is one of MID's largest energy users. The facility is used during the entire year, but peak cooling occurs from May through September. Warehouses #2, #3, and #4 are used to store cases of beverage prior to shipping.

Scope of Project

The Site #2 Custom Rebate Application was for 514 kW and 730,276 kWh for the new AC and EMS. The total incentive is $257,000 based on savings of 514 kW and MID incentive of $500/kW of peak demand savings. The peak demand period is from 2 PM to 6PM Monday through Friday. The incentive represents approximately 27 percent of the $948,502 installed cost.

Schedule of Key Dates

Installation of the equipment and controls was started in February 2001 and the project was completed in December 2001.

Measure Description

Efficiency Improvement: The new AC and EMS serves warehouses #2, #3, and #4. The AC system includes two 500-ton chillers in series and the design chilled water flow through both chillers is 1,600 gallons per minute (gpm). The chilled water temperature drop for chiller #1 is 7 degrees Fahrenheit (i.e., 57F to 50F), and the design temperature across chiller #2 is 7F (i.e., 50F to 43F). Each 500-ton chiller is rated at 0.65 kW/ton and both chillers are served by a 1,000 ton cooling tower with one 60-hp VFD fan. Each chiller has a 40-hp variable-speed condenser water pump. One 25-hp primary chilled water pump serves both chillers. One 25-hp secondary chilled water pump serves warehouse #4 and one 40-hp secondary chilled water pump serves warehouses #2 and #3. Warehouse #4 has eight 20-hp air handler fans and warehouse #2 and #3 have thirteen 7.5-hp air handler fans. A Trane "Summit" Energy Management System (EMS) is used to control the new cooling system and shift the entire AC load to the non-peak period. The new EMS is programmed to operate the AC system from approximately 10:45 PM to 12:45 PM. The warehouse storage areas are cooled down to 68 degrees Fahrenheit (F) at night and beverage cases stored in the warehouses are used as thermal storage to keep the warehouse areas below 74 F without the need for mechanical cooling during peak periods. Computer controls ensure that the beverage and warehouse storage areas are maintained at the desired setpoint of 68 to 74 F throughout the day. The EMS controls the air temperature of the warehouse storage areas and continuously monitors vital functions of the facility including beverage and air temperatures and kW and kWh usage.

Pre-installation Equipment and Operation: Warehouses #2 and #3 - Pre-installation equipment included one 500-ton single-effect gas absorption chiller and low-pressure boiler, 40-hp condenser water pump, 60-hp cooling tower fan, 20-hp chilled water pump, thirteen 7.5-hp air handling units as well as thirty 15-ton RTUs (Model #B85-SACC-C17). Individual thermostats were used to turn on the roof top units (RTUs) and air handling units, and they were operated primarily during the hottest part of the day during peak periods. The old RTUs rated efficiency was 1.43 kW/ton. The old RTUs and gas chiller were removed prior to our M&V site visit so the peak demand for this equipment could not be measured directly.

Warehouse #4 - Pre-installation equipment included 38 packaged RTUs. Each RTU had a capacity of 15 tons and the total cooling capacity for the 38 RTUs was 570 tons. Individual thermostats were used to turn on each RTU, and the RTUs were operated primarily during the hottest part of the day during peak periods. The old RTUs were approximately 30 years old and the rated efficiency was 1.48 kW/ton. The old RTUs were removed prior to our M&V site visit so the peak demand for the 38 RTUs could not be measured directly.

Pre-installation equipment and operation also includes the impact of occupancy sensors installed to reduce lighting use in warehouses #1, #2, #3, #4, and #5.[30] The lighting sensors were installed in two phases. Phase one included 600 sensors installed in warehouses #3, #4, and #5 during the summer of 2000. Phase two included 170 sensors installed in warehouses #1 and #2 during the summer of 2001. Both phases were completed prior to the completion of the new AC and EMS. These savings are accounted

[30] Occupancy sensors installed in warehouse #5 are not included in this report since warehouse #5 is not included in electric utility meter.

for in the M&V analyses through the use of eQuest simulations that are normalized for lighting savings, weather, and other variables such as plant operations.

As-Built Equipment and Operation: The as-built cooling system and controls were inspected and found to be operating as specified by Site #2.

Variability in Schedule and Production: The facility operates twelve months per year with warehouse cooling from May through September.

Square Footage of Affected Area: The affected area is 946,630 square feet in warehouses #2, #3, and #4.[31]

Algorithms for Estimating Energy Savings for Paid Measure

Site #2 Algorithm: Site #2 calculated savings of 514 kW and 730,276 kWh/yr for the new AC and EMS. These savings are based on engineering analysis and the following assumptions and equations.

1. Site #2 kW savings are based on moving the summer AC load to non-peak hours for warehouses #2, #3, and #4. Utility data show an average coincident summer peak of 1,271 kW and an average winter peak of 757 kW. Site #2 took the difference between these two peaks as the kW savings.

   Site #2 Peak kW Savings = 1,271 – 757 = 514 *kW*

2. Site #2 kWh savings are based on improving overall cooling efficiency to 0.77 kW/ton for the new AC system compared to the old RTUs with 1.48 kW/ton. Utility data are used to estimate average summer cooling use of 1,522,265 kWh/year.

   Site #2 kWh Savings = 1,522,265 *kWh/yr* x [1-0.77/1.48] = 730,276 *kWh/yr*

M&V Evaluation Algorithm:

The M&V evaluation algorithms are based on calibrated eQuest simulations, short-term measurements, and utility meter data (i.e., see **Attachments 2** and **3**). The normalized M&V savings are 763 kW as shown in **Table 1**. These savings are plotted in **Figure 2** along with the utility meter data for August 2000 and August 2002. The M&V kW algorithm is as follows.

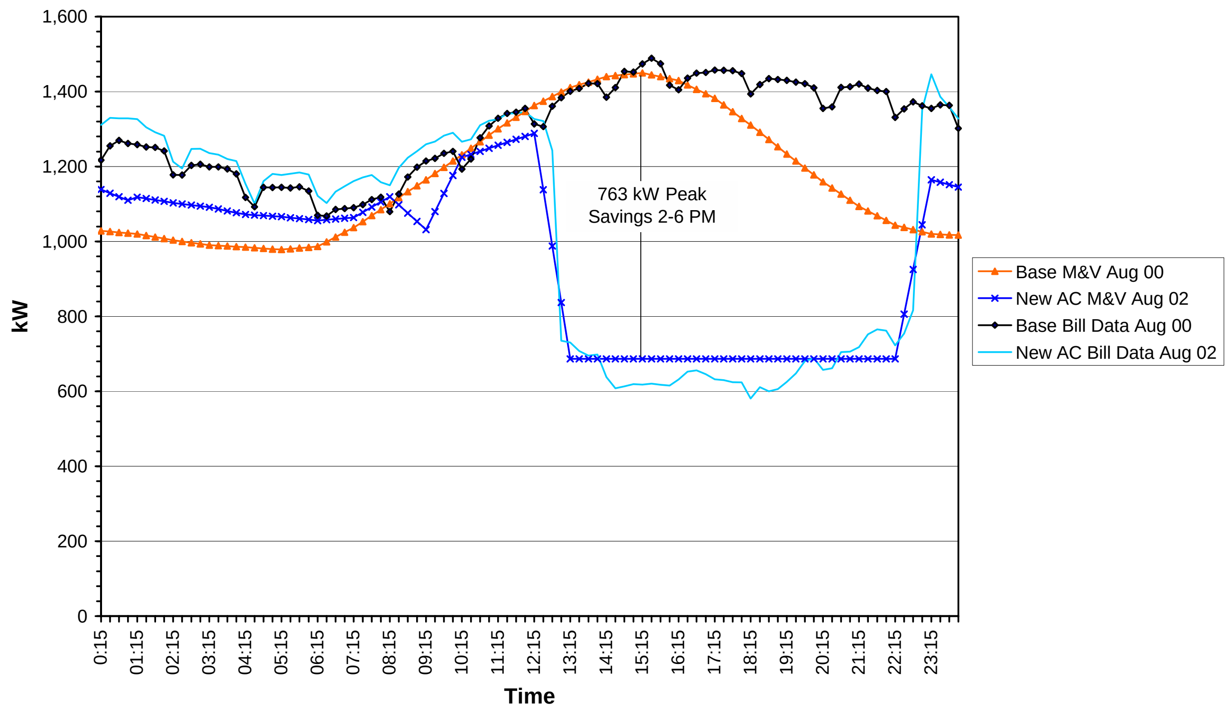
$$\text{M\&V Peak kW Savings} = 1{,}450\ kW_{August\ eQuest\ Baseline} - 687\ kW_{eQuest\ New\ AC} = 763\ kW$$

[31] Warehouse #1 is not cooled by the as-built equipment.

Table 1. M&V Evaluation of kW Savings for Site #2 AC and EMS

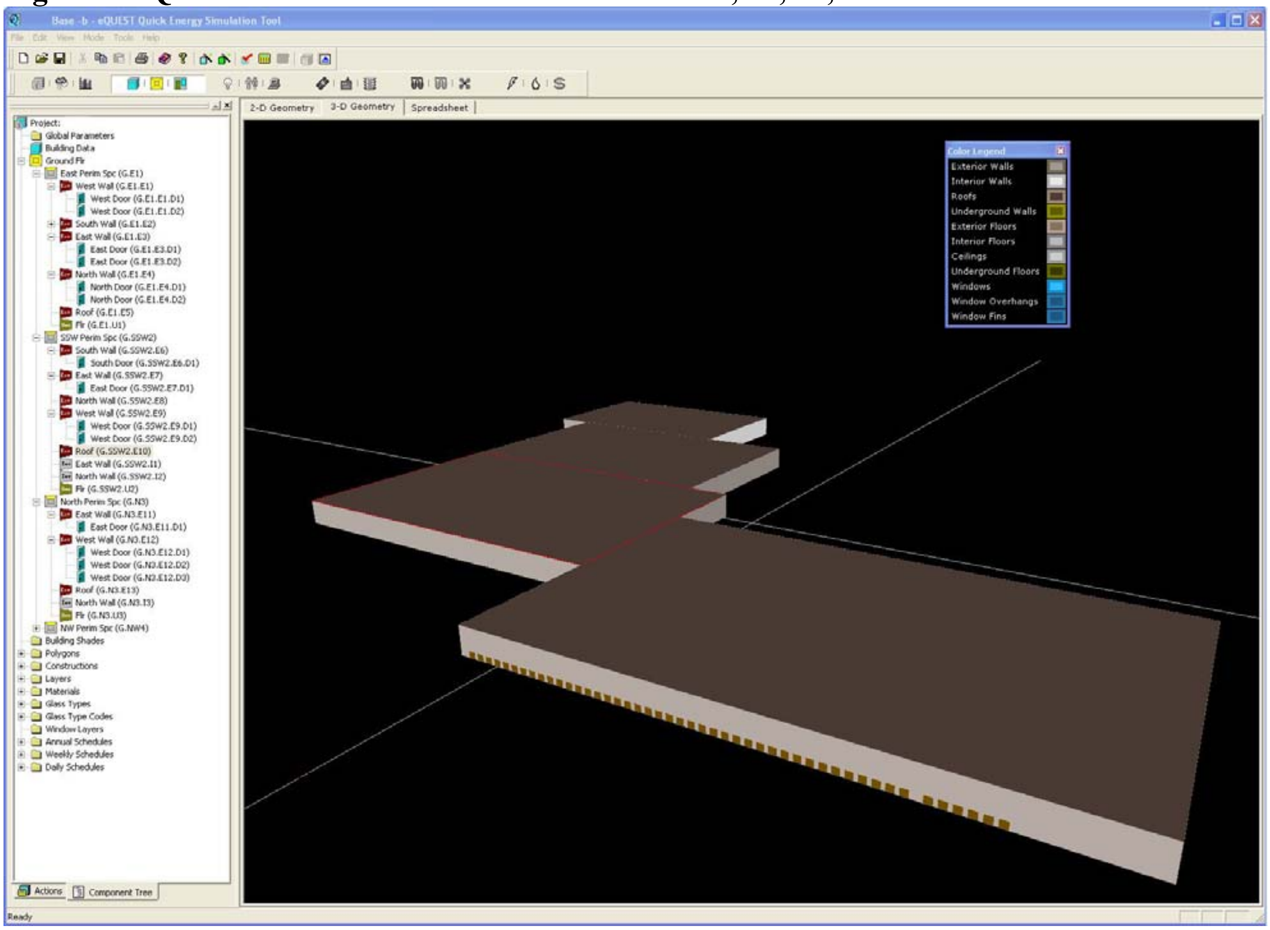
Month	2000 Billing Data kW	2002 Billing Data kW	Non-Normalized Billing Data Savings kW	Normalized eQuest Baseline kW	Normalized eQuest Measure kW	Normalized M&V Savings kW
May	973	575	398	1,287	690	597
June	1,312	610	702	1,366	666	700
July	1,338	609	729	1,380	628	752
August	*1,489*	*698*	*791*	*1,450*	*687*	*763*
September	1,494	724	770	1,239	631	608
Peak kW	**1,489**	**698**	**791**	**1,450**	**687**	**763**

Figure 1. Normalized Peak kW Savings and Billing Data (August 2000 and August 2002)



The eQuest simulations were calibrated using utility meter data, average monthly kW profiles, monthly kWh usage, and short-term measurements. The eQuest 3-D model is shown in **Figure 2**.

Figure 2. eQuest 3-D Model of Site #2 Warehouses #1, #2, #3, and #4



Short-term measurements of the new AC system were made during August and September (see **Table 2**, and **Figure 3**).[32]

[32] Measurements of peak kW demand for the new AC system were made by Robert Mowris, P.E., on 8-28-02 using a true RMS PowerSight data logger manufactured by Summit Technologies and calibrated on 8-05-02.

Table 2. Measured Peak kW of New AC System

Description	Qty.	Size	Efficiency	Measured kW
New AC System – Warehouses #2 and #3				
New Chiller #2	1	500 tons	0.65 kW/ton	194
Primary Chilled Water Pump (shared)	0.5	25 hp		9
Secondary Chilled Water Pump	1	25 hp		26
Condenser Pump VFD	1	40 hp		10
Tower Fan VFD (shared)	0.5	60 hp		11
AHU	13	7.5 hp		40
New AC System – Warehouse #4				
New Chiller #1	1	500 tons	0.65 kW/ton	161
Primary Chilled Water Pump (shared)	0.5	25 hp		9
Secondary Chilled Water Pump	1	40 hp		24
Condenser Pump VFD	1	40 hp		10
Tower Fan VFD (shared)	0.5	60 hp		11
AHU	8	20 hp		124
Total New AC System kW				**629**

Short-term measurements from August 28, 2002 show a peak cooling load of approximately 629 kW for new AC system.[33] The actual peak load is zero since the EMS is used to shift the new AC load to non-peak hours. The new AC system savings are approximately 134 kW (i.e., 763 kW – 629 kW = 134 kW, see **Table 2**). Measurements made in August 2002 of the peak AC load are superimposed as a dashed line on measurements made in September of the cooling load to demonstrate that the peak cooling load has been shifted to non-peak hours. M&V measurements were also made of chiller #1 to verify non-peak operation and kW savings (see **Figure 4**).

[33] The new AC system was temporarily turned on to measure chiller kW usage for the M&V effort. The AC system is normally off from 12:45 PM to 10:45 PM.

