Measurement and Verification Study of 63 NCPA Public Utility Energy Efficiency Programs Funded by Senate Bill 5X

Prepared for the

MAESTRO/CALMAC Evaluation Showcase Agenda

Pacific Energy Center

July 26-27, 2006

851 Howard Street, San Francisco, CA 94103

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NCPA SB5X M&V Study Overview

- Study was funded by Senate Bill 5X and administered by Northern California Power Agency (NCPA) under a joint contract with the California Energy Commission.
- 17 California Public Utilities Implemented 63 Residential, Commercial, and Industrial Programs providing incentives for 281,390 energy efficiency measures.
- Total Budget was $8.7 Million and M&V Budget was $388,000 (4.5% of total budget).
- NCPA/CEC SB5X savings goal was 6.37 MW. Public utility savings goal was 43,410 MWh and 18.9 MW.
- M&V net savings are 37,346 ± 546 MWh/yr and 15.9 ± 0.2 MW and lifecycle savings are 541,242 ± 6,822 MWh.

SB5X Funded 17 Utilities–63 Programs

Utility	Ex Ante kWh	Ex Ante kW	Ex Post kWh	Ex Post kW	Budget	Programs
1. **Alameda**	1,127,255	368.0	954,938	286.7	$272,232	C&I Lighting
2. **Biggs**	96,435	39.1	59,376	20.0	$8,000	Res. CFL, Refrigerator Recycling
3. **Gridley**	233,252	85.9	119,129	45.4	$73,240	C&I Lighting, C&I AC, Res. CFL, Refrig. Recycling
4. **Healdsburg**	210,946	141.0	128,443	29.8	$84,500	C&I Lighting, Res. CFL
5. **Lassen**	183,964	80.4	155,842	62.7	$114,000	C&I Lighting
6. **Lodi**	2,062,413	865.3	1,457,864	1043.3	$446,000	C&I Lighting, C&I AC, C&I Refrig, Refr. Recyc, Misc.
7. **Lompoc**	725,887	94.0	558,837	85.1	$170,000	C&I Ltg, Refrig. Recyc, C&I Custom, LED Traf, Misc.
8. **MID**	4,052,449	4,716.0	3,347,857	4562.7	$1,760,000	C&I Lgt, C&I AC, Load Ctrl, Misc, Res AC, LED Traf
9. **Oakland**	250,000	60.0	250,000	60.0	$66,000	C&I AC
10. **Palo Alto**	3,905,474	1,360.7	2,467,638	1167.5	$750,000	C&I Lighting, C&I AC, Load Ctrl.
11. **PSREC**	1,863,997	546.9	454,296	250.1	$136,814	C&I AC, Res. CFL, Refrig Recycling, Res AC
12. **Redding**	1,875,173	2,219.1	3,515,296	1399.7	$715,000	C&I AC, Res AC, Res CFL
13. **Roseville**	2,589,565	1,131.9	1,553,471	598.1	$825,000	C&I Lighting, C&I AC, Res AC, Misc.
14. **SVP**	18,155,617	3,740.6	17,607,883	3456.7	$1,445,000	C&I Lighting, Refrig Recycling, LED Traffic, Misc.
15. **TDPUD**	624,040	243.5	708,838	263.1	$140,000	C&I Lighting, C&I AC, C&I Custom
16. **TID**	5,385,214	3,166.9	3,985,055	2542.7	$1,150,000	C&I AC, C&I Custom, Res AC, Misc,
17. **Ukiah**	68,415	17.2	21,527	12.3	$104,096	C&I AC, C&I Custom (PV)
Total	**43,410,097**	**18,877**	**37,346,290**	**15,886**	**$8,700,000**	**Including EM&V $388,091, and NCPA $52,027**

Programs were Organized into 10 M&V Program Categories

#	M&V Program Category	Budget	Ex Ante MWh/yr	Ex Ante MW	Ex Ante Lifecycle GWh	M&V Ex Post MWh/yr	M&V Ex Post MW	M&V Ex Post Lifecycle GWh
1	**C&I Lighting**	$2,100,482	21,024	4.94	336.38	20,302	4.41	324.82
2	**C&I HVAC**	$988,748	5,645	2.48	83.72	3,945	2.14	58.50
3	**C&I Refrigeration**	$380,000	1,194	0.77	23.88	822	0.89	16.43
4	**C&I Custom**	$370,550	4,898	1.16	73.86	3,754	0.82	56.61
5	**LED Traffic Signals**	$450,697	2,700	0.31	43.21	2,126	0.24	34.02
6	**Residential HVAC**	$1,344,803	2,712	1.89	40.68	801	1.05	12.02
7	**Residential CFL**	$250,096	1,883	1.95	12.66	3,486	1.06	23.42
8	**Refrigerator Recycling**	$344,647	2,431	0.33	14.59	1,724	0.44	10.34
9	**Miscellaneous Programs**	$246,519	922	0.43	12.06	387	0.18	5.06
10	**Load Control**	$1,600,740	0	4.62	0.00	0	4.64	0.00
	Total	**$8,077,282**	**43,410**	**18.88**	**641.03**	**37,346**	**15.89**	**541.24**

