IMPACT EVALUATION OF SILICON VALLEY POWER'S ENERGY-EFFICIENCY PROGRAMS FY 2011–2012

March 4, 2013

Mary Medeiros McEnroe
Public Benefits Program Manager
Silicon Valley Power
1500 Warburton Avenue
Santa Clara, CA 95050-3796

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CADMUS

Prepared by:
Dr. Ayat Osman
Dr. Allen Lee
Peter Lee
Andrew Wood

The Cadmus Group, Inc.

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Executive Summary

This report documents the findings of The Cadmus Group's (Cadmus) impact evaluation of the FY 2011–2012, electric, energy-efficiency programs Silicon Valley Power (SVP) provides to its customers. SVP, Santa Clara's municipal electric utility, has committed to ensuring an affordable, reliable, and clean future energy supply for its electric ratepayers. In 2005, California Senate Bill 1037 (Kehoe) established several important policies regarding energy efficiency. One key provision makes a statewide commitment to cost-effective and feasible energy efficiency, with the expectation that all utilities consider energy efficiency before investing in any other resources to meet growing demand. A critical component of fulfilling this commitment requires reporting expected and actual energy and demand savings, determined through an evaluation, measurement, and verification (EM&V) process.

SVP provides energy-efficiency programs for both residential and nonresidential sectors. The nonresidential programs constituted the majority of the annual savings realized by these efforts. SVP excluded residential savings from this evaluation, due to the program's small impact relative to the nonresidential program.

This study provides an independent evaluation of annual electricity consumption and demand impacts for SVP's nonresidential programs, and consists of the following tasks:

- Identifying and assessing the quality of data and information obtained to support the impact evaluation; and
- Determining the gross estimates of energy and demand savings.

SVP staff and third-party contractors, specializing in specific market sectors and measures, implemented the FY 2011–2012 programs. Nonresidential programs resulted in incentivizing 149 projects, claiming about 24 GWh of the total *ex ante* annual electricity savings.

The nonresidential programs' portfolio of savings was dominated by a handful of large projects. Cadmus divided the population into four strata, based on *ex ante* annual electric energy savings, representing very large, large, medium, and small projects. The very large projects group is referred to as the census group since all projects were included in the analysis.

Cadmus selected 19 projects in the portfolio as the sampling frame, which represented the large majority of total program claimed savings. The dominance of program savings by a few large projects provided an opportunity to reduce the site visits sample size by including a "census stratum" in the sample design. The very large (census) stratum only consists of three of the largest projects, constituting the majority of program-wide *ex ante* or claimed savings. Within each of the remaining three strata, Cadmus selected a random sample of projects to perform the impact evaluation. The chosen sample frame minimized variability in the final results and maximized the precision associated with *ex post* savings determined through this evaluation.

The 19 projects in the sample captured approximately 86% (about 21.5 GWh sampled out of the 25 GWh) of the total program *ex ante* savings because of the inclusion of the census stratum in the sample. The census stratum consisted of newly constructed data center projects making up about 82% of *ex ante* annual electric savings.

About 4% of *ex ante* electric savings were found to be primarily associated with lighting projects. These savings are captured in the three (large, medium and small) randomly selected strata. The large stratum consisted of 18 projects of which six projects (33% of stratum projects) were randomly selected for the sample. The large stratum and the sample of six projects selected constituted about 13.1% and 3.6% of the total program *ex ante* annual electric savings, respectively. The medium stratum consisted of 23 projects of which six projects (26% of stratum projects) were randomly selected. The medium stratum and projects sampled from it provided about 2.3% and 0.57% of the total program *ex ante* annual electric savings, respectively. The small stratum consisted of 105 projects of which four projects (26% of stratum projects) were randomly selected. The small stratum and selected sample projects provided about 2.6% and 0.05% of the total program *ex ante* annual savings, respectively.

Table 1 summarizes the strata and sample characteristics.

Table 1. Strata and Sample Characteristics

Stratum Name	*Stratum Ex Ante* Reported Savings (kWh)	Number of Projects in Stratum	Percent of Portfolio Savings in Each Stratum	Number of Projects Sampled in Stratum	Sample *Ex Ante* Savings (kWh)	Percent of Portfolio Savings Sampled	Percent of Stratum Savings Sampled
Census	20,411,134	3	82.0%	3	20,411,134	82.0%	100.0%
Large	3,255,364	18	13.1%	6	895,400	3.60%	27.5%
Medium	584,912	23	2.3%	6	142,865	0.57%	24.4%
Small	649,338	105	2.6%	4	12,678	0.05%	2.0%
Total	**24,900,748**	**149**		**19**	**21,462,077**	**86.2%**	**86.2%**

Cadmus visited all 19 projects across the four selected strata for site evaluation. Conducting site visits and associated measurement and verification (M&V) determined the *ex post* savings for each project. Cadmus determined the required M&V methodology and analysis rigor for each site based on several factors, including: measure complexity, savings magnitude, and trend data availability.

Cadmus determined demand savings occurring as a result of each project included in the sample, based on an engineering estimate. The peak demand reductions represented the differences between average peak demands during the peak-demand period for the baseline and actual (verified) case.

The evaluation results produced a 76.3% total program realization rate for FY 2011–2012, with about 10.6 GWh of verified electric savings realized. Based on the evaluation, the census stratum projects produced about 5.8 GWh of savings, or 55% of total program-verified savings. The randomly sampled group (large, medium and small strata) produced about 4.8 GWh of verified electric savings, or a 45%

contribution to the total program verified savings. Table 2 shows a summary of the evaluation results for the overall FY 2011–2012 program.

Table 2. Total Program Savings for FY 2011-2012

Strata	*Ex Ante* Reported Electric Savings (kWh)	Adjusted Reported Ex-Ante Electric Savings (kWh)	Verified Ex-Post Electric Savings (kWh)	Realization Rate
Randomly Sampled Group	4,489,614	-	4,782,006	106.5%
Census Group	20,411,134	9,399,153	5,820,668	61.9%
Total	24,900,748	13,888,767	10,602,674	76.3%

The realization rate for the census stratum had a significant effect on the overall program realization rate because of its large magnitude of savings compared to the overall program savings. The reduction in electric savings from the reported *ex ante* to the verified *ex post* in the census stratum was mainly due to the fact that all three sites in this stratum are newly constructed data centers that have not yet ramped up their operation to the projected full load. These occurrences were anticipated since new construction data center projects rarely achieve their projected load in a short time frame. Since Cadmus performed the evaluation activities during the early stages of operation for these sites, the reported *ex ante* savings were adjusted to reflect the actual load conditions of these data centers as observed during the on-site verification activities, per standard EM&V practices. These adjustments are referred to as "adjusted reported *ex-ante* savings."

If the load at the newly constructed data centers increases, then the energy savings occurring as a result of this program also increase. Cadmus estimates that an additional 3,093,797 kWh will be saved annually if the load increases to expected levels.

Generally, due to the good quality of SVP's database, project-level differences between *ex ante* and *ex post* savings estimates in the randomly selected sample group (large, medium, and small) were driven by the detailed information collected during the evaluation and the few discrepancies identified in the actual project implementation.

Introduction

This report documents the findings of The Cadmus Group's (Cadmus) impact evaluation of the FY 2011–2012, electric, energy-efficiency programs Silicon Valley Power (SVP) provides to its customers. SVP, Santa Clara's municipal electric utility, has committed to ensuring an affordable, reliable, and clean future energy supply for its electric ratepayers. In 2005, California Senate Bill 1037 (Kehoe) established several important policies regarding energy efficiency. One key provision makes a statewide commitment to cost-effective and feasible energy efficiency, with the expectation that all utilities consider energy efficiency before investing in any other resources to meet growing demand. A critical component of fulfilling this commitment requires reporting expected and actual energy and demand savings, determined through an evaluation, measurement, and verification (EM&V) process.

SVP provides energy-efficiency programs for both residential and nonresidential sectors. The nonresidential programs constituted the majority of the annual savings realized by these efforts. SVP excluded residential savings from this evaluation, due to the program's small impact relative to the nonresidential program.

This study provides an independent evaluation of annual electricity consumption and demand impacts for SVP's nonresidential programs, and consists of the following tasks:

- Identifying and assessing the quality of data and information obtained to support impact evaluation; and
- Determining gross estimates of energy and demand savings.

SVP staff and third-party contractors, specializing in specific market sectors and measures, implemented the FY 2011–2012 programs. Nonresidential programs resulted in incentivizing 149 projects, claiming about 24 GWh of the total *ex ante* annual electricity savings.

The nonresidential programs' portfolio of savings was dominated by a handful of large projects. Cadmus divided the population into four strata, based on *ex ante* annual electric energy savings, representing very large, large, medium, and small projects. The very large projects group is referred to as the census group since all projects were included in the analysis.

Cadmus selected 19 projects in the portfolio as the sampling frame which represented the large majority of total program claimed savings. The dominance of program savings by a few large projects provided an opportunity to reduce the site visits sample size by including a "census stratum" in the sample design. This stratum only consists of three of the largest projects, constituting the majority of program-wide *ex ante* or claimed savings. Within each of the remaining three strata (except for the census group), Cadmus selected a random sample of projects to perform the impact evaluation. The chosen sample frame minimized variability in the final results and maximized the precision associated with *ex post* savings determined through this project.

Table 3 shows a summary of the strata and sample characteristics.

Table 3. Strata and Sample Characteristics

Stratum Name	*Stratum Ex Ante* Reported Savings (kWh)	Number of Projects in Stratum	Percent of Portfolio Savings in Each Stratum	Number of Projects Sampled in Stratum	Sample *Ex Ante* Savings (kWh)	Percent of Portfolio Savings Sampled	Percent of Stratum Savings Sampled
Census	20,411,134	3	82.0%	3	20,411,134	81.97%	100.0%
Large	3,255,364	18	13.1%	6	895,400	3.60%	27.5%
Medium	584,912	23	2.3%	6	142,865	0.57%	24.4%
Small	649,338	105	2.6%	4	12,678	0.05%	2.0%
Total	**24,900,748**	**149**		**19**	**21,462,077**	**86.2%**	**86.2%**

The following sections of the report present:

- The methodology used for developing the sample and analyzing the sampled projects and the programs as a whole.
- Evaluation activities and results, including data collection activities and *ex post* verified analysis for the census, sampled stratum, and the overall program.
- The precision based on standard error estimates.
- The conclusions, summary results, and recommendations, and a comparison of final results to previous program years' evaluation results.

Methodology

This impact evaluation has been designed to verify reported program participation and to estimate gross energy savings and gross electricity consumption changes based on measured data collected on site, as well as, from program tracking data and engineering models.

The impact evaluation included the following tasks to determine gross annual electric energy savings attributable to the program:

- Sample development
- Data collection and measurements
- Engineering analysis

Cadmus calculated savings based on changes between baseline and installed efficiency measures. If a project improved the efficiency of functioning equipment or processes, the study used a baseline derived from equipment operating before the project, as documented in the project documents and confirmed by site contacts.

If a project replaced failed equipment, the baseline used standard practice or code requirement for the new equipment. If a project involved construction of a new building, the baseline used the Title 24 energy code, applied at the time of permitting. The evaluated energy savings was calculated relative to the baseline, using program-tracking data (assessed for completeness and accuracy), and data collected through site visits.

The evaluation approach selected for each project can be classified into one of the following four categories:

- **Verification:** Activities at these sites focus on physical inspection and verification of operating conditions for systems under consideration.
- **Verification with spot measurement:** Activities at these sites involve physical inspection of the installation, with spot measurement/reading of the current operating conditions.
- **Verification with basic rigor:** Activities at these sites entail meeting—at a minimum—the standards of IPMVP Option A (Partially Measured Retrofit Isolation),[1] including use of direct measurement.
- **Verification with enhanced rigor:** Activities at these sites entail using IPMVP Option B (Retrofit Isolation)[2] level analysis and/or a regression analysis.

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[1] Field measurement of the key performance parameter(s) determines savings, defining energy use of affected system(s) and/or the project's success. Measurement frequency ranges from short-term to continuous, depending on expected variations in the measured parameter and the length of the reporting period.

[2] Field measurement of the energy use of the affected system determines savings. Measurement frequency ranges from short-term to continuous, depending on expected variations in the savings and the length of the reporting period.

Projects at which Cadmus conducted site visits first received a rigorous review of project documentation. Cadmus compared the assumptions and methodologies of the original analysis to information collected on site. Realization rates (RRs) equal the ratio of *ex post* savings (evaluated savings) to *ex ante* savings (reported savings) for each project.

$$RR_{ij} = \frac{Evaluated\ Savings_{ij}}{Reported\ Savings_{ij}};\ for\ project\ j\ in\ stratum\ i \quad (1)$$

Stratum-Specific *Ex Post* Electricity Savings

Applying the RR for sampled projects within each stratum to *ex ante* savings for the entire stratum determines *ex post* savings for each stratum. The RR for each stratum can be calculated as: the ratio of the sum of *ex post* savings to the sum of *ex ante* savings for the projects within that stratum.

$$RR_i = \frac{\sum_j Evaluated\ Savings_{ij}}{\sum_j Reported\ Savings_{ij}};\ for\ stratum\ i\ across\ all\ sampled\ projects \quad (2)$$

The realization rate for the stratum and the total *ex ante* savings for the stratum produce total *ex post* savings for each stratum, assuming the estimated RR for the stratum can be applied across all projects in the stratum.

$$Evaluated\ Savings_i = RR_i \times \sum_j Reported\ Savings_j;\ for\ all\ projects\ in\ stratum\ i \quad (3)$$

Total Program *Ex Post* Electricity Savings

The sum of *ex post* savings for each stratum, i, produces total *ex post* savings for the program.

$$Evaluated\ Program\ Savings = \sum_i Evaluated\ Savings_i \quad (4)$$

The program realization rate equals the quotient of *ex post* program savings to *ex ante* program savings.

$$RR_{Program} = \frac{Evaluated\ Program\ Savings}{Reported\ Program\ Savings};\ for\ the\ population \quad (5)$$

SVP reported peak-demand reduction is calculated for all deemed savings measures installed and for custom projects for which demand reduction has been calculated. SVP typically requests project proposers to calculate demand savings for all custom projects, but does not have a consistent methodology for calculating demand savings, and does not receive calculated demand savings for all custom projects. California Assembly Bill 2021 requires evaluation of SVP's programs to report "the

reduction in energy demand achieved"[3] by the programs. Therefore, for this evaluation, Cadmus defined peak-demand reduction, based on definitions in the 2006 *California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*[4] (The Protocol). Page 235 of The Protocol, within *Appendix B: Glossary* provides the following two definitions:

1. PEAK DEMAND - The maximum level of metered demand during a specified period, such as a billing month or during a specified peak-demand period.
2. PEAK DEMAND PERIOD - Noon to 7 p.m. Monday through Friday, June, July, August, and September.

[3] AB 2021 (Levine, Chapter 734, Statutes of 2006), Section 3(e).