Figure 3. Peak Demand and Load Shifting for New High-Efficiency AC System

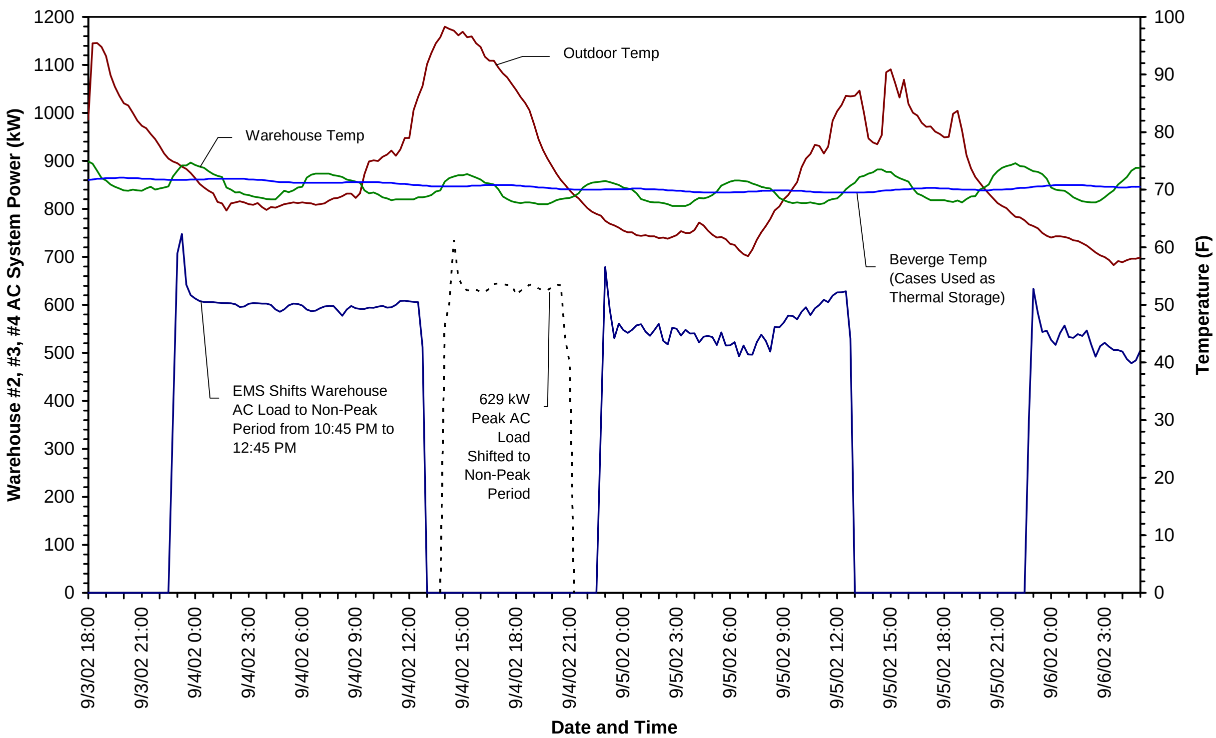
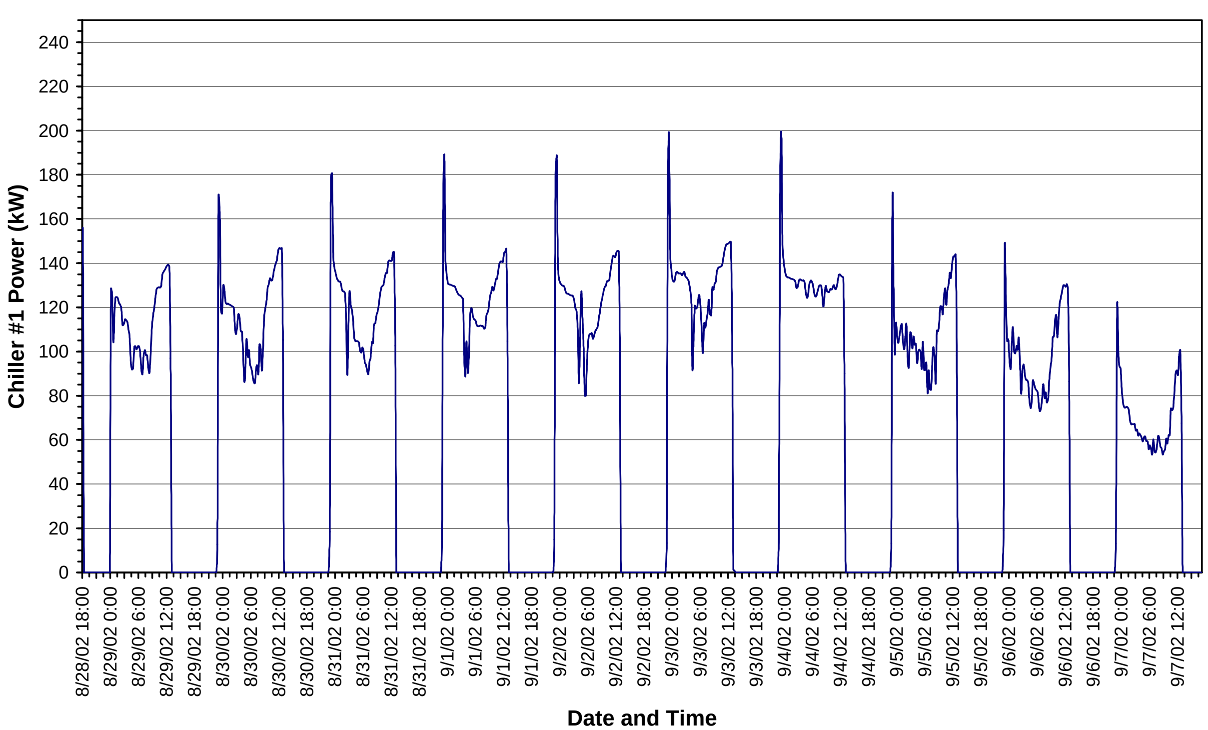


Figure 4. Chiller #1 Data Showing Non-Peak Operation (i.e., 10:45 PM to 12:45 PM)



The normalized M&V kWh savings are 747,600 kWh/yr as shown in **Table 3**. M&V kW algorithm is as follows.

$$\text{M\&V kWh Savings} = \sum_{May}^{Sept} kWh_{eQuest\ Baseline} - \sum_{May}^{Sept} kWh_{eQuest\ New\ AC} = 747{,}600\ kWh$$

Table 3. M&V Evaluation of kWh Savings for Site #2 AC and EMS

Month	2000 Billing Data kWh	2002 Billing Data kWh	Non-Normalized Billing Data Savings kWh	Normalized eQuest Baseline kWh	Normalized eQuest Measure kWh	Normalized M&V Savings kWh
May	611,783	413,503	198,280	770,500	647,200	123,300
June	795,196	601,112	194,084	797,500	647,500	150,000
July	825,803	674,417	151,386	857,700	680,500	177,200
August	927,302	701415	225,887	841,700	677,400	164,300
September	823,101	665684	157,417	767,600	634,800	132,800
Total	**3,983,185**	**3,056,131**	**927,054**	**4,035,000**	**3,287,400**	**747,600**

Therm savings are summarized in **Table 4**. Economic savings are summarized in **Table 5**.

Table 4. M&V Evaluation of Therm Savings for Site #2 AC and EMS

Month	2000 PG&E therm	2002 PG&E therm	Non-Normalized PG&E Savings therm	Normalized eQuest Baseline therm	Normalized eQuest Measure therm	Normalized M&V Savings therm
May	4,613	0	4613	20,300	0	20,300
June	25,420	0	25420	20,800	0	20,800
July	87,774	0	87774	22,700	0	22,700
August	52,387	0	52387	22,200	0	22,200
September	34,714	0	34714	20,100	0	20,100
Total	**204,908**	**0**	**204,908**	**106,100**	**0**	**106,100**

Table 5. M&V Evaluation of Economic Savings for Site #2 AC and EMS

Description	Annual Resource Savings	$/unit	Annual Savings $
kWh	747,600	0.05	35,137
kW	763	10.40	7,935
Therm	106,100	0.63	67,055
Maintenance			7,500
Total			**117,628**

Data Collection

Site Specific Input Parameters: Data were collected during the on-site survey to support the M&V analyses. Make and model numbers of rebated equipment were verified (i.e., chillers, cooling towers, fans, pumps, and controls). Equipment efficiency and relevant performance were also verified. Building characteristics information was collected for eQuest such as the UA of the building envelope and capacity, use and schedules of internal loads such as lights, miscellaneous equipment, and people.

Data Collection Method: Electric power and temperature data loggers were installed to measure kW and kWh usage for all relevant equipment. Data loggers were installed from

8-28-02 through 9-11-02 to obtain short-term measurements. Measurements and observations during the on-site survey were used to verify rebated equipment. Inventories by type and schedules of internal lighting and equipment were collected during the on-site survey to estimate internal loads. Seasonal variations in operating schedules were obtained from building operations staff during the survey. Operational characteristics of the cooling system, such as the computer controls strategy, on/off schedule, and thermostats setpoints were obtained from a combination of direct observations and an interview with operations personnel during the survey. Capacity and efficiencies of motors and pumps were obtained from nameplate data and spot measurements were made to measure electric power usage. Capacities of cooling systems are based on manufacturer's data. Typical operating hours for pumps and motors were obtained from interviews with the operator.

Customer Cost/Benefit Analysis

Cost and Payback: No payback analysis was performed by Site #2 or MID. Based on information provided in the file, the total cost for installed equipment is $948,502 and the MID incentive was $257,000. Site #2 is realizing annual labor and maintenance savings of $7,500 per year from the new AC and EMS. The annual savings in electricity are 747,600 kWh and 763 kW worth approximately $43,072.[34] The annual natural gas savings are 106,100 therms worth approximately $67,055.[35] The total savings in electricity, natural gas, and maintenance are $117,628 and the calculated simple payback is approximately 5.9 years including the rebate (based on 2002 savings). The measure lifetime is 15 years.

Non-Energy Costs and Benefits: Annual labor and maintenance benefits are estimated at $7,500 as per calculations provided by Site #2.

Energy Savings

Comparison of MID Application and Evaluation Estimates:

The M&V evaluation gross savings estimates for the new AC and EMS are 763 kW, 747,600 kWh/yr, and 106,100 therms/yr. Peak demand savings are 48 percent higher and annual electric savings are 2 percent higher than the Site #2 custom application estimate of 514 kW and 730,276 kWh/yr. The estimated savings were calculated without the benefit of as-built post-installation measurements.

Savings Persistence: The expected lifetime for the new AC and EMS is 15 years.

[34] Electricity savings are based on MID Rate 1C1-25 or $0.0487 per peak kWh and $10.40 per peak kW.
[35] The PG&E gas rate is $0.632/therm.

ATTACHMENTS

1. Site #2 Utility Meter Data for 2000 and 2002 (PG&E 2000 Gas Data)
2. Site #2 Utility Meter Monthly Average Weekday kW Data for 2000 and 2002
3. Site #2 Utility Meter Monthly Average Weekend kW Data for 2000 and 2002
4. Site #2 Purchase Order Receipt for New AC and EMS

1. Site #2 Utility Meter Data for 2000 and 2002 (PG&E 2000 Gas Data)

Month	2000 Billing Data kWh	2000 Billing Data Peak kW[1]	2002 Billing Data kWh	2002 Billing Data Peak kW[1]	2000 PG&E Therm
Jan	538,881	777	354,415	505	
Feb	495,115	783	314,468	499	
Mar	529,327	773	334,419	560	
Apr	522,605	770	342,411	561	
May	**611,783**	**973**	**413,503**	**575**	**4,613**
Jun	**796,196**	**1,312**	**601,112**	**610**	**25,420**
Jul	**825,803**	**1,338**	**674,417**	**609**	**87,774**
Aug	**927,302**	**1,489**	**701,415**	**698**	**52,387**
Sep	**823,101**	**1,494**	**665,684**	**756**	**34,714**
Oct	669,330	1,392			
Nov	486,383	677			
Dec	431,356	659			
Total	**7,657,182**	**1,489**	**-**	**756**	**204,908**

[1]Peak kW for May through September (i.e., summer months) is from 2PM to 6PM. Peak kW for January through April and October through December is the site coincident peak demand, not necessarily from 2PM to 6PM.

2. Site #2 Utility Meter Monthly Average Weekday kW Data for 2000 and 2002

Time of Day	May 00 kW	May 02 kW	Jun 00 kW	Jun 02 kW	Jul 00 kW	Jul 02 kW	Aug 00 kW	Aug 02 kW	Sep 00 kW	Sep 02 kW
0:15	807	672	1,088	1,189	1,071	1,246	1,217	1,311	1,091	1,253
00:30	810	691	1,116	1,206	1,111	1,267	1,255	1,330	1,125	1,288
00:45	816	698	1,139	1,204	1,120	1,257	1,270	1,329	1,145	1,299
01:00	823	696	1,139	1,200	1,120	1,258	1,261	1,329	1,148	1,298
01:15	820	695	1,136	1,191	1,120	1,250	1,258	1,326	1,149	1,293
01:30	820	682	1,131	1,179	1,122	1,238	1,252	1,305	1,144	1,274
01:45	820	679	1,134	1,166	1,115	1,233	1,251	1,291	1,135	1,260
02:00	811	675	1,114	1,157	1,108	1,228	1,241	1,282	1,127	1,254
02:15	805	626	1,066	1,104	1,051	1,165	1,178	1,213	1,065	1,189
02:30	807	628	1,074	1,102	1,053	1,150	1,177	1,195	1,069	1,190
02:45	809	669	1,099	1,139	1,081	1,179	1,203	1,247	1,090	1,223
03:00	805	668	1,100	1,136	1,080	1,185	1,206	1,248	1,096	1,232
03:15	806	665	1,096	1,134	1,084	1,179	1,199	1,236	1,092	1,227
03:30	807	664	1,097	1,126	1,084	1,179	1,199	1,232	1,088	1,224
03:45	810	663	1,100	1,127	1,077	1,167	1,193	1,220	1,087	1,217
04:00	803	661	1,088	1,127	1,069	1,158	1,180	1,214	1,077	1,202
04:15	788	620	1,030	1,077	1,014	1,106	1,118	1,154	1,017	1,142
04:30	779	606	1,004	1,042	983	1,075	1,093	1,101	997	1,113
04:45	787	757	1,044	1,092	1,035	1,119	1,145	1,161	1,049	1,172
05:00	788	776	1,053	1,102	1,037	1,122	1,144	1,180	1,049	1,180
05:15	788	753	1,054	1,102	1,038	1,123	1,144	1,177	1,057	1,170
05:30	781	748	1,054	1,102	1,043	1,124	1,143	1,181	1,050	1,171
05:45	781	743	1,040	1,089	1,032	1,121	1,145	1,184	1,042	1,170
06:00	769	730	1,023	1,070	1,016	1,108	1,134	1,178	1,035	1,163
06:15	745	674	978	1,017	957	1,049	1,070	1,121	988	1,121
06:30	747	661	983	1,015	969	1,040	1,068	1,102	1,004	1,121
06:45	753	705	1,014	1,061	999	1,088	1,085	1,133	1,025	1,165
07:00	747	730	1,019	1,086	1,000	1,102	1,088	1,147	1,010	1,160
07:15	747	742	1,019	1,097	1,008	1,119	1,090	1,161	1,006	1,154
07:30	757	746	1,025	1,107	1,012	1,125	1,098	1,171	1,007	1,152
07:45	779	727	1,045	1,116	1,024	1,130	1,112	1,177	1,018	1,151
08:00	779	637	1,055	1,104	1,033	1,125	1,118	1,158	1,021	1,133
08:15	751	634	1,005	1,097	989	1,114	1,080	1,150	983	1,130
08:30	772	660	1,048	1,136	1,027	1,158	1,126	1,196	1,028	1,184
08:45	792	667	1,086	1,168	1,049	1,180	1,172	1,224	1,058	1,209
09:00	781	677	1,101	1,173	1,077	1,201	1,198	1,241	1,086	1,230
09:15	784	674	1,110	1,181	1,089	1,204	1,214	1,259	1,110	1,241
09:30	787	665	1,114	1,189	1,095	1,211	1,222	1,267	1,130	1,253
09:45	787	663	1,130	1,192	1,105	1,231	1,235	1,282	1,144	1,260
10:00	797	667	1,138	1,197	1,116	1,234	1,240	1,290	1,155	1,269
10:15	789	635	1,090	1,164	1,071	1,202	1,193	1,266	1,105	1,244
10:30	792	644	1,121	1,194	1,099	1,216	1,220	1,273	1,130	1,253
10:45	810	666	1,163	1,189	1,144	1,244	1,277	1,310	1,202	1,294
11:00	817	633	1,183	1,083	1,172	1,265	1,308	1,322	1,244	1,309
11:15	843	634	1,188	1,085	1,190	1,264	1,329	1,326	1,273	1,323
11:30	842	634	1,202	1,089	1,196	1,275	1,342	1,341	1,301	1,328
11:45	841	624	1,213	1,089	1,206	1,280	1,345	1,342	1,318	1,341
12:00	854	587	1,218	1,091	1,214	1,281	1,355	1,345	1,326	1,350
12:15	840	529	1,179	1,069	1,172	1,270	1,313	1,327	1,269	1,346
12:30	834	517	1,173	1,058	1,166	1,263	1,307	1,321	1,260	1,343
12:45	859	559	1,224	1,016	1,216	1,176	1,361	1,243	1,319	1,265
13:00	879	565	1,245	647	1,238	660	1,384	735	1,359	781
13:15	885	571	1,249	626	1,248	623	1,401	730	1,385	781
13:30	892	569	1,258	611	1,262	600	1,408	708	1,405	763
13:45	906	568	1,263	606	1,271	593	1,422	695	1,405	753
14:00	900	573	1,261	606	1,278	599	1,421	698	1,410	756
14:15	897	541	1,230	576	1,238	570	1,385	638	1,368	715
14:30	899	549	1,257	582	1,267	577	1,410	608	1,380	710
14:45	915	575	1,280	610	1,305	602	1,454	614	1,435	724