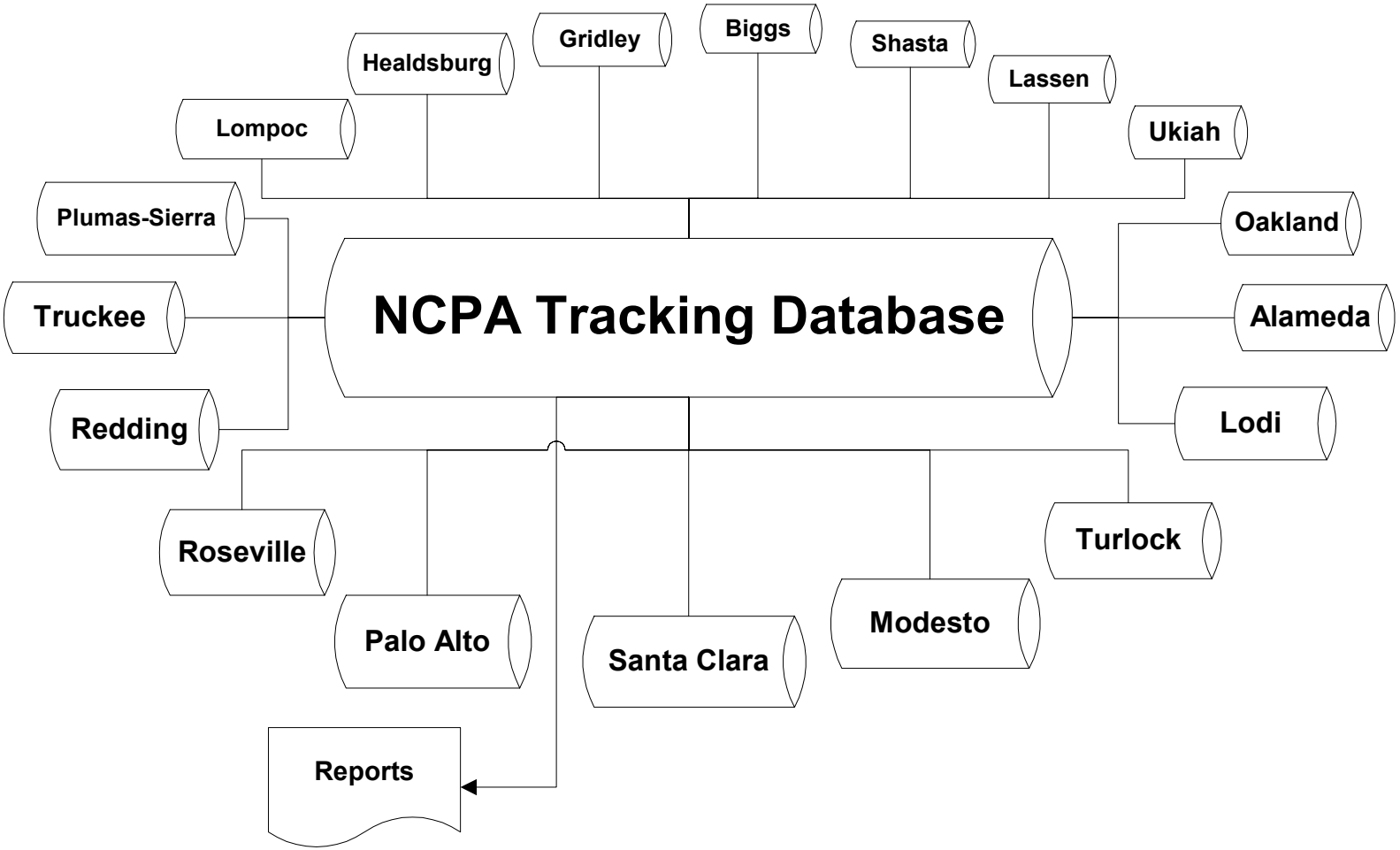
M&V Plan Adhered to IPMVP

- Consistent with the California Public Utilities Commission EM&V Protocols requiring International Performance Measurement and Verification Protocols (IPMVP).
- IPMVP is used by many state and federal agencies and World Bank.
- World Resources Institute is using IPMVP to establish evaluation standards for the Kyoto Protocol.
- US DOE Federal Energy Management Program and NYSERDA use IPMVP.
- US Green Building Council Leadership in Energy and Environmental Design (LEED) requires IPMVP.

Overview of M&V Load Impact Plan

1. Tracking Database provided a framework for M&V Study.
2. Statistical sample design was used to select customers from each program to achieve 90% confidence level.
3. On-site M&V and engineering analysis were used to gather pre/post-retrofit information to evaluate gross kW and kWh savings consistent with IPMVP.
4. Decision maker surveys were used to estimate net-to-gross ratios (NTGR) and net savings.
5. Statistical Analysis was used to extrapolate kW and kWh savings to program level and develop confidence intervals.
6. Gross and net savings were provided for measures and programs at the 90% confidence level.

1. NCPA SB5X Tracking Database



2. Statistical Sample Design

- Sample design focused on programs with largest savings (C&I lighting, HVAC, Custom, and Load Control).

#	NCPA Program Category	Budget %	Lifecycle kWh %	kW %	Units	Program Quantity	M&V Sample
1	**C&I Lighting**	26.0%	60.0%	27.8%	Fixtures	125,966	23,875
2	**C&I HVAC**	12.2%	10.8%	13.5%	Tons	12,489	9,620
3	**C&I Refrigeration**	4.7%	3.0%	5.6%	Tons	560	560
4	**C&I Custom**	4.6%	10.5%	5.2%	hp	239	10
5	**LED Traffic Signals**	5.6%	6.3%	1.5%	Signals	4,924	890
6	**Residential HVAC**	16.6%	2.2%	6.6%	Tons	1,892	60
7	**Residential CFL**	3.1%	4.3%	6.7%	Units	72,627	60
8	**Refrigerator Recycling**	4.3%	1.9%	2.8%	Units	1,609	107
9	**Miscellaneous Programs**	3.1%	0.9%	1.1%	Measures	68,698	50
10	**Load Control**	19.8%	0.0%	29.2%	Units	4,837	3,237
	Total	**100%**	**100%**	**100%**		**293,841**	**38,469**

3. On-Site M&V and Engineering

- Pre/post retrofit kW, operation, and energy use were measured following the IPMVP Options A, B, C, and D.

