Measurement & Verification Load Impact Study for NCPA SB5X Residential HVAC Rebate Programs

Study ID: NCP0001.07

FINAL REPORT

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June 25, 2005

Funded with California Senate Bill 5X Funds

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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 measurements at customer sites were made possible with the cooperation of the following individuals, utilities, and companies: Patrick Morrison, Roseville Electric Company; Peter Govea, Modesto Irrigation District; Patrick Keener and Paul Ahern, Redding Electric Utility; and Nell Thomas and Donna Mills, Plumas-Sierra Rural Electric Utility. Robert Mowris, P.E., and Kathleen Carlson, Esq., were responsible for project management. Robert Mowris, Ean Jones, B.S., Anne Blankenship, B.S., and George Nesbitt installed the electric power data loggers and 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 designed the EM&V plan, database, and survey instruments. Robert Mowris and Anne Blankenship performed the PRISM analyses, DOE-2/eQuest simulations, statistical analyses, and wrote the report. John Berlin was the study manager for Northern California Power Agency. Rick Ridge, Ph.D., Ridge Associates, provided review comments and suggestions regarding the statistical analysis and sample design.

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 Residential Heating, Ventilating, and Air Conditioning (HVAC) Rebate Programs implemented by Modesto Irrigation District (MID), Plumas Sierra Electric Cooperative (PSREC), Redding Electric Utility (REU), Roseville Electric, and Turlock Irrigation District (TID). The programs realized peak kW and kWh savings by paying rebates to consumers for installing high efficiency air conditioners. The programs provided 1,892 air conditioner rebates from 2001 through 2003 with $1,344,803 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 ex ante program savings are 2,712,291 kWh/yr and 1,893 kW. The M&V net ex post program savings are 801,358 ± 145,753 kWh/yr and 1,053 ± 71 kW. The M&V net ex post lifecycle savings are 12,020,370 ± 2,186,295 kWh based on a 15-year effective useful life. The net realization rates are 0.30 for kWh savings and 0.56 for kW savings.

Table 1.1 Ex Ante Savings for NCPA SB5X Residential HVAC Rebate Programs

NCPA Utility	Qty.	Ex Ante Full-Year Unit kWh/yr	Ex Ante Unit kW	Ex Ante Net-to-Gross Ratio kWh/y	Ex Ante Net-to-Gross Ratio kW	Ex Ante Program Savings kWh/y	Ex Ante Program Savings kW
MID	316	350	0.64	1	1	110,645	201.2
PSREC-GSHP	82	16,001	3.96	1	1	1,312,082	324.7
Redding	704	666	0.76	1	1	469,104	536.3
Roseville	134	2,594	2.59	1	1	347,616	347.6
TID	656	721	0.74	1	1	472,845	483.2
Total or Average	**1,892**	**1,434**	**1.00**	**1.00**	**1.00**	**2,712,291**	**1,893**

Note: PSREC includes electric heating savings for the Ground Source Heat Pump (GSHP). Peak kW savings are for cooling only.

Table 1.2 M&V Ex Post Savings for NCPA SB5X Residential HVAC Rebate 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
MID	316	446	0.52	0.82	0.82	115,513	135.8	1.04	0.67
PSREC-GSHP	82	913	2.10	0.84	0.84	62,864	144.6	0.05	0.45
Redding	704	561	0.71	0.83	0.83	327,658	413.2	0.70	0.77
Roseville	134	581	0.79	0.86	0.86	67,011	91.2	0.19	0.26
TID	656	430	0.51	0.81	0.81	228,313	268.4	0.48	0.56
Total or Average	**1,892**	**513**	**0.67**	**0.82**	**0.82**	**801,358**	**1,053.3**	**0.30**	**0.56**

Energy savings are based on billing regression analyses for 60 sites using the PRInceton Scorekeeping Method (PRISM).[1] Peak demand savings are based on field measurements of peak kW for 21 units. The average net-to-gross ratio is 83 percent indicating 17 percent would have

[1] 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.

been purchased without the program.[2] M&V savings and realization rates are lower than anticipated due to lower baseline usage and lower net-to-gross ratios. If deemed savings from DEER had been used for the M&V study, the realization rates would have been 20 to 37 percent lower (see **Section 4.4**).

The M&V study provides average gross savings per unit and net-to-gross ratios. The gross savings are based on in-situ 15-minute true RMS power measurements of 21 air conditioners. 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 is taken as the maximum kW that occurs during the 2 PM to 6 PM weekday time frame from the 15-minute data. Participant telephone surveys were used to evaluate program performance criteria and net-to-gross ratios.

Section 2 presents the M&V approach and results, field measurement methodology, findings of the field measurements and analyses, M&V savings, and the impact of improper refrigerant charge and airflow on air conditioner efficiency. **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, database, baseline, impact analysis, and program evaluation savings estimates. **Appendix A** provides the Residential HVAC Decision-Maker Survey.

2. M&V Approach and Results for Residential HVAC

The measurement and verification approach for the study was based on the *International Performance Measurement & Verification Protocols* (IPMVP) defined **Table 2.1**.[3] Ex post energy savings were determined using IPMVP Option B (i.e., retrofit isolation) and Option C (i.e., whole facility billing regression analysis). Peak demand savings were determined using IPMVP Option B (i.e., retrofit isolation). PRISM billing regression analysis was used to estimate gross kWh/yr savings. Field measurements of air conditioner kW and energy efficiency ratios (EER) were used to estimate gross peak kW savings. These values were compared to peak demand savings based on manufacturer kW ratings for similar indoor and outdoor temperature conditions. The study examined proper refrigerant charge and airflow (RCA) for new and existing air conditioners and how improper RCA might be mitigated by the presence of a Thermostatic Expansion Valve (TXV) on the evaporator coil. The study examined this issue since the California Energy Commission 2001 Title 24 Building Energy Efficiency Standards (CEC Standards) include the Alternative Calculation Method (ACM) or TXV or proper RCA as compliance options for new air conditioners for new and existing residential buildings. Roseville Electric Company required a TXV on participating air conditioners.