2. Site #2 Utility Meter Monthly Average Weekday kW Data for 2000 and 2002 (continued)

Time of Day	May 00 kW	May 02 kW	Jun 00 kW	Jun 02 kW	Jul 00 kW	Jul 02 kW	Aug 00 kW	Aug 02 kW	Sep 00 kW	Sep 02 kW
15:00	928	568	1,279	607	1,304	601	1,452	619	1,461	721
15:15	965	554	1,292	604	1,318	604	1,474	618	1,484	720
15:30	973	556	1,312	598	1,338	605	1,489	620	1,494	713
15:45	963	551	1,299	600	1,330	603	1,474	618	1,477	707
16:00	938	530	1,259	576	1,284	583	1,417	615	1,425	671
16:15	919	530	1,229	582	1,269	591	1,405	632	1,393	646
16:30	923	547	1,263	600	1,301	608	1,436	653	1,433	644
16:45	931	558	1,274	604	1,304	609	1,449	656	1,448	648
17:00	938	561	1,275	603	1,311	607	1,451	645	1,452	631
17:15	947	556	1,277	605	1,303	603	1,457	632	1,449	603
17:30	947	551	1,287	598	1,307	596	1,456	630	1,441	589
17:45	936	544	1,282	597	1,297	595	1,455	624	1,434	586
18:00	931	542	1,276	591	1,295	593	1,448	624	1,423	585
18:15	916	498	1,239	544	1,247	549	1,394	581	1,353	546
18:30	914	532	1,256	581	1,280	579	1,419	611	1,363	569
18:45	925	543	1,271	588	1,285	590	1,435	600	1,376	572
19:00	913	542	1,269	594	1,285	590	1,432	606	1,372	580
19:15	905	540	1,262	588	1,284	588	1,430	625	1,369	596
19:30	903	538	1,263	590	1,275	588	1,425	648	1,369	611
19:45	902	536	1,258	587	1,272	586	1,421	681	1,368	628
20:00	894	536	1,248	583	1,262	583	1,410	688	1,351	637
20:15	875	505	1,199	534	1,204	538	1,355	658	1,274	604
20:30	866	519	1,187	538	1,188	551	1,359	661	1,241	611
20:45	891	572	1,241	603	1,251	612	1,411	705	1,287	643
21:00	891	597	1,247	611	1,255	620	1,413	706	1,301	641
21:15	886	653	1,243	642	1,249	653	1,420	718	1,300	649
21:30	879	642	1,231	667	1,248	701	1,410	752	1,290	654
21:45	878	642	1,236	669	1,246	705	1,403	765	1,283	669
22:00	880	641	1,231	661	1,239	702	1,400	762	1,267	678
22:15	857	598	1,176	617	1,175	657	1,331	723	1,190	658
22:30	862	629	1,203	648	1,201	685	1,354	754	1,214	707
22:45	864	645	1,218	712	1,205	751	1,373	816	1,238	770
23:00	858	712	1,208	1,275	1,200	1,299	1,362	1,353	1,242	1,289
23:15	851	720	1,207	1,345	1,200	1,412	1,355	1,446	1,237	1,351
23:30	858	711	1,210	1,263	1,204	1,353	1,364	1,386	1,227	1,285
23:45	862	701	1,201	1,243	1,195	1,321	1,363	1,358	1,233	1,266
00:00	842	674	1,152	1,204	1,146	1,280	1,302	1,328	1,178	1,246

3. Site #2 Utility Meter Monthly Average Weekend kW Data for 2000 and 2002

Time of Day	May 00 kW	May 02 kW	Jun 00 kW	Jun 02 kW	Jul 00 kW	Jul 02 kW	Aug 00 kW	Aug 02 kW	Sep 00 kW	Sep 02 kW
0:15	753	406	945	986	1,015	1,132	1,123	1,172	947	1,074
00:30	733	401	930	972	995	1,124	1,104	1,145	938	1,076
00:45	729	397	928	966	987	1,124	1,091	1,137	932	1,075
01:00	724	394	921	964	981	1,122	1,086	1,140	921	1,068
01:15	724	389	911	959	974	1,109	1,080	1,118	907	1,054
01:30	719	375	907	944	965	1,082	1,062	1,098	901	1,027
01:45	719	371	901	930	959	1,077	1,056	1,083	894	1,022
02:00	715	370	894	918	951	1,075	1,046	1,068	888	1,002
02:15	709	365	884	904	940	1,066	1,030	1,066	877	1,000
02:30	706	361	874	903	932	1,052	1,016	1,047	870	990
02:45	701	361	877	900	932	1,061	1,016	1,052	875	991
03:00	702	364	871	893	929	1,056	1,010	1,051	873	991
03:15	703	365	865	886	924	1,045	1,008	1,037	866	989
03:30	711	364	864	876	925	1,027	1,000	1,018	861	976
03:45	715	363	862	872	919	1,023	1,000	1,017	856	952
04:00	715	364	857	866	916	1,031	992	1,020	857	953
04:15	710	356	844	868	906	1,015	973	1,007	846	946
04:30	699	352	833	857	899	1,008	962	998	837	940
04:45	695	355	836	858	901	1,006	957	999	844	945
05:00	695	349	839	853	903	996	954	992	846	944
05:15	695	353	838	858	905	996	953	989	847	932
05:30	697	351	833	849	906	988	954	981	844	930
05:45	705	347	819	837	898	968	953	972	847	919
06:00	698	341	814	809	883	943	942	968	854	923
06:15	684	322	800	798	865	935	916	964	846	922
06:30	673	311	790	798	862	934	897	949	836	917
06:45	660	311	777	801	856	935	891	924	821	908
07:00	666	305	789	806	861	934	892	916	812	895
07:15	666	269	799	810	854	943	885	917	810	875
07:30	673	270	800	814	859	947	888	916	817	874
07:45	685	269	799	826	860	953	896	923	800	873
08:00	679	269	792	842	857	956	900	923	785	879
08:15	685	269	804	847	858	965	904	930	778	897
08:30	675	273	817	845	871	975	908	944	782	908
08:45	676	276	814	863	880	983	932	954	793	924
09:00	682	272	823	869	890	993	951	966	807	926
09:15	693	274	827	879	897	1,008	957	977	814	936
09:30	719	277	837	896	904	1,009	969	982	823	952
09:45	731	282	842	897	910	1,011	991	1,001	835	966
10:00	728	279	854	901	917	1,030	1,009	1,009	845	977
10:15	729	276	866	902	930	1,046	1,027	1,021	854	992
10:30	724	274	878	908	954	1,047	1,039	1,033	861	1,008
10:45	738	320	891	902	982	1,056	1,062	1,052	874	1,020
11:00	749	327	910	838	981	1,063	1,068	1,054	903	1,038
11:15	744	326	924	861	992	1,067	1,083	1,060	911	1,043
11:30	763	329	942	873	1,011	1,071	1,102	1,076	956	1,060
11:45	776	338	952	874	1,026	1,084	1,115	1,089	964	1,075
12:00	787	338	963	878	1,037	1,089	1,127	1,104	967	1,085
12:15	794	370	971	881	1,050	1,100	1,139	1,115	975	1,100
12:30	779	378	987	885	1,049	1,108	1,145	1,116	988	1,103
12:45	791	391	994	799	1,060	993	1,160	1,018	1,025	1,002
13:00	792	413	1,021	401	1,076	461	1,183	519	1,054	545
13:15	793	368	1,035	385	1,095	425	1,198	512	1,048	540
13:30	820	368	1,030	371	1,099	403	1,208	480	1,060	528
13:45	809	367	1,037	371	1,089	393	1,211	475	1,073	521
14:00	808	370	1,040	376	1,091	393	1,221	476	1,082	517
14:15	818	369	1,045	376	1,089	399	1,220	442	1,101	498
14:30	808	363	1,058	372	1,092	402	1,224	408	1,107	484
14:45	811	366	1,063	376	1,101	403	1,228	393	1,123	481

3. Site #2 Utility Meter Monthly Average Weekend kW Data for 2000 and 2002 (continued)

Time of Day	May 00 kW	May 02 kW	Jun 00 kW	Jun 02 kW	Jul 00 kW	Jul 02 kW	Aug 00 kW	Aug 02 kW	Sep 00 kW	Sep 02 kW
15:00	809	366	1,069	381	1,109	403	1,240	391	1,133	479
15:15	807	369	1,066	372	1,103	398	1,249	391	1,141	483
15:30	819	367	1,070	369	1,105	401	1,242	389	1,141	471
15:45	816	399	1,064	377	1,110	399	1,257	388	1,141	472
16:00	820	345	1,068	372	1,104	392	1,258	387	1,141	460
16:15	829	336	1,067	371	1,111	394	1,257	388	1,135	438
16:30	820	325	1,076	369	1,112	388	1,253	382	1,143	417
16:45	817	323	1,081	369	1,112	396	1,255	386	1,146	421
17:00	814	327	1,073	364	1,112	386	1,252	378	1,148	408
17:15	810	322	1,071	367	1,114	386	1,252	366	1,149	394
17:30	815	326	1,073	366	1,105	388	1,250	364	1,141	380
17:45	818	319	1,066	370	1,104	389	1,250	363	1,134	376
18:00	822	317	1,063	365	1,101	384	1,246	362	1,121	374
18:15	820	316	1,059	364	1,095	384	1,241	360	1,108	374
18:30	805	321	1,061	361	1,096	387	1,239	360	1,100	373
18:45	800	320	1,065	366	1,091	391	1,234	362	1,094	373
19:00	798	322	1,056	368	1,085	388	1,228	378	1,076	375
19:15	793	327	1,043	368	1,087	383	1,222	401	1,064	393
19:30	790	325	1,036	365	1,079	383	1,209	427	1,058	408
19:45	791	325	1,017	364	1,069	380	1,203	456	1,050	429
20:00	788	328	1,001	358	1,060	379	1,195	463	1,034	432
20:15	791	342	992	364	1,053	378	1,184	481	1,016	432
20:30	783	352	989	367	1,046	390	1,180	479	1,007	436
20:45	784	362	991	386	1,056	411	1,192	486	1,013	436
21:00	783	384	993	391	1,053	410	1,180	480	1,001	440
21:15	778	453	990	416	1,044	449	1,168	500	992	447
21:30	782	456	991	437	1,041	496	1,176	535	988	458
21:45	783	452	980	437	1,030	497	1,171	549	978	474
22:00	781	440	974	433	1,027	493	1,156	543	966	482
22:15	777	443	959	432	1,020	490	1,134	545	950	492
22:30	776	445	957	437	1,018	485	1,128	559	944	522
22:45	767	451	954	491	1,015	547	1,130	619	949	578
23:00	763	455	954	1,034	1,009	1,074	1,124	1,148	944	1,070
23:15	764	448	951	1,039	1,001	1,188	1,107	1,230	936	1,101
23:30	760	449	941	981	994	1,119	1,102	1,145	938	1,032
23:45	762	447	939	968	990	1,109	1,096	1,111	932	1,018
00:00	770	445	925	962	986	1,094	1,085	1,104	919	1,026

4. Site #2 Purchase Order Receipt for New AC and EMS

Project Cost Summary

CIP #	11307			JDE Download Date:	10/17/2002
Project Title	Warehouse 2, 3 & 4 Cooling				
PR #	PR012182				
Location	Modesto				
Area	Plant Engineering Admin.			Start Date:	02/15/2001
Business Unit #	5309	Engineer:		Est. Complete:	12/31/2001

	Committed $	Paid $	Approved Budget $	Committed Over/Under Budget
Purchase Orders (in JDE):	723,745	723,775		
Misc. GL: (includes Checks, Adjusts & Inside Labor)	218,266	218,266		
Storeroom Issues	6,461	6,461		
Adjust for paid freight where order amt = $0	25	n/a		
Unposted Inside Labor:	0	0		
Unposted BofA:				
Other (Adj. Paid):				
Adjust Commit for PO Overpayment:	5	n/a		
Totals:	948,502	948,502	950,000	1,498

COMMENTS: This project is closed in JDE; the last General Ledger posting was 3/31/02.

Appendix D: MID C&I Custom HVAC Site #3

M&V REPORT FOR C&I CUSTOM AC SITE #3

Prepared for the Modesto Irrigation District
and the Northern California Power Agency

Prepared by Robert Mowris & Associates

January 17, 2003

SITE SUMMARY INFORMATION

Company Name:	**N/A**		
Site Name:	**CTO Site #3**		
Site Address:	**Modesto, CA 95355**		
Principal Site Contact:	**N/A**	**Telephone:**	**N/A**
MID Contact:	**Peter Govea**	**Telephone:**	**(209) 526-7344**
Assigned Lead Engineer:	**Robert Mowris, P.E.**	**Telephone:**	**(800) 786-4130**

Site: CTO Site #3, Modesto, CA

PROJECTS PAID BY SB5X FUNDS

Project	Account Number	End Use	NCPA Utility	Program	Project Type
CTO Site #3	N/A	Air Conditioning	MID	SB5X Priority Project	HVAC

MEASURES FOR EACH PROJECT

		Ex Ante Savings Estimate			
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)	Rebate ($)
1	Chiller Tower Optimization	90	221,037	n/a	$15,240

PROGRAM MEASUREMENT AND VERIFICATION SAVINGS ESTIMATE

		M&V Evaluation Savings		
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)
1	Chiller Tower Optimization	51	201,453	n/a

Evaluation of Spillover

No evidence of spillover was found.

Impact Evaluation Report: MID **End Use: HVAC**

Introduction

On August 15, 2002 Robert Mowris, P.E., of Robert Mowris & Associates (RMA), conducted an M&V site visit to evaluate the new Chiller-Tower Optimization (CTO) Software installed at CTO Site #3 in Modesto, California. Peter Govea, Senior Energy Services Engineer for Modesto Irrigation District (MID) arranged and attended the site visits. On September 17 and 26, 2002, Robert Mowris, P.E., and George Nesbitt of RMA conducted additional M&V site visits. Peter Govea arranged and attended the additional site.

MID provides electricity to the facility and PG&E provides natural gas. Electricity use for the facility is metered at multiple panels. Two utility meters serve the affected measures (i.e., chillers and cooling towers). The electrical panel readings indicated electrical demand consistent with design specifications and historical billing data provided by Site #3 and MID. Equipment that received incentives from MID's SB5X funds was examined and verified during the M&V site visits.

Readings of the electric utility meters were obtained from the utility and readings of sub-panels, various gauges, equipment, and controls were made during the site visits. In addition, run-time and short-term power measurements were made to assess equipment operation and energy consumption for the cooling towers and chillers. Electric poly-phase data loggers were installed on the three cooling towers and three chillers to measure true RMS electric power usage. Temperature data loggers were installed on the roof to measure outdoor temperatures. Data loggers were installed from 8-15-02 through 9-26-02. Model numbers and performance data were obtained for cooling towers and chillers. Historical utility billing data for the facility was also reviewed both before and after installation. Historical billing data are provided in **Attachment 1**.

Business Description

Site #3 has been located in Modesto for more than 25 years. Today, it is one of two large hospitals in Modesto. The facility is used during the entire year, but peak cooling occurs from May through September.

Scope of Project

The Custom Rebate Application was for 90 kW and 221,037 kWh for the new CTO software. The total requested incentive is $15,240 based on 50% of $30,480 which is the total cost of the project.[36]

Schedule of Key Dates

Full implementation of project was completed in March of 2002.

Measure Description

Efficiency Improvement: Site #3 has two 700 ton chillers and one 500 ton chiller as well as one 1,200 cooling tower and one 800 ton cooling tower. The Trane Summit Chiller-Tower Optimization (CTO) software continuously monitors (i.e., every 5 minutes) the performance of the chillers and cooling towers and makes adjustments to maintain optimal condenser water

[36] MID's Commercial Power Saver Custom Rebate is based on the minimum of three incentive caps: 1) $500 per kW of peak savings from 2-6PM; 2) 2.5% of account's annual electric bill; or 3) 50% of total cost of project.

temperatures with the least amount of chiller plus cooling tower electric power usage. The software monitors chiller loads and ambient wet bulb temperatures. Using these inputs and the chiller and cooling tower characteristics, the program provides optimal condenser water supply temperatures (i.e., closer to ambient wet bulb temperatures) in order to decrease chiller power consumption. This will increase tower power consumption, but it is more efficient to run a 30-hp tower fan at high speed (cooler condenser water temperatures) than to run a 700-hp chiller compressor at a high compressor lift condition that requires even more power. The software includes the following chiller characteristics: tons; condenser water flow rate, full load efficiency (kW/ton), part-load performance (kW/ton) at design entering condenser water temperature (efficiencies from 10% to 100%) in 10% increments. The CTO software also includes cooling tower characteristics such as water flow rates, wet bulb approach temperatures, total fan power, and tower range (i.e., difference between entering and leaving condenser water temperatures).