IPMVP Option	Savings Calculation	Typical Applications
Option A. Partially Measured Retrofit Savings are determined by partial short-term or continuous field measurement of energy use separate from facility energy use.	Engineering calculations using partial measurements and stipulations.	Lighting pre/post retrofit Watts are measured and hours are stipulated or from interviews.
Option B. Retrofit Isolation Savings are determined by short-term or continuous field measurement of energy use of applicable systems, separate from energy use of rest of facility.	Engineering calculations short-term or continuous measurements of isolated systems.	Lighting or motor pre and post-retrofit Watts and hours are determined by short-term or continuous measurement.
Option C. Whole Facility Savings are determined by measuring whole facility energy use. Short-term or continuous measurements are taken during the pre- or post-retrofit period.	Billing regression analysis of whole facility utility meter or sub-meter data for pre- or post-retrofit period.	LED traffic signal or EMS savings based on regression analysis of utility billing data for pre and post-retrofit period.
Option D. Calibrated Simulation Savings are determined through simulation of energy use components or whole facility and calibrated to pre or post-retrofit utility billing data.	Energy use simulation, calibrated with monthly utility billing data.	Weather-sensitive HVAC with pre-billing data and post-energy use based on calibrated simulations.

4. Decision Maker Net-to-Gross Ratio

- The DMS sample to evaluate the net-to-gross ratio included 388 sites with Cv ranging from zero to 0.46 and relative precision ranging from 0 to 8.1%.

NCPA Program Category	M&V Net Ex Post Savings GWh	M&V Net Ex Post Savings MW	Total Participant Units	M&V NTGR Sample	M&V NTGR C_v	NTGR Relative Precision
C&I Lighting	20.30	4.41	125,996	23,875	0.18	3.4%
C&I HVAC	3.94	2.14	12,489	9,620	0.09	2.3%
C&I Refrigeration	0.82	0.89	560	560	0.00	0.0%
C&I Custom	3.75	0.82	239	10	0.17	8.1%
LED Traffic Signals	2.13	0.24	4,924	890	0.00	0.0%
Residential HVAC	0.80	1.05	1,892	60	0.14	3.0%
Residential CFL	3.49	1.06	72,627	60	0.29	6.1%
Res. Refrigerator Recycling	1.72	0.44	1,609	107	0.46	7.2%
Miscellaneous	0.39	0.18	68,698	50	0.22	7.4%
Load Control	0.00	4.64	4,837	3,237	n/a	n/a
Total	**37.35**	**15.89**	**293,841**	**38,469**		

5. Statistical Analysis of Load Impacts

- Load impacts for programs with discrete measures were normalized based on the number of measures for the program stratum times the sample mean M&V savings.
  - LED Traffic Signals, Residential HVAC, Residential CFL, Refrigerator Recycling, Miscellaneous, Load Control.
- Load impacts for programs with multiple measures per site were normalized on a per unit basis (e.g., kW/fixture, kW/ton, kW/bin, and kW/hp).
  - C&I Lighting, HVAC, Refrigeration, and Custom.
- Relative precision was ±1.3% for MW and ±1.5% for GWh.
- Ex post error bound (EB) was ±0.20 MW and ±0.55 GWh

6. Reports and Recommendations

- NCPA Tracking Database includes pre- and post retrofit measure information, customer names, addresses, phone numbers, costs, rebates, savings, M&V data, and realization rates.
- Individual M&V Reports for Large Projects.
  - 40 M&V reports for large C&I lighting sites.
  - 7 M&V reports for custom C&I HVAC.
- M&V Reports for each of the 10 program categories.
- EM&V Summary Report for all 63 NCPA SB5X Programs. Available online at www.calmac.org.

