Impact Evaluation of Silicon Valley Power 2013–2016 Data Center Program

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Executive Summary

This report documents the findings of The Cadmus Group's (Cadmus) impact evaluation of Silicon Valley Power's (SVP) 2013–2016 Data Center program (the Program). 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.

In 2013, Cadmus completed an evaluation of SVP's existing commercial building energy efficiency program. For that evaluation, Cadmus found that three data centers accounted for 82% of the portfolio reported savings; the evaluation sample included all three projects. The three data centers achieved a realization rate of 46% of the reported savings estimate, largely because the reported savings were based on projected full-load operations. To account for the process of ramping up to full load, we developed an adjusted reported savings estimate. Using this adjusted estimate, we showed that two of the sites achieved realization rates of approximately 90%, while one site achieved a realization rate of 46%. The realization rate for that site was lower because the baseline model used to estimate savings did not properly reflect the required economizer operation. The adjusted realization rate for the three combined data centers was 62%.

Partly in response to our study, SVP modified its existing program to provide data center projects incentives on a performance basis. Projects can claim incentives over five years, based on verified savings each year, and taking into account the facility's operating load.

SVP's Data Center program provides incentives to new and existing data centers for implementing program-eligible energy efficiency measures. The program pays an incentive of $0.03 per kWh saved for eligible projects. The maximum potential incentives are capped at the lesser of $500,000, 120% of the total potential rebate amount, or 65% of the project measure cost.

This evaluation primarily seeks to assess the Program's energy and demand savings impacts and to determine the realization rate for each facility in the sample, evaluated for each year that SVP has paid an incentive. The study provides findings and recommendations for fine-tuning the program.

Program Savings and Realization Rates

As shown in Table 1 and Table 2, Cadmus' impact evaluation calculated evaluated annual savings of 4,448,058 kWh and 508 kW for projects reviewed from program year (PY) 2013–2014, resulting in an energy savings realization rate of 99.9%. For PY 2014–2015, Cadmus evaluated total annual savings to be 4,525,935 kWh and 632 kW, resulting in an energy savings realization rate of 93%. For PY 2015–2016, we evaluated total annual savings to be 6,543,861 kWh and 759 kW, resulting in an energy savings realization rate of 99.9%.

Demand savings data were not available for all projects and years that incentives were paid. Cadmus calculated demand savings for all projects for each year that incentives were paid, but we could not calculate the demand realization rate without having reported demand savings values.

Table 1. Program Energy Savings and Evaluation Results

PY	Reported Energy Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate (kWh)	Savings Variance (kWh)
2013–2014	4,454,142	4,448,058	99.9%	-6,084
2014–2015	4,872,632	4,525,935	93%	-346,697
2015–2016	6,551,691	6,543,861	99.9%	-7,830

Table 2. Program Demand Savings and Evaluation Results

PY	Reported Demand Savings (kW)	Evaluated Demand Savings (kW)	Realization Rate (kW)	Savings Variance (kW)
2013–2014	N/A*	508	N/A	N/A
2014–2015	N/A**	632	N/A	N/A
2015–2016	N/A***	759	N/A	N/A

*For PY 2013-2014, demand saving for Site 2 was not available.

**For PY 2014-2015, demand saving for Site 2 was not available.

***For PY 2015-2016, demand savings for Site 1 and Site 4 were not available.

Introduction

This report documents the findings of The Cadmus Group's (Cadmus) impact evaluation of the 2013–2016 Data Center Program that 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 made a statewide commitment to cost-effective and feasible energy efficiency, with the expectation that all utilities would 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.

The Data Center Program targets data centers with IT server loads greater than 350 kW or IT cooling loads greater than 100 tons. The program pays an incentive of $0.03 per kWh saved per year over five years, based on verified savings at the end of each performance period. Verified savings are adjusted to account for the percentage of design IT load operating at the time of performance. Maximum potential incentives are capped by $500,000 of rebate funds in a single program year. This includes incentives received through all SVP programs. Customers also are limited to receiving a maximum of $500,000 of rebate funds for similar measures installed at the same facility during the five-year period. Therefore, maximum potential incentives are capped at the lesser of $500,000, 120% of the total potential rebate amount, or 65% of the project measure cost.

Overview of Methodology

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

- Initial review of provided documents
- Data collection
- Engineering analysis

Cadmus performed an initial, detailed review of all project data provided by SVP to establish the appropriate measurement and verification (M&V) approach.

Cadmus developed the M&V method for each project type with adherence to the International Performance Measurement and Verification Protocols (IPMVP) and the appropriate California Energy Commission (CEC) protocols for publicly owned utilities (POUs). The appropriate category of the IPMVP for evaluating this program is Option A, Retrofit Isolation: Key Parameter Measurement. This method uses engineering calculations and partial site measurements to verify savings resulting from specific measures. Parameters not measured are estimated based on historical data, manufacturer's specifications, or engineering judgments.

Cadmus estimated the evaluated savings by calculating annual energy consumption for the baseline and the installed energy efficient condition at the verified IT load. We followed Program requirements for defining the baseline. For retrofit projects, we used a baseline derived from equipment operating before the project, as documented in the project documents and confirmed by site contacts. For new facilities, we used a baseline that meets SVP baseline requirements for new construction projects. Cadmus collected installed trend data during the site visits to calculate the installed energy consumption. We then calculated energy savings by comparing energy consumption for the baseline and for the installed energy-efficient condition.

Based on the study scope, Cadmus identified a sample of seven sites to include in the study. These included four new construction sites and three retrofit sites. These projects provided a representative cross-section of the complete set of nine participating facilities. However, given the significant load of each site, the load variations from year to year, and the unique characteristics of each project, we did not attempt to apply our findings to the remaining program participants.

Evaluation Activities and Findings

This section presents data collection activities, findings of engineering analyses, and calculation of realization rates. It also includes general observations regarding discrepancies and other factors influencing site-level realization rates. Appendix A includes a detailed discussion of each site-specific analysis and findings.

Initial Review

The Program requires that applicants provide an initial estimation of measure energy savings through a conventional spreadsheet model or an energy simulation model. In addition, the Program requires submitting an M&V plan for each measure, which may require pre- and post-metering. An M&V report must be submitted three months after the project's completion, documenting final operating conditions and any changes made to the original design. The M&V report also must be updated within 30 days of the end of each performance period before incentive payments can be issued.

To identify additional data needed to complete analysis, Cadmus performed an initial review of all documents provided by SVP for seven participating data center projects. SVP provided existing energy calculation spreadsheets, project summary reports, completed rebate application forms, M&V reports with available pre- and post- monitoring data, and energy models created for new construction projects.

Data Collection Activities

After the initial review of provided documents, Cadmus visited the seven data centers to verify measure installation, determine current operating conditions, collect additional data, and discuss the data center's performance since completion.

Cadmus determined the required M&V methodology and analysis rigor for each site based on several factors, including the original M&V approach selected by the implementer and SVP, the measure's complexity, the savings magnitude, and the trend data availability.

Table 3 summarizes the M&V approach we used for each project as well as the primary data used for our evaluation. These M&V approaches were based on standard M&V methods established by the IPMVP and cited in the CEC EM&V guidelines. We used Option A for all projects, except for one—Site 5, where we approved the original M&V approach selected for reported savings.