Pre-installation Equipment and Operation: *The pre-installation equipment did not have Trane's CTO software. The pre-installation control used a fixed condenser water supply set point (i.e., 85 degrees Fahrenheit), and modulated cooling tower fan speed based on the fixed condenser water supply temperature.*

As-Built Equipment and Operation: The as-built cooling system and CTO controls were inspected and found to be operating as specified by Site #3 and Trane.

Variability in Schedule and Production: The facility operates twelve months per year with most space cooling from May through September.

Square Footage of Affected Area: The affected area is 310,695 square feet.

Algorithms for Estimating Energy Savings for Paid Measure

Ex Ante Savings:

Site #3 provided estimated savings of 90 kW and 221,037 kWh/yr for the CTO software. These savings are based on computer simulations performed by Trane and the simulation results are shown in **Table 1**. Ex Ante kW savings are based on the average difference between the summer Non-CTO baseline peak kW and the summer CTO peak kW.

$$\text{Ex Ante Peak kW Savings} = \frac{\sum_{i=May}^{Sep} \text{Non-CTO kW}_i - \text{CTO kW}_i}{5} = 90\ kW$$

Ex Ante kWh savings are based on the difference between the Non-CTO baseline annual kWh and the CTO annual kWh.

Ex Ante kWh Savings = 18,415,981 *kWh* – 18,194,944 *kWh* = 221,037 *kWh/yr*

Table 1. Trane Computer Simulation Results for Hospital Site #3

Month	Non-CTO Baseline kW	Non-CTO Baseline kWh	CTO kW	CTO kWh	kW Savings	kWh Savings
Jan	2,410	1,483,480	2,410	1,486,087	0	-2,607
Feb	2,416	1,350,543	2,417	1,350,661	-1	-118
Mar	2,421	1,505,737	2,429	1,508,149	-8	-2,412
Apr	2,615	1,523,526	2,523	1,503,332	92	20,194
May	2,630	1,594,008	2,539	1,568,872	91	25,136
Jun	2,646	1,574,989	2,556	1,537,714	90	37,275
Jul	2,726	1,660,296	2,638	1,619,080	88	41,216
Aug	2,682	1,644,626	2,593	1,609,797	89	34,829
Sep	2,656	1,564,494	2,565	1,531,183	91	33,311
Oct	2,594	1,585,857	2,502	1,547,503	92	38,354
Nov	2,428	1,456,847	2,440	1,460,762	-12	-3,915
Dec	2,370	1,471,578	2,371	1,471,804	-1	-226
Total	**2,726**	**18,415,981**	**2,638**	**18,194,944**	**90**	**221,037**

Note: Trane ex-ante Peak kW savings are averaged over the summer peak period (i.e., May through September).

M&V Savings:

The M&V savings are 51 kW and 201,453 kWh/yr or 0.043 kW/ton and 167.9 kWh/yr-ton (based on 1,200 tons). M&V savings are based on calibrated eQuest simulations with and without the CTO enabled using normalized TMY weather data. The calibration is based on historical 2001 billing data (shown in **Attachment 1**) and short-term measurements of the chillers and cooling towers. Short-term measurements for the chillers and cooling towers were made during the months of August and September using poly-phase data loggers as shown in **Figure 1**.[37] Short-term measurements in September 2002 for two similar days (in terms of cooling loads and outdoor temperatures) indicate savings of 56 kW as shown in **Table 2**.

September Peak kW Savings = 723 kW – 667 kW = 56 kW

Table 2. Measured kW Savings for the CTO Software in September

Description	Date and Time	Outdoor Temperature	Chiller plus Cooling Tower kW
Non-CTO baseline peak load	9/23/02, 3:30 PM	106.9 F	723 kW
CTO baseline peak load	9/24/02, 4:00 PM	107.8 F	667 kW
Measured Savings			**56 kW**

Savings in September are greater than savings in July which is the peak cooling month. This is because outdoor temperatures are generally cooler in September (and May) than in July. When outdoor temperatures are cooler the CTO is able to maintain lower cooling tower temperatures, and this lowers compressor lift conditions, which reduces chiller plus coolng tower electrical use.

The M&V savings are based on calibrated eQuest simulations that are normalized to account for weather differences between 2001 and 2002 as well as building operational

[37] Measurements of peak kW demand for the new high efficiency cooling system were made by Robert Mowris, P.E., on 8-28-02 using a true RMS poly-phase PowerSight data logger manufactured by Summit Technologies and calibrated on 8-05-02.

differences. The eQuest simulation results are shown in **Table 3**. The M&V kW and kWh savings are as follows.

$$\text{M\&V kW Savings} = \frac{\sum_{i=May}^{Sep} \text{Non-CTO kW}_i - \text{CTO kW}_i}{5} = 51\ kW$$

$$\text{M\&V kWh Savings} = 16{,}075{,}501\ kWh/yr - 15{,}874{,}048\ kWh/yr = 201{,}453\ kWh/yr$$

Figure 1. Non-CTO Baseline versus CTO Monitoring Data

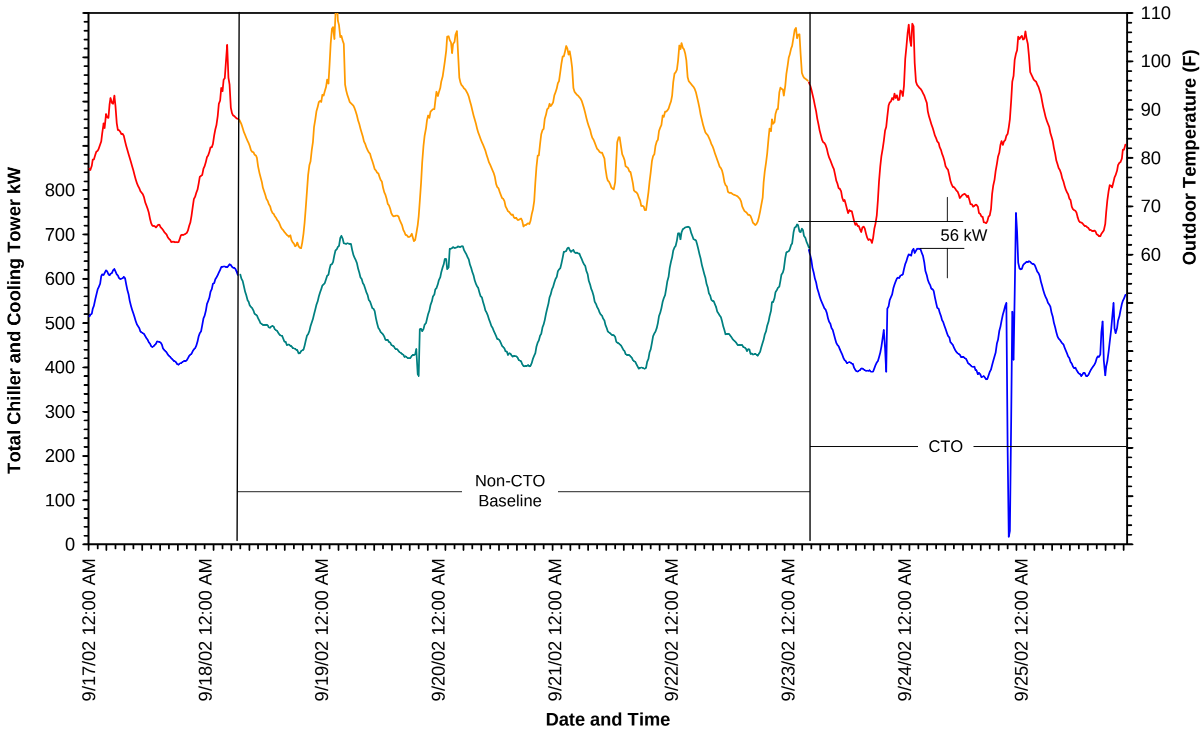


Table 3. Normalized eQuest Simulation Results for Site #3

Month	Non-CTO Peak kW	Non-CTO 2001 kWh	CTO Peak kW	CTO 2002 kWh	Savings kW	Savings kWh
Jan	2,007	1,299,214	1,981	1,290,068	26	9,146
Feb	1,962	1,183,388	1,940	1,173,117	22	10,271
Mar	1,976	1,315,960	1,956	1,303,131	20	12,829
Apr	2,235	1,305,395	2,177	1,291,093	58	14,302
May	2,344	1,383,802	2,302	1,363,243	42	20,559
Jun	2,413	1,369,119	2,339	1,344,458	74	24,661
Jul	2,557	1,459,631	2,526	1,431,388	31	28,243
Aug	2,459	1,447,532	2,418	1,419,946	41	27,586
Sep	2,415	1,374,767	2,349	1,351,344	67	23,423
Oct	2,225	1,371,468	2,165	1,363,171	60	8,297
Nov	2,142	1,269,974	2,019	1,257,192	123	12,782
Dec	2,001	1,295,251	1,981	1,285,897	20	9,354
Total	**2,557**	**16,075,501**	**2,527**	**15,874,048**	51	201,453

Note: M&V peak kW savings are averaged over the summer peak period (i.e., May through September).

Data Collection

Site Specific Input Parameters: Data were collected during the on-site survey to support the M&V analyses. Make and model numbers of rebated equipment were verified (i.e., chillers, cooling towers, and controls). Equipment efficiency and relevant performance were also verified.

Data Collection Method: Electric power and temperature data loggers were installed to measure kW and kWh usage for all relevant equipment. Data loggers were installed from 8-15-02 through 9-26-02 to obtain short-term measurements. Measurements and observations during the on-site survey were used to verify rebated equipment. Inventories by type and schedules of internal lighting and equipment were collected during the on-site survey to estimate internal loads. Capacities of cooling systems are based on manufacturer's data. Seasonal variations in operating schedules were obtained from building operations staff during the survey. Operational characteristics of the cooling system, such as the baseline control strategy, on/off schedule, and thermostats setpoints were obtained from a combination of direct observations and an interview with operations personnel during the survey. Operational characteristics for the CTO were obtained from Trane.

Customer Cost/Benefit Analysis

Cost and Payback: No payback analysis was performed by Site #3 or MID. Based on information provided in the file, the total installed cost for the CTO software was $30,480. The MID incentive was $15,240, (i.e., 50% percent of the total installation cost). The total annual electricity savings are $11,032 (see **Table 4**). The simple payback is 1.4 years including the incentive (based on 2002 savings).[38] The measure lifetime is 15 years.

Table 4. M&V Evaluation of Monetary Savings for CTO

Description	Annual Savings	$/unit	Annual Savings
kWh	201,453	0.0416	$8,380
kW	51	10.4	$2,652
Maintenance			n/a
Total			**$11,032**

Note: kW savings are multiplied times 5 months over the summer peak period (i.e., May through September).

Non-Energy Costs and Benefits: Annual labor and maintenance benefits were not provided by Site #3.

Energy Savings

Comparison of MID and Evaluation Estimates:

The M&V evaluation estimate of gross savings for the CTO software is 51 kW and 201,453 kWh/yr. Peak demand savings are 43 percent lower and annual electric savings are 9 percent lower than the Site #3 custom application estimate of 90 kW and 221,037 kWh/yr. The estimated savings were calculated without the benefit of as-built measurements.

Savings Persistence: The expected lifetime for the new CTO is 15 years.

[38] Electricity savings are based on MID rate schedule GS-4. The $/unit kWh rate is averaged based on the summer peak-, partial-, and off-peak rates and winter peak- and off-peak rates.

ATTACHMENT

1. Historical Billing Data for Site #3

Month	2001 Peak kW	2001 kWh	2002 Peak kW	2002 kWh
Jan	2,044	1,136,429	2,122	1,321,195
Feb	1,970	1,016,028	2,202	1,229,904
Mar	2,198	1,262,460	2,224	1,406,201
Apr	2,285	1,228,370	2,239	1,278,405
May	2,491	1,465,711	2,540	1,373,881
Jun	2,464	1,437,234	2,510	1,402,594
Jul	2,574	1,501,546	2,579	1,526,861
Aug	2,462	1,523,083	2,543	1,543,594
Sep	2,360	1,447,095	2,416	1,424,736
Oct	2,400	1,445,654	2,267	1,339,915
Nov	2,116	1,342,934		
Dec	1,992	1,307,912		
Total	**2,574**	**16,114,456**	**2,579**	**13,847,286**

Appendix E: MID C&I Custom HVAC Site #4

M&V REPORT FOR C&I CUSTOM AC SITE #4

Prepared for the Modesto Irrigation District
and the Northern California Power Agency

Prepared by Robert Mowris & Associates

January 3, 2003

SITE SUMMARY INFORMATION

Company Name:	**N/A**		
Site Name:	**CTO Site #4**		
Site Address:	**Modesto, CA 95350**		
Principal Site Contact:	**N/A**	**Telephone:**	**N/A**
MID Contact:	**Peter Govea**	**Telephone:**	**(209) 526-7344**
Assigned Lead Engineer:	**Robert Mowris, P.E.**	**Telephone:**	**(800) 786-4130**

Site: Site #4, Modesto, CA

PROJECTS PAID BY SB5X FUNDS

Project	Account Number	End Use	NCPA Utility	Program	Project Type
CTO #4	N/A	Air Conditioning	MID	SB5X Priority Project	HVAC

MEASURES FOR EACH PROJECT

		Ex Ante Savings Estimate			
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)	Rebate ($)
1	Chiller Tower Optimization	55	100,295	n/a	$18,719

PROGRAM MEASUREMENT AND VERIFICATION SAVINGS ESTIMATE

		M&V Evaluation Savings		
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)
1	Chiller Tower Optimization	87	270,915	n/a

Evaluation of Spillover

No evidence of spillover was found.

Impact Evaluation Report: MID **End Use: HVAC**

Introduction

On August 2, 2002 Robert Mowris, P.E., of Robert Mowris & Associates (RMA), conducted an M&V site visit to evaluate the new Chiller-Tower Optimization (CTO) Software installed at CTO Site #4 located in Modesto, California. Peter Govea, Senior Energy Services Engineer for Modesto Irrigation District (MID) arranged and attended the site visits. On September 11 and 26, 2002, Robert Mowris, P.E., and George Nesbitt of RMA conducted additional M&V site visits. Peter Govea arranged and attended the additional site visits.

MID provides electricity to the facility and PG&E provides natural gas. Electricity use for the facility is metered at multiple panels. One meter serves the affected measures (i.e., chillers and cooling towers). The electrical panel readings indicated electrical demand consistent with design specifications and historical billing data provided by CTO Site #4 and MID. Equipment that received incentives from MID's SB5X funds was examined and verified during the M&V site visits.

Readings of the electric utility meters were obtained from the utility and readings of sub-panels, various gauges, equipment, and controls were made during the site visits. In addition, run-time and short-term power measurements were made to assess equipment operation and energy consumption for the cooling towers and chillers. Electric poly-phase data loggers were installed on the four cooling towers and four chillers to measure true RMS electric power usage. Temperature data loggers were installed on the roof to measure outdoor temperatures. Data loggers were installed from 8-02-02 through 9-26-02. Model numbers and performance data were obtained for cooling towers and chillers. Historical utility billing data for the facility was also reviewed both before and after installation. Historical billing data are provided in **Attachment 1**.

Business Description

CTO Site #4 has been located in Modesto for more than 25 years. Today, it is one of two large hospitals in Modesto. The facility is used during the entire year, but peak cooling occurs from May through September.

Scope of Project

The Custom Rebate Application was for 55 kW and 100,295 kWh for the new CTO software. The total requested incentive is $18,719 based on 50% of $37,439 which is the total cost of the project.[39]

Schedule of Key Dates

Full implementation of project was completed in March 31, 2002.

Measure Description

Efficiency Improvement: CTO Site #4 has three 700 ton chillers and one 300 ton chiller as well as three 700 cooling towers and one 300 ton cooling tower. The Trane Summit Chiller-Tower Optimization (CTO) software continuously monitors (i.e., every 5 minutes) the performance of the chillers and cooling towers and makes adjustments to maintain optimal condenser water

[39] MID's Commercial Power Saver Custom Rebate is based on the minimum of three incentive caps: 1) $500 per kW of peak savings from 2-6PM; 2) 2.5% of account's annual electric bill; or 3) 50% of total cost of project.

temperatures with the least amount of chiller plus cooling tower electric power usage. The software monitors chiller loads and ambient wet bulb temperatures. Using these inputs and the chiller and cooling tower characteristics, the program provides optimal condenser water supply temperatures (i.e., closer to ambient wet bulb temperatures) in order to decrease chiller power consumption. This will increase tower power consumption, but it is more efficient to run a 30-hp tower fan at high speed (cooler condenser water temperatures) than to run a 700-hp chiller compressor at a high compressor lift condition that requires even more power. The software includes the following chiller characteristics: tons; condenser water flow rate, full load efficiency (kW/ton), part-load performance (kW/ton) at design entering condenser water temperature (efficiencies from 10% to 100%) in 10% increments. The CTO software also includes cooling tower characteristics such as water flow rates, wet bulb approach temperatures, total fan power, and tower range (i.e., difference between entering and leaving condenser water temperatures).