Commercial & Industrial Lighting

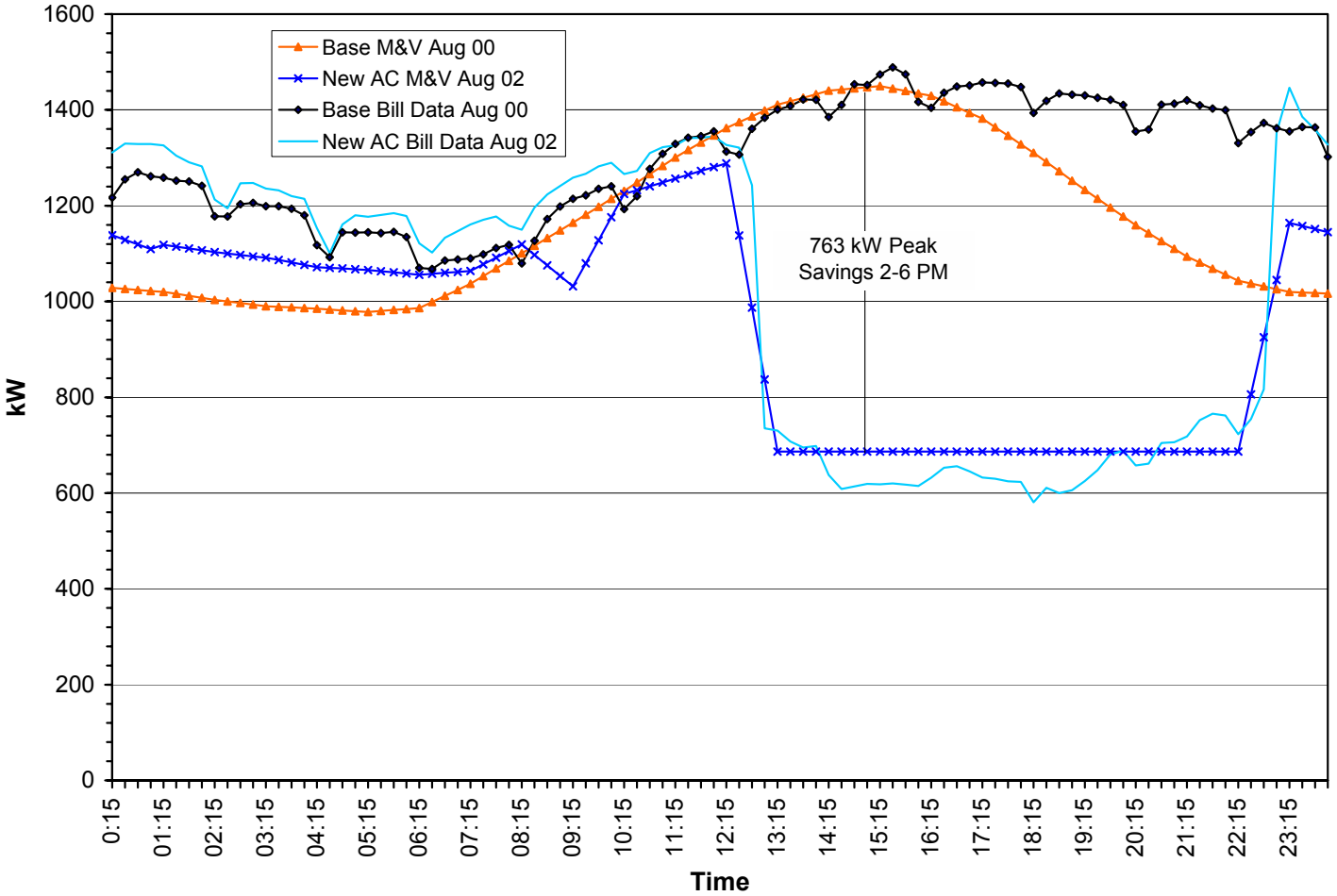
- C&I Lighting programs were implemented by Alameda, Gridley, Healdsburg, Lassen MUD, Lompoc, MID, Palo Alto, Roseville, Santa Clara, TDPUD, and TID.
- 125,966 fixtures with $2,100,482 of SB5X funds.
- Ex ante savings are 21,024 MWh/yr and 4,944 kW.
- M&V savings based on power measurements and light loggers for 23,875 fixtures per IPMVP Options A and B.
- M&V net program savings are 20,302 $\pm$ 214 MWh/yr and 4,414 kW $\pm$ 46 kW. Net-to-gross ratio was 85%.
- M&V net lifecycle savings are 324,824 $\pm$ 3,416 MWh based on 16-year effective useful life.
- Net realization rates are 0.97 for kWh and 0.89 for kW.

Commercial & Industrial HVAC

- C&I HVAC Programs by Gridley, Lodi, MID, Palo Alto, Port of Oakland, PSREC, Roseville, TDPUD, TID, and Ukiah.
- Program measures included high efficiency chillers, cooling towers, CTO, evaporative pre-coolers, thermal storage, PTAC, ground-source heat pumps, AC tune-ups.
- Incentives for 12,489 tons with $988,748 of SB5X funds.
- Ex ante savings are 5,645 MWh/yr and 2,482 kW.
- M&V savings based on field measurements, billing data, engineering analysis, and simulations for 9,620 tons per IPMVP Options B, C, D.
- Savings for 6 custom sites in MID, Palo Alto, and TDPUD accounted for 79% of kWh and 71% of kW savings.