[4] http://www.tecmarket.net/documents/EvaluatorsProtocols_Final_AdoptedviaRuling_06-19-2006.pdf

Sample Development

The nonresidential programs' portfolio of savings was dominated by a handful of large projects. Cadmus divided the population into four strata, based on *ex ante* annual electric energy savings, representing very large, large, medium, and small projects. The very large projects group is referred to as the *census* group since all projects were included in the analysis. Within each stratum (except for the census group), Cadmus selected a random sample of projects for conducting site visits with data collection and analysis.

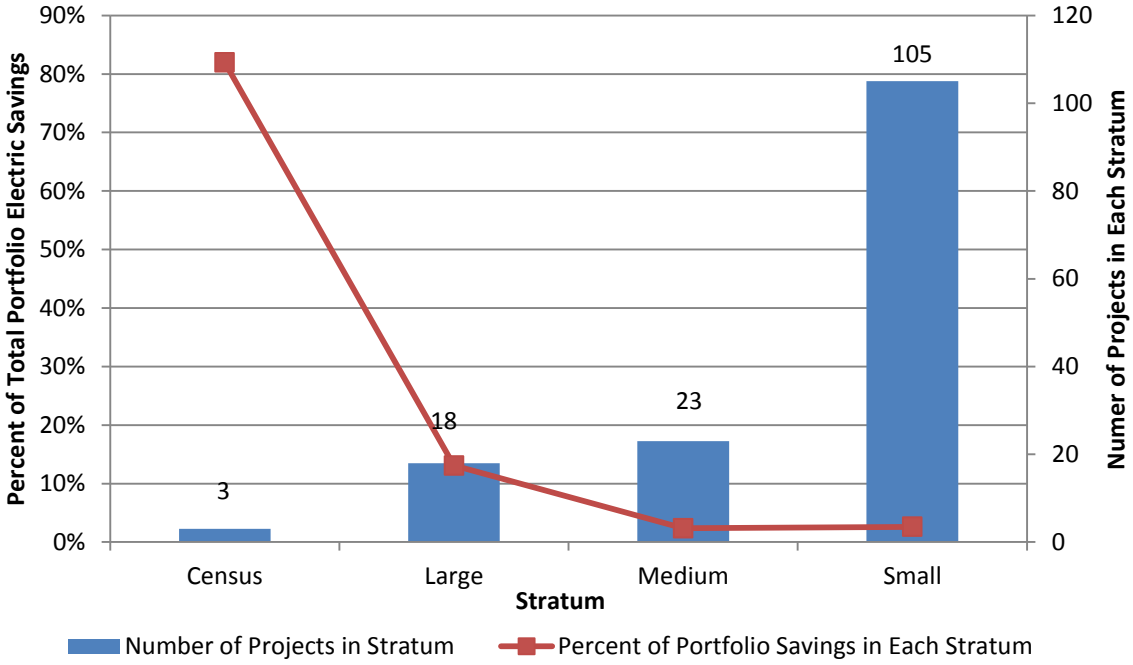
Estimates indicated the three largest projects, in the census stratum, undertaken during this program year would produce over 20.0 GWh of *ex ante* savings, constituting about 82% of the program's claimed savings. Eighteen of the large projects (in the large stratum) were estimated to produce about 3.2 GWh of *ex ante* savings, about 13% of the total program's claimed savings. Estimates also indicated about 1.2 GWh of claimed savings would result from the 128 remaining projects in the medium and small strata. Table 4 summarizes the characteristics of the strata defined for this evaluation.

Table 4. Planned Strata Characteristics

Stratum Name	Stratum *Ex Ante* Savings (kWh)	Number of Projects in Stratum	Percent of Portfolio Savings in Each Stratum
Census	20,411,134	3	82.0%
Large	3,255,364	18	13.1%
Medium	584,912	23	2.3%
Small	649,338	105	2.6%
Total	**24,900,748**	**149**	

Figure 1 shows the project distribution in each stratum, ordered by the cumulative percent of claimed program savings. About 82% of claimed *ex ante* savings originated from the three largest projects in the census stratum; 13% of savings originated from the next 18 projects in the large stratum; and the last two strata constituted about 2% (originating from 23 projects in the medium stratum) and 3% (originating from 105 projects in the small stratum), respectively.

Figure 1. Projects Distribution in Each Stratum, Ordered by Cumulative Percent of Claimed Program Savings



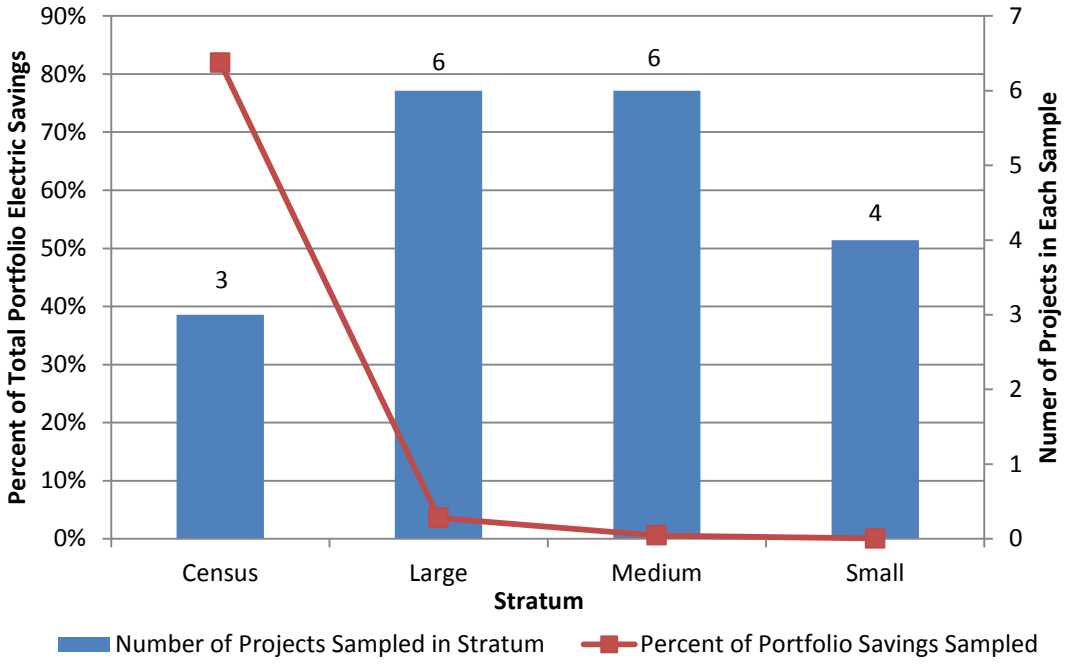
Cadmus selected 19 projects in the portfolio as the sampling frame which represented 86% of total program claimed savings. The dominance of program savings by a few large projects provided an opportunity to reduce the site visits sample size by including a "certainty stratum" in the sample design. This stratum (census stratum) consisted of only three of the largest projects, constituting 82% of program-wide *ex ante* or claimed savings. All of the projects in this stratum were deliberately included in the final sample (i.e., they were not selected randomly), so sampling error did not apply to the estimated savings for this stratum. Cadmus randomly selected projects within each of the remaining three strata. All of the 19 sampled projects received site visits, including data collection and measurement. Table 5 shows the sample distributions in each stratum and a description of each sample.

Table 5: Characteristics of Planned Sample

Stratum Name	Sample *Ex Ante* Savings (kWh)	Number of Projects Sampled in Stratum	Percent of Stratum Savings Sampled	Percent of Portfolio Savings Sampled
Census	20,411,134	3	100.0%	82.0%
Large	895,400	6	27.5%	3.6%
Medium	142,865	6	24.4%	0.6%
Small	12,678	4	2.0%	0.1%
Total	**21,462,077**	**19**	**N/A**	**86.2%**

Figure 2 shows the project distribution in each sample of the respective stratum, ordered by the cumulative percent of claimed program savings. About 82% of claimed *ex ante* savings originated from the three projects in the census stratum; 3.6% of savings originated from the six sampled projects in the large stratum; 0.6% of savings originated from six sample projects in the medium stratum; and 0.1% of savings originated from four projects in the small stratum.

Figure 2. Project Distribution in Each Sample Ordered by Cumulative Percent of Claimed Program Savings



Because measurement error can introduce significant uncertainty in an analysis when a few large projects dominate the results in a census stratum, (which by definition has no sampling error), Cadmus believed it was important to account for site-level measurement error in these cases. However, estimating measurement error at each of the three census stratum sites falls outside this study's scope. Therefore, Cadmus presents the final results using three site-level precision scenarios, estimated to cover the probable range of measurement error and demonstrate the accuracy of portfolio savings. Final analysis provides program-level *ex post* savings and precision estimates, using an estimated measurement error in the census stratum.

Evaluation Activities and Results

This section presents the data collection activities and results of engineering analysis applied to the sample; adjustments to reported values; calculation of realization rates; and extrapolation to the full program population. It also includes general observations regarding discrepancies and other factors influencing measure-level realization rates. Appendix A includes a detailed discussion of each sampled site including the methodology used to evaluate each site, analysis and results.

Data Collection: Site Visits Verification and Metering

Cadmus visited all 19 projects across the four strata selected in this evaluation. Conducting site visits and associated measurement and verification (M&V) determined the *ex post* savings for each project.

Cadmus determined the required M&V methodology and analysis rigor for each site based on several factors, including: measure complexity, savings magnitude, and trend data availability.

Of 19 projects receiving site visits:

- Two projects utilized spot measurements of end-use equipment;
- Five projects utilized long-term trend data provided by the customer; and
- Twelve projects utilized direct observation to verify equipment operation.

Table 6 summarizes: the type of evaluation technique utilized; and the primary data used for the evaluation.

Table 6. Site-Specific Evaluation Methodologies and Primary Data Sources

Stratum	Site Number	Methodology	Primary Data Source
1	1	Enhanced Rigor	Trend Data
1	2	Enhanced Rigor	Trend Data
1	3	Enhanced Rigor	Trend Data
2	4	Basic Rigor	Spot Measurement
2	5	Basic Rigor	Spot Measurement
2	6	Enhanced Rigor	Trend Data
2	7	Verification	Direct Observation
2	8	Enhanced Rigor	Trend Data
2	9	Verification	Direct Observation
3	10	Verification	Direct Observation
3	11	Verification	Direct Observation
3	12	Verification	Direct Observation
3	13	Verification	Direct Observation
3	14	Verification	Direct Observation
3	15	Verification	Direct Observation
4	16	Verification	Direct Observation
4	17	Verification	Direct Observation
4	18	Verification	Direct Observation
4	19	Verification	Direct Observation

Stratum-Specific *Ex Post* Electricity Savings

Census Stratum Results

Cadmus employed enhanced rigor in the verification assessment of the three projects in the census stratum. All were newly constructed data center projects, and the sites included energy conservation measures, such as implementing hot aisle containments, elevated rack and supply air temperature set points to achieve extended economizer operating hours, and fan power savings.

Cadmus conducted site inspections to: confirm installation of the proposed system; determine data points trended through the sites' building management system (BMS); and gather any other relevant information to verify each of the projects' energy savings. During the site inspection, Cadmus conducted a system walkthrough to collect screenshots of operating parameters, with installed equipment verified based on the provided mechanical equipment's schedules.

Cadmus used the trend data provided by the customers to evaluate energy savings for each of the three sites. The calculated annual energy consumptions for the baseline and the installed, energy-efficient measures were used to generate the evaluated savings. Cadmus used standard engineering calculations, based on: data collected on site; operating conditions, as observed from the trend data; and annual 8,760-hour weather data.

Adjusted Reported/*Reported ex ante* Savings

The reduction in electric savings from the reported *ex ante* to the verified *ex post* in the census stratum was mainly due to the fact that all of the three sites in this stratum are newly constructed data centers that have not yet ramped up their operation to the projected full load. These occurrences were anticipated since new construction data center projects rarely achieve their projected load in a short time frame. Since Cadmus performed the evaluation activities during the early stages of operation for these sites, the reported *ex ante* savings were adjusted to reflect the actual load conditions of these data centers as observed during the on-site verification activities, per standard EM&V practices. These adjustments are referred to hereafter as "adjusted reported *ex-ante* savings."

Additional adjustments were made for Site 1 and captured in the "adjusted *ex ante* savings" category. For Site 1, a review of the *reported ex ante* savings baseline energy model revealed that, while the program guidelines required an air-side economizer in the baseline, the eQUEST model did not actually simulate a functional economizer. The model did display eQUEST economizer inputs; however, as input into eQUEST did not include zonal minimum ventilation rates, the model did not simulate economizer operations (a design flaw in eQUEST). Given SVP plans to address this issue with the customer and in reported *ex ante* savings, a rerun of the baseline model was conducted to reflect a functional economizer.

Table 7 shows *ex ante* savings, *ex post* savings, and realization rates for the census stratum projects.

Table 7. Census Stratum Results

Census Stratum	Primary End Use	Reported *Ex Ante* Electric Savings (kWh)	Adjusted Reported *Ex Ante* Electric Savings (kWh)	Verified *Ex Post* Electric Savings (kWh)	Realization Rate
Site 1	Data Center: Fan and Compressors	9,961,867	6, 034,642	2,796,000	46.3%
Site 2	Data Center: Fans, Compressors, UPS	8,316,938	2,794,509	2,501,000	89.5%
Site 3	Data Center: Fans, Compressors. Office: Cooling Unit	2,132,329	570,002	523,668	91.9%
Total Census Stratum		**20,411,134**	**9,339,153**	**5,820,668**	**61.9%**

Each of these data centers was found to be operating at a lower production level than assumed for the development of the reported savings. For Site 1, the data center load determined through the evaluation was 87% of the load assumed in the original analysis and 55% of the design load. For Site 2, the load determined through the evaluation was 34% of the design load. For Site 3, the load determined through the evaluation was 26% of the load assumed in the original analysis and 14% of the design load.

If any of the facilities increase their data center load then the savings achieved by this program will also increase. Cadmus estimates that an additional 3,093,797 kWh will be saved annually if the load increases to expected levels.[5] Additional savings were: 415,779 kWh for Site 1; 1,651,799 for Site 2; and 1,026,219 for Site 3.

Sampled Strata Specific Results

Table 8 shows sampled *ex ante* savings, *ex post* savings, and realization rates for each of the large, medium, and small strata. The types of projects verified in these strata included: existing data center hot aisle containment measures for Sites 4 and 5; a compressed air system retrofit for Site 6; lighting controls for Site 8; and deemed lighting retrofit projects for the remaining sites. The differences between reported *ex ante* savings and *ex post* savings were due to: adjustments made to reported verification savings in Sites 4 and 5; utilization of trend data in Sites 6 and 8; and differences in assumptions between SVP's deemed lighting calculator and information collected by Cadmus during the lighting retrofit site inspections.

Generally, due to the good quality of SVP's database, project-level differences between *ex ante* and *ex post* savings estimates were driven by the detailed information collected during the evaluation and few discrepancies in the actual project implementation.

Stratum Specific *Ex Post* Peak Demand Reductions

Cadmus determined demand savings occurring as a result of each project included in the sample, based on an engineering estimate. The peak demand reductions shown in Table 9 represent the differences between average peak demands during the peak-demand period for the baseline and actual (verified) case.

[5] For Site 1 and Site 2, the expected level Cadmus assumed was based on the ASHRAE 90.1-2010 data center load profile. For Site 3, it was based on the value assumed in the project submittal since the assumption was lower than the ASHRAE 90.1-2010 load profile.