[2] The net-to-gross ratios reflect what customers would have done in the absence of the program (see Section 3).

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

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.

2.1 Field Measurement Methodology

Field measurements of the Energy Efficiency Ratio (EER) were made to determine in-situ efficiency before and after correcting refrigerant charge and airflow (RCA) on a sample of 14 air conditioners with TXVs and seven air conditioners without TXVs.[4] Field measurements, measurement equipment, and measurement tolerances are provided in **Table 2.2**.

[4] 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.

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.[5] 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, and 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) ranging from 7 to 16.[6] Billing data was collected from January 2001 through December 2004 were used to develop annual energy savings.

2.2 Findings of the Field Measurements and Analyses

Field measurements of participant and non-participant air conditioners were made to determine in-situ efficiency before and after correcting RCA. Data loggers were installed at 21 sites to measure peak demand and energy use for standard and high efficiency air conditioners. Average measured versus calculated kW savings based on manufacturer data are shown in **Table 2.3** and **2.4**.[7] The average measured kW savings are based on field measurements of existing and energy efficient air conditioners shown in **Figures 2.1** and **2.2**. For conventional units, the measured savings range from 0.59 kW for a 2.5-ton 14 SEER unit to 0.80 kW for a 5-ton 14 SEER unit.

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

[6] 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).

[7] Manufacturer data is from *Residential and Light Commercial Products and Systems Catalog*, Volume 1, Carrier Corporation for units with similar cooling capacities and efficiencies.

The maximum savings are 2.1 kW for ground source heat pumps (GSHP). The average age of existing units was 10 to 14 years as shown in **Table 2.4**.[8]

Table 2.3 Average Measured versus Calculated Savings from Manufacturer Data

Air Conditioner Capacity Tons	Existing Unit Average Peak kW	Existing Unit SEER	New Unit Average Peak kW	New Unit SEER	Average Measured kW Savings	Manufacturer Rated kW Savings	Indoor & Outdoor Temperature °F
2.5	3.75	9	3.16	14	0.59	0.58	80/67/105
3.0	4.05	10	3.64	12	0.41	0.56	80/67/100
3.0	4.05	10	3.52	13	0.53	0.63	80/67/100
3.0	4.05	10	3.15	14	0.89	0.87	80/67/100
3.5	4.34	10	3.52	13	0.82	0.32	80/67/100
3.5	4.34	10	3.50	14	0.84	0.60	80/67/100
4.0	5.44	10	4.63	14	0.81	0.64	80/67/105
5.0	6.01	10	5.50	12	0.51	0.30	80/67/105
5.0	6.01	10	5.16	14	0.85	0.57	80/67/105
5.0 (GSHP)	6.01	10	4.0	16	2.1	1.59	80/67/110

Table 2.4 Measured kW Savings versus Calculated kW Savings from Manufacturer Data

	Measured kW Baselines and Savings					Calculated kW from Manufacturer Data				
Tons	Existing Unit kW	Age of Existing Unit	12 SEER ΔkW	13 SEER ΔkW	14 SEER ΔkW	Base 10 SEER kW	11 SEER ΔkW	12 SEER ΔkW	13 SEER ΔkW	14 SEER ΔkW
2	n/a	n/a				2.89	0.17	0.26	0.29	0.47
2.5	3.75	1991			0.59	3.36	0.20	0.29	0.37	0.58
3	4.05	1989	0.41	0.52	0.89	4.07	0.24	0.56	0.63	0.87
3.5	4.34	1988		0.82	0.84	4.29	0.17	0.17	0.32	0.60
4	5.44	1991			0.81	5.42	0.22	0.18	0.28	0.64
5	6.01	1992	0.51	0.85	0.80	6.25	0.19	0.30	0.14	0.57

Billing data were collected for 60 sites in MID, PSREC, Redding, and Roseville. These data were used as inputs for the PRInceton Scorekeeping Method (PRISM) to develop baseline cooling values for air conditioners and heating values for ground source heat pumps.[9] Energy savings are based on the program average SEER or COP improvement with respect to the baselines shown in **Table 2.5**. Ex post unit savings for TID are based on savings for MID and scaled by the ratio of the average SEER. The kWh savings for PSREC exclude electric heating, due to uncertainty associated with heating savings and the focus of SB5X on summer peak loads.

Table 2.5 Baseline and High Efficiency SEER for Air Conditioners and COP for GSHP

NCPA Utility	Baseline SEER	Program Average SEER	Baseline Heating COP	Program Average Heating COP
MID	10	12.45	n/a	n/a
PSREC-GSHP	10	16	2	3.6
Redding	10	12.61	n/a	n/a
Roseville	10	13.81	n/a	n/a
TID	10	12	n/a	n/a

[8] National Appliance Energy Conservation Act (P.L. 100-12, P.L. 100-357) required minimum 10 SEER for split-systems on 1-1-92 and for packaged systems on 1-1-93.

[9] Ibid.

