CONSULTANT REPORT

EVALUATION OF THE ENERGY EFFICIENT STATE PROPERTY REVOLVING LOAN FUND PROGRAM

APPENDICES

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APPENDICES

APPENDIX A: Detailed Evaluation Methodology

This appendix discusses the data collection and analysis methodologies observed during the evaluation. The methodology was developed in alignment with the procedures set forth in the evaluation plan.

Data Collection Methods

This section discusses the evaluation team's approach to collecting site-specific evaluation data. Data collection fell into roughly five steps: data requests, site scheduling, site planning, site-specific measurement and verification (M&V) activities, and participant telephone surveys.

Data Requests

In May 2011, the evaluation team made an initial request to the Department of General Services (DGS) for documentation related to the sampled projects. This initial data request included detailed measure descriptions, savings calculation spreadsheets and related documentation, feasibility studies (as appropriate), and contractor, vendor and equipment manufacturer information (where available). In addition, additional requests were made before the scheduling of and planning for on-site activities to ensure the evaluation team had the most up-to-date project information.

Site Scheduling

For each sampled project, an evaluation engineer contacted the site via email or telephone to initiate the site planning process and to schedule the site visit. The evaluation engineer confirmed project details and requested additional documentation, as necessary, to fill gaps not available from DGS and/or the project files. For example, for a typical lighting project, evaluation engineers requested a comprehensive list of installed lights, specifying fixture types and quantities, locations, and wattages of pre-existing and new fixtures. Additional details were discussed, such as whether or not approvals were needed to be granted access to locations where the measures were installed. This was particularly important for California Department of Corrections and Rehabilitation (CDCR) projects. The evaluation team then notified the California Energy Commission (Energy Commission) of upcoming site visits, and obtained approval for the associated travel expenses.

Site Planning

The evaluation engineers developed customized data collection and analysis plans for each sampled project. Different options for M&V were included in some of the plans since not all of the needed project information was known before going on-site. Site plans typically included brief descriptions of the data requirements and analysis approaches that would be used to determine both the preinstallation and postinstallation assumptions and conditions. Site plans also indicated specific M&V activities that could be conducted when site-specific constraints were known in advance—for example, evaluators could only take spot measurements at CDCR projects since long-term metering was disallowed by site contacts.

Site-specific M&V Activities

The evaluation team collected data to catalog preretrofit and postretrofit operations and conditions. At each site visit, an evaluation engineer verified the installation and proper operation of each energy efficiency measure (EEM). The engineer also collected equipment nameplates, feasibility study reviews, and self-reported operational data as the minimum data for all measures per site in the sample. The engineer interviewed site personnel to determine each measure's preretrofit and postretrofit operations, including operating conditions, load, operating hours, and control strategies. In addition to physically observing an installed measure, the engineer collected relevant data available from the site's contact, including any additional feasibility studies or updates, self-reported data from facility personnel, contractor or vendor information, cut sheets and performance curves, billing data, operational records, and research studies.

The evaluation team also requested copies of collected site data that presented pre- and post-conditions, including logged equipment operating schedules, major equipment power and energy consumption or sensor records, and energy management system (EMS) trend data.

End-use metering data were collected to represent the preretrofit and postretrofit conditions when appropriate. The engineer took spot measurements, where feasible, to collect manufacturer's performance curves that would predict performance over the operation load profile and operating conditions. If required, data loggers were installed and long-term measurements were collected over a two-week or more period. Long-term monitoring was performed at all sites except for prison sites where it was not allowed.

Sampling was necessary for sites with multiple measures or a large number of installed measures. The evaluation engineer observed the pre-existing equipment whenever possible and collected metered electrical data and other data on pre-existing operations to establish a baseline.

Telephone Surveys

Evaluators developed a participant survey instrument, which is located in Appendix B, to address research questions that could not be answered by other evaluation channels. One purpose of the survey was to provide the basis for determining net savings attributable to the program.

Evaluators screened candidates to identify the most appropriate person to interview based on his or her knowledge of the Energy Efficient State Property Revolving Loan Fund Program (Loan Fund Program) and involvement with the project's implementation and other details. However, this person was not necessarily the site contact. Because the program was managed by DGS, an agency's project site personnel often did not have information about the Loan Fund Program, and interviews were usually completed by telephone following the site visits, rather than during the site visit as initially planned.

Respondents were asked questions that ranged from their overall impression of the DGS Loan Fund Program, to their opinions about compliance with various application process requirements, to the financial criteria that helped the agency decide about participating, to

program's effect on jobs. An interview concluded with questions that asked about additional projects undertaken without program funding but may have been spurred by current program participation. These responses informed the spillover analysis, if participating sites implemented energy efficient measures without incentives, grants, or loans from utility or government programs and were influenced by the Loan Fund Program. Although job creation resulting from American Recovery and Reinvestment Act of 2009 (ARRA) programs will be addressed in a separate report, Loan Fund Program respondents were asked about the jobs created and retained as a result of the program to provide an on-the-ground indication of the perception of job creation. The survey instrument is provided in Appendix B.

Evaluators attempted to interview all 18 project contacts from the sample. Evaluators completed a total of 12 interviews from the sample group. Despite repeated attempts, the evaluators were not able to schedule and complete interviews for three projects. Since the CDCR projects were centrally managed, one interview was conducted, with the contract manager, for four of CDCR Loan Fund Program projects. The interview addressed all installed measures for these projects. Since the CDCR interview represented four projects, it was counted as four interviews.

Site-specific Analyses to Determine Energy Savings

Calculating energy savings depends on the estimated base-case energy use of a given end use before a retrofit and the estimated energy use subsequent to the retrofit. As defined in the International Performance Measurement and Verification Protocol[1] (IPMVP), there are two ways to estimate savings:

- **Avoided energy basis**. Avoided energy use quantifies savings in the reporting period relative to what energy use would have been without the EEMs.
- **Normalized savings**. "... .the reduction in energy use or cost that occurred in the reporting period, relative to what would have occurred if the facility had been equipped and operated as it was in the baseline period but under a normal set of conditions"[2]

For this evaluation, evaluators used the normalized savings approach to estimate savings. This approach assumes a fixed set of conditions in both the preretrofit and postretrofit cases. Thus the base-case conditions were established for the pre-retrofit conditions as follows:

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1 Efficiency Valuation Organization. *International Performance Measurement and Verification Protocol, Concepts and Options for Determining Energy and Water Savings*, Volume 1. EVO 10000 – 1:2010, September 2010.

2 Efficiency Valuation Organization. *International Performance Measurement and Verification Protocol, Concepts and Options for Determining Energy and Water Savings*, Volume 1. EVO 10000 – 1:2010, September 2010., Section 4.6.1.

- Pre-retrofit data were collected to establish the control scheme, operating conditions, equipment load, and equipment efficiency. In the absence of metered data, information from the feasibility study, site contact, as-built drawings, and research and engineering judgment were used to establish the base-case parameters.
- Postretrofit data were similarly collected, and base-case parameters were established.

Both preretrofit and postretrofit data were normalized to the same operating conditions to establish savings estimates that could be directly compared.

Key Parameters and Terms

This study compares the forecasted energy savings (ex ante) with the savings calculated during the evaluation (ex post). The term *ex ante* refers to the savings estimates reported by the DGS and its contractors. Savings estimates determined from the evaluation are referred to as *ex post* savings.

For each site within the sample, evaluators determined a measure's efficiency, measure life, and remaining useful life (RUL) of the pre-retrofit equipment.

Effective Useful Life (EUL) of the Measure

California's Database for Energy Efficient Resources (DEER) was the primary source used to determine the EUL of a given EEM. For measures not represented in the DEER, the source of the EUL was based on technical research, such as published reports.

Remaining Useful Life (RUL)

For all retrofit projects, evaluators estimated the number of years a piece of pre-retrofit equipment would have continued operating without the retrofit. Typically, evaluators contacted knowledgeable facility contacts and asked for their best estimate of the RUL of the pre-retrofit equipment. This self-reported RUL, when available, is thought to provide a better estimate than the evaluation estimate. Evaluators also reviewed measure life data in the DEER to assess the reasonableness of an interviewee's estimated RUL. Equipment older than the measure life would be expected to have no additional RUL. However, based on the status of the equipment observed during the course of the evaluation, state facilities often retain equipment beyond the EUL. For this evaluation, the site contact-reported RUL was the preferred value, DEER EULs were the second preferred value, and in the absence of both, a minimum of one year RUL was used when equipment was reported as functioning at the time of the retrofit.

Equipment Efficiency

Equipment efficiency data for postretrofit operations were available from the vendor for newly purchased equipment. For older, pre-retrofit equipment, evaluators collected nameplate information during a site visit or from the project files and feasibility studies, in cases when the units' efficiencies were properly documented. In the absence of site-specific data, efficiency was based on a pre-retrofit unit's age and corresponding (past) Title 24 standards. Information on equipment efficiency, based on nameplate information, is available for many units. For example, evaluators used Preston's Guide to determine efficiencies for heating, ventilation, and

air conditioning (HVAC) equipment. This guide has a list of air conditioning units built from 1960 through 2005 and has efficiency ratings based on a model's number and manufacture year.

Life-cycle Savings Calculations

The evaluation team calculated life-cycle savings over the lifetime of the EEMs. Each measure was assigned an EUL, and the savings for each year of EUL were summed over the measure life to determine the life-cycle savings.

Energy savings calculated for this program are relative to two established baselines, referred to as Baseline 1 and Baseline 2.

- Baseline 1 corresponds to the existing conditions found before the EEM's implementation and considers the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes that the pre-existing equipment would have operated for the full EUL of the new equipment regardless if the existing equipment was at the end of its useful life. The Energy Commission requested using this baseline to assist ARRA subrecipients that are comparing their observed preretrofit and postretrofit energy use and are using the savings to pay back loans.
- Baseline 2 uses the pre-existing equipment as the measure baseline only until the end of the existing equipment's RUL. After that, an expected replacement baseline (for example, standard practice or code minimum) is used until the EUL is reached.

Gross Energy Savings Calculations

The gross site savings were calculated using the difference between energy usage for the measure-treated usage and the appropriate baseline. The savings associated with most EEMs were calculated using a spreadsheet analysis. In a few cases, calibrated end-use simulation or building energy simulation models were used to estimate savings.

Spreadsheet Analysis

For lighting controls and interior lighting projects, the evaluation team's engineers determined savings by developing spreadsheets populated with the values gathered from site visits for each fixture type's wattage, counts by fixture type, and operating hours for both existing and pre-retrofit cases. Lighting logger data, which were deployed on representative circuits at the sites, were used to establish operating hours where possible. Typically, the lighting loggers were installed at representative locations representing several occupancy and usage types (offices, hallways, garages) to establish annual operating hours for those types of locations.

For most HVAC projects, evaluation engineers developed an annual load regression analysis that applied pre-existing and newly installed equipment efficiencies and conditions. The data collected on the preretrofit and postretrofit conditions were used to develop the regression analysis to establish the preretrofit and postretrofit energy consumption. To analyze the data, evaluators developed a regression curve relating the outdoor air temperature data to power draw for each unit. Either weather data collected on-site or local weather station data was used

as a basis for establishing weather conditions that affected HVAC use. If the data indicated that loads were internally driven (for example, the power data did not correlate with temperature), evaluators developed a relationship between time-of-day and power draw. Using the installed unit's efficiency (or an efficiency curve if available), evaluators translated the power draw data into load data. Finally, evaluators converted load data back into a pre-retrofit system power-draw estimate using the efficiency, operating parameters, and condition of the pre-retrofit system. In a few cases, end-use metered data were available for the pre-retrofit condition and were used to estimate pre-retrofit system power draw. Annual savings were assessed with a bin analysis using typical meteorological year (TMY3) data (assuming weather dependency) that corresponded to a local weather station. When multiple units were replaced or retrofitted, savings were extrapolated to the remaining units at the facility.