Table 8. Large, Medium and Small Sampled Stratum Specific Results

Site Number	Project Type	Reported *Ex Ante* Savings (kWh)	*Ex Post* Evaluated Savings (kWh)	Realization Rate
Large Stratum				
4	Data Center: Fans	174,672	148,946	85.3%
5	Data Center: Fans	153,163	153,163	100.0%
6	Air Compressor, Air Dryer Savings	51,074	49,721	97.4%
7	Lighting	55,040	72,200	131.2%
8	Lighting	399,691	399,691	100.0%
9	Lighting	61,760	81,600	132.1%
Total: Large Stratum		**895,400**	**905,321**	**101.1%**
Medium Stratum				
10	Lighting	27,827	20,300	73.0%
11	Lighting	18,434	28,200	153.0%
12	Lighting	22,197	35,200	158.6%
13	Lighting	17,874	16,200	90.6%
14	Lighting	17,305	19,100	110.4%
15	Lighting	39,228	27,400	69.8%
Total: Medium Stratum		**142,865**	**146,400**	**102.5%**
Small Stratum				
16	Lighting	580	300	51.7%
17	Lighting	6,034	4,700	77.9%
18	Lighting	4,782	11,500	240.5%
19	Lighting	1,282	900	70.2%
Total: Small Stratum		**12,678**	**17,400**	**137.2%**

Table 9. Sample *Ex Post* Verified Peak Demand Reduction

Site Number	*Sample Ex Post* Annual Peak Demand Reduction (kW)
Census Stratum	
1	590
2	170
3	139
Total: Census Stratum	**899**
Large Stratum	
4	17.0
5	17.5
6	5.8
7	16.0
8	-
9	21.0
Total: Large Stratum	**77.3**
Medium Stratum	
10	2.0
11	5.0
12	7.0
13	5.0
14	5.0
15	10.0
Total: Medium Stratum	**34.0**
Small Stratum	
16	0.0
17	2.0
18	2.0
19	0.3
Total: Small Stratum	**4.3**

Extrapolation to the Program Population

Total Program *Ex Post* Electricity Savings

Cadmus calculated *ex post* savings for each stratum by applying the realization rates for sampled projects within each stratum to *ex ante* savings for the entire stratum. The program's total *ex post* savings result from the sum of *ex post* savings for each stratum.

Table 10 shows the calculation of total *ex post* savings for each stratum, the program, and the overall program realization rate.

Table 10. *Ex Post* Savings and Realization Rates

Stratum Name	Stratum *Ex Ante* Savings (kWh)	Stratum *Ex Post* Verified Savings (kWh)	Realization Rate
Census*	9,399,153*	5,820,668	61.9%
Large	3,255,364	3,291,433	101.1%
Medium	584,912	599,385	102.5%
Small	649,338	891,188	137.3%
Total FY 2011-2012 Program	**13,888,767**	**10,602,674**	**76.3%**

*Census *ex ante* savings include adjustments Cadmus applied to *ex ante* reported savings, as discussed in the Census Stratum Results section.

Total Program *Ex Post* Peak Demand Reduction

To calculate *ex post* peak demand reductions, Cadmus calculated the ratio of *ex post* peak demand reduction for each project in each stratum's sample to *ex post* annual electricity savings for each project in the stratum's sample. These stratum-specific ratios were then multiplied by *ex post* annual electricity savings for all projects in the stratum to determine demand reduction for each stratum. Total peak demand reduction for the program year equals the sum of each stratum's total demand reduction. Table 11 shows calculations of peak demand reductions.

Table 11. Calculation of Total Program *Ex Post* Peak Demand Reduction

Stratum Name	Sample *Ex Post* Annual Savings (GWh)	Stratum Sample *Ex Post* Peak Demand Reduction (kW)	Stratum Sample *Ex Post* Peak Demand Reduction (kW) / Stratum Sample *Ex Post* Savings (GWh)	Total Stratum *Ex Post* Annual Savings (GWh)	Total Stratum *Ex Post* Peak Demand Reduction (kW)
Census	5.82	909	154.4	5.82	899
Large	0.91	143	85.38	3.29	281
Medium	0.16	34.0	232.2	0.60	139
Small	0.02	4.3	247.1	0.89	220
Total FY 2011-2012 Program *Ex Post* Peak Demand Reduction					**1,539**

Precision of *Ex Post* Estimates

Cadmus determined the precision of the *ex-post* savings first for each stratum then for the program overall. The approach accounts for both site level precision and sampling error. Determining site level precision, often referred to as measurement error, for a specific project is extremely arduous and was not an exercise that could be undertaken within the scope of this evaluation. For the purposes of this study, we calculated precision results based on three different site-level precision scenarios: 0%, 10% and 20% relative to the *ex-post* savings for the project. The 0% precision scenario assumes no measurement error exists in the *ex-post* savings estimates. The other two scenarios represented Cadmus' estimate of the range of probable site-level precision occurring in this project. Without taking account of measurement error, this evaluation would have overestimated the accuracy of its results.

Table 12 shows the standard error estimated in each scenario for the census sites *ex post* savings. Site level precision was also assumed in each of the sampled strata. For this analysis, the sampling error and measurement error are assumed to be independent. Table 13 shows the relative portfolio precision for each scenario at the 90% confidence level.

Table 12. Census Stratum Site-Level Standard Error at the 90% Confidence Level

Standard Error by Scenario	Site Level Precision	Site 1 (kWh)	Site 2 (kWh)	Site 3 (kWh)	Census Stratum Total (kWh)
Scenario 1	0%	0	0	0	0
Scenario 2	10%	169,985	152,050	31,837	230,277
Scenario 3	20%	339,969	304,100	63,674	460,554

Table 13. Relative Portfolio Precision at the 90% Confidence Interval

Relative Precision by Scenario	Site Level Precision	*Ex Post* Total Savings Estimate	Relative Precision at the 90% Confidence Interval
Scenario 1	0%	10,602,674	6%
Scenario 2	10%	10,602,674	7%
Scenario 3	20%	10,602,674	10%

Conclusions and Recommendations

SVP's energy-efficiency programs continue to perform well. The programs primarily deliver energy savings to customers through energy-efficiency projects with its nonresidential customers. For FY 2011–2012, the program had a total realization rate calculated at 76.3%, with about10.6 GWh of verified electric savings.

The creation of a census stratum to evaluate these projects and three more strata that were sampled to evaluate the remainder of the population provided an efficient pathway to precise energy-savings estimates. Due to the successful energy-efficient program offerings to the large data centers in SVP's territory, the majority of the program savings was the result of three newly constructed data center projects, estimated to produce 82% of *ex ante* total portfolio energy savings for the program year. In this evaluation, Cadmus deliberately included these newly constructed data center in the sample in the census stratum due to their large contribution to the program's overall expected energy savings. The results from this evaluation showed that these projects contributed about 55% of total program-verified savings. Table 14 summarizes evaluation results for FY 2011–2012.

Table 14. Summary of FY2011-2012 Evaluation Results

Stratum Name	Stratum *Ex Ante* Savings (kWh)	Stratum *Ex Post* Savings (kWh)	Realization Rate	Percent of Stratum Savings of Total Program Verified Savings
Census*	9,399,153	5,820,668	61.9%	55%
Large	3,255,364	3,291,433	101.1%	31%
Medium	584,912	599,385	102.5%	6%
Small	649,338	891,188	137.2%	8%
Total	**13,888,767**	**10,602,674**	**76.3%**	

*Census *ex ante* savings include adjustments Cadmus applied to *ex ante* reported savings, as discussed in the Census Stratum Results section.

The reduction in electric savings from the reported *ex ante* to the verified *ex post* in the census stratum was mainly due to the fact that all of the three sites in this stratum are newly constructed data centers that have not yet ramped up their operation to the projected full load. These occurrences were anticipated since new construction data center projects rarely achieve their projected load in a short time frame. Since Cadmus performed the evaluation activities during the early stages of operation for these sites, the reported *ex ante* savings were adjusted to reflect the actual load conditions of these data centers as observed during the on-site verification activities, per standard EM&V practices.

Generally, due to the good quality of SVP's database, project-level differences between *ex ante* and *ex post* savings estimates in the randomly selected sample group (large, medium, and small) were driven by the detailed information collected during the evaluation and the few discrepancies identified in the actual project implementation.

Cadmus recommends a more rigorous verification process to achieve better realization rates for very large data center projects, with the program providing guidelines for preferred and/or recommended calculation methodologies. Though essentially the same measures were present in Sites 1, 2, and 3, their *ex ante reported ex ante*/reported, savings were assessed differently. Offering a consistent validated calculation approach for different types of projects/measures would lead to more consistency in results and project savings.

The scrutiny level should commensurate with the magnitude of potential savings. Doing so would provide the basis for setting guidelines on minimum information required for SVP to approve energy-efficiency projects, leading to more comprehensive assessment and higher realization rates.

Table 15 shows evaluation results for the previous three program years, and demonstrates SVP's historically high program performance level. The FY 2011-2012 program's realization rate is a departure from the previous high rates and our recommendations should help avoid similar lower rates going forward.

Table 15. Previous Program Years' Evaluation Results

Program Year	Reported Savings (kWh)	Evaluated Savings (kWh)	Realization Rate
FY2008-2009	27,034,016	27,443,309	102%
FY2009-2010	20,013,546	19,108,006	95%
FY2010-2011	28,625,155	28,949,521	101%
FY2011-2012	**13,888,767***	**10,602,674**	76.3%

*Reported savings include adjustments Cadmus applied to *ex ante* reported savings, as discussed in the Census Stratum Results section.

Appendix A. Site Reports

Site 1

Facility and Project Description

Site 1 is a newly constructed data center facility with approximately 48,000 ft^2 of IT space designed for 9 MW of IT load. The facility includes three 3 MW modules, with loads serving two of the three.

This project pertains to two suites with a total IT area of 32,000 ft^2. Each suite site has the following dedicated equipment:

- Twelve supply fans (23 BHP, 48,000 CFM, 2" static pressure);
- Twelve exhaust fans (5 BHP, 48,000 CFM, 0.25" static pressure); and
- Twelve air-cooled direct expansion (DX) condensing units (1,080 MBH cooling).

Each of these systems has an n + 20% redundancy. Redundancy is the duplication of critical components or functions of a system with the intention of increasing reliability of the system.

The project received incentives to install hot aisle containment designed to achieve higher return and supply air temperatures (SATs) that will allow for extended enthalpy economizer operating hours.

Reported *Ex Ante* Savings Methodology

The reported (*ex-ante*) savings methodology used an eQUEST model to estimate energy savings. The documentations included a narrative describing the assumptions, baseline, and proposed modeling techniques, including:

- Design IT Load of 9 MW (2,560 tons): The load estimate was based on the ASHRAE Thermal Guidelines default load profile for two of the three modules (1,075 tons).
- The model considered all three modules, though only two-thirds of the savings could be claimed, as one of the modules (Module 1) was not occupied during the time of verification. For this reason energy savings were not claimed for this module by the applicant.
- The baseline and proposed equipment considered a water-cooled chiller system (Chilled Water Supply Temperature of 42 degree F; Condenser Water Supply Temperature of 75 degree F).
- The baseline and proposed return air temperatures (RATs) were specified at 75 and 95 degree F, respectively.
- The baseline and proposed SATs were specified at 60 and 75 deg F, respectively.
- The baseline economizer control was assumed to be dry bulb and the proposed economizer was assumed to be enthalpy control.

The baseline eQUEST model was made available and reviewed by Cadmus. The proposed eQUEST model was not included in the project documentation.

Evaluation Activities

On November 16, 2012, Cadmus performed a site visit inspection to: confirm the installation of the new system; determine the points trended through the BMS; and gather any other relevant information to verify the energy savings for this project. The site inspection included a walkthrough and the installed equipment was verified based on the provided mechanical equipment schedules. Cadmus collected screenshots of the operating parameters, and discussed and confirmed a verification strategy with the site contact.

The proposed 75 degree Fahrenheit supply air temperature set-point was not observed during the site verification as the cold aisles were maintained at temperatures below 70 degrees Fahrenheit.

Data Collection and Baseline Establishment

To evaluate energy savings for the hot aisle containment and economizer project, Cadmus used the trend data that was provided by the customer.

Approximately two weeks of fan operating speeds, box temperatures, ambient conditions, and power data were used for the verification of the energy-savings for this project. A review of the baseline eQUEST model was used to identify discrepancies between the verified and the reported savings. Cadmus used program guidelines, mechanical equipment specifications, trend data loads, and operating parameters included in the reported savings methodology to establish the baseline performance as follows:

- Operational economizer.
- 75 degree F fixed return air temperature.
- Each air handler was sized for a 15 degree F differential.
- The supply and exhaust fan DSP were 2” and 0.25”, respectively.
- A total cooling load for two of the modules (Module 2 and Module 3) were at 1,075 tons, which was about 87% of the reported average load.

Energy Savings Calculations

Cadmus determined the evaluated savings by calculating the annual energy consumption for the baseline and the installed, energy-efficient equipment. Cadmus used standard engineering calculations based on the data collected on site, and annual 8760 weather data. Table 16 shows the operating conditions obtained from the trend data.

Table 16. Verified Operating Conditions

Space	Average % Flow	Total CFM	Average SAT	Average RAT	Estimated Load (tons)
Module 1	Not Occupied				
Module 2	59%	170,400	61	89	430
Module 3	65%	187,200	61	91	510

Reported *Ex Ante* Savings Adjustments

Cadmus made several adjustments to the reported results from the eQUEST model runs in order to accurately reflect the actual operating conditions of the site. For comparison, Table 17 shows original reported *ex ante* savings estimates.

Table 17. Original Reported *Ex Ante* Savings

Original Reported savings eQUEST model results	Cooling Energy (kWh)	Heat Rejection (kWh)	Pumps & Aux (kWh)	Ventilation fans (kWh)	Total Energy Consumption (kWh)
Original Baseline Model	5,729,999	226,925	472,153	6,377,764	12,806,841
Original Proposed Model	1,839,812	-	23	1,005,201	2,845,036
Original Savings Estimate	3,890,187	226,925	472,130	5,372,563	9,961,805

Economizer Adjustments

While the baseline required an air-side economizer and the documentation stated that a dry-bulb economizer was modeled, the high cooling energy use in the table above shows that eQUEST did not simulate a functional economizer. The model displayed eQUEST economizer inputs; however, the zonal minimum ventilation rates were not used into the model. This prevented the model from simulating economizer operation due to an operational problem in eQUEST.

Cadmus adjusted the baseline model to simulate a functional economizer and the overall baseline energy consumption decreased by almost 24% from 12,806,841 kWh to 9,782,967 kWh. No change related to the economizer was required to the proposed model. This reduced the energy savings for the project to 6,937,931 kWh or 70% of the original savings estimate.

SVP plans to address this issue with the customer and has adjusted the reported (*ex-ante*) savings to 7,424,216 kWh based on updated modeling completed by the project's engineering firm.