Pre-installation Equipment and Operation: The pre-installation equipment did not have Trane's CTO software. The pre-installation control used a fixed condenser water supply set point (i.e., 85 degrees Fahrenheit), and modulated cooling tower fan speed based on the fixed condenser water supply temperature.

As-Built Equipment and Operation: The as-built cooling system and CTO controls were inspected and found to be operating as specified by CTO Site #4 and Trane.

Variability in Schedule and Production: The facility operates twelve months per year with most space cooling from May through September.

Square Footage of Affected Area: The affected area is 498,000 square feet.

Algorithms for Estimating Energy Savings for Paid Measure

CTO Site #4 Savings:

CTO Site #4 provided estimated savings of 55 kW and 100,295 kWh/yr for the CTO software. These savings are based on computer simulations performed by Trane and the simulation results are shown in **Table 1**. Ex Ante kW savings are based on the average difference between the summer Non-CTO baseline peak kW and the summer CTO peak kW.

$$\text{Ex Ante Peak kW Savings} = \frac{\sum_{i=May}^{Sep} \text{Non - CTO kW}_i - \text{CTO kW}_i}{5} = 55\ kW$$

Ex Ante kWh savings are based on the difference between the Non-CTO baseline annual kWh and the CTO annual kWh.

Ex Ante kWh Savings = 16,640,829 – 16,540,534 = 100,295 *kWh/yr*

Table 1. Trane Computer Simulation Results for CTO Site #4

Month	Non-CTO Baseline kW	Non-CTO Baseline kWh	CTO kW	CTO kWh	kW Savings	kWh Savings
Jan	1,805	1,307,757	1,805	1,308,335	0	-578
Feb	1,826	1,189,781	1,859	1,194,097	-33	-4,316
Mar	1,833	1,322,174	1,878	1,329,086	-45	-6,912
Apr	2,134	1,387,388	2,072	1,374,967	62	12,421
May	2,129	1,452,586	2,067	1,435,777	62	16,809
Jun	2,209	1,437,184	2,152	1,419,225	57	17,959
Jul	2,352	1,574,518	2,307	1,550,031	45	24,487
Aug	2,259	1,524,942	2,206	1,505,410	53	19,532
Sep	2,210	1,440,594	2,154	1,422,888	56	17,706
Oct	2,134	1,421,328	2,071	1,405,618	63	15,710
Nov	1,843	1,285,276	1,899	1,296,644	-56	-11,368
Dec	1,771	1,297,301	1,776	1,298,456	-5	-1,155
Total	**2,352**	**16,640,829**	**2,307**	**16,540,534**	**55**	**100,295**

Note: Trane ex-ante Peak kW savings are averaged over the summer peak period (i.e., May through September).

M&V Savings:
The M&V savings are 87 kW and 270,915 kWh/yr or 0.051 kW/ton and 159.4 kWh/yr-ton (based on 1,700 tons[40]). The M&V savings are based on calibrated eQuest simulations with and without the CTO enabled using normalized TMY weather data. The calibration is based on historical 2001 billing data (shown in **Attachment 1**) and short-term measurements of the chillers and cooling towers. Short-term measurements for the chillers and cooling towers were made during the months of August and September using poly-phase data loggers as shown in **Figure 1**.[41] Short-term measurements in September 2002 for two similar days (in terms of cooling loads and outdoor temperatures) indicate savings of 136 kW as shown in **Table 2**.

September Peak kW Savings = 861 – 725 = 136 *kW*

Table 2. Measured kW Savings for the CTO Software in September

Description	Date and Time	Outdoor Temperature	Chiller plus Cooling Tower kW
Non-CTO baseline peak load	9/23/02, 4:00 PM	106.9 F	861 kW
CTO baseline peak load	9/24/02, 4:00 PM	107.8 F	724 kW
Measured Savings			**136 kW**

Savings in September are greater than savings in July which is the peak cooling month. This is because outdoor temperatures are generally cooler in September (and May) than in July. When outdoor temperatures are cooler the CTO is able to maintain lower cooling tower temperatures, and this lowers compressor lift conditions, which reduces chiller plus cooling tower electrical use.

The M&V savings are based on calibrated eQuest simulations that are normalized to account for weather differences between 2001 and 2002 as well as building operational

[40] The site uses two of three 700 ton and one 300 tons chillers/towers at any given time for a total of 1,700 tons.
[41] Measurements of peak kW demand for the new high efficiency cooling system were made by Robert Mowris, P.E., on 8-28-02 using a true RMS poly-phase PowerSight data logger manufactured by Summit Technologies and calibrated on 8-05-02.

differences. The eQuest simulation results are shown in **Table 3**. The M&V kW and kWh savings are as follows.

$$\text{M\&V kW Savings} = \frac{\sum_{i=May}^{Sep} \text{Non-CTO kW}_i - \text{CTO kW}_i}{5} = 87\ kW$$

M&V kWh Savings = 18,524,071 kWh/yr – 18,253,156 kWh/yr = 270,915 kWh/yr

Further evidence to support the M&V peak kW savings is provided by the average weekday peak demand from 2PM to 6PM for CTO Site #4 shown in **Table 4**. The 2001 Non-CTO peak demand from 2PM to 6PM is 2,819 kW compared to the 2002 CTO peak demand of 2,734 kW. The difference is 86 kW, roughly equivalent to the M&V kW savings of 87 kW. September savings shown in **Table 4** are 140 kW and this is roughly equivalent to the short-term measured savings of 136 kW shown in **Figure 1**.

Figure 1. Non-CTO Baseline versus CTO Monitoring Data

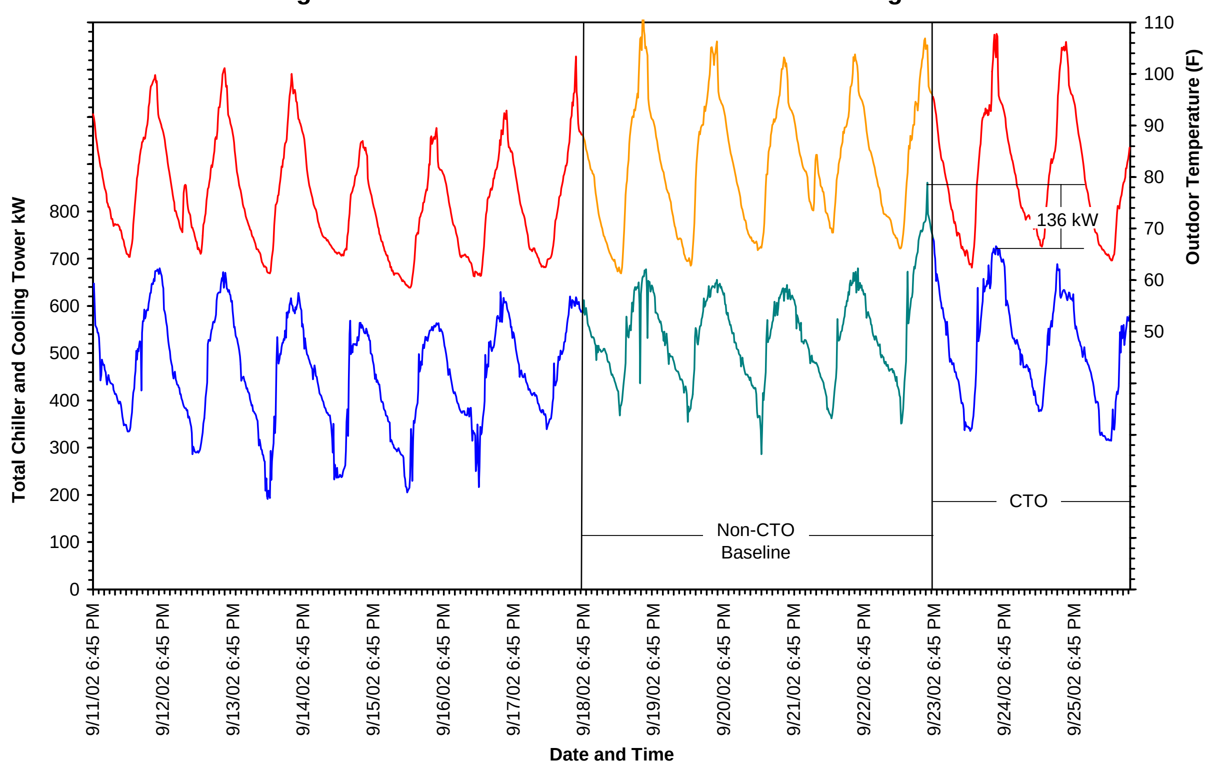


Table 3. Normalized eQuest Simulation Results for CTO Site #4

Month	Non-CTO Peak kW	Non-CTO 2001 kWh	CTO Peak kW	CTO 2002 kWh	Savings kW	Savings kWh
Jan	2,716	1,448,813	2,709	1,438,491	7	10,322
Feb	2,897	1,324,488	2,845	1,311,178	52	13,310
Mar	2,919	1,480,310	2,867	1,461,477	52	18,833
Apr	3,031	1,501,104	2,951	1,478,508	80	22,596
May	3,087	1,630,784	3,000	1,602,590	87	28,194
Jun	3,086	1,597,485	3,012	1,570,200	74	27,285
Jul	3,107	1,732,430	3,025	1,699,295	82	33,135
Aug	3,105	1,710,535	3,020	1,677,922	85	32,613
Sep	3,106	1,610,606	3,001	1,580,040	105	30,566
Oct	3,009	1,610,606	2,974	1,584,460	35	26,146
Nov	2,943	1,439,804	2,900	1,422,378	43	17,426
Dec	2,655	1,437,106	2,523	1,426,617	132	10,489
Total	**3,107**	**18,524,071**	**3,025**	**18,253,156**	87	270,915

Note: M&V peak kW savings are averaged over the summer peak period (i.e., May through September).

Table 4. Average Weekday Peak Demand from 2 PM to 6 PM for CTO Site #4

Month	2001 Non-CTO Peak kW	2002 CTO Peak kW	Savings Peak kW
May	2,740	2,494	245
Jun	2,775	2,701	74
Jul	2,819	2,734	86
Aug	2,763	2,720	43
Sep	2,713	2,573	140

Data Collection

Site Specific Input Parameters: Data were collected during the on-site survey to support the M&V analyses. Make and model numbers of rebated equipment were verified (i.e., chillers, cooling towers, and controls). Equipment efficiency and relevant performance were also verified.

Data Collection Method: Electric power and temperature data loggers were installed to measure kW and kWh usage for all relevant equipment. Data loggers were installed from 8-02-02 through 9-26-02 to obtain short-term measurements. Measurements and observations during the on-site survey were used to verify rebated equipment. Inventories by type and schedules of internal lighting and equipment were collected during the on-site survey to estimate internal loads. Capacities of cooling systems are based on manufacturer's data. Seasonal variations in operating schedules were obtained from building operations staff during the survey. Operational characteristics of the cooling system, such as the baseline control strategy, on/off schedule, and thermostats setpoints were obtained from a combination of direct observations and an interview with operations personnel during the survey. Operational characteristics for the CTO were obtained from Trane.

Customer Cost/Benefit Analysis

Cost and Payback: No payback analysis was performed by CTO Site #4 or MID. Based on information provided in the file, the total installed cost for the CTO software was $37,439. The MID incentive was $18,719, (i.e., 50% percent of the total installation cost). The total annual electricity savings are $14,986 (see **Table 5**). The simple payback is 1.25 years including the incentive (based on 2002 savings).[42] The measure lifetime is 15 years.

Table 5. M&V Evaluation of Monetary Savings for CTO

Description	Annual Savings	$/unit	Annual Savings
kWh	270,915	0.0399	$10,810
kW	87	9.6	$4,176
Maintenance			n/a
Total			**$14,986**

Note: kW savings are multiplied times 5 months over the summer peak period (i.e., May through September).

Non-Energy Costs and Benefits: Annual labor and maintenance benefits were not provided.

Energy Savings

Comparison of MID and Evaluation Estimates:

The M&V evaluation estimate of gross savings for the CTO software is 87 kW and 270,915 kWh/yr. Peak demand savings are 58 percent higher and annual electric savings are 270 percent higher than the CTO Site #4 custom application estimate of 55 kW and 100,295 kWh/yr. The estimated savings were calculated without the benefit of as-built measurements.

Savings Persistence: The expected lifetime for the new CTO is 15 years.

[42] Electricity savings are based on MID rate schedule IC1-98. The $/unit kWh rate is averaged based on the summer peak-, partial-, and off-peak rates and winter peak- and off-peak rates.

ATTACHMENT

1. Historical Billing Data for CTO Site #4

Month	2001 Peak kW	2001 kWh	2002 Peak kW	2002 kWh
Jan	2,412	1,322,491	2,482	1,445,997
Feb	2,488	1,187,849	2,465	1,273,066
Mar	2,750	1,422,596	2,548	1,413,848
Apr	2,829	1,403,118	2,700	1,438,374
May	3,226	1,761,127	2,987	1,582,579
Jun	3,193	1,728,258	3,017	1,689,421
Jul	3,194	1,803,102	3,050	1,743,954
Aug	3,003	1,801,924	3,099	1,715,499
Sep	3,212	1,692,780	2,778	1,585,483
Oct	2,966	1,652,098	2,592	1,510,738
Nov	2,642	1,459,189		
Dec	2,294	1,357,693		
Total	**3,226**	**18,592,225**	**3,099**	**15,398,959**

Appendix F: Palo Alto C&I Custom HVAC Site #56

M&V REPORT FOR C&I CUSTOM AC SITE #56

Prepared for the City of Palo Alto Utilities
and the Northern California Power Agency

Prepared by Robert Mowris & Associates

SITE SUMMARY INFORMATION

Company Name:	**Site #56 – Palo Alto**		
Site Name:	**Site #56 – Palo Alto**		
Site Address:	**Palo Alto, CA 94303**		
Principal Site Contact:	**N/A**	**Telephone:**	**N/A**
City of Palo Alto Contact:	**Bruce Lesch**	**Telephone:**	**(650) 329-2244**
Assigned Lead Engineer:	**Robert Mowris, P.E.**	**Telephone:**	**(800) 786-4130**

Site: **Site #56, Palo Alto, CA**

PROJECTS PAID BY SB5X FUNDS

Project	Account Number	End Use	NCPA Utility	Program	Project Type
Site #56	N/A	Cooling	Palo Alto	SB5X Priority Project	HVAC

MEASURES FOR EACH PROJECT

		Ex Ante Savings Estimate			
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)	Rebate ($)
1	Efficient Chillers with VFD	960	2,776,800	n/a	$460,130

PROGRAM MEASUREMENT AND VERIFICATION SAVINGS ESTIMATE

		M&V Evaluation Savings		
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)
1	Efficient Chillers with VFD	815	1,473,327	n/a

Evaluation of Spillover

Significant spillover was found based on the billing data analysis and information provided by Site #56 and City of Palo Alto. Spillover measures included lighting, VFD drives, and controls. Insufficient budget was available to evaluate savings from spillover.

Impact Evaluation Report: Palo Alto **End Use: HVAC**

Introduction

On October 31, 2001 Robert Mowris, P.E., and Shelly Coben, Certified Energy Manager, of Robert Mowris & Associates (RMA), conducted a Measurement and Verification (M&V) site visit to evaluate the new high-efficiency chillers and variable frequency drives (VFD) installed at Site #56 located in Palo Alto, California. Bruce Lesch, Key Account Representative for City of Palo Alto Utilities arranged the site visits with the Site #56 Utility Operations Manager. On October 8, 2002 Robert Mowris, P.E., George Nesbitt, and Anne Blankenship of RMA conducted a second M&V site visit to install data loggers. Bruce Lesch arranged the second site visit. On November 1, 2002, RMA personnel visited the site for a third time to remove the data loggers.

City of Palo Alto Utilities provides electricity and natural gas to the facility. Electricity use for the facility is metered at multiple panels serving the affected area of buildings FS, R1, R2, R3, R4, R5, R6E, R6W, R7, S1, S2, and S3. The electrical panel readings, chiller panel readings, and electric power data logger readings indicated electrical demand consistent with design specifications and historical utility meter data provided by City of Palo Alto Utilities. Chillers and VFD controllers that received incentives from Palo Alto's SB5X funds was examined and verified during the M&V site visits.

Readings of the electric utility meters were obtained from the utility and readings of sub-panels, various gauges, equipment, and controls were made during the site visits. In addition, run-time and short-term power measurements were made to assess equipment operation and energy consumption for the pumps and chillers. Electric poly-phase data loggers were installed on the chillers to measure true RMS electric power usage. Temperature data loggers were installed to measure outdoor temperatures. Data loggers were installed from 10-8-02 through 11-1-02. Model numbers and performance data were obtained for the chillers. Historical utility meter data for the facility was also reviewed both before and after installation. Historical utility meter data are provided in **Attachment 1**.