Calibrated End-use Simulation Models

If the savings were estimated via a building energy simulation model, evaluators made a data request to obtain these models, and in many cases, the models were available. The models were inspected for general quality control, and when the models were of sufficient quality, the evaluation engineer determined the changes and manipulations that were made to the models to estimate the ex ante energy savings impacts. During a site visit, an evaluation engineer verified key assumptions and noted when on-site observations deviated from the model's assumptions or predictions. After an on-site visit, the site engineer made changes to the as-built model to make it representative of actual conditions, creating an ex post as-built model. This model was run and its results were used to estimate ex post savings. In a limited number of cases, the site engineer created a new model to estimate the savings.

APPENDIX B:
Participant In-depth Interview Guide

Energy Efficient State Property Revolving Loan Fund

Department of General Services

Decision Maker Survey

Interview Date:

Name of Interviewer:

Name of Interviewee:

Decision Maker's Organization:

Introduction

Hello. I'm calling from KEMA on behalf of the California Energy Commission as part of the evaluation of the Energy Efficient State Property Revolving Loan Fund. We are interviewing Loan Fund participants to gain a better understanding of why they decided to install energy efficiency measures with funding from this loan program.

The interview and any information that is provided will remain strictly confidential. We will not identify or attribute any of your comments or organization information.

W. CONFIRMATION OF CORRECT RESPONDENT/ WARM-UP QUESTIONS

W1. May I please speak with <%CONTACT>? According to our records, your organization implemented a project involving <%MEASURES> on approximately <%INSTALL_DATE>, is that correct?

W2. I was told by<REFERENCE NAME> that you were the most knowledgeable and the most involved with the decision to implement the project. Is that correct? [IF YES, SKIP TO W1. IF NO, CONTINUE]

W3. Who would be the person most knowledgeable about the decision to implement the energy efficiency project that I just described? Record <NEW CONTACT NAME> and ask: May I speak with him/her?

W4. What was your specific role in the project? _____

W5. Were others involved with the project decision making, particularly the go/no-go decision? If so, what are their names and contact information?

W6. First, as I mentioned previously, our records indicate there was a project implemented at <%SITE NAME> consisting of <%MEASURES>. [MENTION THE PROJECT DETAILS, INCLUDING MEASURE NAME(S) AND QUANTITIES, DATES IF KNOWN]. Was this the project you were involved with?

1	Yes	Continue
2	No	Probe further until reconciled
88	Don't know	Can you refer me to someone that would know?

W7. Were all of these measures installed as just described?

1 Yes
2 Yes, but the measure count is different _____(record here)
3 No Probe further until reconciled (such as final measure details are confirmed)

77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

W8. In deciding to do a project of this type, there are usually a number of reasons why it may be undertaken. In your own words, can you tell me why your organization decided to implement this project? Were there any other reasons? **DO NOT READ**

1 To replace old or outdated equipment
2 As part of a planned remodeling, build-out, or expansion
3 To gain more control over how the equipment was used
4 The maintenance downtime and associated expenses for the old equipment were too high
5 Had process problems and were seeking a solution

6 To improve measure performance
7 To improve the product quality
8 To comply with codes set by regulatory agencies
9 To improve facility safety
10 To comply with government policies regarding regular/normal maintenance/replacement policy
11 To get funding from the program
12 To protect the environment
13 To reduce energy costs
14 To reduce energy use/power outages
15 To update to the latest technology
77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

W9. Were you actively involved in the Energy Efficient State Property Revolving Loan Fund for <%SITE NAME>?

1	Yes	Continue
2	No	Can you refer me to someone that would know?

C. COMMENT SECTION

C1. What is your overall impression of the Loan Fund program?

_____
_____

C2. Was there any difficulty complying with the ….

a. Davis-Bacon Act (If Needed: define DB Act) If yes: Can you please elaborate?
_____
_____

b. Was there any difficulty complying with the Buy American Act (If Needed: Define BA Act) If yes: Can you please elaborate?
_____
_____

c. Was there any difficulty complying with the National Historic Preservation Act (Section 106 consultation) (If Needed: Define NHP Act)
If yes: Can you please elaborate?
_____
_____

d. Was there any difficulty complying with the Waste Management requirements (If Needed: Define WM Reqs) ____
If yes: Can you please elaborate?
_____
_____

C3. Do you have any comments or suggestions on how to improve the Loan Fund program?

_____
_____

A. ATTRIBUTION QUESTIONS

A1. When and how did the idea for this project originate?

DO NOT READ PROMPTS

1. Internally proposed
2. Outside vendor or consultant (Probe: If applicable, was this person provided by the Loan Fund Program, a Utility Program, a some other type of Program or non-program affiliated?)
3. Audit (Probe: Loan Fund Program, other program or non-program)?
4. Part of a larger modernization or remodeling effort
5. Part of an expansion
6. Other _____
7. Can't remember

A2. What was or were the roles for the Loan Fund program? (Accept multiple)

1. Funding, essential (was needed to move project forward),
2. Funding, helpful,
   a. (project may have proceeded without it, but loan helped somewhat)
3. Funding, non-essential, (loan did not influence implementation)
4. Identification of the measure opportunities
5. Technical assistance specifying the measures
6. Assistance in the selection of a contractor or vendor
7. Technical assistance in commissioning the measures
8. Staff training
9. Other _____

88. Don't Know/Can't remember

A3. Using a scale from 1 to 5, where 1 is "Not at all influential" and 5 is "Very influential" How influential was the Loan Fund Program to the implementation of the project?

(Make sure it is consistent with the responses above)

1. Not at all influential
2.
3.
4.
5. Very influential

A4. Without assistance from the Loan Fund Program, the project

1. Would have been implemented exactly the same at exactly the same time
2. Would have been implemented at the same time but with less efficient equipment
3. Would have been delayed until another funding source was located or the pre-existing equipment failed.
4. Would not have proceeded

77. Other _____

A5. Was the project "co-funded" with other federal funding, state funding, utility or third party energy efficiency program incentives?

1 Yes (continue)

2 No (Skip to F1)

88 Don't know (If you don't who would be the person that would know?)

A6. What other co-funding was obtained for this project in addition to the Loan Fund? (Include all that apply)

1 Utility funding (continue)
2 Federal program funding
3 Other state funding
4 No.
88 Don't know (If you don't who would be the person that would know?_____)

Co-Funding Questions (Ask for each source of Co-Funding)

A7. What was or were the roles for the Co-funding source (source #)? (Accept multiple)

1. Funding, essential (was needed to move project forward),
2. Funding, helpful,
   a. (project may have proceeded without it, but this co-funding source helped somewhat)
3. Funding, non-essential, (this co-funding source did not influence implementation)
4. Identification of the measure opportunities
5. Technical assistance specifying the measures
6. Assistance in the selection of a contractor or vendor
7. Technical assistance in commissioning the measures
8. Staff training
9. Other _____

88. Don't Know Can't remember

A8. Using a scale from 1 to 5, where 1 is "Not at all influential" and 5 is "Very influential" How influential was the Co-funding program (source #) to the implementation of the project?

(Make sure it is consistent with the responses above)

1. Not at all influential
2.
3.
4.
5. Very influential

A9. Without participation in and influence of the co-funding program (source #) that co-funded the project, the project

1. Would have implemented exactly the same at exactly the same time
2. Would have implemented at the same time but with less efficient equipment
3. Would have been delayed until another funding source was located or the pre-existing equipment failed.
4. Would not have proceeded

77. Other _____

Repeat questions for A-8 to A10 for Each Co-Funding Source

Question	CF Source 1	CF Source 2	CF Source 3	CF Source 4
Source Name				
A7				
A8				
A9				

Financial BATTERY (ASK ALL)

F1. What, if any, financial calculations does your organization make before proceeding with a project like this one?

77 RECORD VERBATIM

88 Don't know

99 Refused

F2. [IF PAYBACK OR RETURN ON INVESTMENT MENTIONED] What is the threshold in terms of the simple payback or return on investment your organization uses before deciding to proceed with an investment?

77 RECORD VERBATIM

88 Don't know

99 Refused

F3. Did the funding from the Loan Fund Program play a role in moving your project within this acceptable range?

1 Yes
2 No
88 Don't know

99 Refused

F4. How often does your organization consider the entire life-cycle cost of the equipment, including fuel costs, when purchasing equipment? Would you say it was [read unbracketed items, select one]:

1 Never,
2 Rarely,
3 Sometimes,
4 Most of the time, or
5 Always
88 [Don't know]

99 [Refused]

J. Job Creation Questions

J1. I'd like to ask you about how this project has affected jobs at your operation. Were any jobs retained or added to your operation because of the project?

1 Yes
2 No
77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

J2. Do you know of jobs outside your operation that were retained or added because of the project?

1 Yes
2 No
77 Other (RECORD VERBATIM)
88 Don't know
99 Refused

J3. Describe how the ARRA funding created jobs (probe, request anecdotes)

1 Layoffs avoided (RECORD ADDITIONAL DETAILS VERBATIM)
2 Staff retained (RECORD ADDITIONAL DETAILS VERBATIM)
3 New hires (RECORD ADDITIONAL DETAILS VERBATIM)
4 Contract hires (RECORD ADDITIONAL DETAILS VERBATIM)
5 Jobs for contractors or other outsiders (RECORD ADDITIONAL DETAILS VERBATIM)
77 Other (RECORD VERBATIM)
88 Don't know
99 Refused

J4. What type of jobs were added or retained? (probe)

1 Administration
2 Administration (Sales)
3 Architecture and Engineering
4 Building Envelope (Construction Trades)
5 Building Envelope (Performance Trades)
6 Management (Blue-Collar)
7 Management (White-Collar)
8 Manufacturing
9 Mechanical and Electrical Trades
77 Other (RECORD VERBATIM)
88 Don't know
99 Refused

J5. What was the estimated duration of the jobs? Were the jobs added permanent or temporary?

1 Permanent
2 Temporary
77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

J6. What type of jobs were added or retained? (probe)

1 Administration
2 Administration (Sales
3 Architecture and Engineering
4 Building Envelope (Construction Trades)
5 Building Envelope (Performance Trades)
6 Management (Blue-Collar)
7 Management (White-Collar)
8 Manufacturing
9 Mechanical and Electrical Trades
77 Other (RECORD VERBATIM)

88 Don't know

99 Refused

J7. Do you have any other information about job creation from ARRA funding that you would like to share?

(RECORD VERBATIM)

_____
_____

SPILLOVER QUESTIONS [ASK ONLY IF Program Influence response A3 was somewhat or very influential]

SP1 Did you implement any additional energy efficiency measures at this facility that were directly influenced through your participation in the Loan PROGRAM that did not receive incentives, grants or loans through any utility or government program?

1	Yes	SP2
2	No	THANK AND TERMINATE
88	Refused	THANK AND TERMINATE
99	Don't know	THANK AND TERMINATE C1

SP2 What are the details of these measures? Type of influence, details of the measure (count, efficiency, etc.), what would have occurred in the absence of influence?

