

# **Measurement & Verification Load Impact Study for NCPA SB5X Commercial and Industrial Custom Incentive Programs**

**Study ID: NCP0001.05**

## **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**

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# 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](http://www.calmac.org). This report provides Measurement and Verification (M&V) load impact study results for the NCPA SB5X Commercial and Industrial (C&I) Custom Incentive Programs implemented by Turlock Irrigation District (TID), Ukiah, Lompoc, and Truckee Donner Public Utility District (TDPUD). The programs realized peak kW and kWh savings by paying incentives to C&I customers for installing custom high efficiency measures such as air compressors, variable speed controllers, computer monitors, vacuum pumps, motors, and photovoltaic systems. The programs provided incentives for 64 projects from 2001 through 2003 with \$370,550 of SB5X funding from 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 4,897,986 kWh/yr and 1,156 kW. Total M&V gross ex post savings are 4,465,251 ± 210,158 kWh/yr and 977 ± 41 kW. The M&V net ex post savings are 3,754,038 ± 176,534 kWh/yr and 821.7 ± 34 kW. The net ex post lifecycle savings are 56,613,105 ± 2,648,085 kWh.

**Table 1.1 Ex Ante Savings for NCPA SB5X C&I Custom Incentives 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
TID	60	4,877,817	1148.3	1	1	4,877,817	1148.3
Ukiah	1	15,160	5.0	1	1	15,160	5.0
Lompoc	2	4,680	2.6	1	1	4,680	2.6
TDPUD	1	329	0.1	1	1	329	0.1
<b>Total</b>	<b>64</b>	<b>4,897,986</b>	<b>1,156</b>	<b>1.00</b>	<b>1.00</b>	<b>4,897,986</b>	<b>1,156</b>

**Table 1.2 M&V Ex Post Savings for NCPA SB5X C&I Custom 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
TID	60	4,445,082	969.0	0.84	0.84	3,733,869	814.0	0.77	0.71
Ukiah	1	15,160	5.0	1.00	1.00	15,160	5.0	1.00	1.00
Lompoc	2	4,680	2.6	1.00	1.00	4,680	2.6	1.00	1.00
TDPUD	1	329	0.1	1.00	1.00	329	0.1	0.07	0.03
<b>Total</b>	<b>64</b>	<b>4,465,251</b>	<b>976.7</b>	<b>0.84</b>	<b>0.84</b>	<b>3,754,038</b>	<b>821.7</b>	<b>0.77</b>	<b>0.71</b>

Note: The TID M&V sample included 10 sites with 419 hp, and TID provided incentives for a total of approximately 2,808 hp.

Ex post kWh savings are based on billing data and engineering analysis of 10 custom sites accounting for 31 percent of the total kWh savings and 25 percent of total kW savings. The M&V sample included high efficiency air compressors, variable frequency drives, vacuum pumps, and motors affecting 419 horsepower out of a total of 2,808 horsepower in the program. 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 84 percent indicating approximately 16 percent of high efficiency custom measures would

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have been purchased anyway without the program.<sup>1</sup> The realization rates are 0.77 for kWh savings and 0.71 for kW savings. The M&V savings and net realization rates are lower than anticipated due to lower baseline usage and lower net-to-gross ratios.

The M&V study provides average gross savings per unit and net-to-gross ratios. The gross savings are based on in-situ true RMS power measurements. The peak kW for each unit was taken as the maximum kW that occurs during the 2 PM to 6 PM weekday time frame. 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 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 sample design and statistical analysis methods, database, baseline, impact analysis, and program evaluation savings estimates. **Appendix A** provides the Decision-Maker Survey.

## 2. M&V Approach and Results for C&I Custom

The measurement and verification approach for the study was based on the *International Performance Measurement & Verification Protocols* (IPMVP) defined **Table 2.1**.<sup>2</sup>

**Table 2.1 IPMVP M&V Options**

M&V Option	How Savings are Calculated	Typical Applications
<b>Option A. Partially Measured Retrofit Isolation</b> 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 short-term or continuous. Partial measurement means 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 stipulated values represent probable actual values.	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.
<b>Option B. Retrofit Isolation</b> 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	Electricity use is measured with kW meters. Hours of operation are measured with motor loggers.
<b>Option C. Whole Facility</b> 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.
<b>Option D. Calibrated Simulation</b> Savings are determined through simulation of component or whole facility energy use. 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 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.