Business Description

Site #56 has been located in Palo Alto for more than 30 years. Today, it is one of the largest research companies in the United States and one of Palo Alto's largest energy users. The facility is used throughout the year, and peak cooling occurs from May through October. The chillers are used for conditioning building spaces used for research.

Scope of Project

The site #56 rebate application was for two 1,200 ton and one 800 ton chillers rated at 0.40 Integrated Part Load Value (IPLV) and the VFD controllers. The total incentive was $1,344,000 based on $420 per ton and SB5X funds were used to pay $460,130 of the total incentive. The peak demand period is from 2 PM to 6PM Monday through Friday. The SB5X incentive of $460,139 represents approximately 24.9 percent of the $1,850,000 installed cost. The estimated ex ante savings for the project are 960 kW and 2,776,800 kWh based on a study provided by Xcel Energy for the City of Palo Alto.

Schedule of Key Dates

Installation of the chillers and controls was started in May 2001 and the project was completed in July 2001.

Measure Description

Efficiency Improvement: The efficiency improvement consists of two new 1200 ton VFD hermetic centrifugal chillers manufactured by Trane (Model #CVHF128FA1, Serial #L01E08820 and Serial #L0E08842) and one new 800 ton VFD chiller manufactured by Trane (Model #CVHF091FA1, Serial #L01E0879B). The two new 1200 ton chillers serve buildings

FS, R1, R2, R3, R4, R5, R6E, R6W, and R7. The new 800 ton chiller serves buildings S1, S2, and S3. The new chillers have Air Conditioning and Refrigeration Institute (ARI) IPLV ratings of 0.40 kW/ton. The design chilled water flow rates are 1,800 gallons per minute (gpm) for the two 1200 ton chillers and 1,200 gpm for the 800 ton chillers. The design chilled water temperature drop is 16 degrees Fahrenheit (i.e., 56°F to 40°F). The chillers are served by multiple cooling towers. The design condenser water flow rates are 3,600 gpm for the 1200 ton chillers and 2,400 gpm for the 800 ton chillers. The design condenser water temperature drop is 9.2°F (i.e., 89.2°F to 80°F). The building cooling loads are higher than normal due to 100 percent outdoor air required for research.

Other efficiency improvements have been implemented at the site including lighting improvements, VFD drives, and control improvements. Savings for these efficiency improvements are reflected in the billing data (see **Attachement A**). These savings are accounted for in the M&V analyses through the use of eQuest/DOE-2.2 simulations normalized for lighting savings, VFD drives, control improvements, weather, and other variables such as plant operations.

Pre-installation Equipment and Operation: The pre-installation equipment consisted of two 1200-ton centrifugal chillers and one 800-ton centrifugal chiller installed in the 1970s. The old chillers had an estimated nominal ARI rating of 0.8 to 0.9 kW/ton. These chillers were replaced by the new VSD chillers. The baseline chiller IPLV used in the M&V study is 0.663 kW/ton based on California Energy Commission (CEC) building energy efficiency standards in effect prior to 10/29/01 (see 2001 Energy Efficiency Standards for Residential and Nonresidential Buildings, P400-01-024, June 1, 2001, page 34, Table 1-C3, Water Chilling Packages – Minimum Efficiency Requirements).

As-Built Equipment and Operation: The as-built cooling system and controls were inspected and found to be operating as specified by Site #56.

Variability in Schedule and Production: The facility operates twelve months per year whenever cooling is required.

Square Footage of Affected Area: The affected area is 555,481 square feet in buildings FS, R1, R2, R3, R4, R6E, R6W, R7, S1, S2, and S3.

Algorithms for Estimating Energy Savings for Paid Measure
Ex Ante Algorithm:
The estimated ex ante savings for the new Chillers and VFD are 960 kW and 2,776,800 kWh based on a study provided by Xcel Energy for the City of Palo Alto and Site #56. These ex ante savings are based on engineering analysis performed by Xcel Energy.

M&V Evaluation Algorithm:

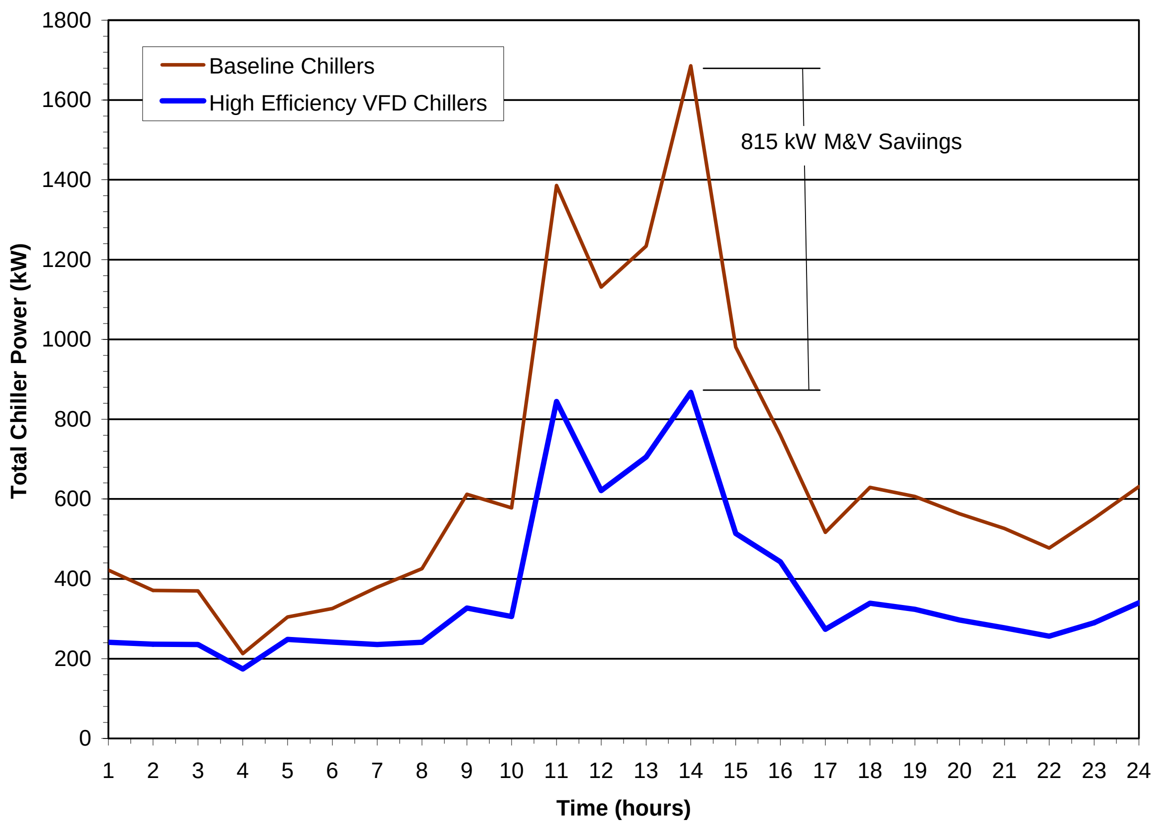
The M&V evaluation algorithms are based on calibrated eQuest/DOE-2.2 simulations, short-term measurements, and utility meter data (i.e., 101545-14700, see **Attachment 1**). The normalized M&V savings are 815 kW as shown in **Table 1**. These savings are plotted in **Figure 1**. The M&V kW algorithm is as follows.

M&V Peak kW Savings = 1,683 $kW_{July\ eQuest\ Baseline}$ - 868 $kW_{eQuest\ New\ AC}$ = 815 kW

Table 1. M&V Evaluation of kW Savings for Site #56 High Efficiency Chillers and VFD

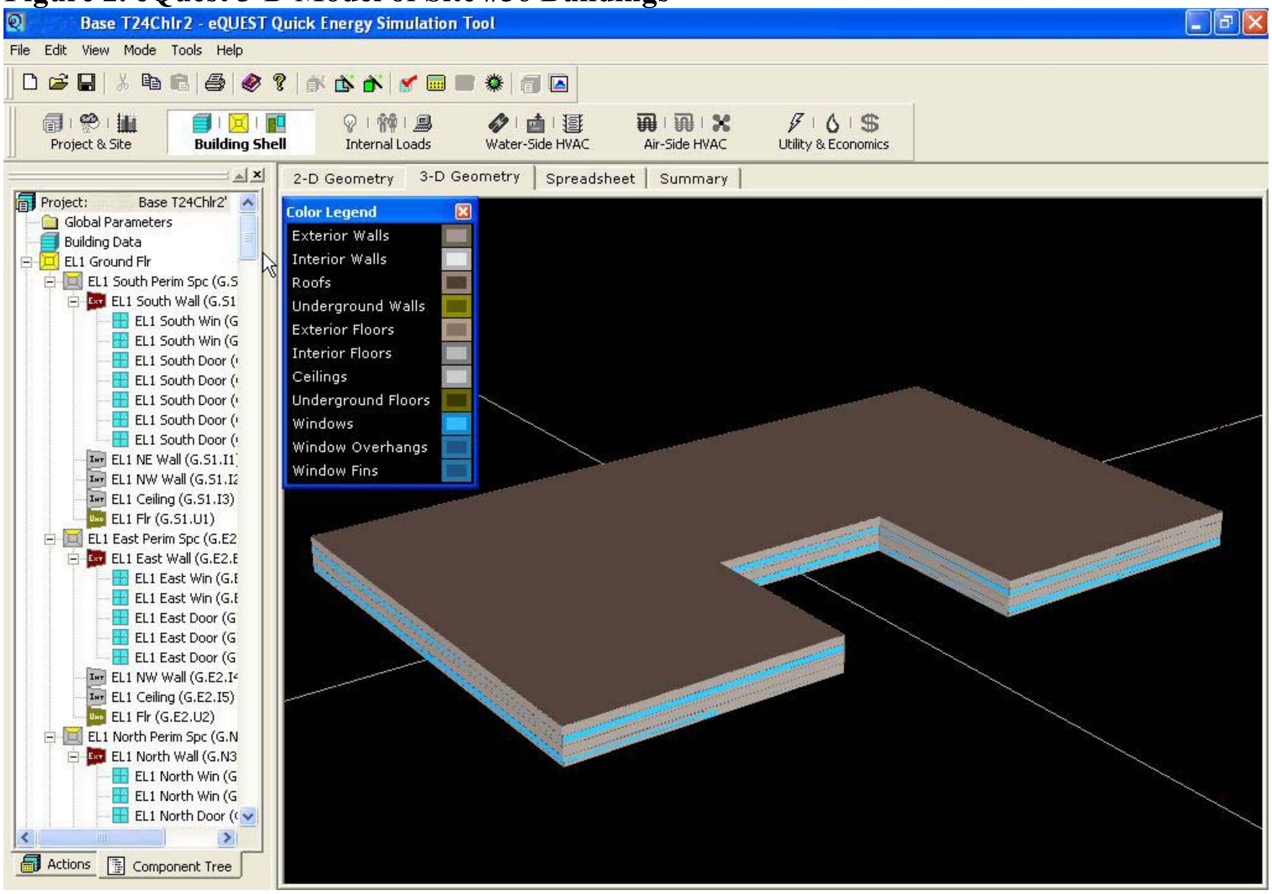
Month	Normalized eQuest/DOE-2.2 M&V Cooling Baseline kW	Normalized eQuest/DOE-2.2 M&V Cooling Measure kW	Normalized eQuest/DOE-2.2 M&V Cooling Savings kW
May	1,152	637	515
Jun	1,233	705	528
Jul	1,637	868	769
Aug	1,200	676	524
Sep	1,180	660	520
Oct	*1,683*	*868*	*815*
Peak kW	**1,637**	**868**	**815**

Figure 1. Baseline Versus High Efficiency VFD Chillers and Peak kW M&V Savings



The eQuest/DOE-2.2 simulations were calibrated using utility meter data, average monthly kW profiles, monthly kWh usage, and short-term measurements. The eQuest/DOE-2.2 3-D model is shown in **Figure 2**. The model represents a simplified aggregate of multiple buildings.

Figure 2. eQuest 3-D Model of Site #56 Buildings



Short-term measurements of the new AC system were made during October (see **Table 2**, and **Figure 3**).[43]

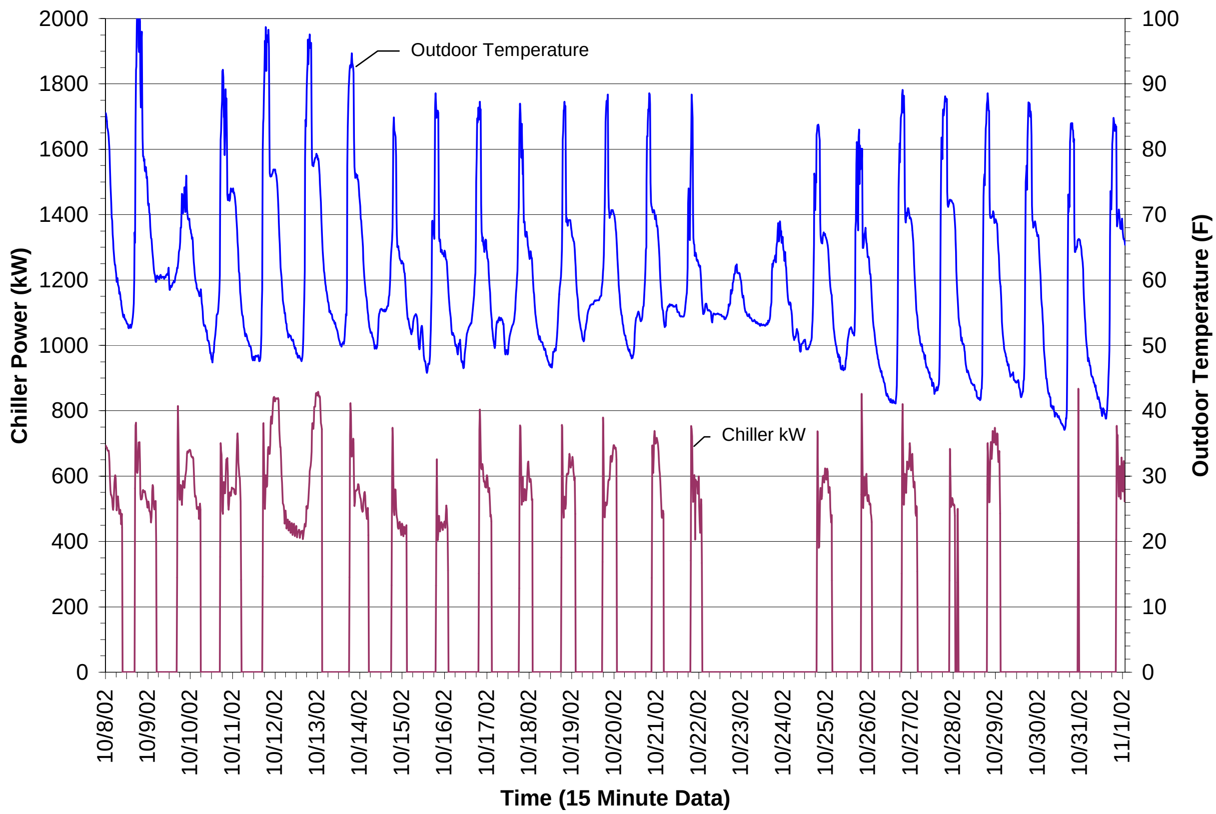
Table 2. Measured Peak kW of New AC System

Description	Qty.	Nominal Size tons	Rated Efficiency kW/ton	Measured Efficiency kW/ton	Measured kW
New Chillers – Buildings FS, R, S					
New 1,200 ton Chiller #1	1	1,200	0.40	0.45	540
New 1,200 ton Back-up Chiller #2	1	n/a	0.40	n/a	n/a
New 800 ton Chiller #3	1	800	0.40	0.41	328
Total High Efficiency VFD Chillers	**3**	**2,000**	**0.40**	**0.434**	**868**

[43] Measurements of peak kW demand for the new AC system were made by Robert Mowris, P.E., on 8-28-02 using a true RMS PowerSight data logger manufactured by Summit Technologies and calibrated on 8-05-02.

Short-term 15-minute measurements from October 2002 show peak cooling loads ranging from zero to 868 kW for the new chillers (see **Figure 3**). These values were used to calibrate the eQuest/DOE-2.2 simulations.