_____

_____

Thank and Terminate

APPENDIX C:
Population Level Program Tracking Data

Table C-1: Program Electric and Natural Gas Savings for All Sites

Loan Group	Loan Number	Sites	Measures	Ex Ante Savings	
				Electric (kWh)	Gas (therms)
CDCR	102	Salinas Correctional Training Facility	Boiler Replacement	730,160	223,021
		Salinas Valley State Prison at Soledad	Lighting, domestic hot water (DHW)	966,396	95,799
		Tehachapi	Boiler Replacement	430,116	345,322
		Corcoran State Prison	HVAC controls, lighting	4,620,466	66,906
	124	Substance Abuse Treatment Facility	HVAC controls, lighting	5,413,745	49,944
		Norco Rehabilitation Center	Boiler Replacement	45,505	220,746
Large Buildings Program	101	Bateson	Lighting controls, HVAC Controls	559,269	-
		Board of Equalization	Boilers, DHW, HVAC controls, lighting controls	2,444,207	28,523
		Bonderson	Lighting	476,073	-
		Energy Commission Building	HVAC controls, lighting controls, DHW	171,200	-
		Caltrans District 11	Lighting	78,582	-
		Caltrans District 11	Chiller replacement	405,830	29,507
		Fresno State Office Building	HVAC	243,426	2,863

Loan Group	Loan Number	Sites	Measures	Ex Ante Savings	
				Electric (kWh)	Gas (therms)
Large Buildings Program		DGS, Jesse Unruh Building	HVAC controls, lighting controls	374,587	-
		Caltrans Mission Valley	Lighting	46,594	-
		Secretary of State Building	HVAC controls	1,015,995	-
	104	Office of Fleet Management, Parking Lots	Lighting	761,436	-
	106	California Highway Patrol Headquarters	Lighting	211,422	-
Office of the Chief Information Officer (OCIO)	112	Gold Camp Data Center	HVAC Equipment, HVAC controls, lighting	3,092,234	-
Small Buildings Program	108	DMH, Atascadero	Lighting	572,066	-
	110	DMH, Patton	Lighting	405,692	-
	114	CHP, Altadena Area	Lighting, lighting controls, HVAC	66,275	-
		CHP, Central Los Angeles Area	Lighting, lighting controls	92,763	-
		CHP, Coalinga	Lighting, lighting controls, HVAC	45,403	-
		CHP, El Cajon Area	Lighting, lighting controls	43,144	-
		CHP, Fort Tejon Area	Lighting, lighting controls	33,523	-
		CHP, Fresno Area	Lighting, lighting controls	97,278	-
		CHP, Hanford Area	Lighting, lighting controls, HVAC	52,630	-
		CHP, Hayward Area	Lighting, lighting controls	75,448	-
		CHP, Hollister-Gilroy Area	Lighting, lighting controls	47,958	422
		CHP, Madera Area	Lighting, lighting controls	38,988	-

Loan Group	Loan Number	Sites	Measures	Ex Ante Savings	
				Electric (kWh)	Gas (therms)
Small Buildings Program		CHP, Merced Area	Lighting, lighting controls, HVAC	226,548	405
		CHP, Modesto Area	Lighting, lighting controls, HVAC	147,187	1,250
		CHP, Oakland Area	Lighting, lighting controls	119,777	-
		CHP, Redwood City Area	Lighting, lighting controls	44,109	-
		CHP, San Jose Area	Lighting, lighting controls	82,777	-
		CHP, South Los Angeles Area	Lighting, lighting controls	137,410	-
		CHP, West Los Angeles Area	Lighting, lighting controls	82,806	-
		CHP, Yuba-Sutter Area	Lighting, lighting controls, HVAC	59,152	181
	116	DMV, Arleta Field Office	Lighting, lighting controls	45,438	-
		DMV, Chula Vista	Lighting, lighting controls	45,996	-
		DMV, El Cajon	Lighting, lighting controls	34,065	-
		DMV, Hanford	Lighting, lighting controls	18,707	-
		DMV, Hollister	Lighting, lighting controls	11,490	-
		DMV, Merced	Lighting, lighting controls	39,651	-
		DMV, Modesto	Lighting, lighting controls	30,068	-
		DMV, Mountain View	Lighting, lighting controls	32,983	-
		DMV, Oakland Claremont	Lighting, lighting controls	57,199	-
		DMV, Oakland Coliseum Field Office	Lighting, lighting controls	37,350	-
		DMV, Redwood City	Lighting, lighting controls	41,468	-
		DMV, Sacramento	Lighting, lighting controls, HVAC	81,137	776

Loan Group	Loan Number	Sites	Measures	Ex Ante Savings	
				Electric (kWh)	Gas (therms)
Small Buildings Program		DMV, San Diego	Lighting, lighting controls	41,654	-
		DMV, San Mateo	Lighting, lighting controls	53,406	-
		DMV, Turlock	Lighting, lighting controls, HVAC	50,701	253
		DMV, Visalia	Lighting, lighting controls	40,494	-
		DMV, Watsonville	Lighting, lighting controls	13,414	-
		DMV, Yuba City	Lighting, lighting controls, HVAC	45,807	713
	118	DWR, Bryte Chemical Lab	Lighting, lighting controls, HVAC	247,165	9,171
		DWR, Oroville Visitors Center	Lighting, lighting controls, HVAC	51,508	1,400
		DWR, Romero Overlook	Lighting, lighting controls, HVAC	31,287	-
		DWR,Vista Del Lago	Lighting, lighting controls, HVAC	173,061	-
	120	DDS, Fairview	Lighting	2,101,987	-
		DDS, Porterville	HVAC controls	1,069,858	79,560
		DDS, Sonoma	Lighting	2,160,715	36,114
Total				31,114,786	1,192,876

Source: DNV KEMA analysis

APPENDIX D:
Evaluation Results for Sampled Sites

Table D-1: Electric Savings for Sampled Sites

Loan Group	Site Name	Ex Ante Electric Savings (kWh)	Ex Post: Baseline 1 Electric Savings (kWh)	Electric Realization Rate : Baseline 1	Ex Post: Baseline 2 Electric Savings (kWh)	Electric Realization Rate: Baseline 2
CDCR	Norco Rehabilitation Center	45,505	144,014	316%	57,186	126%
	Corcoran State Prison	4,620,466	4,667,065	101%	4,667,065	101%
	Salinas Correctional Training Facility	730,160	747,192	102%	747,192	102%
	Salinas Valley State Prison at Soledad	966,396	837,464	87%	834,315	86%
	Substance Abuse Treatment Facility	5,413,745	6,295,111	116%	6,295,111	116%
	Tehachapi	430,116	440,303	102%	431,373	100%
Large Buildings	Caltrans District 11	405,830	371,377	92%	503,889	124%

Loan Group	Site Name	Ex Ante Electric Savings (kWh)	Ex Post: Baseline 1 Electric Savings (kWh)	Electric Realization Rate : Baseline 1	Ex Post: Baseline 2 Electric Savings (kWh)	Electric Realization Rate: Baseline 2
Large Buildings	Energy Commission Building	171,200	76,004	44%	76,004	44%
	Office of Fleet Management, parking lots	761,436	661,318	87%	661,318	87%
	DGS, Jesse Unruh Building	374,587	53,289	14%	53,289	14%
	Secretary of State Building	1,015,995	498,895	49%	498,895	49%
OCIO	Gold Camp data center	3,092,234	2,572,269	83%	2,572,269	83%
Small Buildings	CHP, Oakland Area	119,777	35,394	30%	17,605	15%
	CHP, South Los Angeles Area	137,410	84,629	62%	84,629	62%
	CHP, Coalinga	45,403	63,737	140%	42,377	93%

Loan Group	Site Name	Ex Ante Electric Savings (kWh)	Ex Post: Baseline 1 Electric Savings (kWh)	Electric Realization Rate : Baseline 1	Ex Post: Baseline 2 Electric Savings (kWh)	Electric Realization Rate: Baseline 2
	DMV, Oakland Coliseum Field Office	37,350	41,115	110%	41,115	110%
	DDS, Sonoma	2,160,715	1,612,993	75%	1,612,993	75%
	DMV, Yuba City	45,807	54,822	120%	24,069	53%
Total		20,574,132	19,256,990	94%	19,220,694	93%

*kWh = kilowatt-hour
Source: DNV KEMA analysis

Table D-2: Power Savings for Sampled Sites

Loan Group	Site	Ex Ante: Measure Electric Savings (kW)	Ex Post: Baseline 1 Measure Power Savings (kW)	Ex Post: Baseline 2 Measure Power Savings (kW)	Power Realization Rate Baseline 1	Power Realization Rate Baseline 2
CDCR	Norco Rehabilitation Center	None Claimed	21	5	N/A	N/A
	Corcoran State Prison	None Claimed	466	466	N/A	N/A
	Salinas Correctional Training Facility	48	48	48	99%	99%
	Salinas Valley State Prison at Soledad	124	113	113	91%	91%
	Substance Abuse Treatment Facility	None Claimed	424	424	N/A	N/A
	Tehachapi	None Claimed	50	49	N/A	N/A
Large Buildings	Caltrans District 11	None Claimed	79	46	N/A	N/A

Loan Group	Site	Ex Ante: Measure Electric Savings (kW)	Ex Post: Baseline 1 Measure Power Savings (kW)	Ex Post: Baseline 2 Measure Power Savings (kW)	Power Realization Rate Baseline 1	Power Realization Rate Baseline 2
	Energy Commission Building	None Claimed	-	-	N/A	N/A
	Fleet Parking Lots	None Claimed	55	55	N/A	N/A
	Jesse Unruh Building	None Claimed	16	16	N/A	N/A
	Secretary of State Building	None Claimed	75	75	N/A	N/A
OCIO	Gold Camp Data Center	None Claimed	365	365	N/A	N/A
Small Buildings	CHP, Oakland Area	None Claimed	6	2	N/A	N/A
	CHP, South Los Angeles Area	None Claimed	13	13	N/A	N/A
	CHP, Coalinga	None Claimed	12	6	N/A	N/A

Loan Group	Site	Ex Ante: Measure Electric Savings (kW)	Ex Post: Baseline 1 Measure Power Savings (kW)	Ex Post: Baseline 2 Measure Power Savings (kW)	Power Realization Rate Baseline 1	Power Realization Rate Baseline 2
	DMV, Oakland Coliseum Field Office	None Claimed	5	5	N/A	N/A
	DDS, Sonoma	None Claimed	440	440	N/A	N/A
	DMV, Yuba City	None Claimed	27	3	N/A	N/A
Total		172	2,215	2,130		

Source: DNV KEMA analysis

Table D-3: Natural Gas Savings

Loan Group	Site Name	Ex Ante Savings (Therms)	Baseline 1		Baseline 2	
			Ex Post Savings (Therms)	Realization Rate	Ex Post Savings (therms)	Realization Rate
CDCR	Norco Rehabilitation Center	220,746	215,180	97%	72,251	33%
	Corcoran State Prison	66,906	54,625	82%	54,625	82%

Loan Group	Site Name	Ex Ante Savings (Therms)	Baseline 1		Baseline 2	
			Ex Post Savings (Therms)	Realization Rate	Ex Post Savings (therms)	Realization Rate
	Salinas Correctional Training Facility	223,021	223,021	100%	165,420	74%
	Salinas Valley State Prison at Soledad	95,799	58,027	61%	17,502	18%
	Substance Abuse Treatment Facility	49,944	231,016	463%	231,016	463%
	Tehachapi	345,322	428,250	124%	343,436	99%
Small Buildings	DDS, Sonoma	36,114	51,955	144%	51,955	144%
	DMV, Yuba City	713	339	48%	323	45%
Large Buildings	Caltrans District 11	29507	0	0%	0	0%
Total		1,068,072	1,262,412	118%	936,527	88%

Source: DNV KEMA analysis

APPENDIX E:
Evaluation Site Reports

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Norco Rehabilitation Center Boiler Retrofit

Site Summary

The Norco Rehabilitation Center (NRC is a California Department of Corrections and Rehabilitation (CDCR penitentiary located in Norco, California. A single measure was implemented at this facility: three oversized 17,250 lb/hr fire tube, lower pressure steam boilers were replaced with three 6,900 lb/hr Miura LX-200 low pressure steam boilers with feed water preheating stack economizers. Savings resulted from more efficient steam generation, as well as reduced blower energy usage. Ex ante and ex post savings for the measure are presented in Table E-1.

Table E-1: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
Boiler Retrofit	45,505	None Claimed	220,746	144,014	21.3	215,180	316%	97%
Total	45,505	None Claimed	220,746	144,014	21.3	215,180	316%	97%

Source: DNV KEMA analysis

The boiler retrofit saved considerably more electrical energy than anticipated for two reasons. First, the evaluation revealed that fewer new boilers—and thus few blowers—typically operate than assumed in the ex ante analysis. Second, spot measurements of blower power consumption during the ex post site visit indicated that the installed blowers operate at a reduced electrical demand relative to that assumed in the ex ante analysis.

Boiler gas savings were reduced slightly because gas usage logs from the ex post evaluation period allowed development of a more detailed boiler load regression. However, in spite of the use of new gas usage data and a revised analysis methodology (to be discussed later in this report), gas savings were within 3 percent of the ex ante estimate.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the RUL of the pre-existing equipment is exceeded.