Cooling Load Adjustments

This newly constructed data center project had not achieved the anticipated loads at the time of the evaluation. This is not unusual as newly constructed data centers often take months or years to reach their design capacity. To estimate savings at the current load, Cadmus further revised the baseline and proposed energy models to reflect the actual data center loads observed during site verification. The reduction in load further reduced the baseline model's energy consumption from 9,782,967 kWh to 8,509,267 kWh or 66% of the originally reported consumption of 12,806,841 kWh. Table 18 compares the original baseline model to the adjusted baseline models.

For the purposes of this evaluation, Cadmus used its own adjustments in the analysis of the final results. Cadmus' estimated realization rate for this project uses the adjusted reported savings estimate of 6,034,642 kWh.

Table 18 summarizes the adjustments made to the original baseline model including simulating a functional economizer and using the actual data center cooling loads observed during site verification.

Table 19 summarizes what the estimated *ex ante* savings would have been if the economizer had been correctly modeled and the loads accurately estimated.

Table 18. Adjustments to Energy Model Baseline Energy Consumption

Parameters	Original Baseline Model	Adjusted Baseline I: Economizer	Adjusted Baseline II: Economizer & Reduced Load	Change in Energy Consumption from Original Baseline (Column C- Column A)
Column Label	A	B	C	D
Cooling Load (tons)	1,075	1,075	940	(135)
Cooling Energy (kWh)	5,729,999	1,457,388	1,267,642	(4,462,357)
Heat Rejection (kWh)	226,925	121,406	105,599	(121,326)
Pumps & Aux (kWh)	472,153	127,881	111,231	(360,922)
Ventilation fans (kWh)	6,377,764	8,076,292	7,024,794	647,030
Total Energy Consumption (kWh)	12,806,841	9,782,967	8,509,267	(4,297,574)

Table 19. Adjustments to Proposed Energy Consumption and Savings

Parameter	Original Proposed Model	Original Reported Ex-Ante Savings Estimates	Adjusted Proposed Model: Reduced Load	Adjusted Reported Ex-Ante Savings (Column C - Column G)
Column Label	E	F	G	H
Cooling Load (tons)	1,075	1,075	940	--
Cooling Energy (kWh)	1,839,812	3,890,187	1,600,276	(332,634)
Heat Rejection (kWh)	-	226,925	-	105,599
Pumps & Aux (kWh)	23	472,130	20	111,211
Ventilation fans (kWh)	1,005,201	5,372,563	874,328	6,150,466
Total Energy Consumption (kWh)	2,845,036	9,961,805	2,474,625	6,034,642

* Note: For adjusted baseline energy consumption, refer to Column C in Table 18.

Evaluated Savings

Table 20 shows a summary of verified energy savings modeled after Cadmus made all baseline adjustments and modifications due to the actual site conditions and equipment operation.

Table 20. Final Evaluated Savings

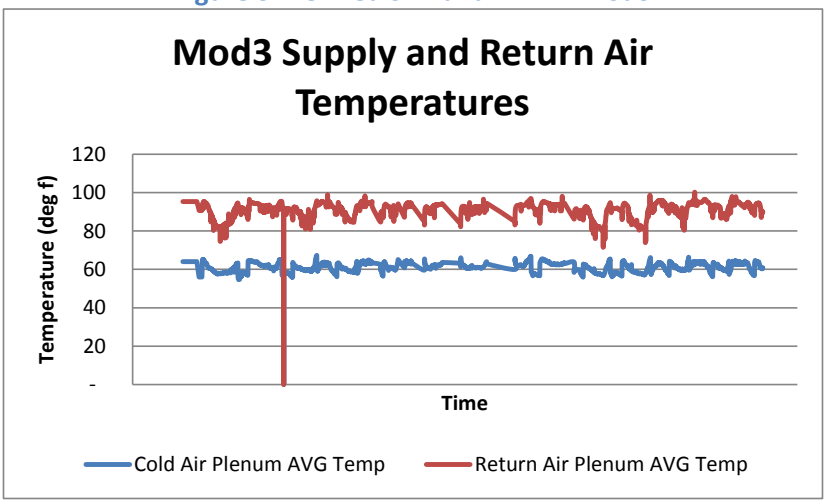
Evaluated Savings	Cooling Energy (kWh)	Heat Rejection (kWh)	Pumps & Aux (kWh)	Ventilation Fans (kWh)	Total Energy (kWh)
Adjusted Baseline Model	2,093,370	-	-	3,164,635	5,258,005
Installed (Actual) Model	1,126,247	-	-	1,335,746	2,461,993
Evaluated (Verified) Savings	967,123	-	-	1,828,889	2,796,012

To calculate the evaluated savings, Cadmus used the following parameters:

- **Lower baseline fan energy**. In the Original Baseline Model (eQUEST model), the three modules applied a design flow of 2,419,200 CFM, which exceeds the mechanical specifications for all on-site fans (excluding redundancy). Based on cooling load requirements, an assumed baseline fixed return air temperature set point of 75 degree F, and a 15 degree differential across the cooling coil, a total baseline CFM was estimated by Cadmus at roughly 700,000 CFM. Considering 2" and 0.25" duct static pressures for supply and exhaust fans, respectively, Cadmus estimated baseline ventilation energy consumption at 3,165,000 kWh, 45% of Adjusted Baseline II Ventilation consumption of 7,024,794 kWh. Cadmus calibrated the proposed usage estimations with fan power trends provided by the facility. Overall verified ventilation fan savings were estimated at 1,829,000 kWh.
- **A baseline assumed to be an air-cooled DX system.** As the site had an air-cooled DX system installed, an air-cooled DX system (with a similar operating efficiency) was assumed in baseline evaluated savings calculations, per standard EM&V protocols.
- **Design set points not achieved**. Based on a review of *reported ex ante* savings project documents, the proposed SATs and RATs were modeled at 75 and 95 degree F, respectively. However, trend data collected as part of the evaluation show that the average SAT and RAT fell between 61 and 91 degrees F, respectively, as shown in Figure 3 Modules 2 and 3 had a field observed average SAT setting of 61 degree F, with a RAT setting of approximately 90 degree F. It is believed that the system was not achieving the proposed supply air temperatures due to the cold aisle temperatures being maintained at roughly 70 degrees F or lower. In order to obtain this cold aisle temperature, the temperature of the air leaving the air handler (i.e., supply air) must be lower than this temperature set-point. The supply air temperature is the parameter that drives the extended economizer operation. Because the cold aisle temperature was maintained at 70 degrees F, it would have been impossible for the supply air to achieve the proposed 75 degree Fahrenheit operating conditions. It would be possible for the site to achieve higher supply air temperatures with greater airflow, and therefore, increase the benefits of the economizer. However, the increase in airflow would result in an increase in fan energy as well. No information was provided by the facility explaining why the facility is supplying colder air than assumed in the original analysis.

Although the site did not achieve the supply air target of 75 degree F, the system still experienced extended economizer operating hours over the baseline scenario, primarily as a result of a higher RAT due to the hot aisle containment project. However, not achieving these set-points prevented the realization of the full savings potential. More importantly, by increasing temperature differences across the air handler compared to the baseline system, the facility could reduce airflows and fan power consumption.

Figure 3: Verified SAT and RAT in Mod3



Final Results

Cadmus verified that the annual energy savings for this project to be 2,796,012 kWh and the peak demand savings was 590 kW. The original reported *ex ante* estimates for annual energy savings was 9,961,805 kWh, which did not include an operating economizer in the baseline and overestimated the first year cooling loads. Consequently, Cadmus revised the reported energy savings to reflect an operating economizer in the baseline and the actual first year data center loads, producing an adjusted *ex ante* savings of 6,034,642 kWh.

The remaining reduction in savings was due to the use of a water cooled chilled water system as the base case when an air cooled system was specified to be installed and the site maintained a cooler rack temperature set-point than originally proposed.

As shown in Table 21, this project had a verified realization rate of 46% based on the adjusted reported *ex ante* saving estimates.

Table 21. Site 1 Final Results

Site 1	Original Reported *Ex Ante* Savings	Adjusted Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	9,961,867	6,034,642	2,796,000	46%
Total Annual Peak Demand Reductions (kW)	-	-	590	-

Site 2

Facility and Project Description

Site 2 is a newly constructed data center facility with approximately 45,000 ft^2 of conditioned space. This project pertains to Collocation 110 of the data center and the equipment serving this area only. The central cooling plant serving the data center includes:

- Five air-cooled McQuay ASW230 240-ton chillers rated for 48 degree chilled water supply, 105 degree condenser, and an efficiency of 10.8 EER.
- Three 20-hp primary pumps (1,200 GPM, 35' head).
- Three 75-hp secondary pumps (1,200 GPM, 120' head, variable speed drive [VSD] control).
- Ten Huntair computer room air handler (CRAH) units (60 ton, 24,000 CFM, 15-hp fan, 90 degree/56.8 degree EAT and LAT).
- Four flywheel uninterruptable power system (UPS) systems powering IT servers.
- Twelve ventilation fans, exhausting air from the server floor.

The project installed the following measures:

- Elevated rack and room temperatures to extend economizer operations, not including the four up-flow CRAH units serving the electrical rooms.
- Flywheel UPS (instead of a standard battery UPS).

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings methodology represented the analysis estimated by the implementer.

Economizer Savings

The reported (*ex ante*) savings methodology estimated the economizer operating hours and the annual energy savings using proprietary software. The software estimated the savings based on the intent to achieve a supply air temperature set point of 68 degree F and maximize the cooling coil capacity of the 14 CRAH units with an assumed design load of 780 tons. This resulted in a target return air temperature of 96 degree F. The reported (*reported ex ante*) savings was estimated at 7,491,295 kWh per year.

Flywheel UPS Savings

The reported flywheel UPS energy savings estimate was derived by comparing the flywheel UPS to a hypothetical static UPS efficiency at a 67% load. The following values were used in the savings calculations:

- The baseline static UPS efficiency at 67% Load was 92.5%
- The proposed flywheel UPS efficiency at 67% Load was 96.9%

The overall energy savings were based on an IT power output of 1.92 MW, equivalent to 550 tons of cooling. This resulted in a reported annual *ex ante* energy savings of 825,643 kWh.

Evaluation Activities

On October 10, 2012, Cadmus performed a site inspection. The inspection was performed to: verify installation and operation of the new system, determine points trended through the EMS, and gather other relevant information to verify the project's energy savings. The evaluation also included a review of the relevant project documentation and savings calculations for each measure.

The following activities were completed during the site visit: verification of equipment installation based on the provided mechanical equipment schedules, collection of screenshots showing the system's operating parameters, and discussions confirming the verification strategy with the site contact.

Data Collection and Baseline Establishment

To evaluate the energy savings for the economizer and UPS measures, Cadmus used the trend data provided by the customer. Cadmus collected one week of the following system wide data points: supply fan speed; SAT; RAT; mixed air temperature (MAT); and the percent of outside air (OSA) damper position. Cadmus also collected ambient air conditions for each of the 10 CRAH Units. The data were used to assess the economizer's performance, the data center's cooling requirements, and the box temperature set points and control strategy.

For the UPS measure, data collection included one week of UPS input/output power used to verify the loads and the operating efficiency of the new flywheel system.

Verified Savings Economizer Baseline

For the 2011 to 2012 SVP program year, the baseline for new construction projects must include either an air or water-cooled economizer, depending on the HVAC System designed. However, this project followed the baseline requirements for the 2010 to 2011 program year since SVP's involvement with this project started prior to the creation of the current program guidelines and delays in construction led to the completion of the project in the most recent program year. Therefore, there was no required economizer in the baseline for this project based on the 2010-2011 program requirements.

For this evaluation, the baseline operating parameters were assumed to be:

- No air-side economizer operation, an SAT of 61 degrees F and a RAT of 73 degrees F (based on the provided trend data and a 12 degree differential).
    - The site initially operated the CRAH units to deliver 65 degree Fahrenheit supply air. However, based on interviews with the site contact, the site operated at 61 degrees F, due to some restrictions associated with CRAH design and poor under-floor air dispersion. At the time, consideration was given to increasing the supply air flow; however, the facility manager estimated this would lead to higher utility costs as it would be cheaper to operate the chillers at a higher compression ratio than to increase the fan power consumption.
    - The achievement of the designed 68 degree F supply air temperature was also limited due to the site's internal operating requirements for the server racks to never exceed 75 degree F.
- Calculated overall flow of 200,000 CFM for the ten CRAH units, and an estimated total IT Load of 200 tons cooling, based on trend data.

Verified Savings UPS Baseline

The baseline UPS efficiency was determined based on the system type and loading at which the power supply operated. The design's redundancy requirements were also considered. Based on our literature review, the best reference currently available documenting baseline UPS part-load performance for data centers was published by Pacific Gas and Electric Company.[6] This report was used to establish the baseline UPS part-load performance assumptions as indicated in Table 22.

Table 22. UPS Baseline Part-load Performance Assumptions

Baseline UPS	
% Load	**Efficiency**
100	86%
75	86%
50	85%
30	84%
20	81%
10	74%

Energy Savings Calculations

Cadmus estimated the evaluated savings for the economizer measure by calculating the annual energy consumption for the baseline and installed conditions. We used standard engineering formulas, data collected on site, and annual 8760 weather data to perform the calculations.

For the UPS measure, trend data were used to establish the system loads and operating efficiencies.

Reported Savings Adjustments

Cadmus adjusted the reported *ex ante* savings estimates for the economizer calculations in an effort to accurately capture the actual operating conditions at the site during the time of this evaluation.

Table 23 shows original reported *ex ante* savings estimates. The reported (*ex ante*) savings were calculated assuming a cooling load of 780 tons. This cooling load of 780 tons is the full design cooling capacity of all CRAH units including the 4 up-flow CRAH units that serve the electrical room that were not included in the scope of this project. The actual cooling load occurring during the trended time period was found to be 205 tons, about 26% of the original assumption and 34% of the 600 tons of cooling capacity serving the space. Consequently, Cadmus adjusted the reported *ex ante* energy savings for the economizer calculations to reflect the actual data center loads observed during site verification, per standard EM&V practices. Table 24 shows the adjusted reported savings including the actual economizer calculations based on site verification. These adjusted reported *ex ante* savings were about 34% of the original savings estimate.

[6] High Tech Energy Efficiency Baselines: DATA CENTERS. Pacific Gas and Electric Company. Rumsey Engineers.2007.

Table 23. Original Reported *Ex Ante* Savings

Original Reported *Ex Ante* Savings	Economizer (kWh)	UPS (kWh)	Total (kWh)
Assumed Load	780 tons	1.92 MW	
Reported Baseline	8,541,000	18,182,919	26,723,919
Reported Proposed	1,049,705	17,357,276	18,406,980
Reported *Ex Ante* Savings	7,491,295	825,643	8,316,938

Table 24. Adjusted Reported *Ex Ante* Savings

Adjusted Reported *Ex Ante* Savings	Economizer (kWh)	UPS (kWh)	Total (kWh)
Assumed Load	205 tons	1.33 MW	
Adjusted Reported Baseline:	2,244,750	18,182,919	20,427,669
Adjusted Reported Proposed	275,884	17,357,276	17,633,160
Adjusted Reported *Ex Ante* Savings	1,968,866	825,643	2,794,509

Evaluated Savings

Table 25 shows the evaluated (verified) energy savings calculated at 2,501,000 kWh, 11% lower than the adjusted reported *ex ante* savings estimate.