Figure 2.1 Measurements of 10 SEER and 14 SEER 4-ton Air Conditioners

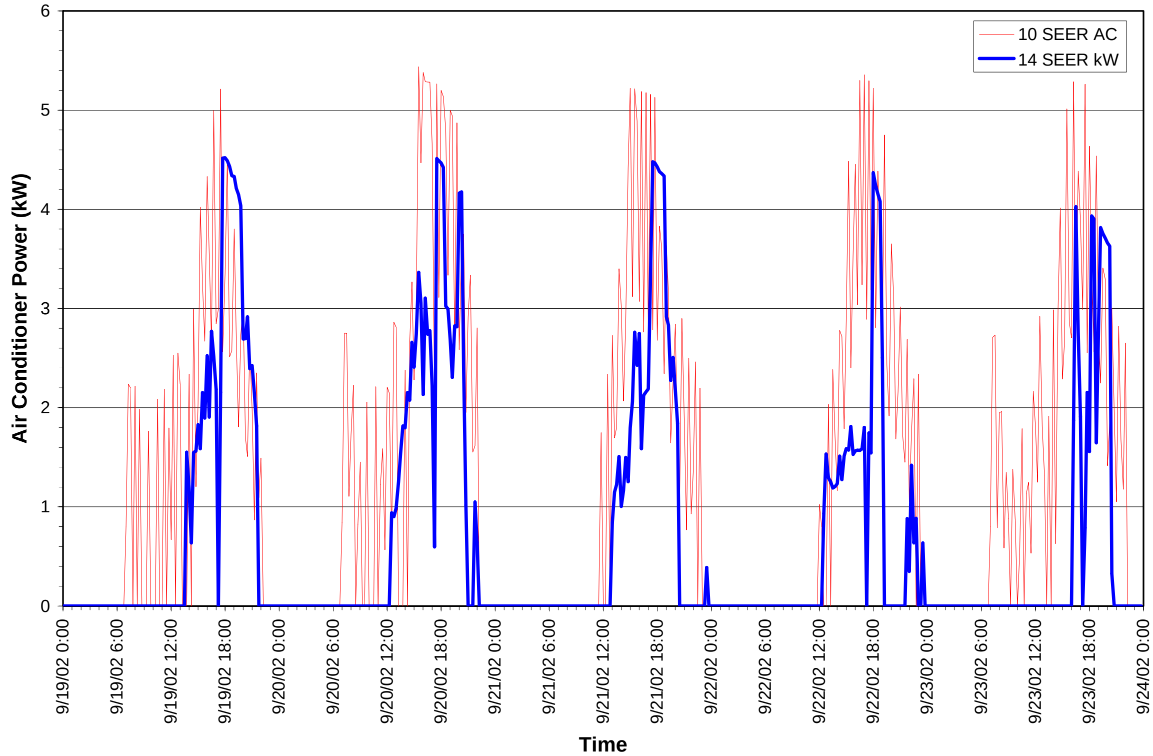
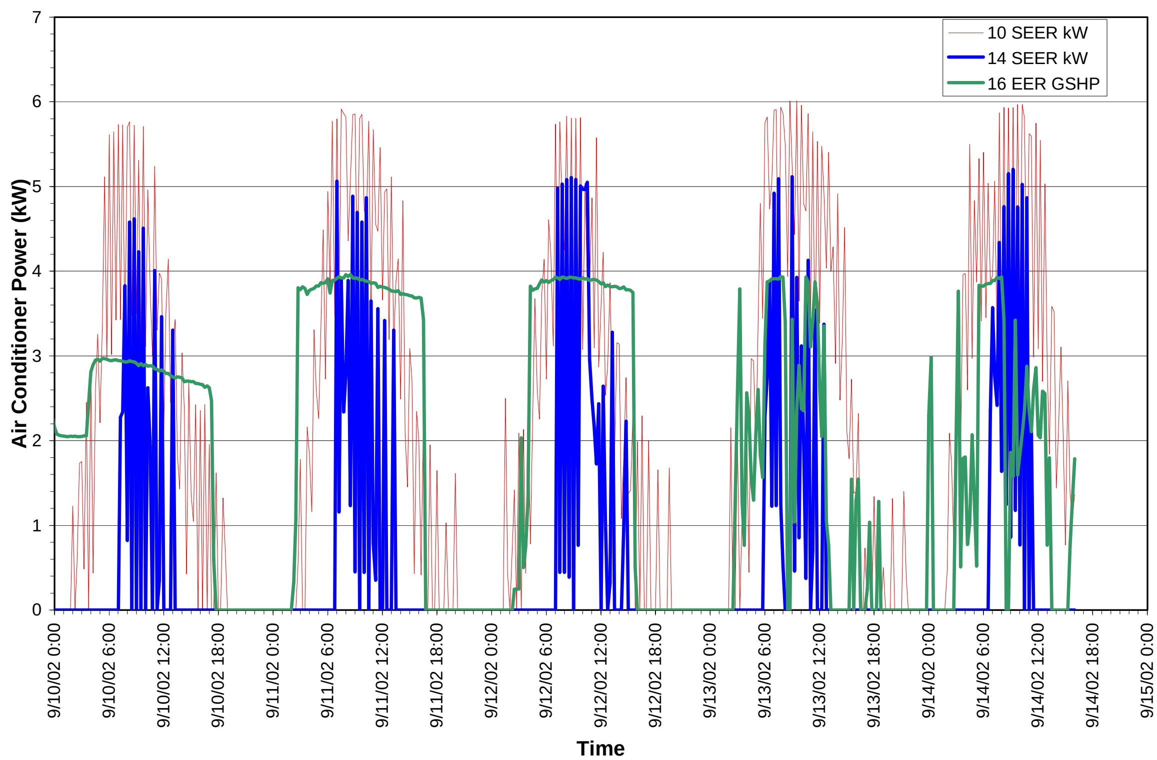


Figure 2.2 Measurements of 10 and 14 SEER 5-ton Air Conditioners and 16 SEER GSHP



The M&V savings for MID are shown in **Table 2.6**. The M&V savings for PSREC GSHP units are shown in **Table 2.7**. For PSREC, a follow-up survey was performed and only two participants previously had electric heat (i.e., baseboard or heat pumps). The others were planning to install propane heat. Another study performed for Redding Electric found ex post savings per GSHP of -1,355 ± 841 kWh per year, 2.1 ± 0.02 kW, and 545 ± 161 therms per year.[10] This study uses cooling-only savings for PSREC due to uncertainty associated with GSHP heating savings and the focus of SB5X funding on summer peak loads. The M&V savings for Redding are shown in **Table 2.8**. The M&V savings for Roseville are shown in **Table 2.9**.