In the case of this project, the pre-existing boilers had already exceeded their EUL (for example, had no RUL), so only one year of pre-existing equipment savings were provided under Baseline 2. These savings were provided under the assumption that the pre-existing boilers would have lasted for at least one more year even though the boilers had theoretically exceeded their EUL.

Table E-2: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	2,880,276	426.1	4,303,608
Baseline 2	1,230,550	110.4	1,587,949

Source: DNV KEMA analysis

Project Description

NRC uses a single central boiler plant for space heating and DHW heating. This project consisted of decommissioning the three pre-existing fire tube boilers comprising their plant and installing three smaller water tube boilers in their place. Savings resulted from more efficient steam generation, better process control, and less energy consumption from smaller, more efficient blowers. The first improvement, increased steam generation efficiency, resulted from better combustion efficiency and reduced blow-down relative to the pre-existing boilers. The second improvement, better process control, resulted from the installation of integrated controls that stage boiler operation automatically as a function of demand. By contrast, the pre-existing boilers had to be brought online and taken offline manually by the plant operator as a result of fluctuations in header pressure. According to the plant engineer, this generally meant that a second boiler was left online throughout the swing season and summer months during periods when only one boiler would have sufficed to avoid any unmet demand. Lastly, the new plant uses less electricity by operating smaller, more efficient blowers for shorter periods of time dictated by the new automatic plant staging controls.

Ex ante Savings

The data and analysis used to derive the ex ante savings estimates were provided in their entirety for review as part of the evaluation.[3] Ex ante savings were calculated on the basis of 140 hours of boiler gas usage logs from the period before project implementation. 72 hours of loggers were taken from December 2008, 44 hours were taken from August 2009, and 24 hours were taken from October 2009. The data from each of these three periods were used to estimate unique pre-existing boiler plant gas-to-steam efficiencies for three seasons: winter, summer, and swing. The data from December, August, and October were matched up to winter, summer, and swing seasons respectively. The logs—which included hourly gas usage by boiler, hourly ambient temperature, hourly stack temperatures, and indications of whether boilers were idling or loaded during any hour—were used to back out the plant load over each representative seasonal period. The load for a given seasonal period was then divided by the gas usage over that same period to arrive at a projection of pre-existing plant efficiency by season. The daily gas usage rates observed over each representative seasonal period were then extrapolated to full seasons (91 winter days, 91 summer days, and 183 swing season days). These projections were then used to arrive at estimates of load across each of the three seasons using the seasonal efficiencies. Finally, the total annual load was compared to the annual gas use to arrive at an annualized estimate of plant efficiency. This pre-existing plant efficiency was then used with the new boiler's projected gas-to-steam efficiency and a year's worth of annual gas billing data to project annual gas savings.

Electrical savings were calculated on the assumptions that two of the base case blowers operated year round, while two of the installed blowers operated during the summer months and three operated the rest of the year. Savings were realized because the installed blowers are 15 hp, while the pre-existing blowers were 25 hp and ran off less efficient motors. In both the pre-existing and installed cases, motor load factors of 80 percent were assumed.

Project Evaluation

A DNV KEMA engineer visited the facility on November 30, 2011 to verify the installation of the boilers, perform flue gas analysis on one of the new boilers, spot measure the power draw of an installed blower, and gather boiler plant operating data to assist in developing savings estimates. Because the CDCR does not permit metering equipment from external parties to be left behind at their facilities, loggers were not used to assist in projecting energy savings.

The site visit revealed that each of the three Miura boilers had been installed as proposed. Boiler combustion analysis indicated that the new boilers operate with roughly 7.5 percent excess air. A spot check on one of the blower motor's indicated that the blowers operate at a full load demand of roughly 7.1 kW as opposed to the 9.8 kW assumed in the ex ante analysis.

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3 See "Att 1 – CRC Norco Boiler Project Validations.xls".

The site contact was able to provide boiler logs from three separate one week periods in September 2011, October 2011, and November 2011. These logs include hourly gas meter and flue gas temperature readings for each boiler. Data from these logs were ultimately used to develop a plant load regression. Additionally, the site contact provided records of boiler and feedwater conductivity for each day of November 2011; these data that were used to estimate blow-down losses for the new boilers.

The primary task of the evaluation was developing a regression relating ambient conditions to boiler load from the data collected on-site. Using this regression, an annual hourly boiler load profile could then be developed using appropriate weather data. Savings could then be determined for each hour of the year on the basis of the differing efficiencies of the installed and pre-existing equipment.

The first step in this analysis was determining hourly boiler load from the plant gas usage logs. The inputs necessary to this calculation were simply the usage logs themselves, and the gas-to-steam efficiency of the installed boilers. The latter parameter was calculated for each hour according to the following formula:

$$n_{hour} = \eta_{combustion} * (1 - l_{blowdown}) - l_{radiant} n_{hour} = \eta_{combustion} * (1 - l_{blowdown}) - l_{radiant}$$

Where,

$n_{hour} n_{hour}$	*= Boiler efficiency for a given hour*
$\eta_{combustion}$	$\eta_{combustion}$ *= Combustion efficiency determined as a function of the net stack temperature (difference between the stack temperature and ambient temperature) and excess oxygen.*[4]
$l_{blowdown}$	$l_{blowdown}$ *= Blowdown loss fraction, which was determined from boiler and feed water conductivity readings to be.9 percent on average. Blowdown was assumed to occur as saturated liquid at the saturation temperature corresponding to the boiler's operating pressure.*
$l_{radiant}$	$l_{radiant}$ *= Radiant losses, assumed equal to 1 percent*[5]

Boiler load for a given hour was calculated by multiplying the boiler efficiency by the boiler gas consumption. Boiler load was then plotted against ambient temperature for each hour corresponding to the three weeks of gas usage data provided by the site. Figure 1 below presents the raw temperature and load data, as well as the regression trend fitted to the data.

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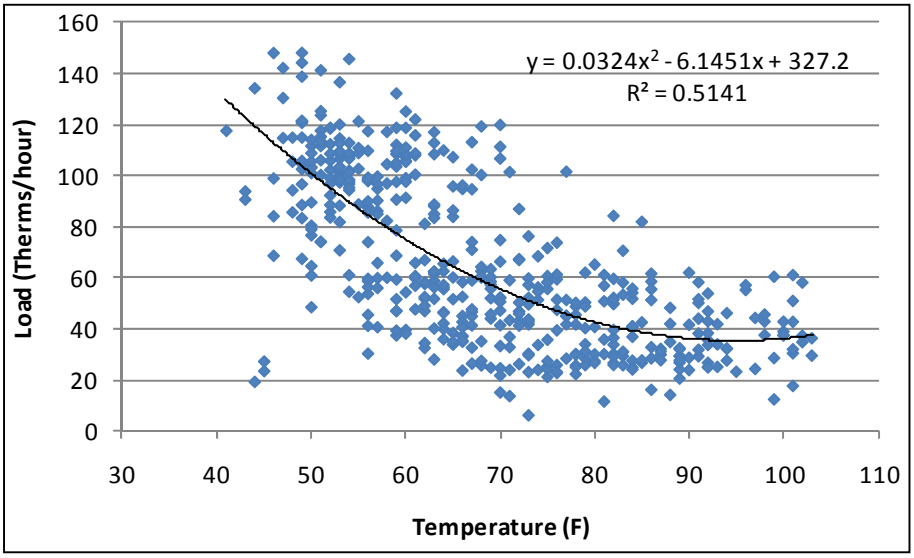
4 Based on the efficiency graph on page 15 of the *Nova Induced FGR Low NOx Combustion System – Installation and Operations Manual.*

5 Based on the Department of Energy's Best Practices End User Training document stating shell losses of well-maintained blowers typically average .1% to 2% (http://www1.eere.energy.gov/industry/pdfs/shellloss.pdf).

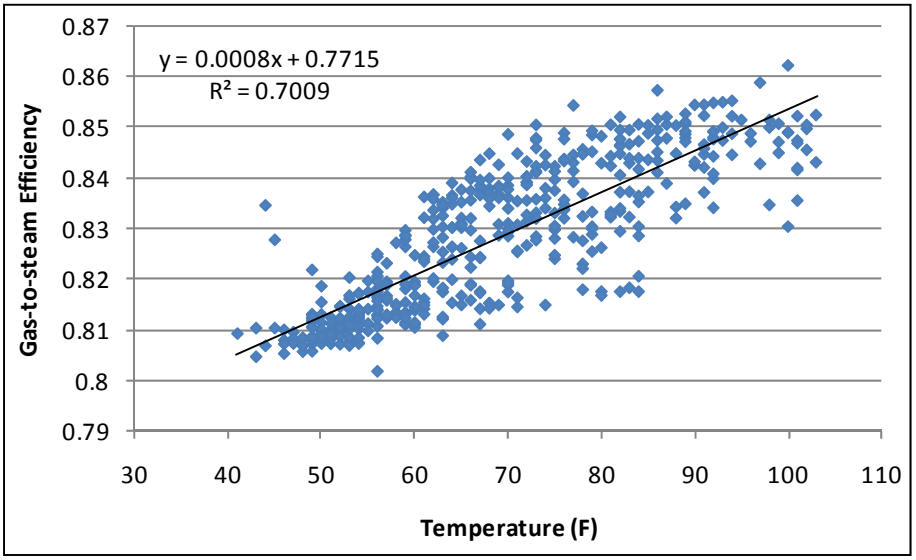
Figure 1: Boiler Load versus Ambient Temperature Data and Trend



Source: DNV KEMA analysis

Using California CTZ climate zone 10 weather data (TMY3 was not used because a TMY station in the NRC was unavailable), boiler load was projected for each hour of the year. For the pre-existing boiler, hourly gas usage was estimated in accordance with the seasonal efficiencies projected in the ex ante analysis. Since new data were not available to adjust these efficiencies, gas usages was left unmodified. For the installed boilers, gas usage was projected using a variable plant efficiency based on the efficiency versus ambient temperature trend below (Figure 2). This trend was developed by plotting projected boiler efficiency against ambient temperature on an hourly basis for the three weeks with available plant logs.

Figure 2: Boiler Efficiency versus Ambient Temperature Data and Trend



Source: DNV KEMA analysis

Electricity savings were estimated by taking the difference between the pre-existing blowers' electrical demand and the installed blowers' electrical demand for each hour of the year. Two pre-existing blowers were assumed to operate continuously for the whole year at a load factor of .8, the same load factor used in the ex ante analysis. The number of operating installed blowers was related to outdoor temperature using the boiler logs provided by the site contact; a minimum of one blower and a maximum of three blowers were assumed to operate at all times. The base case blowers were estimated to draw 16.9 kW each, while the installed blowers were estimated to draw 7.1 kW based on the spot measurements taken on-site.

Peak demand savings were calculated according to the CPUC peak demand definition for weather dependent measures.[6]

Note that when savings were calculated relative to Baseline 2 (the standard practice baseline), the fundamental calculation approach was not changed. However, the base case boiler gas-to-steam efficiency was changed to 75 percent in accordance with the thermal efficiency baseline cited in the Standard Performance Contract (SPC) Program Manual[7] for boilers. Furthermore, the base case blowers were assumed to be the same size and quantity as the installed blowers.

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6 According to the CPUC, peak demand savings are defined as the average demand reduction occurring during the three consecutive hottest weekdays of the year between the hours of 2 p.m. and 5 p.m.

7 Note that the SPC manual uses Title 20 and Title 24 standards and industry standard practice for its baselines.

However, they were assumed to operate with baseline motor efficiencies from the SPC manual at an 80 percent load factor, for an average of 9.8 kW per blower.

Savings Results

Relative to the pre-existing equipment (Baseline 1), the project saved 215,180 therms and 144,014 kWh annually. During the peak demand period, the project resulted in an average of 21.3 kW in savings. Project savings are summarized in Table E-43 at the beginning of this report. The ex ante savings estimates, which were taken from the program's monthly status reports, are also provided as a point of reference. Relative to Baseline 2, gas and electric savings reduced to 72,251 therms and 57,186 kWh respectively; peak demand savings were reduced to 4.69 kW.