<sup>1</sup> The net-to-gross ratios reflect what customers would have done in the absence of the program (see Section 3).

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

Ex post energy and peak demand savings were determined using IPMVP Option B (i.e., retrofit isolation), and Option C (whole facility billing analysis). Three years of whole facility pre- and post-retrofit monthly utility billing data including kWh and kW were collected for 10 sites in TID. The billing data, sub-metered kW data, and engineering analyses were used to develop the kWh and kW baseline usage and savings for each site.

### 2.1 Field Measurement Methodology

Field measurements were made to determine in-situ efficiency on a sample of 10 custom sites. Field measurements, measurement equipment, and measurement tolerances are provided in **Table 2.2**. 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.

**Table 2.2 Field Measurements, Measurement Equipment, and Tolerances**

Field Measurement	Measurement Equipment	Measurement Tolerances
Total power in kilowatts (kW) of air compressors, motors, and controls	True RMS 4-channel power data loggers and 4-channel power analyzer	Data loggers, CTs, PTs: $\pm 1\%$ Power analyzer: $\pm 1\%$

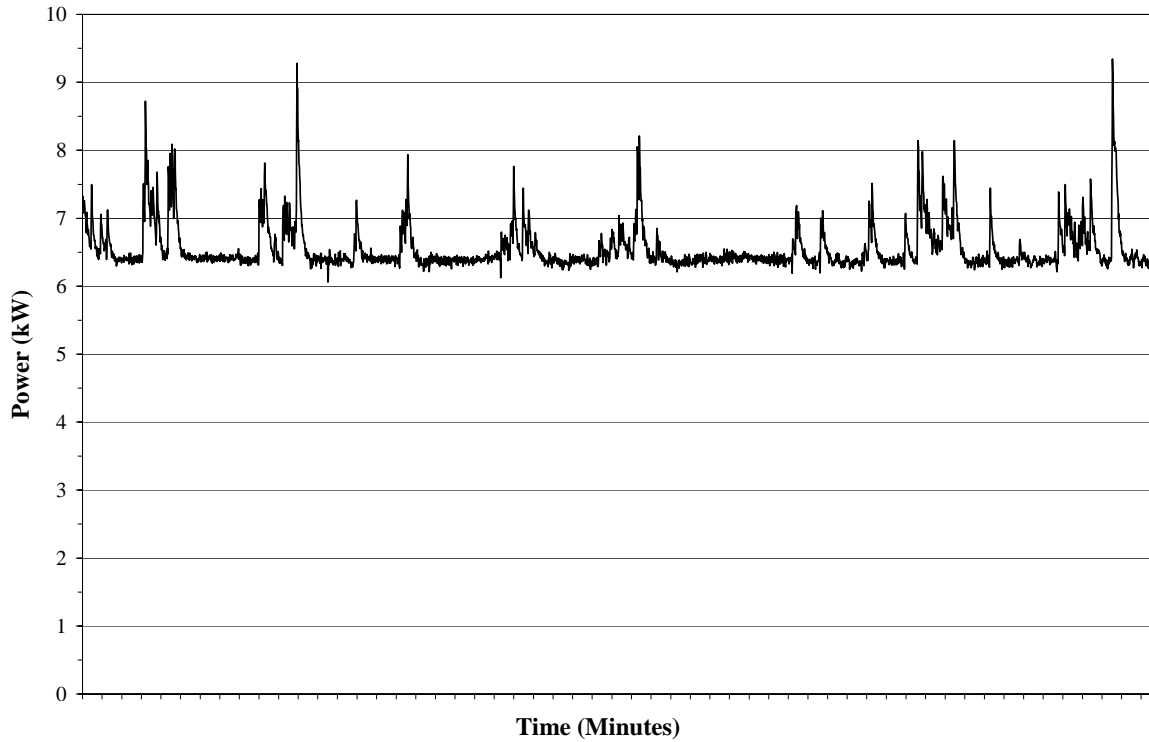
### 2.2 Findings of Field Measurements

Field measurements were made to determine in-situ energy and peak demand savings for TID projects. Multiple data loggers were installed at 10 custom sites to measure peak demand and energy use for standard and high efficiency custom measures. The measurement sample included air compressors, variable speed drives, vacuum pumps, and controls. Insufficient data were available to fully evaluate savings for Solar Photovoltaic projects implemented by Ukiah, Lompoc, and TDPUD. The ex ante savings for PV projects were based on engineering analyses and they were accepted as reasonable ex post savings.