Table 3. Site-Specific M&V Approach and Primary Data Sources

Site	Methodology	Primary Data Source
Site 1	IPMVP Option A	Trend data and SVP baseline guidelines
Site 2	IPMVP Option A	Trend data and SVP baseline guidelines
Site 3	IPMVP Option A	Trend data and SVP baseline guidelines
Site 4	IPMVP Option A	Trend data and SVP baseline guidelines
Site 5	IPMVP Option C	Utility bills
Site 6	IPMVP Option A	Trend data and SVP baseline guidelines
Site 7	IPMVP Option A	Trend data and SVP baseline guidelines

Engineering Analysis

SVP specifies baseline conditions used to measure energy savings in the Program rebate application. For new facilities or major renovations, these include the following requirements and assumptions, in addition to the 2013 Title 24 requirements (as 2013 Title 24 was in effect for all the projects studied):

- Economizer cooling: either air or water-cooled economizers, depending upon the design of the HVAC system.
- HVAC equipment meets all applicable local, state, and federal building codes and appliance standards.
- No humidification controls.
- Chiller type: chillers sizes less than 150 tons, assume air cooled; chiller sizes equal to or greater than 150 tons, assume water cooled.
- Supply and return air temperatures: supply air temperature (SAT) between 55°F and 65°F, with no less than a 15°F difference between supply and return air temperatures.
- Consistent with 2013 Title 24 regulations, supply air fan efficiency during peak IT load operation must be equal to or less than 27 watts per kBtuh of sensible cooling delivered.
- Consistent with 2013 Title 24 regulations, supply air fans must have variable or two-speed control capable of achieving 50% design wattage at 66% fan speed.
- Space cooling loads less than 150 tons: assume computer room air conditioners (CRAC) with direct expansion (DX) cooling coils.
- Space cooling loads equal to or greater than 150 tons: assume computer room air handlers (CRAH) with chilled water coils.
- HVAC system oversizing and redundancy: certain limitations may apply.
- HVAC annual energy use estimate: estimated cooling energy use must be based on the actual heat release of the proposed IT servers. As an alternative, the estimated cooling energy load can be assumed as 62.5% of the total connected IT load downstream of the uninterrupted power supply (UPS).

- Chiller annual plant efficiency, including all pumps, cooling tower fans, and ancillary power: 0.67 kW/ton for a single chiller plant or 0.62 for a multiple chiller plant. Alternatively, annual energy use (or annual plant efficiency) can be determined by modeling the selected equipment's efficiency ratings, system design, and plant energy management control strategies.
- IT equipment: same equipment for standard and proposed designs.

For date center retrofit projects, the Program baseline includes the following requirements:

- No economizer cooling, unless already existing or required by Title 24.
- HVAC equipment meets all applicable local, state, and federal building codes and appliance standards.
- Supply and return air temperatures: same as existing system.
- CRAC/H units: model the same type and size as existing units, with unit efficiencies meeting current standards.
- HVAC system oversizing and redundancy: certain limitations may apply.
- HVAC annual energy use estimate: estimate annual energy consumption using the measured power consumption of the cooling equipment (for a minimum of four weeks of measured data). If estimating energy use of a system expansion (i.e., increased cooling load), estimated cooling energy use must be based on the actual heat release of the proposed IT servers. Alternatively, the estimated cooling energy load can be assumed as 62.5% of the total connected IT load downstream of the UPS.
- Chiller plant efficiency, including all pumps, cooling tower fans, and ancillary power: annual energy use (or annual plant efficiency) can be determined by modeling the existing equipment efficiency ratings, system design, and plant energy management control strategies. Alternatively, for water-cooled chillers, assume 0.71 kW/ton for a single chiller plant, or 0.67 for a multiple chiller plant; for air cooled chillers, assume 0.95 kW/ton for a single chiller plant, or 0.87 kW/ton for a multiple chiller plant.
- IT equipment: the same equipment for standard and proposed designs.

For new construction projects, Cadmus used SVP baseline requirements to calculate baseline energy consumption of equipment, accounting for IT loads achieved at each performance period. For retrofit projects, we used the baseline equipment manufacturer's specifications, operating conditions, and trend data (when available), along with SVP baseline requirements for retrofit projects, to calculate baseline energy consumption. For new construction and retrofit projects, we calculated installed energy consumption based on trend data provided by the customer for each performance period. We used the calculated annual energy consumption for the baseline and installed energy-efficient measures to calculate evaluated savings. Appendix A provides more detailed information on the analysis approach used for each project.

Impact Evaluation Results

Cadmus' impact evaluation calculated evaluated annual savings of 4,448,058 kWh and 508 kW for projects reviewed from program year (PY) 2013–2014, resulting in an energy savings realization rate of 99.9%. For PY 2014–2015, Cadmus evaluated total annual savings to be 4,525,935 kWh and 632 kW, resulting in an energy savings realization rate of 93%. For PY 2015–2016, we evaluated total annual savings to be 6,543,861 kWh and 759 kW, resulting in an energy savings realization rate of 99.9%.

Table 4 summarizes the results for each project and analysis details are presented for each project in Appendix A. Key observations from the site-specific evaluation results include the following:

- For Site 1, evaluated savings differed from reported savings for two reasons. First, the Program realized zero fan savings because actual fan power consumption exceeded program baseline requirements; second, greater available economizer cooling at installed conditions resulted in higher economizer savings.
- For Site 3, reported and evaluated savings primarily differed due to use of actual operating trend data provided by the facility (e.g., actual IT load, actual fan speed). Reported savings were based on actual trend data three months after project completion adjusted for the actual IT load achieved during each performance period (the end of year 1 and the end of year 2). Cadmus calculated the savings based on actual trend data for each performance period. This resulted in the same evaluated savings three months after project completion; lower evaluated savings at the end of year 1; and higher evaluated savings at the end of year 2.
- For site 4, the difference in reported and evaluated savings mostly resulted from the method used to normalize savings at each performance period based on the achieved IT load. Our review indicated that, at the end of year 1, the reported savings were based on multiplying actual logged data by the percent of design IT load achieved at this time. Adjusting the actual load was unnecessary and resulted in a reduced estimate of installed energy consumption and higher reported savings. We assume that this was an inadvertent result of an attempt to linearize the proposed savings. Cadmus revised the savings to use actual logged data (without adjustments for the load) to calculate installed usage at the end of year 1. This site had negative savings for PY 2014 – 2015. The primary reason for this is that the water-side economizer at part load used energy equivalent to a rate greater than 1kW/ton of load. This is not only higher for an economizer system, but is far higher than most water-cooled chillers.
- For Site 5, detailed calculations for proposed savings were not available on any installed measures and the proposed savings were based on utility bill analysis. Cadmus requested the chiller operation and pump speed trend data, but the site contact was unable to provide this information. We performed measure-by-measure custom calculations based on available data and estimated the realization rate at 47%. However, as we did not have actual trend data to verify our engineering analysis, we accepted the reported savings based on billing data. SVP confirmed that no other energy efficiency measures have been implemented at this facility, and the difference between the pre- and post-installation energy usage of the building, adjusted for

the IT load, represents an accurate estimate of energy savings realized through the project's implementation.

Table 4. Site-Specific Energy Savings

Site Number	Project Type	Reported *Energy* Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate
Sample Sites from PY 2013–2014				
Site 1	New Construction	Not initiated	Not initiated	N/A
Site 2	Retrofit	3,448,695	3,448,404	100%
Site 3	Retrofit	1,005,447	999,654	99%
Site 4	New Construction	0	0	N/A
Site 5	Retrofit	Not initiated	Not initiated	N/A
Site 6	New Construction	Not initiated	Not initiated	N/A
Site 7	New Construction	Not initiated	Not initiated	N/A
Total		**4,454,142**	**4,448,058**	**99.9%**
Sample Sites from PY 2014–2015				
Site 1	New Construction	Not initiated	Not initiated	Not initiated
Site 2	Retrofit	3,334,205	3,334,200	100%
Site 3	Retrofit	1,005,447	914,048	91%
Site 4	New Construction	205,447	(49,846)	-24%
Site 5	Retrofit	Not initiated	Not initiated	N/A
Site 6	New Construction	327,533	327,533	100%
Site 7	New Construction	Not initiated	Not initiated	N/A
Total		**4,872,632**	**4,525,935**	**93%**
Sample Sites from PY 2015–2016				
Site 1	New Construction	345,128	283,709	82%
Site 2	Retrofit	0	0	0
Site 3	Retrofit	1,042,637	1,127,121	108%
Site 4	New Construction	670,842	311,247	46%
Site 5	Retrofit	2,429,105	2,429,105	100%
Site 6	New Construction	0	0	N/A
Site 7	New Construction	2,063,979	2,392,679	116%
Total		**6,551,691**	**6,543,861**	**99.9%**

Conclusions and Recommendations

Based on our experience, the 2013–2016 Data Center Program's evaluated energy-impact realization rates for the projects analyzed (99.9%, 93%, and 99.9% for PY 2013–2014, PY 2014–2015, and PY 2015–2016, respectively) are well above average for a program that involves custom engineering analysis and complex technologies. The implementation team followed recommendations from previous evaluation reports, redesigning the program to pay incentives based on a facility's actual operating loads. It appears that the program is implemented effectively, with the required M&V practices providing accurate results overall.