Table 25: Evaluated Savings

Evaluated Savings	Economizer Calculations (kWh)	UPS Calculations (kWh)	Total (kWh)
Assumed Load	205 tons	1.33 MW	
Evaluated Baseline	2,706,551	13,908,455	16,615,007
Evaluated Proposed	1,539,049	12,575,757	14,114,806
Evaluated Savings	1,167,502	1,332,699	2,501,000

Note: Results have been rounded.

The evaluated savings differ from the adjusted reported *ex ante* savings for the following primary reasons:

- **Increased UPS energy savings.** The evaluated UPS energy savings increased as a result of utilizing baseline efficiencies documented in PG&E's report *High Tech Energy Efficiency Baselines: DATA CENTERS*. This document established a UPS baseline of 84% at the respective operating load compared to 92.5% assumed in the *reported ex ante* saving estimates. This increased the baseline consumption and overall energy savings for this measure by about 38%.
- **The facility did not achieve SAT and RAT targets**. The *reported ex ante* energy savings estimates for the economizer measure assumed a 68 degree F SAT and a 96 degree F RAT in the proposed case that would have maximized the economizer operations. These temperature targets were not achieved. The site has an operating requirement for server racks that prevents them from

ever exceeding 75 degrees F. This is supported by the trend data which showed RATs around 73 degrees F for all hours. This substantially reduced the number of available hours in which the system could have utilized its economizer. Table 26 shows the average temperature data from the ten CRAH units provided by the site contact.

- **Reduced fan energy savings** occurred as a result of the change in SAT and RAT discussed above.
- **The actual installed chiller efficiency curves** were used in the evaluated calculations to estimate performance as opposed to assumed efficiency curves in the reported (*reported ex ante*) savings.
- **The reported (*ex ante*) savings assessment included four CRAH units** not impacted by this project. These four CRAHs were up-flow units dedicated to the electrical room with no economizing capabilities and therefore there were not eligible for savings. These units were removed for the determination of the evaluated savings.
- **The reported (*ex ante*) savings assessment assumed full design load. Actual verified loads were estimated at roughly 34% of loads seen at the collocation data center.**

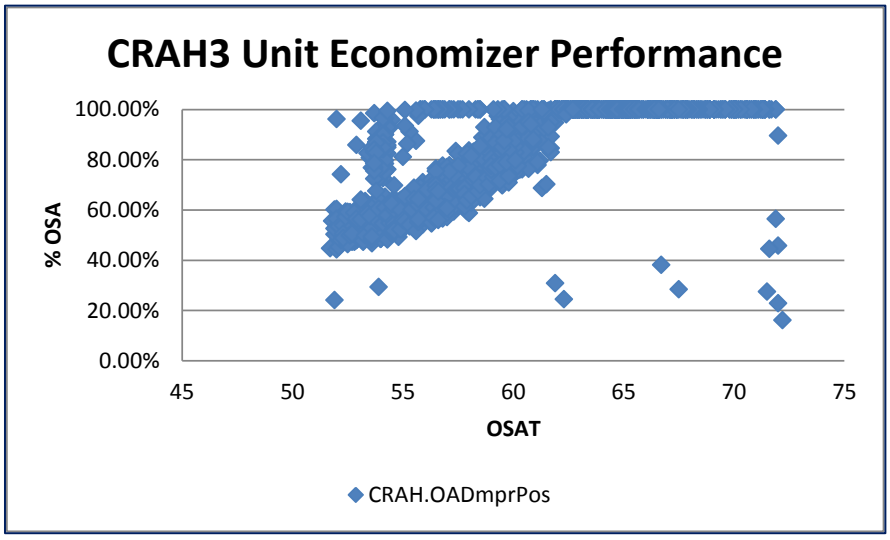
Table 26. Trend Data of Actual Operation Parameters from the CRAH Units

	% Flow	CFM	SAT	RAT	MAT	Delta (MAT-SAT)	Load Tons (RAT-SAT)
CRAH 1	86%	20,573	62	72	66	4	19
CRAH 2	75%	18,078	61	71	67	6	16
CRAH 3	86%	20,572	62	76	68	6	26
CRAH 4	86%	20,572	62	73	67	5	20
CRAH 5	86%	20,572	62	71	67	5	18
CRAH 6	86%	20,572	62	75	68	6	23
CRAH 7	86%	20,572	62	74	68	6	22
CRAH 8	86%	20,572	62	71	68	6	17
CRAH 9	86%	20,572	62	73	68	6	20
CRAH 10	86%	20,572	60	73	64	4	24
Average		205,000	62	73	67	5	Total Load = 205 Tons

Other notable findings from the site verification include the following:

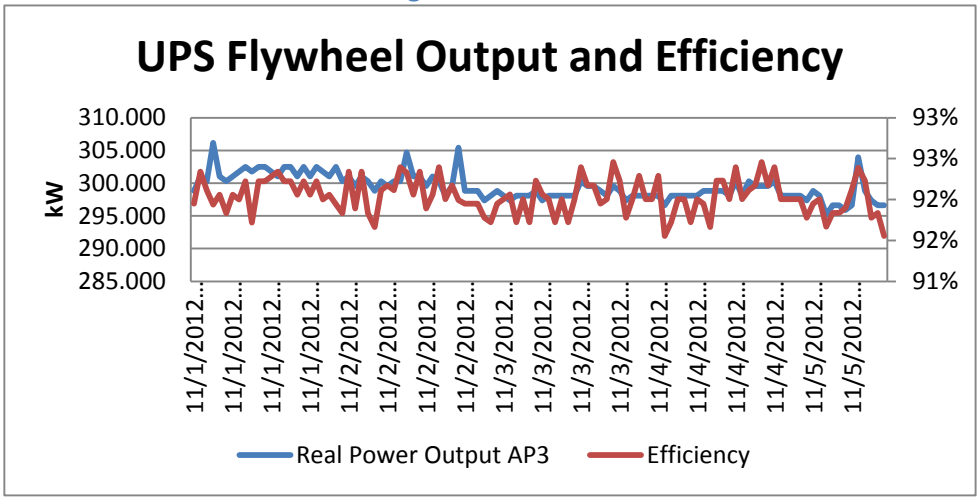
- **Economizer operation**. After reviewing trend data, Cadmus found economizer dampers in each of the ten CRAH units serving the data center space performed as expected under the current control sequences. Figure 4 shows the percent of outside air used versus the outside air temperature. The chart shows that the fraction of outside air is reduced as temperatures drop below the supply air temperature, which verified the economizer operation in addition to the units delivering 100% outside air when ambient temperatures were below return air temperature set-points.

Figure 4: CRAH3 Measure Economizer Performance



- **UPS operation**. UPS efficiency was verified using the input and output power to the UPS recorded on site. The output indicated relative system stability, ranging from 30% to 40% of capacity. The UPS efficiency ranged from 92% to 94% for the four flywheel systems, as shown in Figure 5. The average total UPS output for the facility was 1.334 MW, 69% of the 1.92 MW assumed in the original analysis.

Figure 5: UPS Trend Data



Results

Cadmus verified the annual energy savings for this project to be 2,500,201 kWh with peak demand savings of 170 kW. The evaluation estimated demand savings based on definitions in the *2006 California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*. These definitions include a peak demand period between 12:00 to 7:00 pm, weekdays, June through September. To calculate the demand savings Cadmus averaged the pre and post hourly kW simulation results to determine the associated demand savings.

The reported *ex ante* annual energy savings were 8,316,937 kWh. The difference in energy savings between the reported estimate and the evaluated savings was primarily due to the actual facility load at the time of evaluation being 26% of the load used for the reported estimate. New construction data center projects rarely achieve their anticipated loads within the first year and in time for utility rebate program evaluation. Consequently, Cadmus revised the *reported ex ante* energy savings to reflect the actual data center loads, per standard EM&V practices. The adjusted reported *ex ante* annual energy savings were calculated to be 2,794,509 kWh.

Outside of the load considerations, the differences in energy savings were due to the site not increasing its rack temperatures to achieve elevated SAT set points and therefore extending the economizer operations as assumed in the reported estimates. As shown in Table 27, the project achieved a verified realization rate of 90% of the adjusted reported *ex ante* electric savings estimate.

Table 27. Site 2 Final Results

Site 2	Original Reported *Ex Ante* Savings	Adjusted Reported Ex-Ante Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	8,316,938	2,794,509	2,501,000	90%
Total Annual Demand Reduction (kW)		94	170	180%

Site 3

Facility and Project Description

Site 3 is a newly constructed data center facility. The project implemented efficient HVAC equipment for the three suites in its second-floor of the data center space. Two of these suites are each served by four 150-ton evaporative-cooled DX units, equipped with variable frequency drives (VFDs) and air-side economizing capabilities. The third suite is served by four 120 ton evaporative cooled DX units, also equipped with VFDs and air-side economizing capabilities. The project also included additional energy-savings through office HVAC equipment and envelope upgrades. Overall, the facility is designed for 5.5 MW of IT load and has a total cooling capacity of 1,680 tons.

The project was incentivized for the following energy-efficiency measures:

- Hot/cold aisle containment, with elevated supply temperatures to increase air-side economizer operational hours.
- Direct evaporative cooling
- Reducing fan power consumption through use of VFDs and controls.
- Installation of high-efficiency cooling equipment for office space conditioning.
- Insulation/envelope upgrades above Title 24 Codes.

Reported *Ex Ante* Savings Methodology

Data Center Fan and Compressor Savings

The reported (*ex ante*) savings methodology used an energy modeling tool to assess the opportunities related to the mechanical cooling and the hot/cold aisle containment project. This model was not provided. The baseline model assumed a 55 degree F SAT, targeted at a 70 degree F set point, and an estimated average cooling load of 834 tons or 51% of the facility's cooling capacity.

Other calculations by the implementer estimated *reported ex ante* energy savings related to fan control and efficient design. Estimates of the number of operating fans was based on an assumed load, with the proposed case assuming that additional fans would operate in parallel to achieve additional energy savings.

High Efficiency Office Cooling Equipment and Envelope Upgrades

The energy modeling software was used to estimate the reported savings for the high efficiency office cooling equipment and the envelope upgrades. Cadmus could not verify the modeling assumptions and analysis because the models were not provided.

Evaluation Activities

Data Collection and Baseline Establishment

On October 11, 2012, Cadmus performed a site visit to: verify the new system; determine points trended through the EMS; and gather other relevant information to verify energy savings for this project.

To evaluate the energy savings for the hot aisle containment, economizer, and fan control measures, Cadmus utilized trend data provided by the customer. Where information was missing, we applied engineering assumptions.

Cadmus estimated the cooling loads from IT kW trends provided by the facility. These verified loads were applied to both the baseline and proposed cases to estimate verified savings. Cadmus also utilized trend data to verify the economizer performance and reviewed air handler temperature operating conditions for the units that were available.

Baseline Assumptions

- Integrated economizer operation.
- 70 degree F fixed RAT and 12 degree F SAT set point.
- Total cooling load estimated at 220 tons from IT output trends (26% of the average load assumed in the *reported ex ante* savings).

Energy Savings Calculations

Cadmus estimated the evaluated savings by calculating the annual energy consumption for the baseline and for the proposed, energy efficient condition. Cadmus used standard engineering formulas, data collected on site, and the annual 8760 weather data to calculate the savings. The direct evaporative cooler equipment is assumed to have an average effectiveness of 70%.

Reported *Ex Ante* Savings Adjustments

Adjustments were made to the reported *ex ante* savings estimates in an effort to accurately reflect the actual operating conditions of the site at the time of this evaluation. For comparison, Table 28 shows the original reported *ex ante* savings estimates.

Table 28. Original Reported *Ex Ante* Savings Results

Original Reported/ *Ex Ante* Savings (836 Tons of Cooling)	Compressor Energy (kWh)	Fan Energy (kWh)	Total (kWh)
Reported Baseline	1,381,283	1,960,614	3,333,034
Reported Proposed	204,824	1,004,744	1,209,568
Reported Savings	1,176,459	955,870	2,132,329

New construction data center projects rarely achieve their anticipated loads within the first year and in time for utility rebate program evaluation. Site 3 had an observed cooling load during the trended time period of 220 tons, compared to the 836-ton load assumed in the *reported ex ante* savings. Consequently, Cadmus revised the reported energy savings by multiplying by 26.3% (220/836) to reflect actual data center loads observed during site verification, per standard EM&V practices. Table 29 shows the revised *ex ante* savings including the cooling load adjustment.

Table 29. Adjustments to the Reported *Ex Ante* Savings

Adjusted Reported *Ex Ante* Savings (220 Tons of Cooling)	Compressor Energy (kWh)	Fan Energy (kWh)	Total Energy (kWh)
Adjusted Reported Baseline	372,359	515,951	877,114
Adjusted Reported Proposed	53,901	264,406	318,307
Adjusted Reported Savings	309,594	251,545	561,139

Evaluated Savings

Cadmus calculated the evaluated energy savings to be 523,622 kWh, 7% lower than the adjusted reported *ex ante* savings estimates, as shown in Table 29.

Table 30. Evaluated Savings

Evaluated Savings (220 Tons of Cooling)	Compressor Energy (kWh)	Fan Energy (kWh)	Total Energy (kWh)
Evaluated Baseline	494,360	938,962	1,433,322
Evaluated Proposed	146,751	762,907	909,700
Evaluated Savings	347,609	176,100	523,622

Key findings from the evaluations are as follows:

- **SAT set-point not achieved**. The reported *ex ante* savings estimates assumed a SAT set-point of 70 degree F, which was not achieved. Facility trends show the SAT and RAT at 64 and 76 degree F, respectively. This is the primary reason why the verified compressor energy savings were lower than the reported *ex ante* savings.
- **Economizers appeared to operate ideally.** Trend data showed that the economizers were operating as intended by the current control sequence.
- **Office HVAC and envelope upgrades**. Air-conditioning and Refrigeration Institute specifications could not be located for the installed Trane TCD-330B4 packaged rooftop unit. Full load efficiencies were obtained instead from a similar 25-ton unit, with specified efficiency at 9.7 EER. Based on a 30% overall average load, Cadmus estimated the energy savings for the evaluated high-efficiency packaged unit measure at 2,100 kWh. The *reported ex ante* estimates of 1,995 kWh were deemed to be reasonable. The site visit included a cursory review of the insulation upgrade project, and energy savings for this measure were deemed to be reasonable.

Results

Cadmus estimated this project's total annual energy savings to be 523,668 kWh, with peak demand savings of 139 kW. Cadmus estimated the evaluated demand savings based on definitions in the *2006 California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*. This definition includes a peak demand period between 12:00 to 7:00 pm, weekdays, June through September. To calculate the demand savings Cadmus averaged the pre and post hourly kW simulation results to determine the associated demand savings.

The reported annual *ex ante* energy savings were 2,132,329 kWh. The primary reason for the reduction in savings was due to the difference between the actual IT load at the facility and the assumed load for the reported *ex ante* estimates. Consequently, reported *ex ante* energy savings were revised to reflect actual data center loads, per standard EM&V practices. The adjusted reported annual energy savings were calculated to be 570,002 kWh.