Discussion

As Table E-43 indicates, this project saved nearly as many therms as anticipated and significantly more electricity than projected. The difference in gas savings is a function of the increased data available for the evaluation as opposed to any shortcoming in the ex ante analysis. In the ex post period, more extensive boiler usage logs were available from which to estimate both boiler efficiency and load. As a result, the annualized installed boiler efficiency was reduced slightly from the 82.5 percent used in the ex ante analysis to 81.7 percent in the ex post analysis. Furthermore, the availability of extensive boiler logs ex post allowed the development of a load regression profile normalized to a standard CTZ10 weather year. By contrast, the ex ante analysis relied on a year's worth of gas billing data that may or may not have been representative of a TMY.

The large difference in electric savings has two causes. First, the installed blower electric demand of the installed equipment was reduced from 9.1 kW in the ex ante analysis to 7.1 kW in the ex post analysis based on measured power draw. Second, the annual average number of operating installed blowers was reduced from 2.75 in the ex ante analysis to 2.42 in the ex post analysis. This second modification was made based on a blower usage regression trend developed from the boiler logs provided by the site. Together, these two changes drastically increased the electric savings realized from the boiler retrofit.

Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the energy efficiency measure implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

Table E-3 below provides the annual energy savings estimates that fed into the life-cycle savings calculations, as well as the EUL for the installed measure.

Table E-3: Values Used in Life-cycle Savings Calculations

Measure	Early Replacement / Pre-existing Equipment Baseline		Expected Replacement Baseline		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
Boiler Retrofit	144,014	215,180	57,186	72,251	20	0

Source: DNV KEMA analysis

Table E-4 provides life-cycle savings for the project relative to Baseline 1.

Table E-4: Life-cycle Savings Relative to Baseline 1

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	144,014	21.3	215,180
2	2012	144,014	21.3	215,180
3	2013	144,014	21.3	215,180
4	2014	144,014	21.3	215,180
5	2015	144,014	21.3	215,180
6	2016	144,014	21.3	215,180
7	2017	144,014	21.3	215,180
8	2018	144,014	21.3	215,180
9	2019	144,014	21.3	215,180
10	2020	144,014	21.3	215,180
11	2021	144,014	21.3	215,180
12	2022	144,014	21.3	215,180
13	2023	144,014	21.3	215,180
14	2024	144,014	21.3	215,180
15	2025	144,014	21.3	215,180
16	2026	144,014	21.3	215,180
17	2027	144,014	21.3	215,180

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
18	2028	144,014	21.3	215,180
19	2029	144,014	21.3	215,180
20	2030	144,014	21.3	215,180
21	2031	-	-	-
Life-cycle	Total	2,880,280 kWh	426 kW-Years	4,303,600 therms

Source: DNV KEMA analysis

Table E-5 provides life-cycle savings for the project relative to Baseline 2.

Table E-5: Life-cycle Savings Relative to Baseline 2

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	144,014	21.3	215,180
2	2012	57,186	4.7	72,251
3	2013	57,186	4.7	72,251
4	2014	57,186	4.7	72,251
5	2015	57,186	4.7	72,251
6	2016	57,186	4.7	72,251
7	2017	57,186	4.7	72,251
8	2018	57,186	4.7	72,251
9	2019	57,186	4.7	72,251
10	2020	57,186	4.7	72,251
11	2021	57,186	4.7	72,251
12	2022	57,186	4.7	72,251
13	2023	57,186	4.7	72,251
14	2024	57,186	4.7	72,251
15	2025	57,186	4.7	72,251
16	2026	57,186	4.7	72,251
17	2027	57,186	4.7	72,251
18	2028	57,186	4.7	72,251

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
19	2029	57,186	4.7	72,251
20	2030	57,186	4.7	72,251
21	2031	-	-	-
Life-cycle	Total	1,230,548kWh	110.6 kW-Years	1,587,949 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Corcoran State Prison Retrofit

Site Summary

The California State Prison, Corcoranis a penitentiary serving thousands of inmates. The facility consists of housing blocks of various security levels and support areas such as kitchens, offices, workshops and food storage warehouses. Corcoran implemented a series of EEMs that significantly reduced the prison's energy consumption. These measures included (EEM 1) EMS control upgrades, (EEM 2) programmable thermostats, (EEM 3) constant volume CV to variable air volume (VAV) conversions for four air handlers, and (EEM 4) high bay interior lighting retrofits in multiple buildings. After implemented EEM 1 through EEM 4, Corcoran had additional program loan funds remaining and appropriated these towards completing EEM 5, a retrofit of exterior wall pack lights throughout the facility. Ex ante and ex post savings for the measures are presented in Table E-6.

Table E-6: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1: EMS Upgrades	2,190,874	None Claimed	61,468	1,696,003	108.6	54,625	77.4%	90.3%
EEM 2: Programmable Thermostats	362,889	None Claimed	0	304,066	36.0	0	83.8%	N/A
EEM 3: Variable Speed Drive Fans	83,844	None Claimed	5,438	163,480	0	0	195.0%	0.0%
EEM 4: Interior Lighting Retrofit	1,982,859	None Claimed	0	2,015,759	321.7	0	101.7%	N/A

Measure	Ex Ante			Ex Post			Realization Rate	
EEM 5: Exterior Wall Pack Lighting Retrofit	None Claimed	None Claimed	None Claimed	487,757	0	0	N/A	N/A
Total	4,620,466	None Claimed	66,906	4,667,065	466.4	54,625	101.0%	81.6%

Source: DNV KEMA analysis

Life-cycle savings for these EEMs were based on the appropriate DEER EUL values when available. Life-cycle savings were calculated relative to two baselines. Baseline 1 assumed that the pre-existing equipment would have operated for the full EUL of the new equipment. Baseline 2 used the pre-existing equipment as the measure baseline only so long as it had RUL. Thereafter, an expected equipment baseline was used for the RUL of the new equipment. In the case of this project, EEM 1 through EEM 3 were upgrade measures, not equipment replacement measures. As such, Baseline 1 and Baseline 2 were equivalent for these measures because there was not baseline equipment to consider as part of the analysis. Baseline 1 and Baseline 2 were also equivalent for EEM 4 because the specifications for the pre-existing lighting types matched the standard practice lighting specifications for fixtures of the corresponding types listed in the SPC Manual.[8] For EEM 5, the pre-existing fixtures represented the standard practice for prison wall lighting applications and were, therefore, used under the expected replacement baseline as well. Life-cycle savings were, therefore, equivalent relative to each baseline.

Table E-7: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	71,260,388	7,168.1	819,372
Baseline 2	71,260,388	7,168.1	819,372

Source: DNV KEMA analysis

8 http://asset.sce.com/Documents/Shared/090601_SCE_B_Standard_Fixture_Watts.pdf.

Project Description

EEM 1 and EEM 2

The EMS upgrade and programmable thermostat measures are best classified and discussed together. From an energy conservation perspective, both measures serve the same function: reduce the operating hours of HVAC equipment distributed throughout the prison and allow for fixed programmable set points. Programmable thermostats were used in cases in which certain buildings could not be wired to the prison's EMS system. EMS or programmable thermostat based controls were implemented in a total of 73 buildings.

Even though the two measures serve the same function, the measures were classified separately in the ex ante analysis because different technologies are used. In addition, the EUL of programmable thermostats (11) is less than that of EMS control measures (15), thereby reducing the project's life-cycle savings.

EEM 3

Four air handlers in four buildings were subject to constant volume to variable volume conversions. The air handlers, which range in size from 10 hp to 15 hp, each serve multiple VAV boxes and are now controlled via duct static pressure.

EEM 4

This measure predominantly involved replacing hundreds of HID high bay fixtures with new induction fixtures. In a few instances, high wattage CFLs were removed and in others efficient T5 lights were installed. The table below summarizes the quantities of replaced and newly installed fixtures projected in the ex ante analysis.

Table E-8: Pre-existing and Installed Fixture Counts from Ex Ante Analysis

Pre-existing	
Fixture Type	**Quantity**
150W CFL	13
100W HPS	48
250W HPS	480
400W HPS	21
250W MH	874
250W MH	474

Installed	
Fixture Type	**Quantity**
F54T5HO, 4L	92
F54T5HO, 6L	55
150W Induction	1,019

Source: DNV KEMA analysis

EEM 5

The final EEM consisted of replacing 580 250 W HPS wall pack fixtures with 100 W induction fixtures.

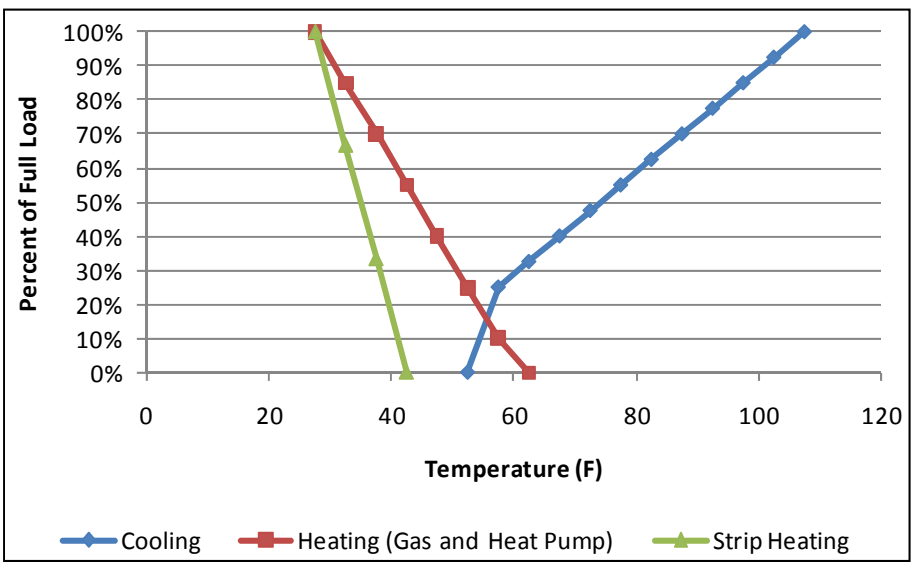
Ex ante Savings

EEM 1 and EEM 2

Savings from the EMS and programmable thermostat measures were calculated in an identical fashion because both measures yielded identical results: both measures reduced HVAC operating hours and raised cooling set points. An estimated full load hours (EFLH) based calculation was used to evaluate measure savings; given the number of buildings affected by these measures (73), it would not have been reasonable to assess savings using a more time intensive approach such as simulation modeling.

EFLH for cooling, heating, and strip heating equipment were estimated using temperature dependent load profiles and binned weather data for Fresno. The load profiles used to estimate EFLH are presented in Figure 3 below; the markers indicate the load percentage corresponding to the middle of each 5 degree temperature bin assembled from the weather data files.

Figure 3: Load Profiles for EFLH Analysis



Source: DNV KEMA analysis

Annual EFLH hours for cooling were calculated as:

$$EFLH_{cool} = \sum_i Hours_i * Load\%_i$$

Where,

$EFLH_{cool}$EFLH$_{cool}$ = Cooling EFLH

$Hours_i$Hours$_i$ = Annual hours in the 5 degree temperature bin, i

$Load\%_i$Load%$_i$ = Load fraction calculated at the midpoint of 5 degree temperature bin, i

EFLH were calculated in an identical fashion for heating and strip heating. A second set of EFLH profiles were then developed for the "weekday" period incorporating all annual hours between 7 a.m. and 6 p.m. on weekdays.

The EFLH values were next used to develop average load factors for the cooling, heating and strip heating equipment. For instance, the annual cooling EFLH was divided by 8,760 to yield an annual cooling load factor of 30 percent. Similarly, the weekday cooling EFLH was divided by the gross annual hours between 7 a.m. and 6 p.m. on weekdays to arrive at a weekday cooling load factor of 41 percent. Why were separate load factors developed for an annual schedule and a weekday-only schedule? The answer lays in the fact that EEM 1 and EEM 2 generated savings by shortening operating schedules. In many cases, the operating schedules were reduced such that equipment remained locked out on weekends, whereas it had previously operated continuously throughout the year. As such, the ex ante analyst clearly thought it necessary to develop a second set of load factors for equipment that would only operate on weekdays following implementation of EEM 1 and EEM 2.