During our evaluation, Cadmus made several observations that provided insights on ways to fine-tune the program and its savings estimation to ensure its continuing success and effectiveness. Key evaluation findings and recommendations include the following:

- Reported savings were adjusted savings for all projects proportionately based on the verified IT load at the end of each performance period. This approach assumes that savings are linearly related to the IT load, which is a useful approach for simplifying the analysis, but might not be completely accurate in real world conditions. We understand that SVP used this approach to streamline the program. When the data are available, Cadmus recommends using the actual operational data to adjust the savings at each performance period. In some cases, actual savings will be greater than a linear estimation, but in other cases, they will be negative, as the retrofit system is not operating efficiently. It is also important when actual post installation energy use is directly metered that this value not be adjusted for IT load since it is an actual energy use and already reflects actual operating conditions.
- Based on the rebate application forms, customers must provide trend data for supply and return air temperatures and trends, or instantaneous IT power data. However, these data may not be sufficient to perform custom engineering analysis for complex projects. Data center facilities are usually capable of logging and archiving additional facility operating parameters. Cadmus recommends expanding the program's trend data requirements to include trend data for all equipment involved in the project (e.g., fan speed, pump speed, chiller plant operating parameters). The trend data requirements should be developed based on site-specific M&V plans for complex projects before each application is finalized and incentives paid by the program.
- SVP provided a tracking database that listed completed projects, project completion dates, and kWh savings for each project. Cadmus verified the kWh savings using the rebate application forms and savings analysis, and found reported values in the tracking database were accurate. Cadmus recommends that SVP expand the tracking database to include incentive amounts paid at each performance period, kW savings, and program year to support future evaluations and more accurate savings reporting.
- Increasingly efficient baselines make saving energy in data centers particularly newly constructed ones, a challenge. Challenges include:

- The need to operate a minimum airflow for a desired subfloor static pressure. Where this minimum static pressure is in fact required, fan savings may be less than estimated.
- Liquid cooling systems have numerous required components including pumps and fans. It appears from our review of Site 4, that the system was operating above 1 kW/ton, far worse than a liquid cooled chiller, and not the result anticipated from an economizer. These systems should be reviewed to confirm that they can exceed the performance of a code compliant air-side economizer.

Appendix A. Site Reports

Site 1[1]

Facility and Project Description

This project is a new data center module with a 3 MW design IT load. This data center module is conditioned by an existing water-cooled chilled water plant that serves other areas of the data center. As part of the project, 13 new CRAH units were installed in this module. These CRAH units are equipped with variable speed drives, and IT equipment racks are arranged in a cold aisle layout. With cold aisle containment, the project proposed to operate this module at elevated supply and return air temperatures of 75°F and 92°F, respectively. The elevated SAT allows for extended economizer operation, which produces energy savings.

Reported Savings

The original reported savings calculation used a bin method to compare baseline and as-built operating parameters (e.g., air temperatures, air flow, fan power). These operating parameters were calculated based on program baseline guidelines and equipment design specifications. The original reported savings calculations assumed the IT load to be 65% of the design IT load (1.95 MW of 3 MW). Total energy savings were estimated to be 1,864,266 kWh for this load.

Three months after project completion, SVP verified the IT load to be 361 kW (about 18.5% of the assumed IT load of 1.95 MW in the original calculations). Therefore, SVP adjusted the final savings associated with the first incentive payment to be 18.5% of the original reported savings, for a total of 345,128 kWh.

This project implemented a single energy efficiency measure (described below), intended to produce both fan and cooling plant energy savings.

Measure 1: Raise Data Center Supply and Return Air Temperatures

Fan Savings

Fan energy savings were predicted based on reduced air flow requirements, resulting from larger temperature deltas between the return and SAT. SVP adjusted the original reported energy savings for this component (based on the verified IT load) to 115,766 kWh.

Central Cooling Plant Savings

Central cooling plant savings were predicted from extended economizer operation resulting from an increased SAT setpoint on the CRAH units. This stands in comparison to baseline program requirements of a SAT setpoint to be 55°F. SVP adjusted the original reported energy savings for this component based on a verified IT load to be 229,362 kWh.

Table 5 shows the adjusted reported savings estimates.

1 Rebate application numbers R16-DCR-0033 and R16-DCR-0035.

Table 5. Adjusted Reported Savings

	Reported Baseline Energy (kWh)	Reported Proposed Energy (kWh)	Reported Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	556,259	211,131	345,128

The reported 345,128 kWh savings include 115,766 kWh for fan savings and an additional 229,362 kWh for central chilled water plant savings.

Evaluation Activities

Data Collection and Baseline Establishment

On November 23, 2016, Cadmus visited the site to verify measure installations and current operating conditions, and to discuss the data center's performance since completion.

Cadmus observed that the central cooling plant consists of five chillers (one 1,500-ton variable speed chiller and four 1,200-ton single speed chillers). The plant operates with a trim compressor and a chilled water temperature (CHWT) setpoint of 51°F. This is a low temperature for a SAT of 70°F, and very low from the planned SAT of 75°F. There could be more savings if the CHWT could be raised. The condenser operates at a minimum condensing temperature of 65°F. Auxiliary equipment also are equipped with variable speed drives.

We observed that thirteen (13) new CRAH units were installed in the new data center module. Each CRAH has four 6-hp fans that operate in parallel and are controlled by one variable speed drive.

During the site visit, Cadmus observed that the data module operated in economizer mode, with the SAT set at 70°F (lower than the proposed SAT). During the site visit, the IT load was 1,672 kW, or nearly five times the load that SVP previously verified, showing that the data center is being filled up. This load is about 83% of the load assumed in the savings calculations.

Energy Savings Calculations

Cadmus estimated evaluated savings by calculating annual energy consumption for the baseline and for the proposed energy-efficient conditions at the verified IT load. Cadmus used standard engineering formulas, data collected on site, and information on operating requirements from the site's engineering team.

Measure 1: Raise Data Center Supply and Return Air Temperatures

Fan Savings

Based on our evaluation, fan savings are not realized because all of the fans are operated at nearly 90% speed. Cadmus verified a connected IT load of about 361 kW (i.e., 12% of the design IT load) when incentives were paid. At this facility, operators indicated that they needed to operate 5 CRAH units at about 90% speed to maintain under-floor pressure even when the load was low. This was confirmed by trend data of fan speed.

SVP prorated the original reported savings, based on the proportion of the design IT load actually achieved during the verification stage. Based on actual fan power consumption data, however, we observed that the fans were operated at nearly full load.

As it is likely that facility operators would have operated the same number of CRAH units in the absence of this measure to raise supply and return air temperatures, Cadmus did not apply an energy penalty to this measure.

Central Cooling Plant Savings

Cadmus estimated savings from extended economizer operation to be 283,709 kWh, higher than the reported energy savings of 229,362 kWh.

The reported savings assumed baseline supply and return air temperatures of 55°F and 70°F, respectively (a temperature difference of 15°F across the CRAH unit coils) to calculate the amount of cooling load provided by outside air for the baseline scenario. We assumed the baseline system has the same air-flow requirements as the installed system,[2] with a baseline SAT of 55°F. Based on this temperature, the required airflow, and the IT load, Cadmus calculated the baseline return air temperature at 63°F—lower than the assumed baseline of 70°F.

As return air temperature decreases, the temperature at which economizer operation will save energy correspondingly decreases. Therefore, we used the calculated return air temperature of 63°F to calculate the amount of cooling load provided by the economizer, which resulted in higher baseline usage and higher energy savings.

Total Evaluated Savings

As shown in Table 6, Cadmus calculated evaluated energy savings at 283,709 kWh, which includes 0 kWh for fan savings and 283,709 kWh for central cooling plant savings.

Table 6. Evaluated Savings

	Evaluated Baseline Energy (kWh)	Evaluated Proposed Energy (kWh)	Evaluated Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	1,137,646	853,937	283,709

[2] Air flow requirement of the installed system was calculated based on the fan speed trend data.