As shown in Table 31, the project achieved a 92% realization rate, relative to the adjusted reported *ex ante* saving estimates. The difference in energy savings results from the system not achieving the targeted SAT of 70 degrees F. No information was provided by the facility discussing why it is supplying colder air than assumed in the original analysis.

Table 31. Site 3 Final Results

Site 3	Original Reported *Ex Ante* Savings	Adjusted Reported Ex-Ante Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	2,132,329	570,002	523,668	92%
Total Annual Demand Reduction (kW)			139	

Site 4

Facility and Project Description

Site 4 is a data center with approximately 2,500 ft^2 of server IT space, served by seven 20-ton CRAH units delivering air through overhead supply ducts. The project retrofitted the following measures:

- Hot aisle containment baths to minimize recirculation airflow;
- VFDs on the supply fans; and
- Increased rack temperatures.

This evaluation found that the supply ducts to the hot aisles have been removed and the RAT set-points of the CRAH units are 82 to 85 degree F. Supply fans and cooling coils engage to meet this set-point. Each unit has a minimum VFD speed of 60%. The project also included the replacement of existing chilled water coil modulating valves, due to leaks in the old valves.

Reported *Ex Ante* Savings Methodology

Fan energy savings for the hot aisle containment project were estimated using a combination of pre-and post- implementation spot measurements and post implementation metered data (amps) for a sample of six the CRAH units of the seven total units. The Pre- and post-average kW data were compared, and savings were calculated based on data collected. Key findings and calculation methodologies are as follows:

- CRAH Unit 29 and 30 showed increased annual fan power consumption.
- CRAH Units 27, 28, 31, and 32 showed reduced demand (kW) between pre- and post-data.
- *Reported ex ante* savings averaged pre- and post-power consumption (kW) for CRAH units showing positive demand savings, and multiplied this value across the five units that showed potential savings.
- CRAH Unit 29 and 30 were not accounted for in this measure's overall energy savings.
- No energy savings were submitted for the chilled water valve replacement.

Evaluation Activities

On October 11, 2012, Cadmus performed a site inspection to: verify baseline operating equipment; observe operating loads; and identify points currently trended on the facility's EMS. The facility's BMS had minimal trending capabilities, and, as the loads did not vary significantly between pre and post measurements collected by SVP, additional trend data or metered data were not collected. To evaluate the savings for the project, Cadmus:

- Collected operational data during the inspection, and
- Reviewed the *reported ex ante* savings methodology and calculations.

Data Collection and Baseline Establishment

Cadmus conducted the site inspection and verified the following:

- The hot aisle containment had been implemented;
- The fan speeds ranged between 60% and 100%; and
- The RATs ranged from 82 to 87 degrees F.

Reductions in fan speeds and RATs were comparable to the operating conditions documented in the project baseline report. The observed operational condition indicated that the hot aisle containment measure had been installed and was operating correctly.

Facility personnel confirmed that the RAT control set-point was roughly 75 degree F before the project was implemented.

Verified Savings Baseline

Based on the project documentations, Area 2 and Area 3 reported a server load of 805 kW (6/11/12). Table 32 highlights the corresponding power measurements used to establish the baseline for the single-speed fan.

Table 32. Baseline Fan Power Consumption

Unit ID	Baseline Spot Power (kW)
CRU 27	5.7
CRU 28	5.4
CRU 29	6.0
CRU 30	5.4
CRU 31	5.7
CRU 32	5.3
CRU 33	No measurements were conducted

Energy Savings Calculations

The evaluated savings were estimated by calculating the annual energy consumption for the baseline and for the installed, energy-efficient measures. Similar to the *reported ex ante* savings analysis, the evaluated savings included fan power calculations based on spot measurements and previously trended fan speed data from the *reported ex ante* savings analysis.

Reported and Evaluated Savings

As the verified loads were similar to those assumed in the *reported ex ante* savings analysis, no changes were made to the methodology, however, changes to the reported *ex ante* savings were made to reflect all CRAH units and assess the project as a complete system. The calculated evaluated savings for this site was determined to be 148,946 kWh, 15% lower than the reported savings estimate.

Table 33 shows the *reported ex ante* and evaluated savings.

Table 33. Reported *Ex Ante* and Evaluated Savings

Savings	Total (kWh)
Evaluated Savings	148,946
Reported *Ex Ante* Savings	174,672

Key findings from this evaluation are as follows:

- Based on project documents, two of the areas (Area 2 and 3) had a server load of 837 kW during the post-installation power metering, which was an increase from 805 kW during the pre-metering measurement. Evaluated energy savings assumed an 837 kW load for both the base and proposed cases.
- The reported (*ex ante*) savings did not include CRAH 29 and CRAH 30, for which the power increased between the pre and post measurements. Since VFDs were installed on all seven CRAH units, the entire system was assessed. Therefore, the evaluation included CRAH 29 and CRAH 30 in the project's overall verified energy savings analysis. Table 34 shows the corresponding power requirements for the supply fans equipped with VFDs.

Table 34. Verified Fan Power Consumption

Unit ID	Proposed Average kW
CRU 27	1.44
CRU 28	1.43
CRU 29	6.53
CRU 30	6.26
CRU 31	2.09
CRU 32	1.20
CRU 33	No measurements conducted

Results

As the verified data center cooling loads exhibited similar load conditions between pre and post fan power measurements by SVP engineers, Cadmus applied these data directly in estimating this project's annual energy savings. Verified savings were calculated based on the system as a whole (including CRAH 29 and CRAH 30), resulting in verified annual energy savings of 148,946 kWh for this measure (as shown in Table 35).

The application documents also listed a chilled water pump and valve control measure. There are no savings associated with this measure since VFDs were not installed on the chilled water pumps, and the modulating valves were pre-existing in the baseline scenario. The evaluation results were consistent with the reported *ex ante* savings estimates that this measure had no eligible savings.

Table 35. Site 4 Final Results

Site 4	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	174,672	148,946	85%
Total Annual Demand Reduction (kW)	18.6	17.0	91%

Site 5

Facility and Project Description

Site 5 is a data center with approximately 12,000 ft^2 of server IT space, conditioned by 10 CRAH units delivering air through under floor plenums. The project installed hot aisle containment baths to minimize recirculation airflow, allowing the facility to shut down three CRAH Units. The site made significant efforts to balance the data center's room airflow to ensure that the three disabled CRAH units would remain non-operational.

Reported *Ex Ante* Savings Methodology

Energy savings for the hot aisle containment project were estimated using a combination of pre- and post-implementation metered amperage data for the four sampled units. Average demand was calculated and then multiplied by the number of disabled CRAH units to estimate the annual energy savings for this project. An energy penalty also applied to account for the increased power consumption of the CRAH units remaining operational in the proposed case.

Evaluation Activities

On October 11, 2012, Cadmus performed a site visit to: verify the baseline operating equipment; observe operating loads; identify points currently trended on the facility's BMS; and determine a verification methodology for the project. The facility's BMS had minimal trending capabilities, and as the loads did not vary significantly between the pre- and post-measurements conducted by the SVP engineer, the evaluation did not collect additional trend or metered data.

Data Collection and Baseline Establishment

Through the site inspection Cadmus determined that hot aisle containment had been implemented, and, with the exception of one unit, the CRAH units operated at a 60% fan speed. One fan operated at 100% speed, due to a control strategy to increase fan speeds to maintain a desired RAT of 82 to 85 degree F. The RAT for this unit (CRAH 40) operated at 87 degree F during the site visit. Of the ten CRAH units in the suite, three CRAH Units (35, 37, and 42) had been disabled.

Verified Savings Baseline

The baseline for verified savings was established using a sample of spot measurements taken on CRAH fans by the SVP Engineer.

Energy Savings Calculations

To evaluate project savings, Cadmus used a combination of the operational data collected during inspection and the pre and post spot measurements conducted by the SVP engineer. The pre and post power measurements utilized in the *reported ex ante* saving methodology exhibited similar cooling demands. For this reason, the fan power measurements collected between the baseline and installed scenario were comparable and the calculated saving approach was deemed reasonable.

Reported Ex Ante Savings Adjustments

As the verified loads were similar to those assumed in the *reported ex ante* savings analysis, no changes to *reported ex ante* savings were made. The calculated evaluated savings match the reported savings of 153,163 kWh. Table 36 shows the original *reported ex ante* savings and the evaluated results.

Table 36. Reported and Evaluated Savings

Annual Energy Savings	
Reported ex ante Savings	153,163 kWh
Evaluated Savings	153,163 kWh

IT load documents provided by the site contact indicated that server loads remained relatively constant from the project's inception (on March 11, 2012) to the time of site evaluation inspection. The SVP engineer documented the baseline, identifying all 10 single-speed CRAH units (Liebert FH740C) in operation. Table 37 summarizes average fan power of the four units metered to establish the baseline fan power consumption (March 28, 2011 through April 4, 2011). The SVP Engineer returned after the project implementation and took additional measurements for a sample of four CRAH Units, and conducted additional metering (August 22, 2011, to August 27, 2011). Documentation at this time also indicated three disabled CRAH units, consistent with Cadmus's inspection findings.

Table 37. Baseline and Installed Fan Power

	Baseline	Installed	Comments
Average Power	6.2	6.4	4 CRAH Units Metered
# CRAH's Operating	10.00	7.00	3 CRAH's Disabled

Results

Cadmus found that the reported savings project files provided adequate documentation and the calculation methodology was appropriate. The site contact provided additional documentation to demonstrate the system exhibiting comparable loads, and the differences between pre and post metered data reflected the project's annual energy savings. As shown in Table 38, the project achieved a 100% realization rate.

Table 38. Site 5 Final Results

Site 5	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh	153,163	153,163	100%
Total Annual Demand Reduction (kW)	17.5	17.5	100%

Site 6

Project Description

Site 6 is a manufacturing facility utilizing compressed air for its packaging process. The project involved replacement of an existing, 25-hp rotary screw load/unload air compressor, operating from 130 to 140 psig, with a new 30-hp VSD air compressor operating at a reduced discharge pressure (~110 psig). The project included installation of a 120-gallon receiver and a new cycling air dryer. All equipment was assumed to operate continuously.

Reported *Ex Ante* Savings Methodology

The reported energy savings for the compressed air retrofit and dryer savings were estimated using a customized, Excel-based analysis tool, utilizing post-installation kW metering data of the compressed air system and generic AirMaster+ performance curves to estimate the flow for the baseline and installed system. For the air dryer, installed equipment specifications and average calculated air flow requirements allowed for the determination of cycling rates, average dryer demand, and expected annual energy savings. In reviewing the trend data and calculation methodology, Cadmus deemed this approach appropriate and acceptable.

Evaluation Activities

Site Inspection

On October 11, 2012, Cadmus performed a site inspection. During this inspection our team observed that the proposed CompAir L22RS Air Station was installed with 120 gallons of receiver capacity. During the time of the inspection, the VSD air compressor was operating at 110 psig, 42 cfm, and 1,160 RPM. Spot measurements taken indicated a machine total output of 9.5 kW. During the inspection, it was also observed that the baseline 25-hp Ingersoll Rand UP6-25-150 Rotary Screw Air Compressor was maintained on-site as a back-up air compressor and its receiver was acting as an additional storage capacity for the compressed air system. The facility manager confirmed the baseline system has not operated since installation of the new VSD air compressor.

During the site visit, power meters were installed to monitor the facility's compressed air consumption over time.

Energy Savings Calculations

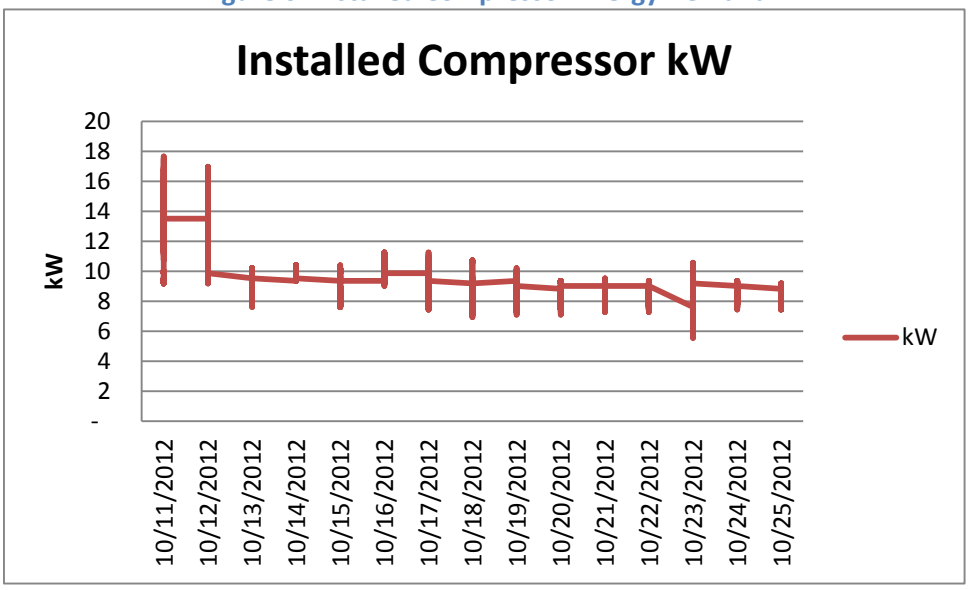
To establish the baseline, Cadmus used a combination of monitored data, equipment CAGI sheets, air compressor part-load performance curves, project documentation and on-site interviews with the facility manager. The baseline values established for this project included the following:

- IR UP625-150 Rotary Screw Load/Unload Air Compressor
- Cut-in/Cut-out Pressure: 130 psig/140 psig
- Estimated Package Input Power/Capacity: 21.65 kW/82 CFM
- IR TS100 Air Dryer—Non Cycling Dryer

Compressor Savings

Cadmus obtained two weeks of metered data (October 11 to October 25, 2012). The metered data (see Figure 6) showed the compressor operated continuously at relatively stable conditions. The average power draw during the metering period was 9.60 kW. During that period, the air compressor operated to maintain a discharge pressure of 110 psig and the average flow was estimated at 36 CFM. If the baseline Ingersoll Rand air compressor had provided this flow, the baseline air compressor would have operated at approximately 44% capacity and would have drawn an estimated 14.24 kW of power. The evaluated annual compressor savings utilizing the metered power data was 40,646 kWh. This is 5.5% lower than the reported *ex ante* estimate of 43,021 kWh per year. The difference in energy savings primarily results from the different data sets used to estimate air demand and the compressor performance curves applied between the *reported ex ante* Savings Methodology and Cadmus' evaluation. Given that the difference between the reported and evaluated savings fell within a reasonable margin of error, Cadmus approved the reported savings estimate of 43,021 kWh as the evaluated savings for this measure.

Figure 6. Installed Compressor Energy Demand



Air Dryer Savings

Cadmus verified that the new CompAir /CES140 Air Dryer was installed, operational, and cycling. Cadmus applied the same savings methodology as that used for the reported *ex ante* energy savings. The reported estimate assumed baseline power consumption of 1.3 kW, given the installed equipment specifications. However, the baseline IR TS100 air dryer specifications indicated a 1.1 kW draw. Using the specific power of 1.1 kW, Cadmus estimated that the air dryer had an annual energy savings of 6,700 kWh. This is 16.8% lower than the reported *ex ante* estimate of 8,053 kWh per year. The reduction in savings resulted from the change in the assumed power draw in the baseline.