#### 2.2.1 Findings for C&I Custom Projects

The custom projects accounted for 99 percent of total ex ante savings for the SB5X C&I Custom Incentives Programs. Data loggers were installed at 10 of the custom sites to measure peak demand and energy use. Peak kW savings are based on kW measurements as shown in **Figure 2.1** for the vacuum pump with variable frequency drive (VFD) at Site #1.

**Figure 2.1 Power Measurements of Vacuum Pump with VFD at Site #1**



**Figure 2.2** shows the old vacuum dairy pump with constant speed drive at site #1, and **Figure 2.3** shows the new vacuum dairy pump with VFD.

**Figure 2.2 Old Vacuum Pump at Site #1**



**Figure 2.3 New Pump w/VFD at Site #1**



Power measurements for the variable speed drive (VSD) air compressor at site #4 are shown in **Figure 2.4**, and measurements for the VSD air compressor at site #6 are shown in **Figure 2.5**.



Figure 2.4 Power Measurements of VSD Air Compressor at Site #4

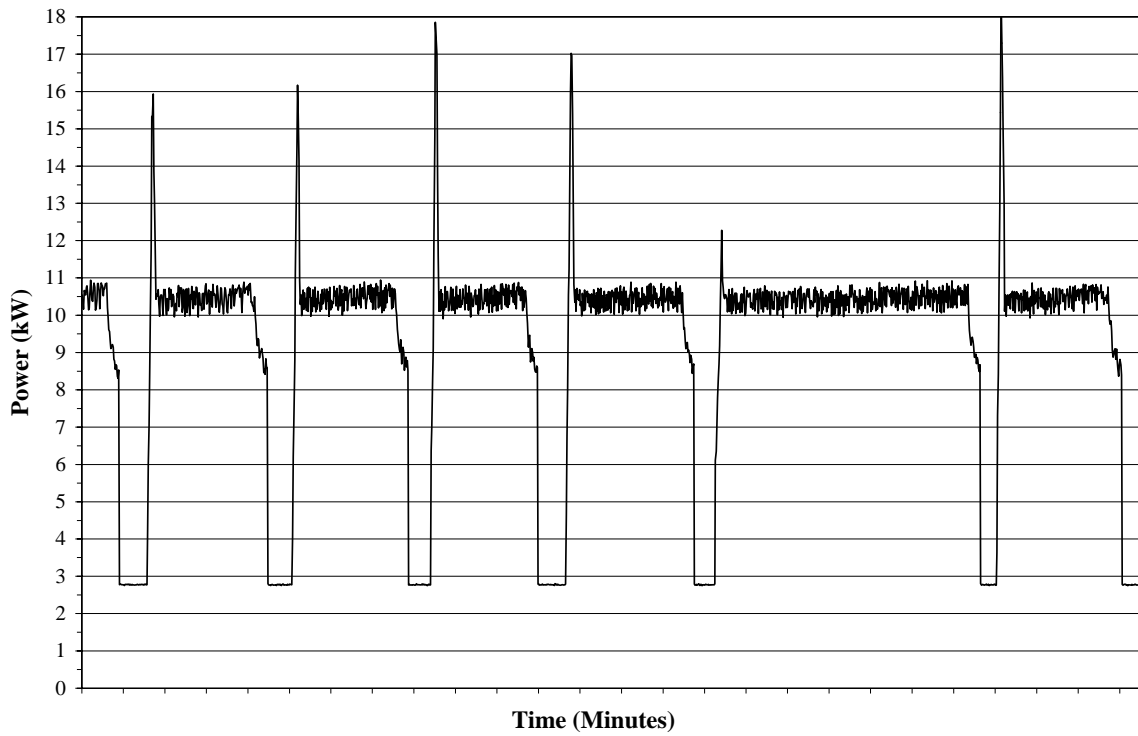
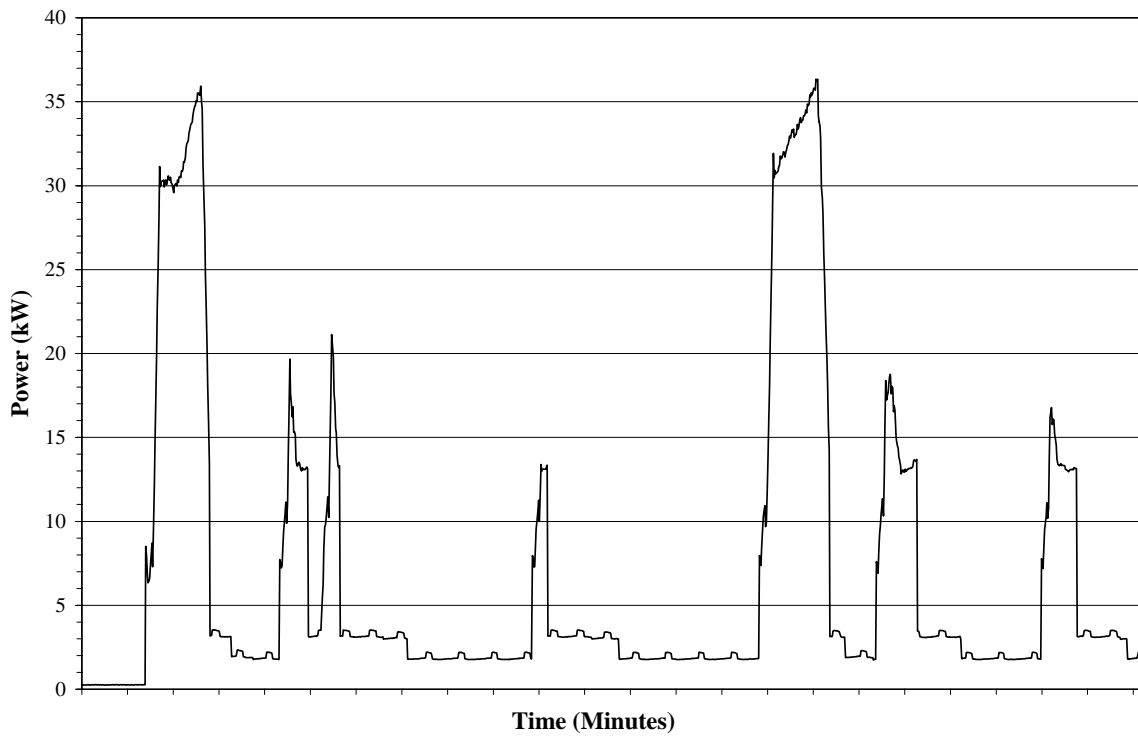


Figure 2.5 Power Measurements of VSD Air Compressor at Site #6



**Figure 2.6** shows the VSD air compressor at Site #4, and **Figure 2.7** shows VSD air compressor at Site #6.