Table 2.6 MID M&V Savings for Residential HVAC Units

Site	Base Cooling (kWh/yr)	Base Heating (kWh/yr)	Tons	SEER	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Ex Post Savings kWh/yr	M&V Ex Post Savings kW	IPMVP Option
1	5,822		5	12	435	0.79	491	0.51	B, C
2	71		4	12	348	0.63	12	0.56	B, C
3	3,762		2.5	12	218	0.4	627	0.38	B, C
4	4,025		2	12	174	0.32	671	0.35	B, C
5	1,570		3	12	261	0.47	262	0.41	B, C
6	2,432		3	12	261	0.47	405	0.41	B, C
7	931		2.5/3.5	12	804	1.46	155	0.44	B, C
8	7,170		3	12	261	0.47	1,195	0.41	B, C
9	896		3	14	261	0.47	256	0.89	B, C
10	1,347		3	14	261	0.47	385	0.89	B, C
Average	**2,802**		**3.14**	**12.45**	**353**	**0.64**	**446**	**0.52**	
90% CI	1,214		0.44	0.07	16	0.03	173	0.11	

Table 2.7 PSREC M&V Savings for 5-ton, 3.6 COP, 16 EER GSHP Units

Site	Base Cooling (kWh/yr)	Ex Post Cooling Savings (kWh/yr)	Base Heating (kWh/yr)	Ex Post Heating Savings (kWh/yr)	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Ex Post Savings kWh/yr	M&V Ex Post Savings kW	IPMVP Option
11	1,226	735	2,035	-6,300	16,001	3.96	735	2.10	B, C
12	2,055	771			16,001	3.96	771	2.10	B, C
13	339	203	1,212	-3,754	16,001	3.96	203	2.10	B, C
14	2,686	1,612	1,250	-3,869	16,001	3.96	1,612	2.10	B, C
15			1,098	-3,401	16,001	3.96			B, C
16	412	247	14,628	10,565	16,001	3.96	247	2.10	B, C
17	5,830	2,186			16,001	3.96	2,186	2.10	B, C
18	2,488	933			16,001	3.96	933	2.10	B, C
19	1,023	614			16,001	3.96	614	2.10	B, C
20			10,148	4,510	16,001	3.96			B, C
Average	**2,007**	**913**	**5,062**	**-375**	**16,001**	**3.96**	**913**	**2.10**	
90% CI	1,036	393	3,934	4,367			393	0.02	

Note: PSREC ex-post kWh savings do not include electric heating savings for the GSHP due to uncertainty. Heating savings for sites 11, 13, 14, and 15 are negative due to pre-retrofit propane heat. Site 16 previously had electric resistance heat and site 20 had an electric heat pump. PSREC cooling-only savings are 913 ± 420 kWh per year and 2.1 ± 0.02 kW.

[10] See *Evaluation, Measurement & Verification Report for the Residential Ground Source Heat Pump Program*, prepared for Redding Electric Utility, Robert Mowris & Associates, 2004.

Table 2.8 Redding M&V Savings for Residential HVAC Units

Site	Base Cooling (kWh/yr)	Base Heating (kWh/yr)	Tons	SEER	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Ex Post Savings kWh/yr	M&V Ex Post Savings kW	IPMVP Option
21	3,664		4	14	1,012	1.13	1,047	0.81	B, C
22	639		4	13	715	0.8	148	0.82	B, C
23	2,523		4	14	886	0.99	148	0.84	B, C
24	240		3	14	886	0.99	69	0.89	B, C
25	2,603		3	14	759	0.847	744	0.89	B, C
26	1,136		4	14	1,012	1.13	325	0.81	B, C
27	910		3	14	633	0.71	260	0.59	B, C
28	942		4	12	517	0.58	157	0.48	B, C
29	1,404		4	13	816	0.91	324	0.68	B, C
30	2,712		4	12	590	0.66	452	0.56	B, C
31	2,712		4	16	1,328	1.48	1,017	0.84	B, C
32	3,913		5	14	1,265	1.41	1,118	0.85	B, C
33	2,626		3	12	443	0.49	438	0.41	B, C
34	655		4	12	517	0.58	109	0.48	B, C
35	3,247		3	16	996	1.11	1,218	0.75	B, C
36	3,691		5	12	738	0.82	615	0.51	B, C
37	1,432		4	13	818	0.91	331	0.68	B, C
38	5,517		4	14	886	0.99	1,576	0.84	B, C
Average	**2,254**		**3.59**	**12.61**	**666**	**0.72**	**561**	**0.71**	
90% CI	553		0.24	0.06	39	0.04	176	0.06	

Table 2.9 Roseville M&V Savings for Residential HVAC Units

Site	Base Cooling (kWh/yr)	Base Heating (kWh/yr)	Tons	SEER	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Ex Post Savings kWh/yr	M&V Ex Post Savings kW	IPMVP Option
39	685		2.5	14	1,821	1.821	196	0.59	B, C
40	2,121		4	14	2,914	2.914	606	0.81	B, C
41	3,445		3	13	2,018	2.018	795	0.53	B, C
42	903		3.5	14	2,550	2.55	258	0.84	B, C
43	2,977		3	14	2,186	2.186	851	0.89	B, C
44	2,511		3.5	14	2,550	2.55	603	0.84	B, C
45	2,018		5	14	3,643	3.643	576	0.85	B, C
46	3,038		5	14	3,643	3.643	868	0.85	B, C
47	1,405		5	13	3,363	3.363	324	0.68	B, C
48	1,977		4	14	2,914	2.914	565	0.81	B, C
49	2,478		4	14	2,914	2.914	575	0.81	B, C
50	1,416		3	13	2,018	2.018	327	0.53	B, C
51	1,421		4	14	2,914	2.914	406	0.81	B, C
52	782		3	14	2,186	2.186	224	0.89	B, C
53	1,234		3	14	2,186	2.186	353	0.89	B, C
54	3,035		2.5	14	1,821	1.821	867	0.59	B, C
55	1,226		3	14	2,186	2.186	350	0.89	B, C
56	3,095		3	14	2,186	2.186	884	0.89	B, C
57	3,912		3	14	2,186	2.186	1,118	0.89	B, C
58	3,827		3.5	14	2,550	2.55	1,093	0.84	B, C
59	1,145		4	14	2,914	2.914	327	0.81	B, C
60	2,197		3	14	2,186	2.186	628	0.89	B, C
Average	**2,129**		**3.5**	**13.86**	**2,594**	**2.59**	**581**	**0.79**	
90% CI	350		0.03	0.12	90	0.09	98	0.04	