For a given piece of equipment, savings were calculated as follows:

$$\begin{aligned} kWh_{saved} &= kW_{eq}\left(Hours_{pre}LF_{pre} - Hours_{Post}LF_{Post}\right)kWh_{saved} \\ &= kW_{eq}\left(Hours_{pre}LF_{pre} - Hours_{Post}LF_{Post}\right) \end{aligned}$$

Where,

$kWh_{saved}kWh_{saved}$ = Annual energy savings for a given piece of equipment

$kW_{eq}kW_{eq}$ = Full load power draw of the equipment (kW)

$Hours_{pre}Hours_{pre}$ = Operating hours before measure implementation (8,760)

$LF_{pre}LF_{pre}$ = Load factor before measure implementation (30 percent)

$Hours_{Post}$ $Hours_{Post}$ = Operating hours following measure implementation (varies by equipment)

$LF_{Post}LF_{Post}$ = Load factor following measure implementation (41 percent or 30 percent)

For equipment that retained weekend operation following measure implementation, the same load factor was used for both the preinstallation and postinstallation cases.

Note that this approach is imperfect because the post-implementation schedules vary significantly from one building to the next, and thus the actual load factors vary as well because the number of hours in the temperature bins used to derive ELFH (and subsequently load factor) depend on the operating schedules. This shortcoming was ultimately addressed in the ex post analysis and largely accounts for the difference between the ex ante and ex post savings claims.

In addition to calculating savings from operating schedule adjustments, savings were also claimed for programming fixed cooling set points. Before measure implementation, the pre-existing manual thermostats allowed prison staff to adjust cooling set points at their discretion, leading to excessive cooling in some cases.

Savings from implementing a 78°F fixed thermostat set point were estimated by first simulating a single representative building in eQUEST. The savings derived from adjusting the set point from some unknown value to 78°F were determined to be 17 percent of the building's cooling and ventilation end uses. The eQUEST model used to develop these savings was not provided for review, so the validity of the results could not be assessed.

The savings factor (17 percent) determined from the eQUEST model runs was then applied to the cooling and ventilation equipment's energy consumption for the post-implementation period to estimate cooling set point adjustment savings. Note that not all buildings and equipment were subject to set point adjustments.

EEM 3

CV to VAV conversion savings were calculated using the very conservative assumption that fan power demand varies linearly with flow. This assumption was implemented indirectly by altering the operating hours assumed for the fans post-implementation. For instance, in the case of one AHU scheduled to operate seven days per week between 6 a.m. and 4 p.m., it was assumed that on weekends, 75 percent of VAV boxes servicing the air handler would close. On this basis, the reduced operating hours for the post-implementation period were calculated as:

$Hours_{post} = Hours_{pre}\left(\frac{5}{7} * 100\% + \frac{2}{7} * 25\%\right) Hours_{post} = Hours_{pre}\left(\frac{5}{7} * 100\% + \frac{2}{7} * 25\%\right).$
Savings were then simply determined by multiplying the full load operating power of the fan by the pre- and post-implementation operating hour differential.

Gas savings were also claimed as part of this EEM. These gas savings, however, were a holdover from the "Phase 1" part of this project and should not have been claimed under this "Phase 2" part of the project. Only those measures implemented during "Phase 2" of this project were claimed for savings as part of the loan application. As such, the gas savings associated with this measure were zeroed out as part of the evaluation.

EEM 4

For each area of the prison affected by the lighting retrofit, savings were calculated using the following equation:

$$kWh_{saved} = \left(n_{pre}kW_{fix-pre} - n_{post}kW_{fix-post}\right)Hours$$
$$kWh_{saved} = \left(n_{pre}kW_{fix-pre} - n_{post}kW_{fix-post}\right)Hours$$

Where,

kWh_{saved} = *Lighting energy savings [kWh]*

n_{pre} = *Number of pre-existing fixtures*

$kW_{fix-pre}$ = *Fixture wattage of the pre-existing fixtures [kW]*

n_{post} = *Number of installed fixtures*

$kW_{fix-post}$ = *Fixture wattage of the installed fixtures*

$Hours$ = *Operating hours of the affected fixtures*

$kWh_{saved} n_{pre} kW_{fix-pre} n_{post} kW_{fix-post} Hours$In each case, care was taken to modify the operating hours to account for those fixtures operating on emergency circuits.

EEM 5

Ex ante savings were not claimed for EEM 5 because Corcoran did not intend to implement this measure at project inception. The original project scope of EEM 1 through EEM 4 was expected to use the full project budget. When additional loan funds remained after implementing the other four EEMs, those funds were redirected towards implementing EEM 5.

Project Evaluation

Given the number of buildings (70+), quantity of HVAC equipment (200+ items), and number of lights affected by this project (1,700+), the focus of the evaluation was (1) verifying a sample of the installed equipment; and (2) confirming that the installed equipment operates in the manner specified in the ex ante calculations.

The scope of the project also impacted the analysis approaches taken for EEM 1 through EEM 3. Under normal circumstances, control measures such as EEM 1 and EEM 2 would be evaluated primarily using simulation tools such as eQuest. However, the number of buildings affected by this projected made it unreasonable to conduct the analysis in a simulation program. The evaluation team, therefore, leveraged the existing ex ante analysis and made modifications when possible to improve the calculations. The site findings and analysis modifications are discussed subsequently on a measure by measure basis.

EEM 1 and EEM 2

For the EMS and programmable thermostat controls measures, it was necessary to verify that the equipment affected by these measures was properly accounted for in the ex ante calculation. As such, HVAC equipment was verified at three buildings. A total of 10 packaged and split systems were verified. While minor errors were identified in the recorded model numbers for a few units, the equipment sizes and types were correct in all cases.

Aside from spot verifying HVAC equipment, the majority of on-site time dedicated to these measures was spent observing the EMS system and verifying the operating schedules used in the ex ante analysis. The site contact was asked to provide the schedules for each piece of equipment affected by EEM 1 and EEM 2. The operating schedules for all 217 EMS or programmable thermostat controlled pieces of equipment were recorded; 121 of these schedules were found to differ from the schedules used in the ex ante analysis.

Following the site work, the analysis began by using the newly collected scheduling data to revise the ex ante EFLH savings calculations. As mentioned previously, the ex ante approach was flawed in that it used EFLH values from the whole year and one other schedule (7 a.m. to 6 p.m. on weekdays) to come up two sets of cooling, heating, and strip heating load factors, which were then applied to each unique schedule in the analysis. For the evaluation, this approach was modified by directly calculating EFLH for all equipment based on the 26 unique schedules identified during the site visit. This analysis required: (a) TMY3 data for Visalia, California (the nearest weather station), (b) the load profiles developed for the ex ante analysis, and (c) the scheduling data collected during the site visit. As an example, cooling EFLH for a given operating schedules identified on-site were calculated according to the following formula:

$$EFLH_{cool} = \sum_{h=1}^{8,760} Load\%_h * Avail_h \; EFLH_{cool} = \sum_{h=1}^{8,760} Load\%_h * Avail_h$$

Where,

$EFLH_{cool}$	*= Cooling EFLH*
$Load\%_h$	*= Cooling load fraction in hour h as determined from the ambient temperature and the trend in Figure 3.*
$Avail_h$	*= System availability in hour h as dictated by the operating schedule programmed in the EMS system or thermostat (for example, if a unit is on for 45 minutes during a given hour, then the availability is 45/60, or .75)*

$EFLH_{cool} Load\%_h Avail_h$An identical approach was used to derive ELFH values for each piece of heating or strip heating equipment.

The revised EFLH values were used directly to calculate scheduling savings using the generalized formula,

$$kWh_{saved} = kW_{eq}\left(EFLH_{pre} - EFLH_{post}\right) kWh_{saved} = kW_{eq}\left(EFLH_{pre} - EFLH_{post}\right)$$

Where,

kWh_{saved}	*= Annual kWh saved by the project*
kW_{eq}	*= Full load electrical demand of the equipment (kW)*
$EFLH_{pre}$	*= EFLH prior to measure implementation [h]*
$EFLH_{post}$	*= EFLH following measure implementation [h]*

$kWh_{saved} kW_{eq} EFLH_{pre} EFLH_{post}$As in the ex ante analysis, cooling set point adjustment savings were calculated using the results of eQuest simulation models. However, because the model used in the ex ante analysis was not available, the impact of cooling set point adjustments was estimated instead using DEER prototypes. Three DEER prototypes—office, restaurant, and multi-family residence—were run to approximate the various prison buildings affected by this measure. In each case, the cooling set point was assumed to have shifted from 74°F—a temperature claimed to be typical of the pre-existing conditions by the site contacts— to 78°F. Table E-9 below summarizes the annual cooling load savings attributable to the set point adjustment by building type:

Table E-9: DEER Prototype Cooling Set Point Adjustment Savings Factors

DEER Building Prototype	Cooling Load Reduction Due To Set Point Adjustment	Types of Spaces Applied To in Analysis
Restaurant	17%	Kitchens
Office	12%	Offices (Facility Support, Counselors Offices, Personnel Trailers, and so forth)
Multi-family Residential	24%	Housing Blocks

Source: DNV KEMA analysis

The savings fraction from the appropriate prototype was then applied to the post-implementation energy consumption of the cooling equipment affected by the set point adjustments.

Demand savings for EEM 1 and EEM 2 were addressed by assessing which equipment had previously operated during the summer peak demand period,[9] but currently remains off due to the scheduling adjustments. In the event that a scheduling change resulted in partial operation during the peak demand period, savings were calculated by multiplying the fraction of the peak period during which the equipment no longer operates by its full load electrical demand. For instance, if an AC unit previously operated throughout the peak demand period (2 p.m. to 5 p.m.), but now only operates from (2 p.m. to 4 p.m.), demand savings were estimated as one third of the unit's full load power draw.

EEM 3

During the site visit, the site contact was asked to confirm that each of the four air handlers affected by the CV to VAV conversion had previously operated as constant volume fans. Additionally, the site contact and the consultant responsible for this portion of the analysis were asked to clarify the assumptions made in the ex ante analysis. In particular, the ex ante analysis assumed that the CV to VAV conversion would allow a certain quantity of the VAV boxes to close during the weekends. The consultant explained that this assumption was made to simply estimate the impact of the CV to VAV conversion. In reality, loads dictate the position of the VAV dampers at any time. Based on this finding, and the overly conservative method in which savings were assigned to this measure, the EEM 3 savings analysis was revisited in the evaluation with a new approach.

9 According to the CPUC, peak demand savings are defined as the average demand reduction occurring during the three consecutive hottest weekdays of the year between the hours of 2 p.m. and 5 p.m.

For each hour of the year, the cooling and heating load percentages were first calculated using the load profiles above in Figure 3. The load in a given hour was then checked against the operating schedule for a given air handler to verify that the air handler was on during that hour. The percent load during the hour was then assumed to correspond directly with the airflow percentage during that hour. The airflow percentage was then multiplied by the number of VAV boxes fed off a given air handler. For instance, if an air handler was estimated to require 70 percent flow, and air handler served 11 VAV boxes, then approximately 7.7 VAV boxes (.7*11) would be required to be open (assuming equivalent sizing). On this basis, the number of open VAV boxes was projected to be 8, thereby yielding a final airflow percentage estimate of 8/11, or 73 percent. This flow percentage was then used in an air handler variable frequency drive (VFD) percent flow versus percent power curve provided in the California Alternative Compliance Method Approval Manual[10] and also used in DOE2 for all VFD supply fan calculations. The power percentage determined from the curve was then multiplied by the full load power draw of the fan to arrive at the power draw estimate for a given hour. This demand was then compared directly to the full load power draw of the fan (the base case condition) to determine savings. Savings from each fan during each hour of the year were then summed to arrive at measure savings. Peak demand savings were calculated as the average kW savings realized during the nine hours comprising the CPUC defined peak period.