**Figure 2.6 VSD Air Compressor at Site #4**



**Figure 2.7 VSD Air Compressor at Site #6**



Three years of pre-retrofit and post-retrofit monthly utility billing data were collected for the 10 custom sites in TID from 2000 through 2002. Monthly utility billing data including both kWh and kW, sub-metered kW data, and engineering analyses were used to develop the kWh and kW baselines and savings for each site. Baseline kWh and kW values and ex ante and M&V ex post normalized savings per horsepower are summarized in **Table 2.3**. The ex ante mean savings for the ten sites are 3,814 kWh/hp-yr and 0.72 kW/hp. The gross M&V ex post mean savings for the ten sites are  $3,476 \pm 164.3$  kWh/yr and  $0.61 \pm 0.03$  kW/hp. The average gross realization rates (AGRR) are 0.9113 for kWh and 0.8439 for kW. The AGRR values are multiplied by the TID ex ante values of 4,877,817 kWh and 1,156 kW to calculate the gross M&V ex post savings of  $4,445,082 \pm 210,157$  kWh/yr and  $969 \pm 40.5$  kW. The net-to-gross ratio (NTGR) for TID is 0.84 (see **Section 3.2**). Multiplying the NTGR times the M&V gross savings yields the net M&V savings for TID of  $3,733,869 \pm 176,532$  kWh/yr and  $814 \pm 34$  kW. The M&V sample included high efficiency air compressors, variable frequency drives, vacuum pumps, and motors affecting 419 horsepower out of a total of 2,808 horsepower in the program. Custom measures included air compressors, variable speed drives, vacuum pumps, motors, and controls. The effective useful lifetime for these custom measures is 15 years.<sup>3</sup>