2.3 Impact of Improper Refrigerant Charge and Airflow

Several studies indicate approximately 50 to 67 percent of new air conditioners have improper refrigerant charge and airflow (RCA), and this reduces efficiency by roughly 10 to 20 percent.[11] Three studies have shown that improper RCA can be mitigated by installing a TXV device.[12] The studies found TXV systems only had a clear advantage when the system is undercharged, and found no difference in performance at the rating condition between TXV and non-TXV (i.e., fixed orifice) when systems were properly installed. Unfortunately, TXVs can have their own performance problems associated with incorrect installation leading to a phenomenon known as "valve hunting." This can occur when the evaporator coil experiences reduced heat loads caused by many problems including low airflow, low refrigerant charge, dirty evaporator coils, and icy evaporator coils due to over charging.[13] Under these circumstances the TXV can lose control and successively overfeed and then underfeed refrigerant to the evaporator while attempting to stabilize control causing reduced capacity and efficiency. Overfeeding liquid to the evaporator can also damage the compressor. The tendency for hunting can be reduced by correcting RCA, by relocating the TXV sensing bulb to a better location inside the evaporator coil box, and by insulating the sensing bulb.

TXV sensing bulbs are often installed without insulation, without adequate linear contact, and at incorrect orientations (see **Figure 2.3** and **2.4**).

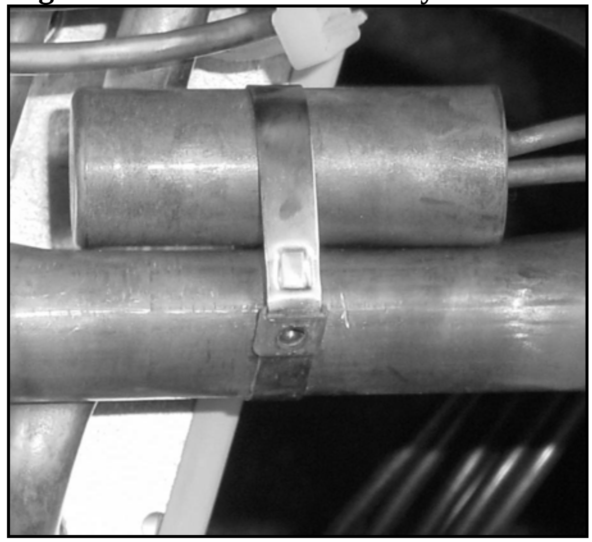
[11] Palani, M., O'Neal, D., and Haberl, J. 1992. *The Effect of Reduced Evaporator Air Flow on the Performance of a Residential Central Air Conditioner*, The Eighth Symposium on Improving Building Systems in Hot and Humid Climates. Parker, D. 1997. *Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems,* FSEC-PF-321-97. Cocoa, Fla.: Florida Solar Energy Center. 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.

[12] Farzad, M., O'Neal, D. 1993. "Influence of the Expansion Device on Air Conditioner System Performance Characteristics Under a Range of Charging Conditions." Paper 3622. *ASHRAE Transactions*. Atlanta, Ga.: American Society of Heating Refrigerating and Air-Conditioning Engineers. Davis, R. 2001a. *Influence of the Expansion Device on Performance of a Residential Split-System Air Conditioner.* Report No.: 491-01.4. San Francisco, Calif. Pacific Gas and Electric. Davis, R. 2001b. *Influence of Expansion Device and Refrigerant Charge on the Performance of a Residential Split-System Air Conditioner using R-410a Refrigerant.* Report No.: 491-01.7. San Francisco, Calif.: Pacific Gas and Electric.

[13] Tomczyk, J. 1995. *Troubleshooting and Servicing Modern Air Conditioning and Refrigeration Systems*. ESCO Press. Mt. Prospect, Ill.: Educational Standards Corporation.

Figure 2.3 Uninsulated TXV Bulb in Attic

Figure 2.4 Uninsulated Factory TXV Bulb



Manufacturers recommend tightly clamping the sensing bulb to the vapor line with good thermal contact at the recommended orientation to guard against false readings due to air or liquid in the suction line. Manufacturers also recommend insulating the sensing bulb to prevent ambient air from causing false readings.[14] Factory-installed TXVs with un-insulated sensing bulbs inside the evaporator coil box will be influenced by mixed supply-air temperatures which are typically 10-20°F higher than vapor line temperatures. Field-installed TXVs with un-insulated sensing bulbs located in attics or garages will be influenced by attic or garage temperatures which are 50 to 80°F higher than vapor line temperatures (e.g., attic temperatures range from 110 to 130°F compared to vapor line temperatures of 35 to 50°F). The three laboratory studies measured TXV-equipped air conditioners with the evaporator coil, TXV, and well-insulated sensing bulb located in conditioned space and this is not typical of field conditions. Furthermore, none of these three studies recommended TXVs as a substitute for proper RCA.

The relative efficiency gains due to proper RCA for fourteen TXV and seven non-TXV air conditioners are shown in **Tables 2.10** and **2.11**. Sites labeled “n/a” had improper RCA but the customer either refused corrections or no refrigerant change was necessary. The TXV efficiency gain excludes sites where customers refused charge corrections, where the efficiency gain was undefined (i.e., pre-capacity and pre-EER were zero due to a leaky system with no refrigerant charge), and sites where no charge adjustment was necessary.