Figure 3. 1200 Ton Chiller Power and Outdoor Temperature (15 Minute Data)



The normalized M&V kWh savings are 1,473,327 kWh/yr as shown in **Table 3**. M&V kW algorithm is as follows.

$$\text{M\&V kWh Savings} = \sum_{\text{Jan}}^{\text{Dec}} \text{kWh}_{\text{eQuest Baseline}} - \sum_{\text{Jan}}^{\text{Dec}} \text{kWh}_{\text{eQuest New Chlr}} = 1{,}473{,}327\ kWh$$

Table 3. M&V Evaluation of kWh Savings for Site #56 VFD Chillers

Month	Normalized eQuest Baseline kWh	Normalized eQuest New Chiller Measure kWh	Normalized M&V Savings kWh
Jan	290,834	246,230	44,604
Feb	310,262	245,418	64,844
Mar	366,971	285,040	81,931
Apr	389,283	292,224	97,059
May	482,465	343,885	138,580
Jun	547,067	371,706	175,361
Jul	622,909	417,289	205,620
Aug	629,256	419,311	209,945
Sep	557,989	377,191	180,798
Oct	493,422	344,543	148,879
Nov	336,948	265,420	71,528
Dec	317,655	263,477	54,178
Total	**5,345,061**	**3,871,734**	**1,473,327**

Monetary savings are summarized in **Table 4**.

Table 4. M&V Evaluation of Monetary Savings for Site #56 VFD Chillers

Description	Annual Resource Savings	$/unit	Annual Savings $
kWh	1,473,327	0.0486	$71,603.69
kW	815	12.16	$9,910.40
Maintenance			n/a
Total			**$81,514.09**

Data Collection

Site Specific Input Parameters: Data were collected during the on-site survey to support the M&V analyses. Make and model numbers of rebated equipment were verified (i.e., chillers, VFDs, and controls). Equipment efficiency and relevant performance were also verified. Building characteristics information was collected for eQuest such as the UA of the building envelope and capacity, use and schedules of internal loads such as lights, miscellaneous equipment, and people.

Data Collection Method: Electric power and temperature data loggers were installed to measure kW and kWh usage for all relevant equipment. Data loggers were installed from 10-08-02 through 11-01-02 to obtain short-term measurements. Measurements and observations during the on-site survey were used to verify rebated equipment. Inventories by type and schedules of internal lighting and equipment were collected during the on-site survey to estimate internal loads. Seasonal variations in operating schedules were obtained from building operations staff during the survey. Operational characteristics of the cooling system, such as the computer controls strategy, on/off schedule, and thermostats setpoints were obtained from a combination of direct observations and an interview with operations personnel during the survey. Capacity and efficiencies of motors and pumps were obtained from nameplate data and spot measurements were made to measure electric power usage. Capacities of cooling systems are based on field measurements and manufacturer's data. Typical operating hours for pumps and motors were obtained from interviews with the operator.

Customer Cost/Benefit Analysis
Cost and Payback: No payback analysis was performed by Site #56 or Palo Alto Utilities. Based on information provided in the file, the total cost for installed equipment is $1,850,000 and the Palo Alto incentive was $1,344,000. No annual labor or maintenance savings are expected from the new Chillers and VFD. The annual savings in electricity are 1,473,327 kWh and 815 kW worth approximately $81,514.[44] The calculated simple payback is approximately 6.2 years including the rebate (based on M&V savings). The measure lifetime is 20 years based on the replaced chillers which were more than 20 years old.
Non-Energy Costs and Benefits: None assumed.

Energy Savings
Comparison of Palo Alto Application and Evaluation Estimates:
The M&V evaluation gross savings estimates for the new VFD chillers are 815 kW and 1,473,327 kWh/yr. Peak demand savings are 15 percent lower and annual electric savings are 47 percent lower than the ex ante estimate of 960 kW and 2,776,800 kWh/yr provided by Xcel Energy. The estimated savings were calculated without the benefit of as-built post-installation measurements.

Savings Persistence: The effective useful lifetime is 20 years for the new chillers and VFD.

[44] Electricity savings are based on City of Palo Alto Utilities Rate E-7 or $0.0486 per kWh and $12.16 per peak kW.

ATTACHMENTS

1. Site #56 Utility Meter Data for 2000 and 2003 (City of Palo Alto Utilities Data)

Month	2000 kWh	2000 Peak kW[1]	2003 kWh	2003 Peak kW[1]	Billing Data kWh Savings	Billing Data kW Savings
Jan	5,160,000	9,540	3,204,000	6,660	1,956,000	2,880
Feb	5,508,000	9,840	3,054,000	5,460	2,454,000	4,380
Mar	6,192,000	11,280	3,270,000	6,540	2,922,000	4,740
Apr	5,473,369	11,162	3,336,000	6,780	2,137,369	4,382
May	6,332,871	12,197	3,942,000	8,580	2,390,871	3,617
Jun	6,314,375	11,772	3,780,000	8,760	2,534,375	3,012
Jul	4,802,898	12,487	4,602,000	8,340	200,898	4,147
Aug	6,001,590	12,191	3,948,000	8,640	2,053,590	3,551
Sep	4,684,098	12,561	3,876,000	8,280	808,098	4,281
Oct	4,869,801	12,377	3,906,000	7,860	963,801	4,517
Nov	4,895,700	12,130	3,012,000	6,240	1,883,700	5,890
Dec	4,370,039	11,763	3,456,000	6,120	914,039	5,643
Total	**64,604,741**	**12,561**	**43,386,000**	**8,760**	**21,218,741**	**3,801**

[1]Peak kW for May through October (i.e., summer months) is from 2PM to 6PM. Peak kW for January through April and November through December is the site coincident peak demand, not necessarily from 2PM to 6PM.

Appendix G: TDPUD C&I Custom HVAC Site #57

M&V REPORT FOR C&I CUSTOM AC SITE #57

Prepared for the Truckee Donner Public Utility District
and the Northern California Power Agency

Prepared by Robert Mowris & Associates

SITE SUMMARY INFORMATION

Company Name:	**Site #57**		
Site Name:	**Site #57 – TDPUD**		
Site Address:	**Truckee, CA 96161**		
Principal Site Contact:	**N/A**	**Telephone:**	**N/A**
TDPUD Contact:	**Scott Terrell**	**Telephone:**	**(530) 582-3931**
Assigned Lead Engineer:	**Robert Mowris, P.E.**	**Telephone:**	**(800) 786-4130**

Site: Site #57, Truckee, CA

PROJECTS PAID BY SB5X FUNDS

Project	Account Number	End Use	NCPA Utility	Program	Project Type
VSD Chiller	500350024	Space Cooling	TDPUD	SB5X Priority Project	HVAC

MEASURES FOR EACH PROJECT

		Ex Ante Savings Estimate			
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)	Rebate ($)
1	VSD Hermetic Centrifugal Chiller	87	229,166	n/a	$10,000

PROGRAM MEASUREMENT AND VERIFICATION SAVINGS ESTIMATE

		M&V Evaluation Savings		
Item No.	Efficiency Measure	(kW)	(kWh/yr)	(therms)
1	VSD Hermetic Centrifugal Chiller	116	305,628	n/a

Evaluation of Spillover

No evidence of spillover was found.

Impact Evaluation Report: TDPUD **End Use: HVAC**

Introduction

On April 12, 2002 Robert Mowris, P.E., of Robert Mowris & Associates (RMA), conducted a Measurement and Verification (M&V) site visit to evaluate the new high-efficiency Variable Speed Drive (VSD) hermetic centrifugal chiller installed at Site #57 located in Truckee, California. Scott Terrell, Planning Director for Truckee Donner Public Utility District (TDPUD) arranged and attended the site visits with the Site #57 Engineering Department Head. On September 19, 2002 Robert Mowris, P.E., conducted a second M&V site visit to install a true RMS data logger on the chiller to measure electrical demand. On October 25, 2001 Robert Mowris conducted a third site visit to download measurements and pick up the data logger. On December 3, 2002 Robert Mowris conducted a fourth site visit to obtain additional information.

TDPUD provides electricity to the facility and Southwest Gas provides natural gas. Electricity use for the facility is metered at two utility panels. The electrical panel readings indicated electrical demand consistent with design specifications and historical utility meter data provided by TDPUD. Equipment that received incentives from TDPUD's SB5X funds was examined and verified during the M&V site visits.

Readings of the electric utility meters were obtained from the utility and readings of sub-panels, various gauges, equipment, and controls were made during the site visits. In addition, run-time and short-term power measurements were made to assess equipment operation and energy consumption for the fans, pumps, cooling tower, and chillers. Electric poly-phase data loggers were installed on the chiller to measure true RMS electric power usage. Data loggers were installed from 9-19-02 through 10-25-02. Model numbers and performance data were obtained for air handling equipment, fans, pumps, cooling tower, and chillers. Historical utility meter data for the facility was also reviewed both before and after installation. Historical utility meter data are provided in **Attachment 1**. The eQuest (DOE-2.2) results are in **Attachment 2**.

Business Description

Site #57 has been located in Truckee for more than 50 years. Today, it is the largest hospital in the Tahoe Truckee area and one of the largest energy users in the TDPUD service area. The facility is used during the entire year, but peak cooling occurs from May through September.

Scope of Project

The rebate was for 87 kW and 229,166 kWh for the new VSD chiller. The peak demand period is from 2 PM to 6PM Monday through Friday. The total incentive is $10,000. The incentive represents approximately 7.4 percent of the $135,981 installed cost.

Schedule of Key Dates

Installation of the new VSD chiller was completed in July of 2001.

Measure Description

Efficiency Improvement: The efficiency improvement consists of a new 370-ton VSD hermetic centrifugal chiller manufactured by York (Model # YTG3A2C3-CMJ, Serial # GCKM190260). The new chiller serves the main hospital buildings previously served by the old chiller (i.e., buildings 52, 66, 78, 86, and 90). The new chiller has a nominal ARI rating of 0.682 kW/ton with a 0.393 kW/ton NPLV. The design chilled water flow rate through the chiller is 742 gallons per minute (gpm). The chilled water temperature drop is 5 degrees Fahrenheit (i.e., 50F to 45F). The chiller is served by a Baltimore Air Coil (BAC) cooling tower (Model # 15294ALM) with 15-hp VFD fan. The chiller has a 7.5-hp primary chilled water pump, a 25-hp VFD secondary chilled water pump, and a 20-hp VFD condenser water pump. The interior cooling setpoint is 72 degrees Fahrenheit (F) for the buildings.

Pre-installation Equipment and Operation: The pre-installation equipment consisted of an old 200-ton open centrifugal chiller manufactured by Chrysler Corporation. The old chiller had an estimated nominal ARI rating of 1.2 kW/ton chiller. This chiller was replaced by the new VSD chiller. Pre-installation equipment also includes a 70-ton two-stage air-cooled reciprocating chiller manufactured by Carrier with an ARI rating of 1.0 kW/ton. This chiller is still installed and used primarily on cool days and as a back-up for the new VSD chiller.

As-Built Equipment and Operation: The new as-built chiller and controls were inspected and found to be operating as specified.

Variability in Schedule and Production: The facility operates 24 hours per day, seven days per week and 52 weeks per year.

Square Footage of Affected Area: The affected area is 78,722 square feet in buildings 52, 66, 78, 86, and 90.

Algorithms for Estimating Energy Savings for Paid Measure

Ex-Ante Algorithm:

The ex-ante savings for the new VSD chiller were 87 kW and 229,166 kWh/y. These savings are based on DOE-2.1E simulations performed by Planergy.[45]

M&V Evaluation Algorithm:

The M&V evaluation algorithms are based on calibrated eQuest simulations, short-term measurements, and utility meter data (i.e., see **Attachments**).[46] The normalized M&V savings are 116 kW and 305,628 kWh/yr (see **Table 1** and **Table 2**). Field measurements were made on September 19, 2002 to verify the new VSD chiller efficiency. The measured efficiency for the new VSD chiller at part-load was 0.297 kW/ton based on measured true RMS power use of 44 kW, chiller load of 148.3 tons, and outdoor ambient temperature of 82F.[47] For comparison the old chiller would have used 1.2 kW/ton or 178 kW on average to provide 148.3 tons of cooling. The difference is 134 kW of savings for

[45] See Comprehensive Energy Analysis, Planergy, Inc. (formerly Energy Masters International), 444 N. 3rd St., Sacramento, CA 95814, November 1999.

[46] EQuest simulations were performed using TMY weather data for California Climate Zone 16.

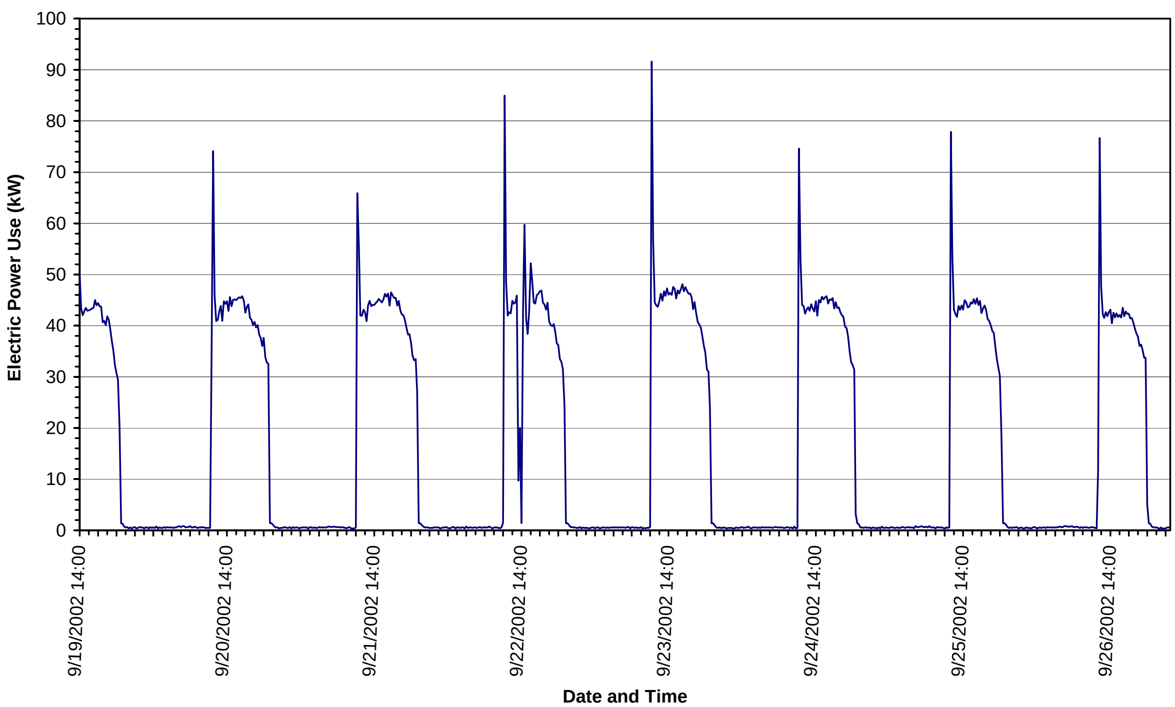
[47] Measured chiller performance of 0.297 kW/ton is the ratio of 44 kW divided by 148.3 tons. Tonnage is based on a measured 4.8F chilled water temperature drop (i.e., 49.6F minus 44.8F) and chilled water flow rate of 742 gallons per minute.

a non-peak day when the outdoor temperature was 82F. Average power measurements for the new VSD chiller are shown in **Figure 1**. M&V evaluation monetary savings are $22,700 per year for the new VSD chiller (see **Table 4**).

Table 1. M&V Evaluation of kW Savings for New VSD Chiller at Site #57

Month	2000 Bill Data[48] kW	2002 Bill Data kW	Non-Normalized Savings kW	Normalized eQuest Baseline kW	Normalized eQuest Measure kW	Normalized M&V Savings kW
May	555	502	53	579	456	123
June	572	535	37	582	466	116
July	575	516	59	581	465	116
August	574	551	23	579	462	117
September	597	542	55	579	463	116
Peak kW	**597**	**542**	**55**	**582**	**466**	**116**

Figure 1. Measured kW for the New VSD Chiller at TDPUD Site #58



The eQuest simulations were calibrated using utility meter data, average monthly kW profiles, monthly kWh usage, and short-term measurements. The eQuest 3-D model is shown in **Figure 2**.

[48] This is the historical billing data from Truckee Donner PUD.