Final Results

Table 7 presents reported and evaluated energy savings and realization rates. Cadmus also estimated peak demand savings for the first payment at 25.7 kW (as shown in Table 8). We calculated peak demand savings based on the difference between the amount of cooling load provided by the economizer for the baseline and installed scenarios between June 1 and September 30, on weekdays between 2:00 PM and 5:00 PM.[3]

Table 7. Final Energy Savings Results (kWh)

	Reported Energy Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	345,128	283,709	82%

Table 8. Final Demand Savings Results (kW)

	Reported Demand Savings (kW)	Evaluated Demand Savings (kW)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	0	25.7	N/A

Findings from the evaluations include:

- No fan savings were realized as installed power consumption exceeded program baseline assumptions. This resulted from low system loads, requiring a minimum number of CRAH units to operate for maintaining underfloor plenum pressure.
- The system operating at low partial loads contributed to an increased baseline cooling consumption when compared to assumptions made in the reported savings calculations. This resulted from a smaller CRAH temperature delta (return air temperature - SAT) reduced the amount of baseline cooling load provided by an economizer.

[3] Based on the Technical Reference Manual for the California Municipal Utilities Association.

Site 2[4]

Facility and Project Description

This retrofit project involves retrofitting 53 dual-fan CRAH units with electronically commutated (EC) fans with fan speeds controlled based on underfloor static pressure. The data center is set up in a hot aisle/ cold aisle layout, but based on project description the baseline system was not balanced and over-delivered air. The project rebalances the airflow based on the actual server load. Wireless temperature sensors also were installed in cold aisle containment to control chilled water valves based on the cold aisle temperature. The room temperature set point was raised from 70°F to 75°F. Increasing the SAT setpoint enabled the facility to increase the chilled water temperature set point from 46°F to 52°F for optimized cooling plant performance.

The central plant consists of six 400-ton air-cooled chillers and three VSD chilled water pumps.

Reported Savings

Reported savings used existing fan nameplate data and post-installation fan speed trend data to estimate energy savings associated with the fans. The implementer provided pre- and post-chiller operating performance data to demonstrate efficiency gains from increasing the chilled water temperature setpoint. The overall reported energy savings for payment one and two are 3,448,695 kWh and 3,334,205 kWh, respectively.

Measure 1: Fan Optimization

For this project, fan energy savings were expected to result from reduced fan speeds, achieved by installing EC fans to control fan speeds, based on underfloor pressure. Savings were relative to baseline 51 CRAH units (out of 53 units), operating continuously at a constant speed. Each existing CRAH unit was equipped with two 7.5-hp supply fans that ran continuously.

Measure 2: Chilled Water Temperature Setpoint Adjustments

Central cooling plant savings for this project were expected through increasing chilled water temperature setpoints from 46°F to 52°F. Increasing these setpoints will allow chillers to operate at reduced compression ratios while still satisfying air temperature setpoints required to maintain space temperatures.

Table 9 shows the reported savings.

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[4] Rebate application numbers R14-DCR-0142 and R14-DCR-0142-2.

Table 9. Reported Savings

	Reported Baseline Energy (kWh)	Reported Proposed Energy (kWh)	Reported Savings (kWh)
2013–2014 (3 months after project completion)	9,970,462	6,521,767	3,448,695
2014–2015 (end of year 1)	9,437,859	6,103,654	3,334,205
2015–2016 (end of year 2)	0	0	N/A

Evaluation Activities

Data Collection and Baseline Establishment

On December 8, 2016, Cadmus visited the site to verify measure installations, verify current operating conditions, and discuss the data center's performance since completion.

Cadmus observed that four of the six chillers operated during the site visit, delivering chilled water at a temperature setpoint of 52°F. We also observed that 51 CRAH units remained in operation during the site visit. Though the SAT setpoint varied between units, we observed that temperature deltas across CRAH units were more than 20°F. Per project documentation, temperature deltas across the CRAH units ranged from 10°F to 12°F before project implementation.

Cadmus collected nameplate data for CRAH units, all of which were CRAH units of the same size, were previously equipped with two operating 7.5-hp supply fans. These units were not equipped with air-side economizers

Energy Savings Calculations

Cadmus estimated the evaluated savings by calculating annual energy consumption for the baseline and for the proposed energy efficient condition at the verified IT load. We used standard engineering formulas, data collected on site, and information on operating requirements from the site's engineering team. The evaluated calculation methodology used the same approach as reported savings.

Measure 1: Fan Optimization

Cadmus calculated fan savings based on installed fan speed trend data and spot power measurements provided by the facility. We performed regression analysis on the spot power measurement data to calculate equation coefficients of the fan performance curve. The performance curve outputs represented fan power as a function of fan speed. For the baseline case, all fans operated at full speed.

As the data center operates 8,760 hours per year, we used the fan performance curve to calculate demand savings, based on the average power usage of fans before and after project implementation.

For the first payment (three months after project completion), the difference between reported and evaluated fan savings was marginal, due to different regression coefficients estimated for the relationship between fan operating speeds and power performance.[5]

For the second payment (end of year 1), the difference between reported and evaluated fan savings also was marginal, again due to slightly different regression coefficients.

Measure 2: Chilled Water Temperature Setpoint Adjustments

Cadmus calculated central cooling plant savings based on actual chiller operating performance data (i.e., chiller plant total kW, chilled water supply and return temperatures) prior to and after project implementation. We normalized savings based on actual IT loads at the time of incentive payment.

As the data center operates 8,760 hours per year, we used the average power usage of the central cooling plant to calculate demand savings.

For the first payment (three months after project completion), reported and evaluated savings associated with this measure were the same.

For the second payment (end of year 1), reported and evaluated savings associated with this measure also were the same.

Total Evaluated Savings

As shown in Table 10, Cadmus evaluated energy savings for the first and second payments to be 3,448,404 kWh and 3,334,200 kWh. The marginal difference in savings resulted from different regression coefficients applied between the fan operating speeds and power performance.

Table 10. Evaluated Savings (kWh/yr)

	Evaluated Baseline Energy (kWh)	Evaluated Proposed Energy (kWh)	Evaluated Savings (kWh)
2013–2014 (3 months after project completion)	9,970,094	6,521,690	3,448,404
2014–2015 (end of year 1)	9,437,859	6,103,659	3,334,200
2015–2016 (end of year 2)	0	0	N/A

Final Results

Table 11 presents reported and evaluated energy savings and realization rates. Cadmus also estimated peak demand savings for the first and second payments to be 394 kW and 381 kW, as shown in Table

5 The differences resulted from rounding the estimated coefficients.

12.[6] The project achieved energy savings realization rates of 100% both years. As demand savings values were not available for this project, we could not calculate the demand savings realization rate.

Table 11. Final Energy Savings Results (kWh/yr)

Site 2	Reported Savings	Evaluated Savings	Realization Rate
2013–2014 (3 months after project completion)	3,448,695	3,448,404	100%
2014–2015 (end of year 1)	3,334,205	3,334,200	100%
2015–2016 (end of year 2)	0	0	N/A

Table 12. Final Demand Savings Results (kW)

Site 2	Reported Demand Savings	Evaluated Demand Savings	Realization Rate
2013–2014 (3 months after project completion)	Not Reported*	394	N/A
2014–2015 (end of year 1)	Not Reported	381	N/A
2015–2016 (end of year 2)	0	0	N/A

*Demand saving was not available for this project.

6 We calculated the demand savings based on actual trend data.

Site 3[7]

Facility and Project Description

This retrofit project involves retrofitting 56 CRAH units with EC fans to control the fan speed, based on underfloor static pressure. The data center is set up in a hot aisle/cold aisle containment layout, and the existing 56 CRAH units are equipped with EC fans, but the baseline system was not balanced and over-delivered air. The facility installed new floor tiles to minimize the amount of bypass air flow, increased the space temperature setpoint, and rebalanced the air flow to match the actual server load. In addition, wireless temperature sensors were installed in cold aisle containment to control the chilled water valve, based on cold aisle temperatures. Increasing the air temperature setpoint enabled the facility to increase chilled water temperature setpoints from 46°F to 53°F for optimized cooling plant performance.

The facility installed EC fans on two additional CRAH units used for the node room. The central plant consists of three 525-ton water-cooled chillers.