Results

The total project savings equal the sum of the estimated reported savings for the air compressor measure and the evaluated savings for the air dryer measure, resulting in annual evaluated savings of 49,721 kWh. Demand savings were not submitted with this application; Cadmus estimated the demand savings at 5.8 kW.

Table 39. Site 6 Final Results

Site 6	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	51,074	49,721	97.4%
Total Annual Demand Reduction (kW)		5.8	

Site 7

Facility and Project Description

Site 7 is a car dealership, with an office, showroom, and maintenance servicing area. This project implemented the following measures:

- Fifty one 4' 2-lamp T12 replaced by 39 4' 2-lamp T8 – Area 1
- Three 3 4' 3-lamp T12 replaced by three 4' 2-lamp T8 – Area 2
- Fifty three 4' 4-lamp T12 replaced by 43 4' 2-lamp T8 – Area 3
- Four (4) 4' 3-lamp T12 replaced by four 4' 3-lamp T8 – Area 4
- One 4' 4-lamp T12 replaced by one 4' 4-lamp T8 – Area 5
- Eleven U-bend 2-lamp T12 replaced by 11 U-bend 2-lamp T8 – Area 6
- One hundred and six 8' 2-lamp T12 replaced by 106 4' 2-lamp T8 – Area 7
- Twelve 8' 1-lamp T12 replaced by 12 4' 2-lamp T8 – Area 8

Reported Ex Ante Savings Methodology

The *reported ex ante* savings were determined using deemed values for each measure in the project, estimated at 55,040 kWh/year. No demand savings were included.

Evaluation Activities

Site Inspection

On November 16, 2012, Cadmus performed a site inspection. The Cadmus field engineer inventoried 20-fewer NLO 4' 2-lamp F28T8 fixtures on site than those accounted for in the application documents. Ballast information could not be observed on site due to fixture locations. All the observed bulbs were 28 watts. The site contact specified building occupation and that the lighting operated between 9:00 am and 8:00 pm, Monday through Saturdays, and from 10:00 am to 7:00 pm on Sundays. All fixtures were operating during the inspection.

Energy Savings Calculations

Cadmus used the lighting counts conducted during the site inspection, invoices, interviews with the site contact, and manufacturer's specifications to verify energy savings for this project. Table 40 compares the invoiced fixture count to the number of observed fixtures on site. Cadmus was able to verify 185 out of the 205 invoiced NLO 4' 2-lamp F28T8 fixtures. Cadmus discussed the missing 20 NLO 4' 2-lamp F28T8 with the site contact and was not able to determine the location of these lamps as all areas of the facility were inspected. Due to the uncertainty associated with these 20 lamps, Cadmus used the invoiced quantity of lamps to calculate energy savings.

Table 40. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
NLO 4' 2-lamp F28T8	205	185
NLO 4' 3-lamp F28T8	4	4
NLO 4' 4-lamp F28T8	1	1
2L 28W T8 U-tube	11	11

Baseline

Cadmus established the baseline as the existing fixtures prior to project implementation:

- Fifty one 4' two-lamp T12
- Three 4' three-lamp T12
- Fifty three 4' four-lamp T12
- Four 4' three-lamp T12
- One 4' four-lamp T12
- Eleven U-bend two-lamp T12
- One hundred and six 8' two-lamp T12
- Twelve 8' one-lamp T12

Based on interviews with the site contact, the lighting system operated an estimated 3,900 hours/year.

Results

Based on the annual operating hours, the baseline fixtures and wattages, and the proposed equipment, Cadmus estimated that the annual energy savings for this project to be 72,200 kWh and 16 kW. The evaluated savings, based on observed equipment characteristics and operating hours, exceeded the reported savings, which were based on deemed values.

Table 41. Site 7 Final Results

Site 7	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	55,040	72,200	131%
Total Annual Demand Reduction (kW)	-	16	

Site 8

Facility and Project Description

Site 8 is a data center, with roughly 150,000 square feet of IT space. The lighting system primarily consisted of three-lamp T8 fixtures with 32 watt bulbs. These fixtures operated 24 hours per day, 365 days per year. The project incorporated these lighting fixtures into the facility's energy management system (EMS). The lighting management system was divided into about 50 zones and was programmed to turn off during low traffic times (6:00 pm to 7:00 am weekdays, and all day on weekends).

Reported *Ex Ante* Savings Methodology

The reported (*ex ante*) savings estimate was 399,691 kWh per year. Spot measurements of each lighting circuit in the data center space were used to establish the baseline power draw. The reduction in operating hours was then estimated based on the proposed lighting system schedule (7:00 am to 6:00 pm weekdays; off on weekends). Cadmus deemed this approach appropriate and acceptable.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection. The Cadmus field engineer verified installation of the new lighting control panels and their incorporation into the building's EMS. The review of the EMS screenshots confirmed the proposed lighting schedule was in place and programmed as stated in the tracking estimate. The EMS trend data showed the lighting system's status for each zone controlled by the EMS. The facility manager confirmed no changes or upgrades had been made to fixtures located in the data center area since the project took place.

Energy Savings Calculations

Analysis of the trend data provided by the facility contact was used to determine the number of hours when the new system turned the lights off. These data ranged from 15 to 50 days of post-installation archived data for each zone being controlled through the EMS. Cadmus analyzed the data to determine the percent of hours lights in the zone remained off. This percentage was applied to all hours of the year, as no seasonal usage variations occurred at the facility. The reported power readings for the baseline lighting circuits during the incentive approval stage were used in the analysis as no changes had been made to lighting fixtures located in the data center spaces. Table 42 shows the submitted and verified savings results.

Table 42. Submitted and Approved Savings

		Submitted Savings		Verified Savings	
Area	Baseline kW	Estimated Percent Reduction Hours	Estimated Savings (kWh)	Percent Actual Reduction Hours	Estimated Savings (kWh)
Phase 1					
Zone 1	4.04	65%	23,004	57%	20,100
Zone 2	5.46	64%	30,611	59%	28,300
Zone 3	4.04	64%	22,650	61%	21,600
Zone 4	4.46	64%	25,005	58%	22,500
Phase2					
NOC & Node	1.63	66%	9,424	64%	9,100
Zone 1	3.43	63%	18,929	64%	19,300
Zone 2	4.32	62%	23,463	61%	23,200
Zone 3	4.24	66%	24,514	64%	23,700
Zone 4	4.38	64%	24,556	64%	24,700
Zone 5	3.52	65%	20,043	64%	19,800
Zone 6	4.04	63%	22,296	65%	22,800
S&R Lighting	0.94	67%	5,517	63%	5,200
PH1 UPS	0.97	68%	5,778	67%	5,700
PH2UPS	1.52	67%	8,921	67%	8,900
Phase 3					
Zone 1	4.49	60%	23,599	64%	25,300
Zone 2	4.6	47%	18,939	63%	25,300
Zone 3	3.71	60%	19,500	64%	21,000
Zone 4	6.29	59%	32,509	62%	34,100
Zone 5	4.29	60%	22,548	65%	24,600
	3.55	61%	18,970	65%	20,200
Total Energy Savings (kWh)			399,691		405,400

Results

Through the use of archived trend data, the verification assessment produced energy savings (405,400) within one percent of the reported (399,691 kWh). Therefore, the original reported project estimate was deemed reasonable and accepted as the evaluated energy savings for this project.

The reported *ex ante* demand savings was 65.7 kW. This demand impact was not coincident with the peak period as the lighting systems were on during the peak period, resulting in zero peak demand impact for this project.

Table 43. Site 8 Final Results

Site 8	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	399,691	399,691	100%
Total Annual Demand Reduction (kW)	65.7	0	-

Site 9

Facility and Project Description

Site 9 is a recently constructed recreational facility with 62,000 square feet of rentable space. The warehouse area's installed lighting system consists of 80 energy-efficient, high bay, 4' four-lamp T5 fixtures with 54 watt bulbs. Per specifications, these fixtures consumed 240 watts/fixture, and were upgrades over the baseline 400 watt metal halide fixtures.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project, with each fixture assumed to save 772 kWh per year and operated 3,446 hours per year. The total estimated savings for this project was reported as 61,760 kWh/year. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection, inventorying 82 4' four-lamp T5 high-output fixtures. Two fixtures were not operating during the site visit; the site contact stated these fixtures remained solely for back-up emergencies. Typically, the lighting system was operated per the following schedule:

- Monday to Thursday: 12:00 pm to 10:00 pm
- Friday: 11:00 am to 11:00 pm
- Saturday: 10:00 am to 11:00 pm
- Sunday: 10:00 am to 8:00 pm

Energy Savings Calculations

To verify energy savings for this project, Cadmus used lighting counts conducted during the site inspection, interviews with the site contact, and reviews of the manufacturer's specifications. Table 44 compares the quantities included in the invoice provided with the application to the equipment observed during the inspection. Cadmus verified all 80 lighting fixtures as installed and operating.

Table 44: Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
High Bay 4' 4-lamp F54T5	80	80

Baseline

For this new construction project, baseline fixtures for this high-bay lighting application were 400 watt metal halide fixtures. Based on standard fixture wattage tables[7], the baseline equipment consumed approximately 458 watts/fixture. The annual hours of operation were estimated, based on the operating schedule provided by the site contact, at 3,900 hours/year.

[7] 2009 SPC Procedures Manual: Appendix B: 2009 Table of Standard Fixture Wattages. Ver. 1.6. SCE, 1 June 2009. <http://www.sce.com/b-rs/small-medium/spc/application-software-manual.htm

Results

As shown in Table 45, Cadmus estimated the annual energy savings for this project to be 81,600 kWh and demand savings to be 21 kW. The increase in savings from the reported *ex ante* estimates was due to the difference between the assumed operating hours used to develop the deemed savings estimates and the actual fixture operating hours determined through this evaluation.

Table 45. Site 9 Final Results

Site 9	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	61,760	81,600	132%
Total Annual Demand Reduction (kW)	0	21	

Site 10

Facility and Project Description

Site 10 is a small manufacturing space, with 3,000 square feet of rentable area. The project consisted of the replacement of two types of lighting fixtures:

- Fourteen 4' four-lamp T12 fixtures and ballasts replaced by 14 more efficient 4' two-lamp T8 fixtures, and
- Four 8' two-lamp T12 fixtures replaced by three more efficient 4' two-lamp T8 fixtures.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project, with estimated savings of 27,827 kWh per year. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection, inventorying 17 4' two-lamp T8 fixtures, with 32 watt bulbs. The site contact stated the building and lights operated continuously.

Energy Savings Calculations

Cadmus used the lighting counts from the site inspection, interviews with the site contact, and reviews of manufacturer's specifications to verify energy savings for this project. Table 46 compares the lighting proposed counts obtained from the application documents to the equipment observed during the site inspection. Cadmus verified all 17 4' two-lamp fixtures with 32 watt bulbs were installed and operating during the inspection.

Table 46. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
NLO 42 2-lamp F32T8	17	17

Baseline

Cadmus established the baseline as the existing equipment, prior to project implementation:

- Fourteen 4' four-lamp T12 fixtures
- Four 8' two-lamp T12 fixtures

The lighting system was assumed to be operating 8,760 hours/year.

Results

Cadmus estimated the annual energy savings for this project to be 20,300 kWh and 2 kW of demand. The reason for the difference between the reported and evaluated savings was due to a data entry error in the project documentation. Final results are shown in Table 47.

Table 47. Site 10 Final Results

Site 10	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	27,827	20,300	73%
Total Annual Demand Reduction (kW)	-	2	

Site 11

Facility and Project Description

Site 11 is a restaurant. The project consisted of the installation of the following LED fixtures:

- Twenty-nine Par38 20-d 11W LEDs
- Sixty-one A19 8W LEDs
- Twelve BR30 50-d 12W LEDs
- Twenty-seven BR30 25-d 12W LEDs
- Four RESC6 6" Can LEDs

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project estimated at 18,434 kWh per year. No demand savings were included.

Evaluation Activities

Site Inspection

On November 12, 2012, Cadmus performed a site inspection. During the inspection, the Cadmus field inspector verified that the quantity of lamps installed was consistent with the quantities that were provided in the invoices contained in the application documents. During the inspection, all fixtures were found to be operating.

Energy Savings Calculations

To verify energy savings for this project, Cadmus used lighting counts conducted during the site inspection, reviews of invoices and manufacturer's specifications, and interviews with the site contact. Table 48 compares the lighting counts as included on the invoices to the quantities verified during the site inspection.

Table 48. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
Par38 20-d 11W LED	29	29
A19 8W LED	61	61
BR30 50-d 12 W LED	12	12
BR30 25-d 12 W LED	27	27
RESC6 6" Can LED Light	4	4

Baseline

Cadmus utilized the deemed measure spreadsheet provided by SVP to establish incandescent equivalents for installed LED fixtures:

- An 11 watt Par38 LED is a standard replacement for 50 watts.
- An 8 watt A19 LED is a standard replacement for 40 watts.
- A 12 watt BR30 LED is a standard replacement for 65 watts.
- A 10.5 watt RESC 6" Can LED is a standard replacement for 60 watts.

Based on interviews with the site contact, the lighting system operated an estimated 4,238 hours/year.

Results

As shown in Table 49, Cadmus estimated the annual energy savings for this project to be 28,200 kWh and demand savings to be 5 kW. The increase in savings resulted primarily from an increase in operating hours from the default assumptions used in the deemed savings estimates to the actual operation determined through the evaluation.

Table 49. Site 11 Final Results

Site 11	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	18,434	28,200	153%
Total Annual Demand Reduction (kW)	-	5	

Site 12

Facility and Project Description

Site 12 is a restaurant. The project consisted of the following LED fixture installations:

- One Par20 40-d 8W LED
- One-hundred and forty RESC6 6" Can 10.5W LEDs.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project, with estimated savings at 22,197 kWh per year. No demand savings were included.

Evaluation Activities

Site Inspection

On November 12, 2012, Cadmus performed a site inspection. The field engineer inventoried the quantities of lamps installed and found that the quantities were consistent with invoices provided in the application documents. During the inspection, all LEDs were found to be operating.

Energy Savings Calculations

Cadmus used lighting counts conducted during the site inspection, reviews of invoices and manufacturer specifications, and interviews with the site contact, to verify the energy savings for this project. Table 50 compares lighting quantities included in the invoices to the quantities observed during the site inspection.

Table 50. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
Par20 40-d 8W LED	1	1
RESC6 6" Can LED Light	140	140

Baseline

Cadmus utilized the deemed measure spreadsheet provided by SVP to establish the baseline energy consumption:

- An 8 watt Par20 LED is a standard replacement for a 40 watt incandescent
- A 10.5 watt RESC 6" Can LED is a standard replacement for a 60 watt incandescent

Based on interviews with the site contact, the lighting system operated an estimated 4,238 hours/year.

Results

As shown in Table 51, Cadmus estimated the project annual energy savings to be 35,200 kWh and the demand savings to be 7 kW. The increase in energy savings was primarily due to increasing the operating hours from the default assumption used in the deemed estimates to the actual hours of operation determined through this evaluation.