Figure 2. eQuest 3-D Model of Site #57

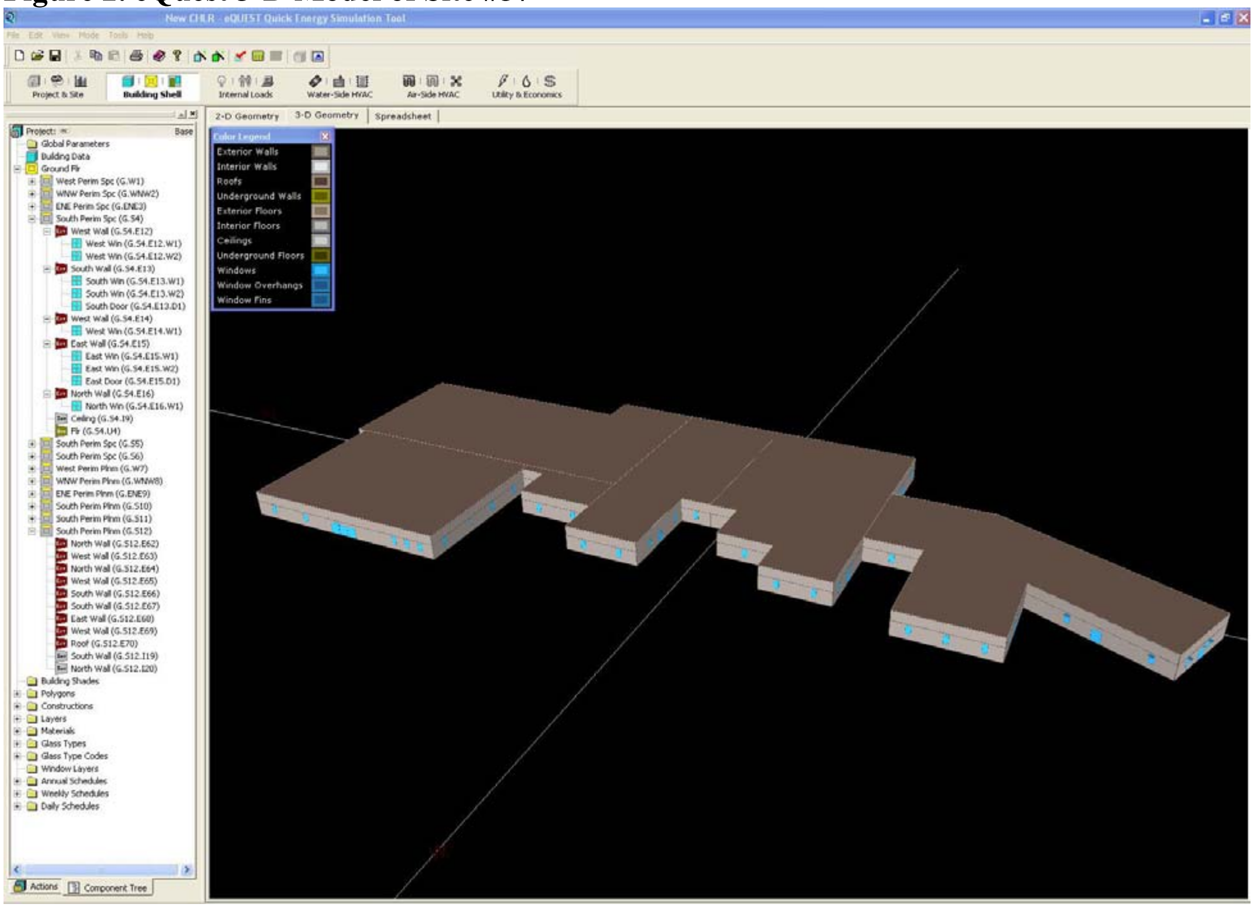


Table 3. M&V Evaluation of kWh Savings for for New VSD Chiller at Site #57

Month	2000 Billing Data kWh	2002 Billing Data kWh	Non-Normalized Savings kWh	Normalized eQuest Baseline kWh	Normalized eQuest Measure kWh	Normalized M&V Savings kWh
January	251,720	262,720	-11,000	221,532	220,665	867
February	229,920	233,120	-3,200	202,647	201,197	1,450
March	227,920	248,320	-20,400	235,290	227,927	7,363
April	249,840	243,360	6,480	240,967	225,663	15,304
May	238,840	254,640	-15,800	287,931	252,120	35,811
June	267,680	199,200	68,480	311,434	260,326	51,108
July	308,240	176,560	131,680	350,939	284,959	65,980
August	290,100	266,640	23,460	336,377	279,919	56,458
September	308,800	262,960	45,840	299,986	253,805	46,181
October	245,400	252,800	-7,400	259,188	238,570	20,618
November	223,120	n/a	n/a	221,155	217,519	3,636
December	293,840	n/a	n/a	221,292	220,440	852
Total	**3,135,420**	**TBD**	**218,140**	**3,188,738**	**2,883,110**	**305,628**

Table 4. M&V Evaluation of Monetary Savings for new VSD Chiller at Site #57

Description	Annual Savings	$/unit	Annual Savings
kWh	305,628	0.07291	$22,283
kW	16	9.27	$1,075
Maintenance			n/a
Total			**$23,358**

Data Collection

Site Specific Input Parameters: Data were collected during the on-site survey to support the M&V analyses. Make and model numbers of rebated equipment were verified (i.e., new VSD chiller). Equipment efficiency and relevant performance were also verified. Building characteristics were collected for the eQuest simulations including UA of the building envelope, affected floor area, chiller capacities, air flow rates, schedules, and internal loads such as lights, miscellaneous equipment, and people.

Data Collection Method: Electric power and temperature data loggers were installed to measure kW and kWh usage for all relevant equipment. Data loggers were installed from 9-19-02 through 10-25-02 to obtain short-term measurements. Measurements and observations during the on-site survey were used to verify rebated equipment. Inventories by type and schedules of internal lighting and equipment were collected during the on-site survey to estimate internal loads. Seasonal variations in operating schedules were obtained from building operations staff during the survey. Operational characteristics of the cooling system, such as the controls strategy, on/off schedule, and thermostats setpoints were obtained from a combination of direct observations and an interview with operations personnel during the survey. Capacity and efficiencies of motors and pumps were obtained from nameplate data and spot measurements were made to measure electric power usage. Capacities of cooling systems are based on manufacturer's data. Typical operating hours for pumps and motors were obtained from interviews with the operator.

Customer Cost/Benefit Analysis

Cost and Payback: Based on information provided by Site #57 staff, the total cost for the new VSD chiller is $135,981. The incentive was $10,000. Annual savings in electricity are 305,628 kWh and 116 kW worth approximately $23,358.[49] The calculated simple payback is approximately 5.4 years including the rebate (based on 2002 savings). The measure lifetime is 15 years.

Non-Energy Costs and Benefits: Site #57 personnel did not provide non-energy costs and benefit information such as annual labor and maintenance savings for the new VSD chiller.

[49] Electricity savings are based on TDPUD Rate 25 of $0.07291 per kWh and demand charge of $9.27 per kW.

Energy Savings

Comparison of TDPUD Application and Evaluation Estimates:

The M&V evaluation gross savings estimates for the new VSD chiller are 116 kW and 305,628 kWh/yr. Peak demand savings and annual electric savings are 33 percent higher than the ex-ante estimates of 87 kW and 229,166 kWh/yr. The estimated savings were calculated without the benefit of as-built post-installation measurements.

Savings Persistence: The expected lifetime for the new VSD chiller is 15 years.

ATTACHMENT 1

1. Site #57 Utility Meter Data for 2000, 2001, and 2002

Month	2000 kWh	2000 kW	2001 kWh	2001 kW	2002 kWh	2002 kW
January	251,720	456	248,280	477	262,720	460
February	229,920	442	223,040	474	233,120	452
March	227,920	443	222,520	450	248,320	464
April	249,840	538	218,400	451	243,360	507
May	238,840	555	265,120	477	254,640	502
June	267,680	572	257,840	519	199,200	535
July	308,240	575	257,680	528	176,560	516
August	290,100	574	277,440	597	266,640	551
September	308,800	597	260,640	616	262,960	542
October	245,400	575	217,840	563	252,800	555
November	223,120	552	234,720	538	n/a	n/a
December	293,840	449	258,800	504	n/a	n/a
Total	**3,135,420**	**597**	**2,942,320**	**616**	**2,400,320**	**542**

[1]Peak kW for May through September (i.e., summer months) is not necessarily from 2PM to 6PM.

ATTACHMENT 2– eQuest DOE-2.2 Baseline Results

Site #57 Base DOE-B2.2-41j 12/06/2002 17:37:25 BDL RUN 16

REPORT- PS-F Energy End-Use Summary for EM1 WEATHER FILE- CZ16RV2 WYEC2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
JAN													
KWH	69288.	0.	46811.	0.	5459.	118.	16039.	83817.	0.	0.	0.	0.	221532.
MAX KW	93.1	0.0	62.9	0.0	113.9	3.4	29.4	112.7	0.0	0.0	0.0	0.0	415.4
DAY/HR	1/ 1	0/ 0	1/ 1	0/ 0	13/13	13/13	13/13	1/ 1	0/ 0	0/ 0	0/ 0	0/ 0	13/13
FEB													
KWH	62582.	0.	42281.	0.	7291.	203.	14584.	75705.	0.	0.	0.	0.	202647.
MAX KW	93.1	0.0	62.9	0.0	156.6	3.7	31.4	112.7	0.0	0.0	0.0	0.0	460.4
DAY/HR	1/ 1	0/ 0	1/ 1	0/ 0	18/15	18/15	18/15	1/ 1	0/ 0	0/ 0	0/ 0	0/ 0	18/15
MAR													
KWH	69288.	0.	46811.	0.	18200.	551.	16624.	83817.	0.	0.	0.	0.	235290.
MAX KW	93.1	0.0	62.9	0.0	212.8	4.8	33.3	112.7	0.0	0.0	0.0	0.0	519.6
DAY/HR	1/ 1	0/ 0	1/ 1	0/ 0	31/16	31/16	31/ 2	1/ 1	0/ 0	0/ 0	0/ 0	0/ 0	31/16
APR													
KWH	67053.	0.	45301.	0.	29830.	802.	16868.	81113.	0.	0.	0.	0.	240967.
MAX KW	93.1	0.0	62.9	0.0	245.5	5.3	33.3	112.7	0.0	0.0	0.0	0.0	550.6
DAY/HR	1/ 1	0/ 0	1/ 1	0/ 0	28/16	27/17	4/13	1/ 1	0/ 0	0/ 0	0/ 0	0/ 0	28/16
MAY													
KWH	69288.	0.	46811.	0.	67132.	1694.	19190.	83817.	0.	0.	0.	0.	287931.
MAX KW	93.1	0.0	62.9	0.0	270.5	6.1	33.3	112.7	0.0	0.0	0.0	0.0	578.6
DAY/HR	1/ 2	0/ 0	1/ 2	0/ 0	31/20	31/20	1/13	1/ 2	0/ 0	0/ 0	0/ 0	0/ 0	31/20
JUN													
KWH	67053.	0.	45301.	0.	95329.	2410.	20228.	81113.	0.	0.	0.	0.	311434.
MAX KW	93.1	0.0	62.9	0.0	271.9	8.6	33.3	112.7	0.0	0.0	0.0	0.0	581.8
DAY/HR	1/ 2	0/ 0	1/ 2	0/ 0	14/15	14/17	1/13	1/ 2	0/ 0	0/ 0	0/ 0	0/ 0	14/17
JUL													
KWH	69288.	0.	46811.	0.	125844.	2983.	22196.	83817.	0.	0.	0.	0.	350939.
MAX KW	93.1	0.0	62.9	0.0	271.5	7.9	33.3	112.7	0.0	0.0	0.0	0.0	580.9
DAY/HR	1/ 2	0/ 0	1/ 2	0/ 0	31/22	16/14	1/10	1/ 2	0/ 0	0/ 0	0/ 0	0/ 0	29/14
AUG													
KWH	69288.	0.	46811.	0.	112640.	2475.	21347.	83817.	0.	0.	0.	0.	336377.
MAX KW	93.1	0.0	62.9	0.0	270.9	6.2	33.3	112.7	0.0	0.0	0.0	0.0	578.8
SEP													
KWH	67053.	0.	45301.	0.	84843.	2013.	19664.	81113.	0.	0.	0.	0.	299986.
MAX KW	93.1	0.0	62.9	0.0	270.6	6.6	33.3	112.7	0.0	0.0	0.0	0.0	578.7
OCT													
KWH	69288.	0.	46811.	0.	40395.	988.	17888.	83817.	0.	0.	0.	0.	259188.
MAX KW	93.1	0.0	62.9	0.0	270.3	6.0	33.3	112.7	0.0	0.0	0.0	0.0	575.8
NOV													
KWH	67053.	0.	45301.	0.	11532.	337.	15820.	81113.	0.	0.	0.	0.	221155.
MAX KW	93.1	0.0	62.9	0.0	220.4	5.6	33.3	112.7	0.0	0.0	0.0	0.0	528.0
DEC													
KWH	69288.	0.	46811.	0.	5233.	105.	16039.	83817.	0.	0.	0.	0.	221292.
MAX KW	93.1	0.0	62.9	0.0	116.8	3.4	29.6	112.7	0.0	0.0	0.0	0.0	418.4
TOTAL													
KWH	815806.	0.	551161.	0.	603727.	14682.	216486.	986874.	0.	0.	0.	0.	3188739.
MAX KW	93.1	0.0	62.9	0.0	271.9	8.6	33.3	112.7	0.0	0.0	0.0	0.0	581.8

ATTACHMENT 3 – eQuest DOE-2.2 VSD Chiller Results

Site #57 New VSD Chiller DOE-B2.2-41j 12/06/2002 17:16:42 BDL RUN 17

REPORT- PS-F Energy End-Use Summary for EM1 WEATHER FILE- CZ16RV2 WYEC2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
JAN													
KWH	69288.	0.	46811.	0.	5271.	115.	15363.	83817.	0.	0.	0.	0.	220665.
MAX KW	93.1	0.0	62.9	0.0	67.3	3.4	20.6	112.7	0.0	0.0	0.0	0.0	359.9
FEB													
KWH	62582.	0.	42281.	0.	6548.	204.	13877.	75705.	0.	0.	0.	0.	201197.
MAX KW	93.1	0.0	62.9	0.0	67.2	3.6	20.6	112.7	0.0	0.0	0.0	0.0	360.0
MAR													
KWH	69288.	0.	46811.	0.	12113.	535.	15363.	83817.	0.	0.	0.	0.	227927.
MAX KW	93.1	0.0	62.9	0.0	67.3	3.8	20.6	112.7	0.0	0.0	0.0	0.0	360.1
APR													
KWH	67053.	0.	45301.	0.	16402.	795.	15000.	81113.	0.	0.	0.	0.	225663.
MAX KW	93.1	0.0	62.9	0.0	140.8	4.5	35.3	112.7	0.0	0.0	0.0	0.0	447.8
MAY													
KWH	69288.	0.	46811.	0.	33985.	1567.	16653.	83817.	0.	0.	0.	0.	252120.
MAX KW	93.1	0.0	62.9	0.0	147.0	5.0	35.3	112.7	0.0	0.0	0.0	0.0	455.9
JUN													
KWH	67053.	0.	45301.	0.	47127.	2169.	17563.	81113.	0.	0.	0.	0.	260326.
MAX KW	93.1	0.0	62.9	0.0	154.1	8.0	35.3	112.7	0.0	0.0	0.0	0.0	465.5
JUL													
KWH	69288.	0.	46811.	0.	62552.	2631.	19861.	83817.	0.	0.	0.	0.	284959.
MAX KW	93.1	0.0	62.9	0.0	153.9	7.2	35.3	112.7	0.0	0.0	0.0	0.0	464.7
AUG													
KWH	69288.	0.	46811.	0.	58427.	2243.	19334.	83817.	0.	0.	0.	0.	279919.
MAX KW	93.1	0.0	62.9	0.0	153.0	5.2	35.3	112.7	0.0	0.0	0.0	0.0	462.0
SEP													
KWH	67053.	0.	45301.	0.	41564.	1840.	16933.	81113.	0.	0.	0.	0.	253805.
MAX KW	93.1	0.0	62.9	0.0	153.4	5.9	35.3	112.7	0.0	0.0	0.0	0.0	463.3
OCT													
KWH	69288.	0.	46811.	0.	21651.	951.	16052.	83817.	0.	0.	0.	0.	238570.
MAX KW	93.1	0.0	62.9	0.0	147.7	4.5	35.3	112.7	0.0	0.0	0.0	0.0	455.2
NOV													
KWH	67053.	0.	45301.	0.	8849.	336.	14868.	81113.	0.	0.	0.	0.	217519.
MAX KW	93.1	0.0	62.9	0.0	67.3	4.1	20.6	112.7	0.0	0.0	0.0	0.0	360.3
DEC													
KWH	69288.	0.	46811.	0.	5059.	102.	15363.	83817.	0.	0.	0.	0.	220440.
MAX KW	93.1	0.0	62.9	0.0	67.2	3.4	20.6	112.7	0.0	0.0	0.0	0.0	359.9
TOTAL													
KWH	815806.	0.	551161.	0.	319547.	13488.	196230.	986874.	0.	0.	0.	0.	2883110.
MAX KW	93.1	0.0	62.9	0.0	154.1	8.0	35.3	112.7	0.0	0.0	0.0	0.0	465.5