[14] Advanced Distributor Products (ADP). 2003. *TXV Installation Instructions.* 0991710-01 Rev 1, October 03. Stone Mountain, Ga.: Advanced Distributor Products, Available online: www.adpnow.com. AllStyle Coil Company, L.P. 2001. *Evaporator Coil Installation Instructions.* Brittmore, Texas: AllStyle Coil Company, L.P. Carrier Corporation. 2002. *Installation Instructions: Thermostatic Expansion Valve Kit for R22 and R410a*. Syracuse, N.Y.: Carrier Corporation. Emerson Climate Technologies, Inc. 1998. *Installation Instructions Expansion Valve Kits.* Lewisburg, Tenn.: Emerson Climate Technologies, Inc.

Table 2.10 EER Measurements and Efficiency Gain for TXV Air Conditioners

Site	Tons	Factory Charge oz.	Charge Adjust +Add –Remove	Pre-EER	Post-EER	Relative Efficiency Gain	Average Outdoor Temp °F	Ave. Ret. DB/WB Temp °F	Notes
1	5	114	Refused (9%)	10.4	n/a	n/a	82	75/64	R410A
39	2.5	96	-78%	8.3	11.8	43%	90	79/66	R410A
40	4	140	40%	11.2	13.1	17%	80	78/63	R410A
41	3	100	18%	9.9	12.1	22%	82	77/63	R22
42	3.5	100	16%	10.9	11.8	8%	79	75/62	R410A
44	3.5	170	Refused (6%)	n/a	n/a	n/a	80	74/61	R22
45	5	200	0%	10.8	n/a	n/a	96	75/65	R22
46	5	200	9%	10.5	11.3	8%	95	77/65	R22
47	5	176	11%	10.8	11.7	8%	88	70/60	R22
48	4	170	15%	10.3	12.4	20%	86	74/63	R22
49	4	170	Refused (7%)	11.6	n/a	n/a	89	77/65	R22
50	3	150	34%	9	12.3	37%	95	79/69	R22
51	4	162	n/a (100%)	0	n/a	n/a (100%)	86	85/69	R22
61	5	166	0%	11	n/a	n/a	84	77/65	R22
Ave	**4.0**	**151**	**25.0%**	**9.6**	**12.1**	**20.4%**	**86**	**77/64**	

Table 2.11 EER Measurements and Efficiency Gain for non-TXV Air Conditioners

Site	Tons	Factory Charge oz.	Charge Adjust +Add –Remove	Pre-EER	Post-EER	Relative Efficiency Gain	Average Outdoor Temp °F	Ave. Ret. DB/WB Temp °F	Notes
43	4	117	Okay	10.8	10.8	n/a	95	77/61	R22
62	3	130	Okay	9.9	9.9	n/a	81	70/59	R22
63	5	96	Okay	12.2	12.2	n/a	81	73/59	R22
64	3.5	130	-7%	9.6	10	4%	91	84/72	R22
65	3.5	82	Okay	9.3	9.3	n/a	84	76/66	R22
66	4	112	38%	8.5	9.9	16%	90	81/67	R22
67	5	158	-15%	8.6	9.8	14%	81	75/63	R22
Ave	**4**	**118**	**20.0%**	**9.8**	**10.3**	**11.3%**	**86**	**77/64**	

Charge adjustments in parentheses are software recommendations. The average efficiency gain was 20.4 ± 8 percent for TXV air conditioners with an average charge adjustment of 25 ± 14 percent. The average efficiency gain for non-TXV air conditioners was 11.3 ± 8 percent with an average charge adjustment of 20 ± 14 percent. The average measured airflow improvement was 9.8 ± 2.5 percent at the 90 percent confidence level. The average measured pre-retrofit airflow was 314 ± 28 cfm for non-TXV systems and 316 ± 16 cfm for TXV systems.

Three laboratory studies indicate the efficiency degradation for TXV units is roughly 5 percent at plus or minus 20 percent of the correct charging condition.[15] Findings from this study indicate an average efficiency degradation of 20.4 ± 8 percent for TXV air conditioners with an average charge adjustment of 25 ± 14 percent. The student t-test was used to evaluate the mean efficiency difference between field and laboratory measurements and the differences were found to be statistically significant (i.e., 0.008 probability of t less than 3.3). Findings from this study indicate TXVs are less effective than proper RCA in terms of delivering rated efficiency.

[15] Farzad and O'Neal, 1993, Davis 2000a, and Davis 2000b (above footnote).

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 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. The uncertainty associated with field measurements of capacity and EER was evaluated using the propagation of error technique including: sensor accuracy; recording system accuracy; data display or recording resolution; and sampling error.[16] The uncertainty associated with instrument error is ± 2.8 percent, and the measurement error is ± 3.4 percent. Therefore, the total uncertainty error is ± 4.4 percent and this is comparable to uncertainty errors reported in laboratory studies.[17]

3. Participant Survey Results

This study uses participant surveys to estimate the net-to-gross ratios for kWh and peak kW savings. Participant surveys were completed for 54 participants in five NCPA utility service areas.

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 lighting improvements in the absence of the program. Ten participant survey questions are 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 is assigned to responses of “don’t know”, “refused to answer,” or “other.”

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[16] American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE). 2002. *ASHRAE Guideline 14-2002 – Measurement of Energy and Demand Savings*. Atlanta, Ga.: ASHRAE. 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*, Appendix to Chapter 7: 191-195. Uncertainty Calculation. San Francisco, Calif.: California Public Utilities Commission.

[17] See Farzad and O’Neal, 1993, Davis 2000a, and Davis 2000b (above footnote).