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<sup>3</sup> The net-to-gross ratio and effective useful lifetime (EUL) are taken from the *Energy Efficiency Policy Manual*, Chapter 4, page 22, prepared by the California Public Utilities Commission, 2001.

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**Table 2.3 TID Baseline and M&V Savings for C&I Custom Projects**

Site	Baseline (kWh/yr)	Base kW	Rebated Measure	Hp	Ex Ante Savings kWh/hp-yr	Ex Ante Savings kW/hp	M&V Savings kWh/hp-yr	M&V Savings kW/hp	IPMVP Option
1	363,000	93	VFD Vacuum Pump	20	2,735.8	0.47	2,929.2	0.45	B, C
2	306,480	63	VFD Vacuum Pump	15	3,426.1	0.59	1,982.5	0.35	B, C
3	252,160	52	VFD Vacuum Pump	20	2,730.2	0.47	4,144.0	0.47	B, C
4	228,320	177	VSD Air Compressor	67	1,296.0	0.30	1,190.0	0.28	B, C
5	2,133,379	759	VSD Air Compressor	40	3,396.6	0.94	1,926.0	0.54	B, C
6	152,448	74	VSD Air Compressor	40	5,504.2	1.89	4,109.9	1.41	B, C
7	605,440	260	VSD Air Compressor	75	2,594.6	0.46	2,169.7	0.38	B, C
8	152,587	47	Eff. Air Compressor	15	2,148.5	0.75	2,378.9	0.83	B, C
9	4,270,578	843	Eff. Air Compressor	117	6,446.5	0.74	6,449.5	0.74	B, C
10	328,080	70	VSD Air Compressor	10	1,347.7	0.93	1,096.7	0.76	B, C
<b>Mean</b>					<b>3,814</b>	<b>0.72</b>	<b>3,476</b>	<b>0.61</b>	
<b>90% CI</b>							<b>164.3</b>	<b>0.03</b>	
<b>Cv</b>							0.59	0.52	
<b>AGRR</b>							<b>0.9113</b>	<b>0.8439</b>	

### 2.2.2 Findings for Solar Photovoltaic Systems

Insufficient data were available to fully evaluate savings for Solar Photovoltaic systems. The ex ante savings were based on engineering analyses and were accepted as reasonable. Ex ante and ex post savings for Ukiah, Lompoc, and Truckee are summarized in **Tables 2.4, 2.5, and 2.6**. The effective useful lifetime for photovoltaic systems is 30 years.<sup>4</sup> The relative precision for PV savings is 5% based on manufacturer's data.<sup>5</sup>

**Table 2.4 Ukiah Baseline and M&V Savings for C&I Custom Project**

Site	Baseline (kWh/yr)	kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option or Report
11	n/a	n/a	Solar Photovoltaic System	15,160	5	15,160	5	n/a

**Table 2.5 Lompoc Baseline and M&V Savings for C&I Custom Project**

Site	Baseline (kWh/yr)	kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option or Report
12	n/a	n/a	Solar Photovoltaic System	4,680	2.6	4,658	2.6	n/a

**Table 2.6 TDPUD Baseline and M&V Savings for C&I Custom Project**

Site	Baseline (kWh/yr)	kW	Rebated Measure	Ex Ante Savings kWh/yr	Ex Ante Savings kW	M&V Savings kWh/yr	M&V Savings kW	IPMVP Option or Report
13	n/a	n/a	Solar Photovoltaic System	329	0.08	329	0.08	n/a

<sup>4</sup> According to the Solar Electric Light Fund, photovoltaic modules from crystalline cells have a lifetime of over twenty years. Available Online: [http://www.self.org/shs\\_tech.asp](http://www.self.org/shs_tech.asp). According to PV-WEB photovoltaic modules can be expected to operate for over 30 years with minimal maintenance. Available Online: [http://www.pv-uk.org.uk/technology/why\\_pv.html](http://www.pv-uk.org.uk/technology/why_pv.html).