Reported Savings

Reported savings used existing fan nameplate data and fan speed trend data to estimate energy savings associated with the fans. The implementer provided pre- and post-project implementation chiller operating performance data to demonstrate efficiency gains from increasing chilled water temperature setpoints. Overall reported energy savings for payments one, two, and three are 1,005,447 kWh, 1,005,447 kWh, and 1,042,637 kWh, respectively.

Measure 1: Fan Optimization

For this project, fan energy savings were expected to result from reduced fan speeds due to balancing air flow and installing new floor tiles to minimize the bypass flow. Based on project documentation, the baseline system was set up in a cold aisle containment layout. However, the system was not balanced and over-delivered cold air into the aisle to ensure reliable operations. This over-delivery decreased the overall efficiency of the cooling system as excess fan energy was used to move additional volumes of air.

Measure 2: Chilled Water Temperature Setpoint Adjustments

Central cooling plant savings for this project were expected through increasing the chilled water temperature setpoints of the chillers from 46°F to 53°F. Increasing these setpoints allows chillers to operate at a reduced compression ratios, while still satisfying air temperature setpoints required to maintain space temperatures.

Table 13 shows the reported savings estimates.

[7] Rebate application numbers R14-DCR-0117, R15-DCR-0117-2, and R16-DCR-0117-3.

Table 13. Reported Savings

	Reported Baseline Energy (kWh)	Reported Proposed Energy (kWh)	Reported Savings (kWh)
2013–2014 (3 months after project completion)	6,511,702	5,506,256	1,005,447
2014–2015 (end of year 1)	6,511,702	5,506,256	1,005,447
2016–2017 (end of year 2)	6,511,702	5,469,065	1,042,637

Evaluation Activities

Data Collection and Baseline Establishment

On December 8, 2016, Cadmus visited the site to verify measure installations and current operating conditions, and to discuss the data center's performance since completion.

Cadmus found the three 525-ton water-cooled chillers operated at a temperature setpoint of 53°F, as proposed. We observed 56 CRAH units operated during the site visit. The SAT setpoint varied between units; however, temperature deltas across CRAH units were around 20°F or more. Per project documentation, temperature deltas across the CRAH units were 12 to 15°F before project implementation.

Cadmus collected nameplate data for the CRAH units, which were all the same size and were equipped with two operating 10-hp supply fans. These units did not have an ability for air-side economization.

Energy Savings Calculations

Cadmus estimated the evaluated savings by calculating annual energy consumption for the baseline and for the proposed energy efficient condition at the verified IT load. Cadmus used standard engineering formulas, trend data provided in the project documents, information collected on site, and information on operating requirements from the site's engineering team. The evaluation calculation methodology used the same approach as the reported savings.

Measure 1: Fan Optimization

Cadmus calculated fan savings based on installed fan speed trend data and spot power measurements provided by the facility. We performed regression analysis on the spot power measurement data to calculate the equation coefficients of the fan performance curve. The performance curve outputs represented fan power as a function of fan speed. For the baseline case, we assumed all fans operated at full speed.

As the data center operates 8,760 hours per year, we used the fan performance curve to calculate demand savings, based on average power usage of the fans before and after project implementation.

For the first payment (three months after project completion), the difference between the reported and evaluated fan savings was marginal due to different regression coefficients applied between the fan operating speeds and power performance.[8]

For the second payment (end of year 1), Cadmus evaluated fan savings less than reported fan savings due to CRAC units in zone 6 operating at 100% speed compared to an average of 46% speed during the first payment verification period.

For the third payment (end of year 2), Cadmus evaluated the overall operating speed of CRAH fans to be lower than that reported. This resulted in additional fan savings.

Measure 2: Chilled Water Temperature Setpoint Adjustments

Cadmus calculated the central cooling plant savings based on actual chiller operating performance data (i.e., chiller plant total kW, chilled water supply, and return temperatures) prior to and after project implementation. We normalized the savings based on the actual IT load at the time of incentive payments.

As the data center operates 8,760 hours per year, we used the average power usage of the central cooling plant to calculate demand savings.

For the first payment (three months after project completion), reported and evaluated savings associated with this measure were the same.

For the second payment (end of year 1), Cadmus evaluated savings associated with this measure to be higher than reported savings due to higher IT loads for this period. We adjusted evaluated savings based on the actual IT load.

For the third payment (end of year 2), the difference between the reported and evaluated fan savings was marginal.

Total Evaluated Savings

Cadmus evaluated energy savings for first, second, and third payments to be 999,654 kWh, 914,048 kWh, and 1,127,121 kWh, as shown in Table 14.

Table 14. Evaluated Savings (kWh/yr)

	Evaluated Baseline Energy (kWh)	Evaluated Proposed Energy (kWh)	Evaluated Savings (kWh)
2013–2014 (3 months after project completion)	6,511,702	5,512,048	999,654
2014–2015 (end of year 1)	7,197,703	6,283,655	914,048
2015–2016 (end of year 2)	6,523,712	5,396,591	1,127,121

8 The differences in the coefficients were due to rounding.

Final Results

Table 15 presents reported and evaluated energy savings and realization rates for each payment period. Realization rates ranged from 91% to 108%.

Table 16 presents evaluated peak demand savings, reported demand savings, and realization rates. Demand realization rates ranged from 96% to 105%.

Table 15. Final Energy Savings Results (kWh/yr)

	Reported Energy Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate
2013–2014 (3 months after project completion)	1,005,447	999,654	99%
2014–2015 (end of year 1)	1,005,447	914,048	91%
2015–2016 (end of year 2)	1,042,637	1,127,121	108%

Table 16. Final Demand Savings Results (kW)

	Reported Demand Savings (kW)	Evaluated Demand Savings (kW)	Realizatio n Rate
2013–2014 (3 months after project completion)	114.8	114.1	99%
2014–2015 (end of year 1)	114.8	121.1	105%
2015–2016 (end of year 2)	119	114.2	96%

The evaluation produced the following key findings:

- The reported savings and M&V methodology were appropriate for this project. The difference in reported and evaluated savings mostly resulted from utilization of actual operating data for the facility (e.g., actual IT load, actual fan speed).

Site 4[9]

Facility and Project Description

This project is a new 3,000 square foot data center, with a 600 kW design IT load. The project involves installing a water-side economizer system, consisting of three cooling towers, associated pumps, and two heat exchangers to deliver cooled water to radiant tubes within each server rack. The standard baseline design for space cooling loads greater than 150 tons calls for CRAH units with chilled water coils.

Although this system serves as the primary method to maintain server temperatures, three rooftop packaged units are also used to cool the data center space. Though the facility has an electrical room served by CRAC units, this space is not included in this project.

Reported Savings

Reported savings were based on an Energy Pro model to estimate energy savings of 910,720 kWh at the design IT load. Based on the Energy Pro model, estimated baseline and installed energy consumption were 1,249,012 kWh and 338,292 kWh, respectively.

For the first payment (three months after project completion), the facility did not claim any energy savings since there was no IT load during this period.

For the second payment (end of year 1), reported savings used the sub-metered power data of the water-side economizer system to calculate installed energy usage. The reported savings were then calculated based on the difference between Energy Pro full-load baseline usage and actual installed usage, adjusted for connected IT load.

For the third payment (end of year 2), reported savings were estimated by adjusting the full-load Energy Pro model savings with the IT load during the corresponding time period. The water-side economizer system was not metered for this period.

Measure 1: Water-side Economizers

Energy savings were expected to result from cooling server racks utilizing a water-side economizer system with no mechanical compression and no distribution fan. Based on SVP guidelines, the baseline cooling system for cooling loads greater than 150 tons consists of CRAH units with chilled water coils and air or water-side economizers. Installing the water-side economizer system was expected to produce compressor and fan energy savings.

Table 17 shows adjusted reported savings estimated using the Energy Pro model, adjusted for actual IT loads.

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9 Rebate application numbers R14-DCR-0109, R14-DCR-0109-2, and R14-DCR-0109-3.

Table 17. Adjusted Reported Savings

	Adjusted Reported Baseline Energy (kWh)	Adjusted Reported Proposed Energy (kWh)	Adjusted Reported Savings (kWh)
2013–2014 (3 months after project completion)	0	0	0
2014–2015 (end of year 1)	353,887*	148,440	205,447
2015–2016 (end of year 2)	1,155,542**	484,700	670,842

*This is the adjusted Energy Pro baseline usage based on the actual IT load.