EEM 4

During the site visit, more than 350 fixtures were verified to confirm the fixture types and quantities specified in the ex ante analysis. Table E-10 below summarizes the findings and ex ante claims for each verified area.

Table E-10: Verified and Ex Ante Claimed Fixture Count Comparison

Fixture Type	Ex Ante Quantity	Verified Quantity	Differential
Plant Ops			
150W Induction	49	49	0
Stationary Engineers			
150W Induction	18	17	-1
Boiler House			
150W Induction	19	17	-2
IWL Tool Barn			
150W Induction	11	11	0

10 http://www.energy.ca.gov/2008publications/CEC-400-2008-003/CEC-400-2008-003-CMF.PDF, Pg. 2-81.

Fixture Type	Ex Ante Quantity	Verified Quantity	Differential
IWL Open Canopy			
150W Induction	7	7	0
PIA Warehouse			
150W Induction	6	6	0
F54T5HO, 6L	55	64	+9
F54T5HO, 4L	13	12	-1
PIA Plumbers Ops			
150W Induction	50	49	-1
Housing Units 3A5 & 3A4			
150W Induction	78	78	0
Housing Units 4B4 (Left Half) & 4B3 (Right Half)			
150W Induction	60	60	0
Totals	366	370	+4

Source: DNV KEMA analysis

Because the observed quantities generally match those specified in the ex ante analysis, it was deemed unnecessary to verify additional fixtures during the site visit, or modify the fixture counts in the subsequent analysis beyond the few changes noted above.

Time was also spent during the site visit to verify that the lighting operating hours assumed for each retrofit area of Corcoran were correct. Of the 1,910 fixtures affected by the retrofit, only 118 were identified that operate on schedules different than those assumed in the ex ante analysis.

As in the ex ante analysis, savings were determined simply based on the difference between the pre-existing and installed connected load and the operating hours of the lights.

EEM 5

The DNV KEMA site visit occurred before Corcoran had finished implementing the wall pack lighting retrofit. As such, EEM 5 was not verified on-site. The site contact provided invoicing showing that 580 new fixtures had been purchased and provided assurances that all fixtures were installed. Savings were determined based on the difference between the pre-existing and installed connected load and the operating hours of the wall pack lights. Given that all other measures at Corcoran had been implemented as proposed, the evaluation team included these claimed savings with telephone and invoice verification only.

Savings Results

Relative to Baseline 1 and Baseline 2, the Corcoran project achieved savings of 4,667,065 kWh and 54,625 therms annually, while reducing peak demand by 466.4 kW. Savings are the same under both baselines for EEM 1 through EEM 3 because those measures were upgrades, not

replacement, projects. For EEM 4 and EEM 5, the removed fixtures were standard practice equipment for their respective applications. In fact, the wattages used in the EEM 4 analysis for each of the pre-existing high bay fixtures were equivalent to the wattages for the corresponding fixtures types specified in the SPC Manual. Altogether, the project achieved realization rates of 101 percent and 81.6 percent for electricity and gas respectively.

Discussion

Excluding EEM 5, which was implemented in addition to the original scope, the project saved 9.5 percent less electrical energy than projected in the ex ante analysis. The savings differential is attributable to EEM 1 and EEM 2. These two measures were both implemented properly; savings were reduced because of modifications made to the ex ante analysis. In particular, the EFLH approach used in the ex ante analysis incorrectly used only two sets of scheduling load factors, which were applied to all equipment in the postretrofit case. In the evaluation analysis, EFLH were instead determined uniquely for each of the 26 schedules implemented with the EMS and programmable controls. Unfortunately, this analysis modification had the net effect of reducing savings.

In contrast to EEM 1 and EEM 2, EEM 3 saved considerably more energy than anticipated, achieving a realization rate of 195 percent. The increased savings are attributable to changes in the analysis method. The ex ante analysis relied on the very conservative assumption that savings were directly proportional to reduced airflow. The evaluation analysis instead used industry accepted VSD flow versus power curves to project savings based on hourly load.

Note that the gas savings for EEM 3 were zeroed out because the savings were achieved as part of a "Phase 1" project that was not funded through this loan application (see the brief discussion in the "Ex Ante Savings" section).

EEM 4 saved slightly more energy than anticipated, realizing 101.7 percent of ex ante savings. The small savings boost resulted from revised the operating schedules for a few fixture groups.

The additional savings provided by EEM 5, which was outside of the scope of the original project, bolster savings enough to yield an overall realization rate of 101.0 percent for kWh.

Life-cycle Savings

Table E-11 below provides the annual energy savings estimates that fed into the life-cycle savings calculations, as well as the EUL for the installed measure. Note that the EUL for the lighting measure is a non-standard 15.984 years. This was caused by the fact that induction fixtures have an EUL of 16 years,[11] while T5 high bay fixtures have an EUL of 15 years. The average EUL, as weighted by the annual energy savings achieved by each fixture, is 15.984 years.

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11 Appropriated from the 2001 *CPUC Energy Efficiency Policy Manual, Pg. 21* because induction fixtures are not covered in DEER. See http://docs.cpuc.ca.gov/published/Graphics/11474.pdf.

Table E-11: Values Used in Life-cycle Savings Calculations

Measure	Savings Relative to Pre-existing Equipment		Savings Relative to Standard Practice Equipment		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 1: EMS Upgrades	1,696,003	54,625	1,696,003	54,625	15	0
EEM 2: Programmable Thermostats	304,066	0	304,066	0	11	0
EEM 3: Variable Speed Drive Fans	163,480	0	163,480	0	15	0
EEM 4: Interior Lighting Retrofit	2,015,759	0	2,015,759	0	15.984	0
EEM 5: Exterior Wall Pack Lighting Retrofit	487,757	0	487,757	0	16	0

Source: DNV KEMA analysis

Table E-12 provides life-cycle savings for the project relative to Baseline 1 and Baseline 2.

Table E-12: Life-cycle Savings Relative to Baseline 1 and Baseline 2

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	4,667,065	466.4	54,625
2	2012	4,667,065	466.4	54,625
3	2013	4,667,065	466.4	54,625
4	2014	4,667,065	466.4	54,625
5	2015	4,667,065	466.4	54,625
6	2016	4,667,065	466.4	54,625
7	2017	4,667,065	466.4	54,625
8	2018	4,667,065	466.4	54,625
9	2019	4,667,065	466.4	54,625
10	2020	4,667,065	466.4	54,625
11	2021	4,667,065	466.4	54,625
12	2022	4,362,999	430.4	54,625

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
13	2023	4,362,999	430.4	54,625
14	2024	4,362,999	430.4	54,625
15	2025	4,362,999	430.4	54,625
16	2026	2,470,682	316.5	0
17	2027	-	-	0
Life-cycle	Total	71,260,393 kWh	7,168.5 kW-Years	819,375 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Salinas Correctional Training Facility Energy Efficiency Improvements

Site Summary

The Salinas Correctional Training Facility (CTF) provides level 1 to level 3 inmates with housing and program services. The Salinas CTF applied for ARRA funds to replace a central boiler system that was used to generate steam for uses throughout the facility. ARRA funds were also used to implement a facility wide lighting retrofit and to add direct digital controls (DDC) to the rooftop air conditioners at the South Administration Building. Ex post and ex ante energy savings are presented in Table E-13 below.

Table E-13: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1 – Boiler Replacement	0	0	222,983	0	0.0	222,983	N/A	100%
EEM 2 – DDC Controls	8,900	0	38	7,905	0.0	38	89%	100%
EEM 3 – Exterior Lighting	321,804	0	0	322,565	0.0	0	100%	N/A
EEM 4 – Interior Lighting	399,456	47.84	0	416,722	47.6	0	104%	N/A
Total	730,160	47.84	223,021	747,192	47.6	223,021	102%	100%

Source: DNV KEMA analysis

The project was installed as described with only minor discrepancies. Hence, ex post energy savings are nearly identical to ex ante estimates.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the RUL of the pre-existing equipment is exceeded.

Under Baseline 1, the life-cycle energy savings is 11,853,015 kWh and 4,460,227 therms. Under Baseline 2, the life-cycle savings is 11,853,015 kWh and 3,596,212 therms (Table E-14).

Table E-14: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	11,853,015	714	4,460,227
Baseline 2	11,853,015	714	3,596,212

Source: DNV KEMA analysis

Project Description

The Salinas CTF is large facility broken up into three sections (north, central, and south). Different sections of the facility house inmates at different security levels. The project was for various energy efficiency upgrades performed throughout the facility. There were four main EEMs: high efficiency boiler replacement, interior lighting retrofit, exterior lighting retrofit, and conversion of 10 rooftop air conditioner units to DDC controls.

EEM 1: Boiler Replacement – Before the retrofit, two boilers were used to provide steam, the first as the main boiler and the second as backup. Steam was used to heat up water for space heating, cooking, and DHW uses. This measure is for the replacement of these boilers with high efficiency units rated at 85 percent.

EEM 2: DDC Controls – The South Administration building is served by 10 rooftop direct expansion (DX) units and hydronic heat from a small boiler located in the mechanical room. Zone temperatures were manually controlled before the retrofit. The measure is to convert the units to DDC controls.

EEM 3: Exterior Lighting – The exterior building and yard lights are composed of 250 to 1,000 Watt high pressure sodium (HPS) lamps. This measure is to convert these lamps to induction or metal halide lamps.

EEM 4: Interior Lighting – The interior building lighting are largely composed of 100 to 400 Watt HPS lamps. This measure is to convert these lamps to linear fluorescent T5 or T8 lamps.

Ex ante Savings

Ex ante energy savings were calculated using a spreadsheet approach using best estimates of operation parameters.[12]

EEM 1: Boiler Replacement – The existing boiler efficiency (72 percent) was estimated using the boiler logs which showed the amount of steam produced along with total gas consumed. This was leveraged with the site's average annual billing data over two years to determine the total annual gas usage. A new efficiency relative to the existing efficiency was applied to determine energy savings. The algorithm can be summarized with the following equation:

$$\begin{aligned} &Annual\ Therms\ Savings \\ &\quad = Annual\ Usage - Annual\ Usage\ \times \left(\frac{\eta_{old}}{\eta_{new}}\right) Annual\ Therms\ Savings \\ &\quad = Annual\ Usage - Annual\ Usage\ \times \left(\frac{\eta_{old}}{\eta_{new}}\right) \end{aligned}$$

Where η_{old} is the old efficiency at 72 percent and η_{new} is the new efficiency at 85 percent.

EEM 2: DDC Controls – The total rated tons of all HVAC units serving the South Administration Building were collected. The algorithm predicted energy consumption of the units using an estimate on effective full load hours that was taken from DEER. Energy savings were assumed as 10 percent of the total HVAC consumption due to the DDC controls and reference an Energy Commission guidebook literature source.

EEM 3: Exterior Lighting—The analysis used pre and postinstallation fixture quantities and wattages to determine the demand savings. The hours of operation were estimated at 4,380 hours per year for all exterior lights.

EEM 4: Interior Lighting — The same algorithm was used as in EEM 3. Hours of operation was estimated at 6,570 to 8,760 hours and was determined by the space type.

Project Evaluation

A DNV KEMA field engineer visited the project's site on February 2, 2012 to verify measure installation. Due to security restrictions at the site, no monitoring of any of the equipment was performed. DNV KEMA verified the lighting hours of use with the facility's site contact.

Nameplate data for the boilers along with checks on the pre-existing conditions were performed. DNV KEMA requested billing data as an additional check to the boiler measure

12 The main workbooks were provided by Newcomb Anderson McCormick, the contractor overseeing the efficiency projects.

energy calculations. An updated lighting worksheet was provided to DNV KEMA by personnel from the CDCR. No major discrepancies were found when information from this spreadsheet was compared with site installed fixtures. Table E-15 lists a summary of the site findings with further details for each measure provided in the section immediately after.