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 lighting efficiency upgrade 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 0.82 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 is consistent with the California Public Utilities Commission statewide residential program net-to-gross ratio of 0.80.[18]

Table 3.2 Findings of Participant Surveys

NCPA Utility	Rebate 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
MID	316	10	165.6	0.1301	0.82	0.15	6	0.11
PSREC-GSHP	82	11	172.1	0.1352	0.84	0.23	12	0.11
Redding	704	10	497.8	0.3911	0.83	0.17	8	0.32
Roseville	134	19	106.0	0.0833	0.86	0.10	3	0.07
TID	656	10	331.4	0.2603	0.81	0.16	7	0.21
Total	**1,892**	**60**	**1,273.0**	**1.0000**		0.15	**58**	**0.82**

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). The required sample size with finite population

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

corrected (FPC) to meet the 90% confidence and 10% relative precision (i.e., 90/10 criteria) for each program is shown in **Table 3.2**. The participant survey sample sizes met the 90/10 criteria (except for PSREC which was close with 11 surveys and a required sample size of 12).

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, database tracking, baseline, and program evaluation savings estimates are discussed below.

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.[19] 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 1**.

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

Where,

$\bar{y}_h$ = M&V mean kW or kWh savings for stratum "h."

N_h = Number of measures or sites in stratum "h."

y_k = M&V kW or kWh 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 2**.

Eq. 2 $$\text{Program Category Sample Mean} = \bar{y}_p = \sum_{h=1}^{L} W_h \bar{y}_h$$

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.

[19] 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.

The variance, s_h^2, of the sample mean for a utility program stratum within a program category was calculated using **Equation 3**.

Eq. 3 $$s_h^2 = \frac{\sum_{k=1}^{n}\left(y_k - \bar{y}_h\right)^2}{N_h - 1}$$

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 4**.

Eq. 4 Sample Coefficient of Variation = $Cv_h = \frac{s_h}{\bar{y}_h}$

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 5**.

Eq. 5 Utility Program Stratum Sample Size = $n_h = \frac{t_o Cv_h^2}{r_h^2}$

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.[20]

Eq. 6 FPC Sample Size = $n_{FPC\,h} = \frac{n_h}{1 + \left(n_h - 1\right)/N_h}$

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 7**.

Eq. 7 Stratum Error Bound = $Eb\left(\bar{y}_h\right) = t_o \frac{s_h}{\sqrt{n_h}}$

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.

[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.

An unbiased estimate of the program category variance was calculated using **Equation 8**.

Eq. 8 $$s_p^2 = \sum_{h=1}^{L} \frac{W_h^2 s_h^2}{n_h} - \sum_{h=1}^{L} \frac{W_h s_h^2}{N_p}$$

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 9**.

Eq. 9 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. The program category savings estimate was calculated as the sum of the number of measures for the utility program stratum times the M&V gross ex post sample mean savings as shown in **Equation 10**.

Eq. 10 $\hat{Y}_p =$ M&V Gross Ex Post Program Category Savings $= \sum_{h=1}^{L} \left[N_h \times \bar{y}_h \right]$

Where,

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

The M&V Average Gross Realization Rates (AGRR) for kW and kWh savings were calculated using **Equation 11**.

Eq. 11 $$AGRR_h = \frac{\hat{Y}_h}{\hat{X}_h}$$

Where,

$AGRR_h =$ Average Gross Realization Rate for kW or kWh savings defined as the sum of M&V kW savings for measures in program stratum “h” divided by the ex ante kW savings.

$\hat{Y}_h =$ Ex post program stratum “h” savings (kW or kWh).

$\hat{X}_h =$ Ex ante program stratum “h” savings (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 12**.[21]

[21] 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

Eq. 12 $$\hat{E}b(\bar{y}_p) = \sqrt{\sum_{i=1}^{m} \left[Eb(\bar{y}_h) \right]^2}$$

The AGRR is combined with the Net-to-Gross Ratio (NTGR) to develop the Net Realization Rate (NRR) relative to planning using **Equation 13**.

Eq. 13 $$NRR_h = NTGR_h \times AGRR_h$$

Where,

NRR_h = Net Realization Rate for kW or kWh savings in program stratum "h."

$NTGR_h$ = 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).

Some statistics were calculated using other equations.[22]

The sample coefficient of variation is 0.11 for kWh savings, the Cv is 0.24 for kW savings, and the participant survey Cv is 0.15. To achieve the 90/10 criteria with these Cv values required a sample size of 3 for estimating kWh savings, 15 for estimating kW savings, and 6 for the participant surveys. The billing data kWh sample was 60, the kW metering sample was 21, and the participant survey sample was 60.[23] The results in this report are presented at the 90/10 confidence level.

4.2 Database

Data for the new residential air conditioner rebate programs was 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 source of the tracking system data is based on reports provided by the respective utilities. The database includes general customer information, quantity and type of units recycled, make and model number, SEER value, capacity (tons), and NCPA account number (if available). Tracking data was delivered electronically by utility program staff and entered into the database after the programs were completed.

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.

[22] 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.

[23] Samples were randomly selected in each utility service area. Billing data and electricity metering data of air conditioners were obtained for participants and non-participants in MID, PSREC, Redding, and Roseville.

4.3 Baseline

The baseline kWh values are based on billing data and PRISM analyses, and the baseline kW values are based on metering results for a random sample of new high efficiency air conditioners and old standard air conditioners (see **Section 2**). The sample mean baseline full-year unit energy consumption for old air conditioners was 2,267 ± 311 kWh/yr at the 90 percent confidence level. The sample mean baseline kW varied from 3.75 ± 0.37 kW for 2.5 ton standard air conditioner to 6.01 ± 0.6 kW for 5-ton standard units. The baseline Unit Energy Consumption (UEC) values found in this study are higher than the 2004 California Statewide Residential Appliance Saturation Survey (RASS, available online at: http://websafe.kemainc.com/RASSWEB).[24] The 2004 RASS Study provides the following single family UEC values shown in **Table 4.1**.