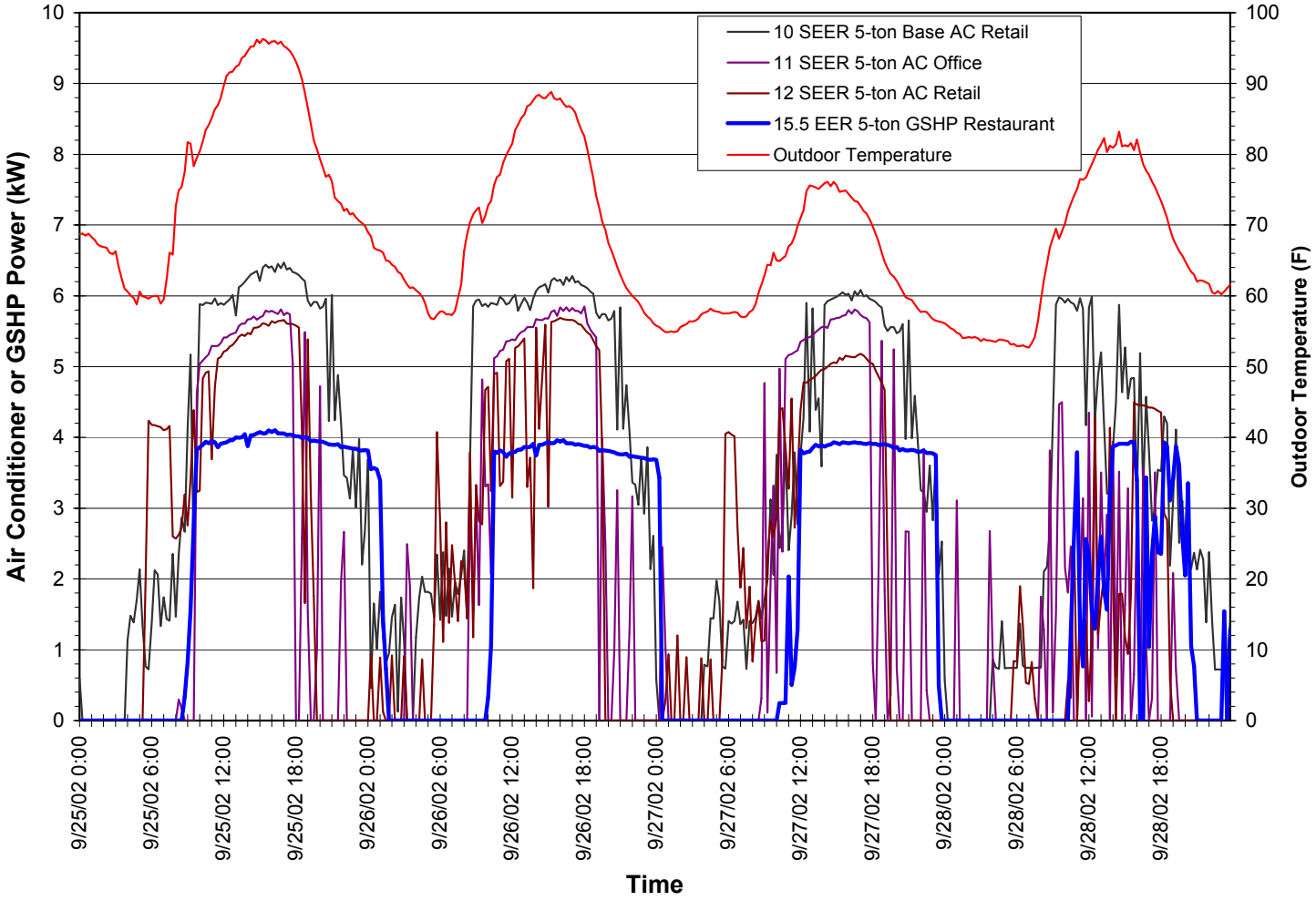
C&I HVAC (Continued)

- Thermal storage at beverage warehouse saved 763 kW.



C&I HVAC (Continued)

- Field measured peak kW savings for packaged AC.



C&I HVAC (Continued)

- Savings for Gridley, Lodi, MID, Redding, Roseville, TID, Ukiah, and PSREC based on PRISM billing regression and engineering analyses for 54 sites.
- Savings for Roseville commercial tune-ups are based on billing regression and analyses for 11 sites with 20 units.
- kW savings based on field measurements of 19 packaged units, 16 GSHPs, and 6 AC projects per IPMVP Option B.
- M&V net savings are 3,945 ± 225 MWh/yr and 2,142 ± 156 kW. Net-to-gross ratio is 96%.
- M&V net lifecycle savings are 58,499 ± 3,371 MWh based on an 15-year effective useful life.
- Net realization rates are 0.70 for kWh and 0.86 for kW.

C&I Refrigeration

- C&I Refrigeration Program implemented by Lodi replaced hydro-cool refrigeration with energy efficient internal air-cool refrigeration system.
- Incentives for $380,000 of SB5X funds.
- Ex ante savings are 1,194 MWh/yr and 765 kW.
- Savings based on billing data, production, and engineering analysis per IPMVP Option B and C.
- M&V new program savings are 822 ± 117 MWh/yr and 889 ± 39.2 kW. Net-to-gross ratio is 98%.
- M&V net lifecycle savings are 16,434 ± 2,331 MWh based on a 20 year effective useful lifetime.
- Net realization rates are 0.69 for kWh and 1.16 for kW.

Commercial & Industrial Custom

- C&I Custom Programs by TID, Ukiah, Lompoc, and TDPUD installed air compressors, VSD, motors, vacuum pumps, sunscreens, and PV systems.
- 64 projects with $370,550 of SB5X funds.
- Ex ante savings are 4,898 MWh/yr and 1,156 kW.
- Savings based on IPMVP Options B and C at sites accounting for 31% of kWh and 25% of kW savings.
- M&V net program savings are 3,754 ± 177 MWh/yr and 821.7 ± 34 kW. Net-to-gross ratio is 84%.
- M&V net lifecycle savings are 56,613 ± 2,648 MWh based on a 15 year effective useful lifetime.
- Net realization rates are 0.77 for kWh and 0.71 for kW