**This is the adjusted Energy Pro baseline usage based on the actual IT load.

Evaluation Activities

Data Collection and Baseline Establishment

On December 8, 2016, Cadmus visited the site to verify the measure installation, verify current operating conditions, and discuss the data center's performance since completion.

During the site visit, Cadmus verified installation of the following equipment (equipment specifications were collected from permit drawings provided by the site contact):

- Three 325-ton BAC cooling towers equipped with variable speed drives (VSDs)
- Three 30-hp cooling tower pumps
- Two 75-hp heat exchanger pumps equipped with VSDs
- Two 800-ton plate and frame heat exchangers
- Two 7.5-ton and one 4-ton Trane rooftop packaged units

Cadmus discussed the sub-metering data provided for two electrical panels (HDB1 and H5) with the site contact. We reviewed the as-built electrical drawings on site and confirmed that the HDB1 panel includes all equipment noted above that pertains to the project. Panel H5 is for the electrical room, which is not included in this project's scope.

The server racks also use DX compressors that would operate if the proposed cooling system could not provide sufficient cooling loads. However, based on our conversations and on information provided by the design engineer and site contact, these compressors are not expected to operate often. Based on the current IT load and available cooling capacity, it is reasonable to assume these compressors will not operate.[10]

[10] This assumption must be verified with weather data at full load capacity, but, with the current IT load, this is a reasonable assumption.

Energy Savings Calculations

Cadmus estimated the evaluated savings by calculating annual energy consumption for the baseline and for the proposed energy efficient condition at the verified IT load. We used standard engineering formulas, data collected on site, and information on operating requirements from the site's engineering team.

Measure 1: Water-side Economizers

For the first payment (three months after project completion), zero energy savings were claimed for the project as there was no IT load.

For the second payment (end of year 1), the adjusted reported savings were calculated using the following equation:

> Adjusted energy savings = (Energy Pro baseline usage at design IT load – actual installed usage) x (actual IT load/ design IT load)

Using the equation above discounts the actual part load by applying the ratio of actual IT load to design IT load. Given that the actual IT load was measured, adjusting it for part load conditions is unnecessary. Multiplying the actual part load by the ratio of part load to design load underestimates the actual usage at part load. To use this basic approach to adjust savings for part-load operation, Cadmus recommends using the equation below, which does not discount the actual part-load usage:

> Adjusted energy savings = (Energy Pro baseline usage at design IT load x (actual IT load/ design IT load)) – actual installed usage

Cadmus did not use the Energy Pro baseline to evaluate savings, but used a temperature bin analysis to calculate baseline usage, based on SVP guidelines for the baseline system. We used actual logged data to calculate the installed usage at the end of year 1. This resulted in negative savings primarily due to a low IT load (175 kW) and a designed system that is not capable of operating efficiently at low load when compared to the baseline.[11] Based on the logged data, the installed water-side economizer system has an efficiency value of greater than 1 kW/ton, which is high when compared to the baseline chilled-water system operating at the same partial load.

For the third payment (end of year 2), Cadmus evaluated the energy savings as lower than the reported savings. This occurred primarily because the equation shown above for adjusting partial load consumption discounted the actual load in year 2, overestimating the savings.

Total Evaluated Savings

Cadmus evaluated energy savings for the first, second, and third payment periods to be 0 kWh, -49,846 kWh, and 311,247 kWh, as shown in Table 18.

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[11] One other factor that made a smaller contribution to negative savings is the continuous operation of the constant-volume rooftop packaged units serving the data center space.

Table 18. Evaluated Savings

	Evaluated Baseline Energy (kWh)	Evaluated Proposed Energy (kWh)	Evaluated Savings (kWh)
2013–2014 (3 months after project completion)	0	0	0
2014–2015 (end of year 1)	466,750	516,596	-49,846
2015–2016 (end of year 2)	964,651	653,403	311,247

Final Results

Table 19 presents reported and evaluated energy savings and realization rates. Cadmus also estimated peak demand savings for the first, second, and third payments at be 0 kW, 0.5 kW, and 48.3 kW,[12] as shown in Table 20.

The project achieved energy savings realization rates of -24% for the second payment and 46% for the third payment periods, relative to reported energy saving estimates. For demand savings, the project achieved a realization rate of 1% for the second payment period. Demand savings for the third payment were not reported.

Table 19. Final Energy Savings Results (kWh)

	Reported Energy Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate
2013–2014 (3 months after project completion)	0	0	N/A
2014–2015 (end of year 1)	205,447	-49,846	-24%
2015–2016 (end of year 2)	670,842	311,247	46%

Table 20. Final Demand Savings Results (kW)

	Reported Demand Savings (kW)	Evaluated Demand Savings (kW)	Realization Rate
2013–2014 (3 months after project completion)	0	0	100%
2014–2015 (end of year 1)	59.8	0.5	1%
2015–2016 (end of year 2)	Not Reported	48.3	N/A

The evaluations produced the following key findings:

- The installed water-side economizer system has an efficiency of greater than 1 kW/ton while operating at low partial load an efficiency that is worse than operating a chiller instead of an

[12] Cadmus calculated demand savings based on economizer operations between June 1 and September 30, on weekdays between 12:00 PM and 7:00 PM.

economizer. We expect the system will operate more efficiently once the load increases; however, the operation of the liquid cooled economizer should be checked for turn down ratio.

Site 5[13]

Facility and Project Description

This retrofit project involves installing the following measures in the facility's main data center space:

- Removing humidifiers located inside the CRAC units
- Installing VSDs on condenser and chilled water pumps
- Installing hot aisle containment and increasing SAT setpoints to 70°F
- Improving chilled water plant operating efficiency by increasing chilled water supply temperature setpoints from 40°F to 46°F

The main data center's design IT load is 1,300 kW, based on the total power output of power distribution units (PDUs) serving the main data center. Three primary areas are located within the main data center served by the same central cooling plant. Descriptions of all areas and their project measures following:

- Area 1: This area is served by 17 CRAC units for a total cooling capacity of 366 tons (fourteen 24-ton units and three 10-ton units). These are water-cooled units not equipped with VSDs and without air-side economizers. Hot aisle containment was implemented in this area.
- Area 2: This area is served by six 44-ton CRAH units for a total cooling capacity of 264 tons. These are water-cooled units not equipped with VSDs and without air-side economizers. Hot aisle containment was implemented in this area.
- Area 3: This area is served by four 24-ton CRAC units for a total cooling capacity of 96 tons. These are water-cooled units not equipped with VSDs and without air-side economizers. No hot aisle containment was implemented in this area.

The central cooling plant consists of the following equipment:

- Two water-cooled 225-ton chillers with six compressors each
- Three BAC cooling towers with a total heat rejection capacity of 1,520 tons (two 480-ton and one 560-ton units)
- Four 15-hp condenser water pumps for CRAC units
- Three 20-hp condenser water pumps for chillers
- Three 30-hp chilled water pumps that deliver chilled water to the CRAH units

Everything in the central plant is currently equipped with VSDs, except for the chillers.

[13] Rebate application number R16-DCR-0025.

Reported Savings

Reported savings were based on three months of pre-installation and three months of post-installation sub-metered data of the PDUs and total data center energy use from utility bills to estimate the facility's power usage effectiveness[14] (PUE) before and after project implementation. The calculated pre and post PUEs were used to estimate savings for three months and were then extrapolated to the entire year. Reported annual energy savings and demand savings are 2,429,105 kWh and 277 kW, respectively.

SVP provided the original calculations that resulted in higher savings than reported savings (3,280,047 kWh). However, SVP revised the original savings by using billing analysis in the absence of better data to perform measure-by-measure analysis. Supply and return air temperature trend data and PDU outputs were the only information provided by the facility.

Measure 1: Humidifier Removal

Based on project documentation, at a 70°F server inlet temperature in Santa Clara, relative humidity will never drop below the ASHRAE allowable limit of between 20% and 80%.[15] Therefore, the project proposed removing the existing humidifiers. The existing CRAC and CRAH units are equipped with electric humidifiers rated at 12.9 amp and 11.6 amp, respectively. Based on project description provided by the site contact, six CRAC/CRAH units were in continuous humidification mode. Energy savings were expected through disabling the electric humidifiers in all units.