<sup>5</sup> According to manufacturer's specifications, minimum Photovoltaic system power is within 10 percent of rated power for most systems (see [http://www.aetsolar.com/Solar\\_Products\\_Services/solar\\_components.htm](http://www.aetsolar.com/Solar_Products_Services/solar_components.htm)).

### 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 12 participants in three NCPA utility service areas. This sample size exceeded the M&V plan of 10 sites, and included all of the custom sites accounting for 31 percent of the total kWh savings and 25 percent of total kW 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 the 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 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 <i>same</i> 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 0.841 based on average participant survey results multiplied times gross ex post savings for each program divided by total gross ex post savings for all programs.<sup>6</sup>

**Table 3.2 Findings of Participant Surveys**

NCPA Utility	Rebates	Completed Surveys	Gross Ex Post Program Savings kWh/yr	Gross Ex Post Program Savings kW	Weighting Factor	Actual Net-to-Gross Ratio	Weighted Net-to-Gross Ratio
TID	60	10	4,445,082	969.0	0.992	0.840	0.833
Ukiah	1	1	15,160	5.0	0.005	1.000	0.005
Lompoc	2	1	4,680	2.6	0.003	1.000	0.003
Truckee	1		329	0.1	0.000	1.000	0.000
<b>Total</b>	<b>64</b>	<b>12</b>	<b>4,465,251</b>	<b>977</b>	<b>1.000</b>		<b>0.841</b>

## 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.<sup>7</sup> 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/hp). 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**.

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

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.”

<sup>6</sup> Participant survey results for programs with lower savings are weighted lower in terms of the total weighted average NTGR for all sites.

<sup>7</sup> 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.

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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**.

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

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 3**.

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

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**.

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

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**.

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

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.<sup>8</sup>

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

Where,

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<sup>8</sup> 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.

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$n_{FPC_h}$  = 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**.

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

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.

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

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

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**.

$$\text{Eq. 9} \quad \text{Program Category Coefficient of Variation} = \text{Cv}_p = \frac{s_p}{\bar{y}_p}$$

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 AGRR for kW and kWh savings were calculated using **Equation 10**.

$$\text{Eq. 10} \quad \text{AGRR}_h = \frac{\sum_{k=1}^n \text{M \& V Sample Savings}_k}{\sum_{k=1}^n \text{Ex Ante Sample Savings}_k}$$

Where,

$\text{AGRR}_h$  = Average gross realization rate for program stratum “h.” 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 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 11**.

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$$\text{Eq. 11} \quad \hat{Y}_p = \text{M\&V Gross Ex Post Program Category Savings} = \sum_{h=1}^L [\hat{X}_h \times \text{AGRR}_h]$$

Where,

$\hat{Y}_p$  = M&V gross ex post program category 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 stratum and was calculated using **Equation 12**.<sup>9</sup>

$$\text{Eq. 12} \quad \hat{\text{Eb}}(\bar{y}_p) = \sqrt{\sum_{h=1}^L [\text{Eb}(\bar{y}_h)]^2}$$

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 **Equation 13**.

$$\text{Eq. 13} \quad \text{NRR}_h = \text{NTGR}_h \times \text{AGRR}_h$$

Where,

$\text{NRR}_h$  = Net Realization Rate for kW or kWh savings in program stratum “h.”

$\text{NTGR}_h$  = 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.<sup>10</sup>

The weighted sample coefficient of variation (Cv) is 0.59 for kWh savings, the weighted Cv is 0.52 for kW savings, and the weighted participant survey coefficient of variation is 0.17. To achieve the 90/10 level of confidence criteria with these Cv values required a sample size of 93 for estimating kWh savings, 73 for estimating kW savings, and 8 for estimating net-to-gross ratios with participant surveys. The M&V load impact savings (normalized by horsepower) are based on a random sample of 10 sites involving 419 horsepower out of 2,808 horsepower in the program. The net-to-gross ratio analysis is based on a random sample of 12 participant surveys.