LED Traffic Signals

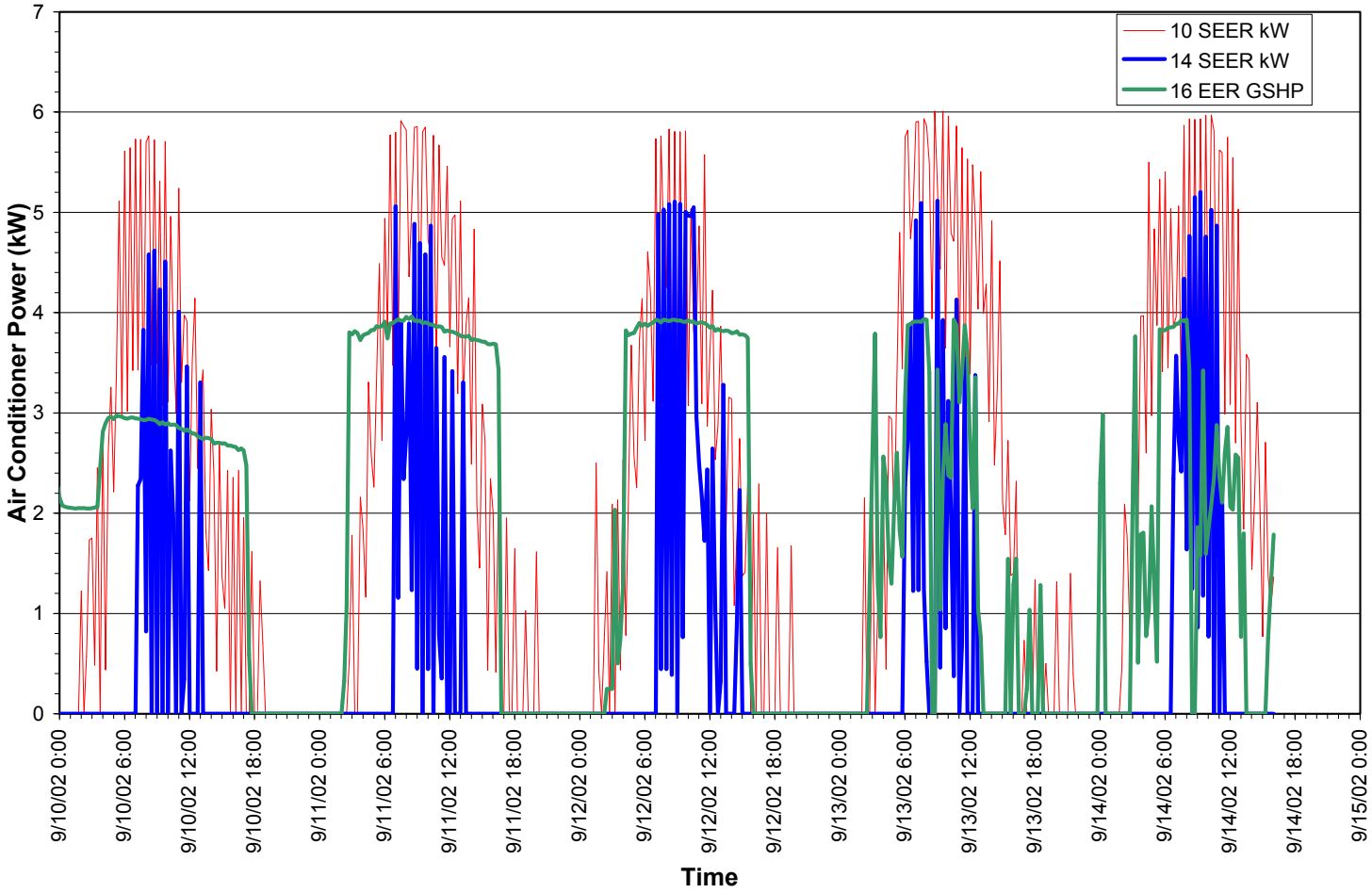
- LED Traffic Signals Programs were implemented by Lompoc, MID, and Silicon Valley Power.
- 4,924 LED traffic signals with $450,697 of SB5X funds.
- Ex ante savings are 2,700 MWh/yr and 308 kW.
- M&V savings based on field measurements, CalTrans data, and billing data for 890 signals consistent with IPMVP Options A, B, and C.
- M&V net program savings are 2,126 ± 20 MWh/yr and 242.8 kW ± 3 kW. Net-to-gross ratio is 84%.
- M&V net lifecycle savings are 34,019 ± 322 MWh based on a 16 year effective useful lifetime.
- Net realization rates are 0.79 for kWh and kW.

Residential HVAC

- Residential HVAC Programs were implemented by MID, PSREC, Redding, Roseville, and TID.
- Programs provided 1,892 air conditioner rebates with $1,344,803 of SB5X funds.
- Ex ante savings are 2,712 MWh/yr and 1,893 kW.
- kWh savings are based on billing regression per IPMVP Option C, and kW savings are based on Option B.
- M&V net program savings are 801 ± 146 MWh/yr and 1,053 ± 71 kW. Net-to-gross ratio is 83%.
- M&V net lifecycle savings are 12,020 ± 2,186 MWh based on a 15-year effective useful life.
- Net realization rates are 0.30 for kWh and 0.56 for kW.

Residential HVAC (continued)

- Peak kW savings based on 15-minute measurements per IPMVP Option B.