Table 4.1 Average Residential Single Family UEC Values from 2004 RASS

End use	Climate Zone	Existing kWh/yr	New kWh/yr
Cooling (average)	All	1,215	1,423
Cooling (hottest climate zone)	7	1,908	n/a

The hottest climate zone 7 has a cooling UEC of 1,908 kWh per year. The M&V report for NCPA SB5X programs found an average cooling UEC of 2,267 kWh/yr and this is 18.6% higher than the highest 2004 RASS UEC values. The 2004 RASS is based on Conditional Demand Analysis of billing data for 21,153 homes. For space cooling the sample frame included 7,706 existing homes and 1,073 new homes.

4.4 Program Evaluation Savings Estimates and DEER

Gross M&V program evaluation savings (i.e., kWh/yr and kW) are based on sample mean savings estimates based on billing data analysis of 60 air conditioners. Gross program kW savings are based on sample mean savings estimates and field measurements of 14 new high efficiency air conditioners and 7 existing air conditioners. Gross kW savings for the sampled units were compared to kW savings based on manufacturer kW ratings for similar indoor and outdoor temperature conditions. 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 3**.

The ex ante program savings are summarized in **Table 4.2**, and the ex post M&V savings are summarized in **Table 4.3**.

[24] "California Statewide Residential Appliance Saturation Survey." Prepared by KEMA-Xenergy, Inc. Prepared for the California Energy Commission. P300-00-004. June 2004.

Table 4.2 Ex Ante Savings for NCPA SB5X Residential HVAC Rebate Programs

NCPA Utility	Qty.	Ex Ante Full-Year Unit kWh/yr	Ex Ante Unit kW	Ex Ante Net-to-Gross Ratio kWh/y	Ex Ante Net-to-Gross Ratio kW	Ex Ante Program Savings kWh/y	Ex Ante Program Savings kW
MID	316	350	0.64	1	1	110,645	201.2
PSREC-GSHP	82	16,001	3.96	1	1	1,312,082	324.7
Redding	704	666	0.76	1	1	469,104	536.3
Roseville	134	2,594	2.59	1	1	347,616	347.6
TID	656	721	0.74	1	1	472,845	483.2
Total or Average	**1,892**	**1,434**	**1.00**	**1.00**	**1.00**	**2,712,291**	**1,893**

Note: PSREC includes electric heating savings for the Ground Source Heat Pump (GSHP). Peak kW savings are for cooling only.

Table 4.3 M&V Ex Post Savings for NCPA SB5X Residential HVAC Rebate 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
MID	316	446	0.52	0.82	0.82	115,513	135.8	1.04	0.67
PSREC-GSHP	82	913	2.10	0.84	0.84	62,864	144.6	0.05	0.45
Redding	704	561	0.71	0.83	0.83	327,658	413.2	0.70	0.77
Roseville	134	581	0.79	0.86	0.86	67,011	91.2	0.19	0.26
TID	656	430	0.51	0.81	0.81	228,313	268.4	0.48	0.56
Total or Average	**1,892**	**513**	**0.67**	**0.82**	**0.82**	**801,358**	**1,053.3**	**0.30**	**0.56**

The ex ante program savings are 2,712,291 kWh/yr and 1,893 kW. The gross program ex post evaluation savings are 970,263 ± 177,315 kWh/yr and 1,273 ± 114 kW at the 90 percent confidence level. Net program evaluation savings are 801,358 ± 145,753 kWh/yr and 1,053 ± 71 kW at the 90 percent confidence level. The net ex post lifecycle savings are 12,020,370 ± 2,186,295 kWh based on the effective useful lifetime for air conditioners of 15 years.[25] The M&V net ex post savings per unit are 424 ± 77 kWh/yr and 0.56 ± 0.04 kW.

M&V savings and net realization rates are lower than anticipated primarily due to lower baseline usage and lower net-to-gross ratios. The Database for Energy Efficiency Resources (DEER) was used to evaluate the reasonableness of the M&V results.[26] The average M&V unit cooling-only savings for each utility are compared to savings from the 2001 DEER Update Study in **Table 4.4** (PSREC is excluded since DEER doesn't include GSHP units).

Table 4.4 Average M&V Gross Savings per Unit Compared to DEER

NCPA Utility	Qty.	Program Average Tons	Program Average SEER	Ex Ante Unit kWh/yr	Ex Ante Unit kW	M&V Gross Unit kWh/yr	M&V Gross Unit kW	DEER Unit kWh/yr	DEER Unit kW
MID	316	3.2	12.45	350	0.64	446	0.52	430	0.42
Redding	704	3.6	12.61	666	0.76	561	0.71	453	0.44
Roseville	134	3.6	13.81	2,594	2.59	581	0.79	630	0.62
TID	656	3.0	12	721	0.74	430	0.51	306	0.30
Average		**3.4**	**12.50**	**801**	**0.87**	**503**	**0.61**	**418**	**0.40**

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

[26] Energy and peak demand savings are from the 2001 DEER Update Study, High Efficiency Split A/C, prepared by XENERGY, Inc., prepared for the California Energy Commission, Contract 300-99-008, August 2001.

The average M&V gross savings per unit are 503 ± 94 kWh/yr and 0.61 ± 0.06 kW. The average deemed savings from DEER are 418 kWh per year and 0.40 kW. The average M&V gross kWh savings per unit are 20% greater than DEER, and the average M&V gross kW savings per unit are 53% greater than DEER. The M&V savings would have been lower if deemed savings from DEER were used instead of basing the results on billing data and field measurements. If air conditioning diversity factors were included in the analyses, the M&V kW realization rates would be even lower.

Appendix A: NCPA Residential HVAC 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.

RESIDENTIAL HVAC 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 once, 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: ____

RESIDENTIAL HVAC 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

RESIDENTIAL HVAC 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.