Based on temperature trend data provided by the facility, the average SATs in Area 1, 2, and 3 are 62°F, 52°F, and 52°F, respectively.

Measure 2: VSD Installation on Pumps

Three sets of pumps serve the central utility plant (as described in the project description section). Based on project documentation, in the baseline scenario, all pumps operated continuously. The project proposed installing VSDs on all 10 chilled water and condenser water pumps.

Measure 3: Air Flow Management

This measure consists of installing blanking panels in unsealed floor openings as well as installing hot aisle containment to improve air circulation through the servers. This will enable the facility to increase the SAT of the CRAC/CRAH units and the temperature differences between supply and return air to improve cooling performance and to reduce the number of CRAC/CRAH units operating.

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14 PUE is the ratio of total amount of energy used by the data center to the energy delivered to IT equipment.

15 For class A1 data centers and dry bulb temperature between 59°F and 95°F, the allowable humidity range is between 20% and 80% relative humidity.

Measure 4: Chilled Water Temperature Setpoint Adjustments

Central cooling plant savings were expected through increasing the chilled water temperature setpoints from 40°F to 46°F. This increase will allow the chillers to operate at reduced compression ratios, while still satisfying air temperature setpoints required to maintain space temperatures.

Table 21 summarizes reported energy savings (not disaggregated among different measures).

Table 21. Reported Savings

	Reported Baseline Energy (kWh)	Reported Proposed Energy (kWh)	Reported Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2016–2017 (3 months after project completion)	Not Provided*	Not Provided	2,429,105

*SVP used billing analysis of 3 months prior and after the project implementation. Total baseline and proposed energy consumptions were not available to Cadmus.

Evaluation Activities

Data Collection and Baseline Establishment

On December 6, 2016, Cadmus visited the site to verify measure installation, verify current operating conditions, and to discuss the data center's performance since completion. Cadmus observed that the central plant equipment matches the project description.

Based on project documentation, only one chilled water pump and one condenser pump are required to operate when only one chiller operates. However, we observed all pumps operating at near full speed when only one chiller was running. Based on this, it appears the proposed control sequence of the pumps was not commissioned properly. SVP will be following up on proper installation and commissioning of this measure. Proof of commissioning and proper operation will be required for future payments on this project.

We also observed that two CRAC units were turned off during the site visit due to implementing the air-flow management measure.

Energy Savings Calculations

Cadmus estimated the evaluated savings by calculating annual energy consumption for the baseline and for the proposed energy-efficient condition at the verified IT load. Cadmus used standard engineering formulas, data collected on site, and information on operating requirements from the site's engineering team. Because the reported savings used a billing analysis approach for this project, we could not compare reported and evaluated savings on a measure-by-measure basis. [16]

Measure 1: Humidifier Removal

Cadmus observed that the original humidifiers were removed. We calculated the SATs of CRAC units to be 62°F and 58°F in the areas where humidifiers were removed.

We calculated savings based on the number of humidifiers operating before project implementation and the power rating of humidifiers collected on site. Based on project description provided by the site contact, six humidifiers ran continuously prior to project implementation. Evaluated savings for this measure are 469,858 kWh—the maximum savings that could be achieved, given it assumes 8,760 operation at full capacity.

Baseline humidity control was not centralized, which can cause inefficient operation if one unit is humidifying while a nearby unit is dehumidifying. This might have resulted in high usage in the baseline case.

Measure 2: VSD Installation on Pumps

Cadmus observed that all pumps operated at nearly full speed during the site visit. Based on our conversation with the site contact, it appears the proposed VSD measures were not commissioned correctly. We calculated savings based on the VSD speed of each pump collected on site. As the IT load is fairly constant, we do not expect significant flow fluctuations.[17] Therefore, regardless of seasons and outside temperatures, observed performance is not expected to change. Evaluated savings for this measure are 181,670 kWh.

Measure 3: Air-Flow Management

During the site visit, Cadmus observed two CRAH units not running. We confirmed this observation with the supply and return temperature data provided by the site contact after measure implementation. We calculated the evaluated savings based on this observation, the power rating of the CRAH units, and the assumption of all units operating before measure implementation. Evaluated savings for this measure are 90,862 kWh.

It is common practice to install redundant cooling capacity through additional CRACs or CRAHs, as in this data center. We could not verify that all units operated continuously in the baseline condition, but this evaluation assumed they did so.

Additional savings might have been realized at this facility by increasing the SAT in Area 1. We could not verify this, however, based on data provided by SVP and the site contact.

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16 Cadmus found a preliminary energy audit report on site with cost-savings breakdowns for four measures. Also, SVP provided the original calculations, but they differed from the reported savings.

17 Cadmus requested the pump speed trend data, but the site contact did not provide this information.

Measure 4: Chilled Water Temperature Setpoint Adjustments

Cadmus observed the supply temperature of the chiller has been raised to 46°F. We calculated savings based on the efficiency improvement of the chiller. We assumed that for each degree rise in chilled water temperature, the chiller will gain about 2% efficiency. Evaluated savings for this measure are 399,073 kWh.

Cadmus requested the chiller operating trend data of the chillers, but the site contact could not provide this information.

Total Evaluated Savings

Based on Cadmus custom measure-by-measure engineering analysis, we calculated energy and demand savings for the first payment to be 1,141,463 kWh and 130 kW. However, we consulted with SVP and confirmed that no other energy efficiency measures have been implemented at this facility, and the difference between the pre- and post-installation energy usage of the building, adjusted for the IT load, provides an accurate estimate of energy savings realized through implementation of the measures. Therefore, as we did not have actual trend data to verify our engineering analysis, we approved the reported savings shown in Table 22.

Table 22. Evaluated Savings

	Evaluated Baseline Energy (kWh)	Evaluated Proposed Energy (kWh)	Evaluated Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	Not Provided*	Not Provided	2,429,105

*SVP has used billing analysis of 3 months prior and after the project implementation. Total baseline and proposed energy consumption were not available to Cadmus.

Final Results

As shown in Table 23, the project achieved a realization rate of 100% for the first payment, relative to the reported energy savings estimates.

Table 23. Final Energy Savings Results (kWh)

	Reported Energy Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	2,429,105	2,429,105	100%

As shown in Table 24, the project achieved a realization rate of 100% for the first payment, relative to the reported demand savings estimates.

Table 24. Final Demand Savings Results (kW)

	Reported Demand Savings (kW)	Evaluated Demand Savings (kW)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	277	277	100%

Site 6[18]

Facility and Project Description

This project is a new data center with a 500 kW design IT load, and involves installing a new cooling technology called Inertech cooling system. This system consists of two cooling distribution units (CDUs) and 36 eSYNC absorption units located in the server room. The CDUs circulate liquid refrigerant to the eSYNCs, which are located above the hot aisles. The eSYNCs circulate hot air from the aisle across an integral set of coils containing the liquid refrigerant that evaporates and cools the air, which is then circulated to the cold aisle. The liquid/vapor mixed phase refrigerant is circulated back to the CDU, where it will be condensed and cooled by circulating condenser water. The condenser water is cooled by roof-mounted adiabatic fluid coolers.

The standard baseline design for space cooling loads less than 150 tons uses CRAC units with DX cooling coils and either an air- or water-cooled economizer.

Reported Savings

The original reported savings calculation used manufacturer's specification data of seven Libert air-cooled DX CRAC units (for the baseline case) and manufacturer's specification data of the Inertech system (for the installed case), along with a temperature bin analysis to calculate the savings. The original reported savings at a design IT load of 500 kW was estimated to be 1,029,978 kWh.

For the first payment (three months after project completion), SVP verified the IT load to be 159 kW and adjusted the final savings associated with the first incentive payment to be 327,533 kWh, based on the ratio of the verified IT load to the design load.