Residential CFLs

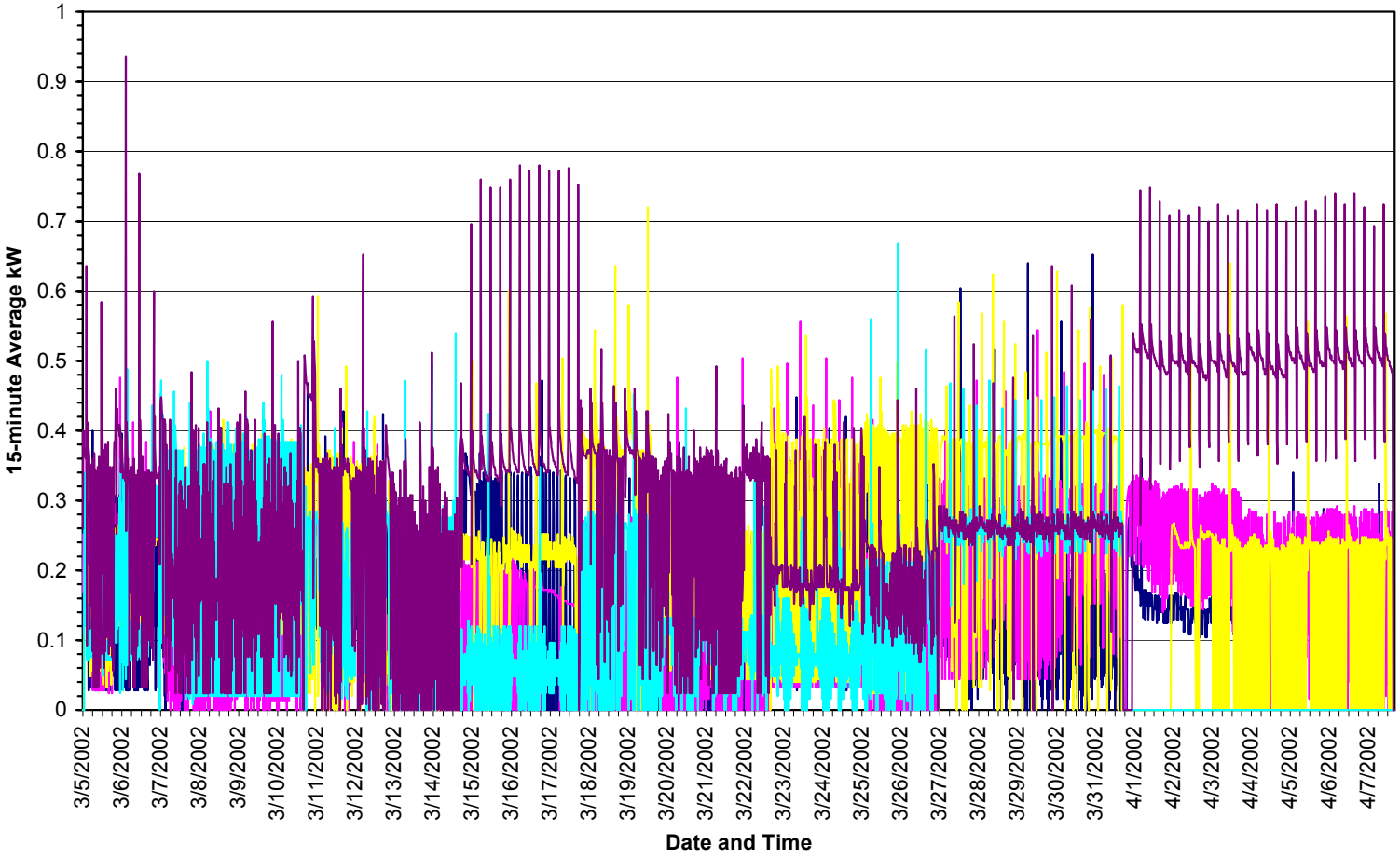
- Residential CFL Programs implemented by Biggs, Gridley, Healdsburg, Redding, and PSREC gave away 72,627 CFLs with $250,096 of SB5X funds.
- Ex ante savings are 1,883,234 kWh/yr and 1,951 kW.
- Savings based on measurements of pre/post Watts and hours based on interviews per IPMVP Option A.
- M&V unit savings 66.4 ± 6.9 kWh/y and 0.02 ± 0.001 kW.
- M&V net program savings are 3,486 ± 360 MWh/yr 1,057 ± 60 kW. Net-to-gross ratio is 72%.
- M&V net lifecycle savings are 23,425 ± 2,422 MWh based on a 6.7 year effective useful life.
- Net realization rates are 1.85 for kWh and 0.54 for kW.

Residential Refrigerator Recycling

- Programs implemented by Biggs, Gridley, Lodi, Lompoc, PSREC, and Santa Clara recycled 1,609 refrigerators and freezers with $344,647 of SB5X funds.
- Ex ante savings are 2,431 MWh/yr and 335 kW.
- M&V gross unit savings for refrigerators and freezers is 1,682 kWh/yr ± 122 kWh/yr and 0.362 kW ± 0.02 kW.
- M&V net program savings are 1,724 ± 126 MWh/yr and 445 ± 29 kW. Net-to-gross ratio is 76%.
- M&V net lifecycle savings are 10,343 ± 757 MWh based on a 6-year effective useful life.
- Net realization rates are 0.71 kWh and 1.33 kW savings.

Refrigerator Recycling (continued)

- kWh and peak kW savings based on field measurements of 91 refrigerators and 16 freezers per IPMVP Option B.