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<sup>9</sup> 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., Prah, 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.

<sup>10</sup> Hall, N., Barata, S., Chernick, P., Jacobs, P., Keating, K., Kushler, M., Migdal, L., Nadel, S., Prah, 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

The C&I Custom Incentive Program data 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, horsepower, efficiency, 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.

### 4.3 Baseline

The baseline kWh values are based on billing data analyses. The baseline kW values are based on monthly utility billing data and sub-metering data for a random sample of high efficiency custom measures (monthly kWh and kW), and the appropriate baseline prior to retrofit (see **Section 2**).

### 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 and kW savings are based on billing data, engineering analyses, and field measurements of 10 custom sites accounting for 31 percent of the total kWh savings and 25 percent of total kW savings. The M&V sample included high efficiency air compressors, variable frequency drives, vacuum pumps, and motors affecting 419 horsepower out of a total of 2,808 horsepower in the program. 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**.

Ex ante program savings are summarized in **Table 4.1**, and ex post savings are summarized in **Table 4.2**. The ex ante program savings are 4,897,986 kWh/yr and 1,156 kW. The M&V gross ex post program savings are  $4,465,251 \pm 210,158$  kWh/yr and  $977 \pm 41$  kW at the 90 percent confidence level. The M&V net ex post program savings are  $3,754,038 \pm 176,534$  kWh/yr and  $821.7 \pm 34$  kW. The M&V net ex post lifecycle savings are  $56,613,105 \pm 2,648,085$  kWh as shown in **Table 4.3**. The net realization rates are 0.77 for kWh savings and 0.71 for kW savings. Ex post kWh savings are based on billing data and engineering analysis of 10 custom sites accounting for 31 percent of the total kWh savings and 25 percent of total kW savings. The M&V sample included high efficiency air compressors, variable frequency drives, vacuum pumps, and motors affecting 419 horsepower out of a total of 2,808 horsepower in the program. The net-to-gross ratios are 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**). M&V savings are lower than anticipated due to lower baseline usage and net-to-gross ratios.

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**Table 4.1 Ex Ante Savings for NCPA SB5X C&I Custom Incentives 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
TID	60	4,877,817	1148.3	1	1	4,877,817	1148.3
Ukiah	1	15,160	5.0	1	1	15,160	5.0
Lompoc	2	4,680	2.6	1	1	4,680	2.6
TDPUD	1	329	0.1	1	1	329	0.1
<b>Total</b>	<b>64</b>	<b>4,897,986</b>	<b>1,156</b>	<b>1.00</b>	<b>1.00</b>	<b>4,897,986</b>	<b>1,156</b>

**Table 4.2 M&V Ex Post Savings for NCPA SB5X C&I Custom 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
TID	60	4,445,082	969.0	0.84	0.84	3,733,869	814.0	0.77	0.71
Ukiah	1	15,160	5.0	1.00	1.00	15,160	5.0	1.00	1.00
Lompoc	2	4,680	2.6	1.00	1.00	4,680	2.6	1.00	1.00
TDPUD	1	329	0.1	1.00	1.00	329	0.1	0.07	0.03
<b>Total</b>	<b>64</b>	<b>4,465,251</b>	<b>976.7</b>	<b>0.84</b>	<b>0.84</b>	<b>3,754,038</b>	<b>821.7</b>	<b>0.77</b>	<b>0.71</b>

Note: The TID M&V sample included 10 sites with 419 hp, and TID provided incentives for a total of approximately 2,808 hp.

**Table 4.3 M&V Ex Post Lifecycle Savings for NCPA SB5X C&I Custom 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/yr
TID	60	3,733,869	15	56,008,035	2,647,978
Ukiah	1	15,160	30	454,800	22,740
Lompoc	2	4,680	30	140,400	7,020
Truckee	1	329	30	9,870	494
<b>Total</b>	<b>64</b>	<b>3,754,038</b>		<b>56,613,105</b>	<b>2,648,085</b>

## Appendix A: NCPA C&I 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 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 efficiency upgrade(s) 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 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 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

**Time relative to the installation date. 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.