Table 51. Site 12 Final Results

Site 12	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	22,197	35,200	157%
Total Annual Demand Reduction (kW)	-	7	

Site 13

Facility and Project Description

Site 13 is a small office building, with 5,000 square feet of occupied space. The project implemented the following measures:

- Fifty-four 4' four-lamp T12 replaced by 54 4' two-lamp T8 with 32 watt bulbs.
- Three 4' two-lamp T12 replaced by three 4' two-lamp T8 with 32 watt bulbs.
- Three wall-mounted motion sensors installed.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project, and were estimated to be 17,874 kWh/year. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection, inventorying all 57 4' two-lamp T8 fixtures as well as the three wall-mounted motion sensors. During the inspection, all lighting fixtures and motion sensors were verified to be installed and operating. The motion sensors were located in three office spaces, controlling six 2-lamp T8 fixtures. The site contact reported the building and lights typically operated from 7:30 am to 5:30 pm, Monday through Friday.

Energy Savings Calculations

Cadmus used lighting and motion sensor counts conducted during the site inspection, interviews with the site contact, and reviews of the manufacturer specifications to verify energy savings for the project. Table 52 compares the quantities obtained from the invoices to the quantities observed during the site inspections.

Table 52. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
NLO 4' 2-lamp F32T8	57	57
Occupancy Wall Switch Sensors	3	3

Baseline

The baseline was established based on existing equipment, prior to project implementation:

- Fifty-four 4' four-lamp T12 fixtures.
- Three 4' two-lamp T12 fixtures.
- No motion sensors.

Based on the schedule provided by the site contact, the lighting system operated an estimated 2,540 hours/year.

The energy savings associated with occupancy sensors were derived from studies assessing the average reductions, based on occupancy type. The reported *ex ante* savings for occupancy sensors were determined by assuming a 20% reduction in fixture operating hours. Cadmus utilized a recent study that has shown a 22% reduction in operating hours is typically achieved through this measure.[8] Therefore, Cadmus used a 22% reduction in the baseline operating hours.

Results

Based on annual operating hours and fixture wattages of baseline and proposed equipment, Cadmus estimated the annual energy savings for this project to be 16,200 kWh and demand savings of 5 kW (see Table 53). The reduction in savings from the reported value was due to fewer actual annual operation hours than assumed in the deemed savings.

Table 53. Site 13 Final Results

Site 13	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	17,874	16,200	91%
Total Annual Demand Reduction (kW)	0	5	

[8] A. Williams, Atkinson B., Karina G., Rubinstein F. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Lawrence Berkeley National Laboratory. Contract No. DE-AC02-05CH11231. 2011.

Site 14

Facility and Project Description

Site 14 is a small office, with 4,000 square feet of rentable space. The project implemented the following measures:

- Fifty-three 4' four-lamp T12 fixtures and ballasts replaced by more efficient 4' two-lamp T8 fixtures with 28 watt bulbs.
- Four 2'x2' two-lamp T12/U6 fixtures replaced by more efficient 2' two-lamp T8 fixtures with 17 watt bulbs.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project, and were estimated to be 17,305 kWh per year. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection, inventorying all 53 4' two-lamp T8 and four 2'x2' two-lamp T8 fixtures. The site contact stated the building and lights typically operated from 6:00 am to 6:00 pm, Monday through Friday. Due to ceiling heights and no access, bulb and fixture model numbers could not be verified.

Energy Savings Calculations

Cadmus used lighting counts conducted during the site inspection, interviews with the site contact, reviews of implementation documents, and manufacturer specifications to verify energy savings for this project. Table 54 compares the lighting quantities as shown in the invoices to the quantities observed during the site inspection. Cadmus verified the installation of 53 4' two-lamp and four 2' two-lamp fixtures. All fixtures were verified to be operating during the inspection.

Table 54. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
NLO 4' 2-lamp F32T8	53	53
NLO 2' 2-lamp F32T8	4	4

Baseline

The baseline was established based on existing equipment, prior to project implementation, as follows:

- Fifty-three 4' four-lamp T12 fixtures
- Four 2'x2' two-lamp T12/U6 fixtures.

Based on the operating schedule provided by the site contact, the lighting system operated an estimated 3,048 hours/year.

Results

Based on the annual operating hours, and fixture wattages of the baseline and proposed equipment, Cadmus estimated that the annual energy savings for this project were 19,100 kWh and demand savings were 5 kW (see Table 55). The increase in savings was due to the increase in operating hours from the assumptions used in the deemed savings estimate to those found during the evaluation site visit.

Table 55. Site 14 Final Results

Site 14	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	17,305	19,100	110%
Total Annual Demand Reduction (kW)	-	5	

Site 15

Facility and Project Description

Site 15 is a mechanic shop with 12,000 square feet of office and working space. The project implemented the following measures:

- Thirty-nine 4' four-lamp T12 (high bay) fixtures replaced by 39 4' four-lamp T8 fixtures.
- Eight 8' four-lamp T12 fixtures replaced by six 4' four-lamp T8 fixtures.
- Two 8' two-lamp T12 fixtures replaced by one 4' four-lamp T8 fixtures.
- Thirteen 4' four-lamp T12 fixtures replaced by 13 4' two-lamp T8 fixtures.
- Four 4' two-lamp T12 fixtures replaced by four 4' two-lamp T8 fixtures.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project and were estimated to be 39,228 kWh/year. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection. Using application documents, the field engineer verified specified fixtures and counts on site. Ballast information could not be observed during the site inspection since there were no spares available and the fixtures were inaccessible. All bulbs observed were 32 watts. The site contact specified lights operated between 8:00 am and 5:00 pm, Monday through Friday. All fixtures were verified to be operating during the inspection.

Energy Savings Calculations

To verify energy savings for this project, Cadmus used the lighting counts conducted during the site inspection, interviews with the site contact, and reviews of the manufacturer's specifications. Table 56 compares the quantity of lighting shown on the invoices to the quantity observed during the site inspection. Cadmus verified that all the invoiced lamps had been installed and were operating.

Table 56. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
High Bay 4' 4-lamp F32T8	39	39
NLO 4' 4-lamp F32T8	6	6
NLO 4' 2-lamp F32T8	18	18

Baseline

The baseline was established based on existing equipment prior to project implementation, as follows:

- Thirty-nine 4' four-lamp T12 (high bay) fixtures.
- Eight 8' four-lamp T12 fixtures.
- Two 8' two-lamp T12 fixtures.
- Thirteen 4' four-lamp T12 fixtures.
- Four 4' two-lamp T12 fixtures.

Based on the schedule provided by the site contact, the lighting system operated an estimated 2,286 hours/year.

Results

Cadmus estimated the annual energy savings for this project to be 27,400 kWh and the annual demand to be 10 kW (see Table 57). The reduction in savings r was due to less actual operating hours of fixtures found during the evaluation than were assumed in the deemed savings estimates.

Table 57. Site 15 Final Results

Site 15	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	39,228	27,400	70%
Total Annual Demand Reduction (kW)	-	10	

Site 16

Facility and Project Description

Site 16 is a small office building with 5,000 square feet of rentable space. The project installed wall-mounted motion sensors in three office spaces.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project and were estimated to be 580 kWh/year based on the three rebated motion-sensors. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection. The site contact identified the locations of the motion sensors. The three motion sensors were observed in three offices and controlled nine 4' two-lamp T8 fixtures. The site contact stated the building and lights typically operated between 7:30 am and 5:30 pm Monday through Friday.

Energy Savings Calculations

To verify energy savings for this project, Cadmus used lighting counts conducted during the site inspection, interviews with the site contact, and reviews of the manufacturer's specifications. Table 58 compares the quantities shown on the invoices to the quantities observed during the site inspection. Cadmus verified that the three motion sensors were installed and operating.

Table 58. Invoiced and Observed Sensors Quantities

Measure Description	Invoiced Quantity	Rebated Quantity	Observed Quantity
Occupancy Wall Switch Sensors	5	3	3

Baseline

The baseline was established based on the following existing equipment prior to project implementation:

- Nine 4' two-lamp T8 fixtures without occupancy sensors.

Based on schedule information provided by the site contact, the lighting system operated 2,540 hours/year assuming that the fixtures were always on when the building was occupied, prior to the installation of the sensors.

Results

Based on recent research, Cadmus assumed that the installation of an occupancy sensor in each office space reduced fixture operating hours by 22% to 1,981 hours per year.[9] The reported savings estimates were based on a deemed assumption of a 20% reduction.[10,11]

Based on this reduction in annual operating hours and the fixture wattages, Cadmus estimated the annual energy savings for this project to be 300 kWh as shown in Table 59. The reduction in savings was due to the lower average fixture wattages controlled by the occupancy sensors resulting from the reduction in operating hours between what was assumed in the deemed energy savings estimates to that found during this evaluation.

Table 59. Site 16 Final Results

Site 16	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	580	300	52%
Total Annual Demand Reduction (kW)	–	-	

[9] Williams A, Atkinson B, Karina G, Rubinstein F. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Lawrence Berkeley National Laboratory*. Contract No. DE-AC02-05CH11231. 2011.

[10] SCE Work paper WPSCNRLG0025.1

[11] Itron, Inc. *2004-2005 Database for Energy Efficiency Resources Update Study Final Report.* December 2005. Page 3-12.

Site 17

Facility and Project Description

Site 17 is an office building with 12,000 square feet of office and working space. The project implemented the following measures:

- Eighteen 4' four-lamp T12 fixtures replaced by 18 4' two-lamp T8 fixtures.
- Two 8' four-lamp T12 fixtures replaced by two 4' four-lamp T8 fixtures.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each project measure and were estimated to be 6,034 kWh/year. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection. The field engineer verified the specified fixtures and counts on site matched those in the application documents. Ballast information could not be observed on site. All bulbs observed were 32 Watts. The site contact specified that the building was occupied between 8:30am and 6:00 pm, Monday through Friday, and that the lights operated during that period. All fixtures were verified to be on during the inspection.

Energy Savings Calculations

To verify energy savings for this project, Cadmus used the lighting counts conducted during the site inspection, reviews of invoices and manufacturer specifications, and interviews with the site contact. Cadmus verified that all the invoiced lamps had been installed. Table 60compares the quantities of fixtures included on the invoice to the quantities observed during the site inspection.

Table 60. Invoiced and Observed Fixtures Quantities

Measure Description	Invoiced Quantity	Observed Quantity
NLO 4' two-lamp F32T8	18	18
NLO 4' four-lamp F32T8	2	2

Baseline

Cadmus established the baseline as the following existing equipment prior to project implementation:

- Eighteen 4' four-lamp T12 fixtures
- Two 8' four-lamp T12 fixtures

Based on the schedule provided by the site contact, the lighting system operated an estimated 2,413 hours/year.

Results

Based on the annual operating hours, and the fixture wattages of the baseline and the proposed equipment, Cadmus estimated the annual energy savings for this project to be 4,700 kWh and the demand savings to be2 kW (see Table 61). The savings reduction was due to lower actual operating hours than assumed in the deemed measure estimates.

Table 61. Site 17 Final Results

Site 17	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	6,034	4,700	78%
Total Annual Demand Reduction (kW)	–	2	

Site 18

Facility and Project Description

Site 18 is a fire station. The project included the following measures:

- Thirty-five 4' two-lamp T12 fixtures replaced by 35 4' two-lamp T8 fixtures.
- Four 4' three-lamp T12 fixtures replaced by four 4' two-lamp T8 fixtures.
- Eight 8' four-lamp T12 fixtures replaced by eight 8' four-lamp T8 fixtures.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project, with submitted savings estimated to be 4,782 kWh/year. No demand savings were included. These savings were based on a lighting proposal that was submitted on April 14, 2011. SVP provided Cadmus an updated proposal (November 13, 2012) which was consistent with the inspection findings.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection. The field engineer verified that all the proposed lighting fixtures had been installed as documented in the updated proposal. All of the 4' and 8' lamps observed used 28 and 59 watts, respectively. The site contact specified building lights typically operated between 7:00 am and 10:00 pm, seven days per week. All fixtures were verified to be operating during the site inspection.

Energy Savings Calculations

To verify the energy savings for this project, Cadmus used the lighting counts conducted during the site inspection, reviews of the invoices and manufacturer specifications, and interviews with the site contact. Table 62compares the quantities shown on the invoices to the quantities observed during the site inspection.

Table 62. Invoiced and Observed Fixture Quantities

Measure Description	Invoiced Quantity	Observed Quantity
NLO 4' two-lamp F28T8	39	39
NLO 4' four-lamp F28T8	8	8

Baseline

Cadmus established the baseline as the existing equipment prior to the project implementation:

- Thirty-five 4' two-lamp T12 fixtures
- Four 4' three-lamp T12 fixtures
- Eight 8' four-lamp T12 fixtures

Based on the schedule provided by the site contact, the lighting system operated an estimated 5,370 hours/year.

Results

Based on the annual operating hours, and the fixture wattages of the baseline and the proposed equipment, Cadmus estimated the annual energy savings for this project to be 9,600 kWh and the demand savings to be 2 kW (see Table 63). Savings increased due to changes in the project's scope.

Table 63. Site 18 Final Results

Site 18	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	4,782	11,500	240%
Total Annual Demand Reduction (kW)	–	2	

Site 19

Facility and Project Description

Site 19 is a dry cleaning retail store with 1,000 square feet of rentable space. The project replaced three four-lamp T12 fixtures and ballasts with more efficient 4' two-lamp T8 fixtures, with 32 watt bulbs.

Reported *Ex Ante* Savings Methodology

The reported *ex ante* savings were determined using deemed values for each measure in the project and were estimated to be 1,282 kWh/year. No demand savings were included.

Evaluation Activities

Site Inspection

On October 16, 2012, Cadmus performed a site inspection and verified that the three 4' two-lamp T8 fixtures were installed. The site contact stated the building and lights typically operated between 9:00 am and 7:00 pm during weekdays, and from 10:00 am to 5:00 pm on Saturdays. All fixtures were verified to be operating during the site inspection.

Energy Savings Calculations

To verify the energy savings for this project, Cadmus used the lighting counts conducted during the site inspection, interviews with the site contact, and reviews of the manufacturer specifications. Table 64 compares the quantity of fixtures invoiced to those observed during the site inspection.

Table 64. Invoiced and Observed Fixture Quantities

Measure Description	Invoiced Quantity	Operating Quantity
NLO 4' two-lamp F32T8	3	3

Baseline

Cadmus established the baseline as the existing equipment prior to project implementation, which were the three 4' four-lamp T12 fixtures.

Based on the schedule provided by the site contact, the lighting system operated an estimated 2,904 hours/year.

Results

Based on the annual operating hours, and the fixture wattages of the baseline and the proposed equipment, Cadmus estimated the annual energy savings of this project to be 900 kWh and the demand savings to be 0.3 kW (see Table 65). The reduction in savings was due to lower actual operating hours than assumed in the deemed measure savings estimates.

Table 65. Site 19 Final Results

Site 19	Original Reported *Ex Ante* Savings	Evaluated *Ex Post* Savings	Realization Rate
Total Annual Electric Savings (kWh)	1,282	900	70%
Total Annual Demand Reduction (kW)	–	0.3	