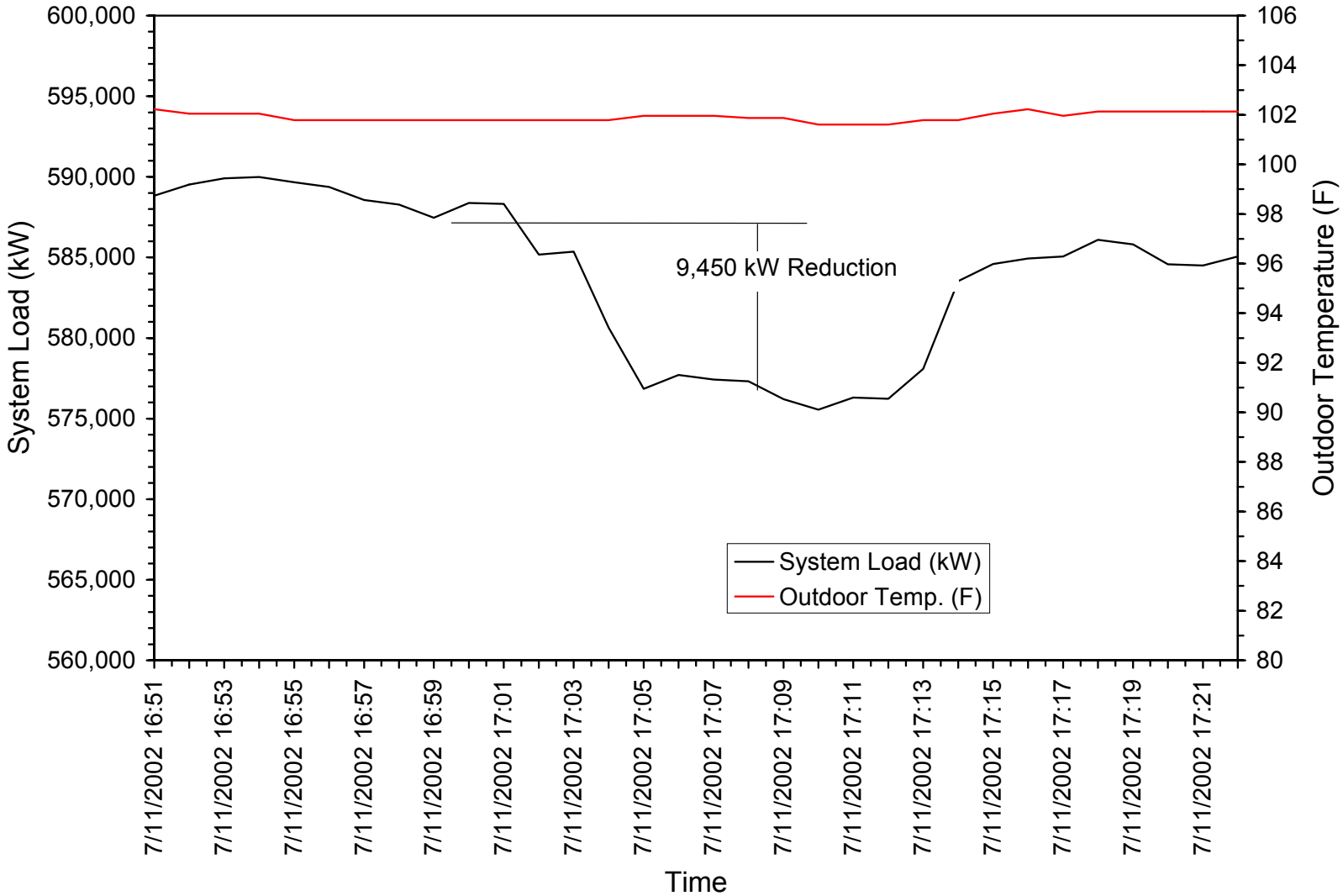
Miscellaneous Programs

- Miscellaneous programs were implemented by Lodi, Lompoc, MID, Roseville, and TID for vender misers, refrigerators, kits, mattress pads, windows, sun screens, window film, and whole house fans, plug load sensors.
- Provided 1,726 incentives for 68,698 measures from with $246,519 SB5X funds administered by NCPA.
- Ex ante savings are 922 MWh/yr and 427 kW.
- Savings based on billing data, sub-metered data, engineering analyses per IPMVP Options A, B, and C.
- M&V net ex post savings are 387 ±19 MWh per year and 182 ± 20 kW. Net-to-gross ratio is 85%.
- Net realization rates are 0.42 for kWh and kW.

Load Control

- Load Control Programs were implemented by MID, TID, and City of Palo Alto with $1,600,740 of SB5X funds.
- MID program installed 3,234 AC Load Controllers and TID installed 1,502 AC Load Control Thermostats.
- Palo Alto load curtailment at City Hall, Main Library, and Water Quality Control Plant.
- Ex ante savings are 4,615 kW.
- M&V savings are based on SCADA measurements for MID and Palo Alto sites per IPMVP Options A, B, and C.
- M&V net program savings are 4,640 kW $\pm$ 58.9 kW.
- Net realization rate is 1.01 for kW.

Load Control (Continued)



Conclusions

- M&V net ex post portfolio savings are 37,346 ± 546 MWh/year and 15,886 ± 204 kW.
- Net lifecycle portfolio savings are 541,242 ± 6,822 MWh with average EUL of 14.5 years.
- Net realization rates are 0.86 ± 0.01 for kWh and 0.84 ± 0.01 for kW.
- Net ex post TRC is 3.4 ± 0.05 or 0.06 ± 0.001 $/kWh.
- Net Cost per kW saved is $548 ± $7 per kW.
- Customers generally expressed very high satisfaction with the programs (i.e., no negative comments).

Recommendations–Lessons Learned

- Develop ex ante savings from M&V studies available from the California Measurement Advisory Council.
- Utilities haven't conducted M&V studies and were unfamiliar with tracking and measuring results.
- Future programs should budget 5 to 10% for M&V studies to improve reliability and reduce uncertainty.
- Future evaluations should include the following requirements: 1) tracking database, 2) net savings including precision and error bounds, 3) process evaluation, 5) independent study management, 6) adequate time, and 7) M&V contractors must have experience with IPMVP field measurement procedures