Measure 1: Inertech System

Savings were expected to result from cooling the server racks with a mechanical cooling system that used less fan power and allows for more economizer hours. The heat rejection unit is an air-cooled adiabatic rejection system, which consists of a fluid cooler with an indirect evaporative cooling mode and a compressor trim unit. When the outdoor temperature is below 55°F, the system runs at dry free cooling mode; when the outdoor temperature is between 55°F to 75°F, the unit provides cooling using the evaporative cooling mode. When the outside temperature is above 75°F, the unit automatically uses the trim compressor. This allows more economizer hours and fewer hours of compressor operations, saving energy relative to the SVP guidelines baseline cooling system of CRACs, DX cooling coils, and an air- or water-cooled economizer.

Table 25 shows the adjusted reported savings estimates.

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[18] Rebate application number R16-DCR-0190.

Table 25. Adjusted Reported Savings

	Adjusted Reported Baseline Energy (kWh)	Adjusted Reported Proposed Energy (kWh)	Adjusted Reported Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015 (3 months after project completion)	434,244	106,711	327,533
2015–2016	0	0	N/A

Evaluation Activities

Data Collection and Baseline Establishment

On December 13, 2016, Cadmus visited the site to verify the measure installation and current operating conditions, and to discuss the data center's performance since completion.

During the site visit, Cadmus verified installation of the equipment except the roof-mounted fluid coolers, which were not accessible at the time of the visit. We confirmed the system configuration and operating parameters at the main control panel.

Per our observations, the system consists of two fluid coolers, with two water pumps equipped with VSDs delivering condenser water to two CDUs. Each CDU uses two refrigerant pumps that deliver refrigerant to eSYNCs located at the top of a contained server rack. At the time of the inspection, we observed a condenser water setpoint of 69°F, a total IT load of 199.6 kW, and a total eSYNC power of 5.2 kW.

Energy Savings Calculations

Cadmus estimated the evaluated savings by calculating annual energy consumption for the baseline and for the proposed energy efficient condition at the verified IT load. We used standard engineering formulas, data collected on site, and information on operating requirements from the site's engineering team.

Measure 1: Inertech System

Cadmus evaluated savings equaled reported savings. SVP provided some trend data that included power usage of the CDUs and eSyncs as well as the IT load. However, the provided trend data were not recorded at specific time intervals and many data gaps appeared. Cadmus contacted Inertech and the EMS vendor to request trend data for the power usage of the cooling system addressing the period for which incentives were paid. They could not provide these requested data as the facility did not archive old data in their database.

Consequently, we evaluated the inputs and assumptions used in the original calculations and compared these with the available data. We developed a temperature bin analysis based on available data, manufacturer's specifications, and assumptions made in the original calculations, and we found original inputs and assumptions consistent with the available data; our bin analysis produced results that agreed with reported savings.

Total Evaluated Savings

Cadmus evaluated the energy savings of 327,533 kWh for the first payment period, as shown in Table 26.

Table 26. Evaluated Savings

	Evaluated Baseline Energy (kWh)	Evaluated Proposed Energy (kWh)	Evaluated Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015 (3 months after project completion)	434,244	106,711	327,533
2015–2016	0	0	N/A

Final Results

Table 27 presents reported and evaluated energy savings and realization rates. Cadmus also estimated peak demand savings for the first payment at 129 kW, as shown in Table 28.

The project achieved energy savings realization rates of 100% for the first payment, relative to the reported energy saving estimates. For demand savings, the project achieved a realization rate of 100% for the first payment period.

Table 27. Final Energy Savings Results (kWh)

	Reported Energy Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015 (3 months after project completion)	327,533	327,533	100%
2015–2016	0	0	N/A

Table 28. Final Demand Savings Results (kW)

	Reported Demand Savings (kW)	Evaluated Demand Savings (kW)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015 (3 months after project completion)	129	129	100%
2015–2016	0	0	N/A

Site 7[19]

Facility and Project Description

This project is a major renovation of a retired fabrication plant that was converted to a data center with a 12.5 MW design IT load. The project involves installing a water-side economizer system that consists of four cooling towers,[20] associated pumps, and three heat exchangers to deliver cooled water to fan coils inside the server rooms. The standard baseline design for space cooling loads greater than 150 tons consists of CRAH units with chilled water coils and air- or water-side economizers. Supply air fans must have variable or two-speed controls.

Reported Savings

The original reported savings calculation used a bin method, equipment ratings, and SVP baseline guidelines to compare baseline and as-built energy consumption. The original reported savings at design IT load of 12.5 MW was estimated to be 12,728,043 kWh.

For the first payment (three months after project completion), SVP verified the IT load to be 2.027 MW and adjusted the final savings associated with the first incentive payment to be 2,063,979 kWh by multiplying the expected design IT load savings by the ratio of the verified load to the design load.

Measure 1: Water-side Economizers

Energy savings were expected to result from cooling the server racks using a water-side economizer system without mechanical compression and with smaller distribution fans. Installing this system was expected to produce compressor and fan energy savings compared to the baseline cooling system of CRAH units with chilled water coils and air-side economizer.

Table 29 shows the adjusted reported savings estimates based on the actual IT loads.

[19] Rebate application number R16-DCR-0016.

[20] The facility overhauled three existing cooling towers with new evaporative media and installed one new cooling tower.

Table 29. Adjusted Reported Savings

	Adjusted Reported Baseline Energy (kWh)	Adjusted Reported Proposed Energy (kWh)	Adjusted Reported Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	2,629,958*	565,979	2,063,979

*This is the adjusted baseline usage based on the actual IT load.

Evaluation Activities

Data Collection and Baseline Establishment

On December 13, 2016, Cadmus visited the site to verify the measure installation and verify current operating conditions, and to discuss the data center's performance since completion.

During the site visit, Cadmus verified installation of the equipment listed below.

- Four Marley cooling towers with designed flow rate of 3,000 gallons per minute each
- Three 125-hp cooling tower pumps equipped with VSDs
- Three 60-hp process cooling water pumps equipped with VSDs
- Three 12,990 million Btu/hr heat exchangers
- Forty 3-hp fan coils equipped with VSDs
- 7.5-hp makeup air units

Cadmus discussed the provided power trend data with the site contact and confirmed that the data provided included power readings of all mechanical components of the installed cooling system.

Energy Savings Calculations

Cadmus estimated the evaluated savings by calculating annual energy consumption for the baseline and for the proposed energy-efficient condition at the verified IT load. We used standard engineering formulas, data collected on site, and information on operating requirements from the site's engineering team.

Measure 1: Water-side Economizers

For the first payment (three months after project completion), Cadmus evaluated the savings to be higher than the adjusted reported savings. For the baseline case, we used a temperature bin analysis based on the actual IT load to calculate energy consumption of a cooling system that includes CRAH units with chilled water coils and water-side economizers. We used the actual installed logged data provided by the facility to adjust the efficiency values used in our baseline bin analysis. For the installed case, we used the actual logged data that includes all components of the mechanical system (e.g., cooling towers, pumps, makeup air units, and fan coils).

Cadmus used the same temperature bin analysis to calculate peak demand savings, based on system operation between June 1 and September 30, on weekdays between 2:00 PM and 5:00 PM.[21]

Total Evaluated Savings

Cadmus evaluated energy savings for the first payment period to be 2,392,678 kWh, as shown in Table 30.

Table 30. Evaluated Savings

	Evaluated Baseline Energy (kWh)	Evaluated Proposed Energy (kWh)	Evaluated Savings (kWh)
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	3,765,428	1,372,749	2,392,678

Final Results

Table 31 presents reported and evaluated energy savings and realization rates. Cadmus also estimated peak demand savings for the first payment to be 294 kW, as shown in Table 32.

The project achieved an energy savings realization rate of 116% for the first payment, relative to the reported energy saving estimates. For demand savings, the project achieved a realization rate of 120% for the first payment period.

Table 31. Final Energy Savings Results (kWh)

	Reported Energy Savings (kWh)	Evaluated Energy Savings (kWh)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	2,063,979	2,392,678	116%

21 Based on the Technical Reference Manual for the California Municipal Utilities Association.

Table 32. Final Demand Savings Results (kW)

	Reported Demand Savings (kW)	Evaluated Demand Savings (kW)	Realization Rate
2013–2014	Not initiated	Not initiated	N/A
2014–2015	Not initiated	Not initiated	N/A
2015–2016 (3 months after project completion)	245	294	120%