Table E-15: Site Findings

Measure	Ex Ante Quantity	Ex Post Quantity	Notes
EEM 1 – Boiler Replacement	2	2	Found as claimed, commissioning of the 2nd unit was being performed during the site visit
EEM 2 – DDC Controls	1	1	These controls managed 67 tons of nominal capacity at an average EER rating of 9.0
EEM 3 – Exterior Lighting	318	319	
EEM 4 – Interior Lighting	173	172	

Source: DNV KEMA analysis

EEM 1 – Boiler Retrofit

The preretrofit boilers were still intact at the time of the site visit but were not operating. Two new Miura boilers rated at 85 percent efficiency were found installed at the time of the visit. Each boiler is rated at maximum input of 8,300 kBtu/h. The preretrofit boilers were found to have a 61,000 kBtu/h input rating indicating that it was indeed oversized relative to the new boilers. Billing data[13] was obtained for the central plant showing typical annual gas consumption of ~1,400,000 therms. This value is in line with the ex ante assumptions on therms usage and, therefore, no adjustment were made to the energy savings calculation for this measure. This measure, therefore, saved 222,983 therms from the efficiency improvement of the new boilers.

EEM 2 – DDC Controls

This measure was found installed as described. Nameplate information for the 10 DX air conditioning units was collected. Using the nameplate data, DNV KEMA was able to look up the rated efficiencies of the units.[14] A composite efficiency of 9 EER was calculated which takes into account the tonnage weighting for each unit. The units were found to be relatively new looking and assumed to be in good working condition.

Ex post and ex ante energy savings calculations used the same algorithm. The higher EER (9 versus 8) of the units found resulted in a lower annual energy consumption which impacted the

13 Provided by Newcomb Anderson McCormick.

14 Using the Preston Guide, a database that lists pre 2005 HVAC units and their efficiencies.

energy savings for this measure. Energy savings for this measure is calculated at 7,905 kWh and 38 therms.

EEM 3 – Exterior Lighting

DNV KEMA drove throughout the facility with the site contact to verify the installation of the exterior lights which included both high mast and exterior building lights. General counts of different sections matched what was recorded in the lighting spreadsheet. The actual number of fixtures examined represented about 76 percent of the exterior lighting quantities. Since many of the buildings are identical, it was not necessary to spend additional time to capture the counts for the other lights.[15] DNV KEMA inquired about the hours of operation for these lights and found the hours are consistent with the values used in the spreadsheets. There was one line item at one of the buildings showing one more fixture than found in the spreadsheet calculations. Only this value was adjusted resulting in a total energy savings of 322,565 kWh and was nearly identical to ex ante estimates.

EEM 4- Interior Lighting

The lighting quantity and technology was verified and matched with the analysis spreadsheet provided with the exception of one line item. This fixture was located at the gym and did not impact the energy savings calculated significantly. Lighting hours of operation at the gym, however, were found to be higher than previously assumed. These lights are left on 8,760 hours a year versus the 6,570 hours predicted in the ex ante calculations. After adjusting for these hours, the energy savings for this measure was found to be 416,722 kWh.

Savings Results

Considering the implementation of all four EEMS, this site saved 747,192 kWh and 223,021 therms of energy in its first year. Table E-43 breaks down the ex post energy savings by measure. The ex ante energy savings are also provided for comparison.

Discussion

EEM 1 – Boiler

The boilers were found installed as described. DNV KEMA examined the ex ante calculations that were performed and found the estimates and methodology to be reasonable. Estimates of the boiler load were compared to the past two years of usage at the central plant where the boiler is located at. These values were found to be very close to the ex ante baseline estimates. Therefore, no adjustments to the energy savings for this measure were made.

EEM 2 – DDC Controls

One parameter in the energy savings for this measure was adjusted which reduced the energy savings to 89 percent of the ex ante value. This parameter is the composite efficiencies of all the

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15 Also, some secure areas were not accessible with a vehicle so it was not practical to visit those buildings at the time.

HVAC units affected by the measure. The efficiency was found to be higher than what was assumed (9.0 EER versus 8.0 EER) using the Preston guide and HVAC nameplate information collected on-site. Since the previous EER of the units were assumed in the ex ante analysis, updating the algorithm with actual unit efficiencies represent an improvement to the energy savings estimates. Though this may be the case, there is still significant uncertainty in the energy savings for this measure because it is virtually impossible to measure the effects of the DDC controls. The current calculation methodology which relies on the literature, however, was determined to be reasonable based on all available data and for the magnitude of energy savings claimed.

EEM 3 – Exterior Lighting

Ex post energy savings are nearly identical to ex ante estimates since no major discrepancies were found in the lighting quantity or hours of operation.

EEM 4 – Interior Lighting

Ex post energy savings are 104 percent of ex ante values. The slightly higher energy savings is due to a change in hours of operation at the North Gym which was found to operate 8,760 hours a year rather than 6,570 hours as assumed. There were no major discrepancies found in the audit for the interior lights.

Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

Nameplate from the boiler shows it was made in 1959. The unit had been well maintained over the years and was still in good shape according to the boiler engineer. Although the boiler is past its useful life according to the nameplate, DNV KEMA estimates the unit can still be operated for five more years. Therefore, Baseline 2 will use the current boiler efficiency for the first five years and revert to code standard thereafter.

Baseline 1 and Baseline 2 are the same for the interior lighting measure because the pre-existing setup is assumed to be already code compliant. The other two measures are either add on measures or measures where there is no standard practice in place. For these measures Baseline 1 and Baseline 2 are the same. Table E-16 summarizes the energy savings and life-cycle parameters by measure used in the life-cycle savings calculations. EUL values come from the DEER.

Table E-16: Values Used in Life-cycle Savings Calculations by Measure

Measure	Baseline 1		Baseline 2		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
Boiler	0	222,983	0	165,382	20	5
DDC Controls	7,905	38	7,905	38	15	0
Exterior Lighting	322,565	0	322,565	0	17[16]	0
Interior Lighting	416,722	0	416,722	0	15	0

Source: DNV KEMA analysis

When only considering Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 11,853,015 kWh and 4,460,227 therms (Table E-17). However, if Baseline 2 is used, the life-cycle savings comes to 11,853,015 kWh and 3,596,212 therms. Source: DNV KEMA analysis

Table E-18 tabulates the energy savings by year starting with 2011, using Baseline 2.

Table E-17: Baseline 1 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	747,192	48	223,021
2	2012	747,192	48	223,021
3	2013	747,192	48	223,021
4	2014	747,192	48	223,021
5	2015	747,192	48	223,021

16 Based on similar values used in the literature: "Demonstration Assessment of LED Roadway Lighting on Residential and Commercial Streets," PNNL, 2010. The report has estimates on EUL for induction lighting. While the end use is slightly different the technology is similar.

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
6	2016	747,192	48	223,021
7	2017	747,192	48	223,021
8	2018	747,192	48	223,021
9	2019	747,192	48	223,021
10	2020	747,192	48	223,021
11	2021	747,192	48	223,021
12	2022	747,192	48	223,021
13	2023	747,192	48	223,021
14	2024	747,192	48	223,021
15	2025	747,192	48	223,021
16	2026	322,565	0	222,983
17	2027	322,565	0	222,983
18	2028	0	0	222,983
19	2029	0	0	222,983
20	2030	0	0	222,983
21	2031	0	0	0
Life-cycle	Total	11,853,010	720	4,460,230

Source: DNV KEMA analysis

Table E-18: Baseline 2 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	747,192	48	223,021
2	2012	747,192	48	223,021
3	2013	747,192	48	223,021
4	2014	747,192	48	223,021
5	2015	747,192	48	223,021
6	2016	747,192	48	165,420
7	2017	747,192	48	165,420
8	2018	747,192	48	165,420
9	2019	747,192	48	165,420

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
10	2020	747,192	48	165,420
11	2021	747,192	48	165,420
12	2022	747,192	48	165,420
13	2023	747,192	48	165,420
14	2024	747,192	48	165,420
15	2025	747,192	48	165,420
16	2026	322,565	0	165,382
17	2027	322,565	0	165,382
18	2028	0	0	165,382
19	2029	0	0	165,382
20	2030	0	0	165,382
21	2031	0	0	0
Life-cycle	Total	11,853,010	720	3,596,215

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Salinas Valley State Prison at Soledad Energy Efficiency Improvements

Site Summary

The Salinas Valley State Prison (VSP) in Soledad, California, is a high security level correctional facility that houses level I and IV inmates in its 180 and 240 building units. The Salinas VSP used ARRA funds to replace the DHW heaters throughout these facilities. In addition, two lighting retrofit projects were implemented with the help of the ARRA funds. The first is an interior lighting retrofit which replaced existing HPS and T12 fixtures with next generation T8 fixtures. The second was for an exterior lighting project which replaced the existing HPS fixtures with lower wattage metal halide fixtures. Ex post and ex ante energy savings are presented in Table E-19 below.

Table E-19: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1 – Interior Lighting	520,700	Not reported	Not reported	520,700	92.9	0	100%	N/A
EEM 2 – Exterior Lighting	285,322	Not reported	Not reported	258,353	0.0	0	91%	N/A
EEM 3 – Domestic Water Heaters	168,529	Not reported	95,799	58,411	19.6	58,027	35%	61%
Total	974,551	0.0	95,799	837,464	112.5	58,027	86%	61%

Source: DNV KEMA analysis

Ex post gas energy savings are lower because data available from the water heaters show that the load factor for DHW at this facility was much lower than previously assumed. The major

reasons for a lower ex post electric energy savings were due to downwardly revised DHW pump power consumption and exterior lighting hours of operation.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the RUL of the pre-existing equipment is exceeded.

Under Baseline 1, the life-cycle energy savings is 12,561,960 kWh and 870,405 therms. Under Baseline 2 the life-cycle savings is 12,517,874 kWh and 303,055 therms (Table E-20).

Table E-20: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	12,561,960	1,687.5	870,405
Baseline 2	12,517,874	1,687.5	303,055

Source: DNV KEMA analysis

Project Description

This project was implemented throughout the Salinas VSP facilities. The DHW replacements affected the 270 and 180 design buildings and collectively involved 35 total DHW heaters. Interior lighting involved delamping and fixture retrofits to the dining hall, inmate cell, under tier, and mechanical room lights. The pre-existing lights were either T12 or HPS lamps and were replaced with T5 or T8 lamps. The exterior lighting measure involved high mast lights spread throughout the facility. The pre-existing high mast lights were 1,000 Watt HPS lights and were replaced with 750 Watt metal halides.

Ex Ante Savings

Ex ante energy savings were calculated using a spreadsheet approach using best estimates of operation parameters.

EEM 1: Interior Lighting — The analysis used pre and postinstallation fixture quantities and wattages to determine the demand savings. Hours of operation were estimated based on space type. These hours ranged from 2,000 for the mechanical rooms to 8,760 for the dining room area.

EEM 2: Exterior, High Mast Lighting—The same algorithm was used as in EEM 1. Hours of operation were estimated at 4,380 for all high mast fixtures.

EEM 3: DHW Heaters—This measure had both an electrical energy savings component and a natural gas energy savings component. The electrical savings component assumed that the new heaters were equipped with smaller draft fans, eliminated the need for an internal circulation pump, or reduced the operating hours of the DHW pump. Gas savings come from an efficiency upgrade of the units along with the elimination of existing leaks in the system.

Project Evaluation

A DNV KEMA field engineer visited the project's site on January 11, 2012 to verify measure installation. Due to security restrictions at the site, no monitoring of any of the equipment was performed. The placement of time-of-use sensors at the interior lighting fixtures would provide useful data on hours of use. However, it was not practical to install the data loggers even if permitted due to the nature of the facility. Instead, DNV KEMA verified the lighting hours of use with the facility's site contact.

Nameplate data for the boilers along with checks on the pre-existing conditions were performed. At the time of the site visit, a DHW heating system similar to the preretrofit case was present. DNV KEMA examined the system to verify the parameters used in the ex ante calculations. Any differences were noted and adjusted in the ex ante calculation spreadsheets. Table E-21 lists a summary of the site findings with further details for each measure provided in the section immediately after.

Table E-21: Site Findings

Measure	Ex Ante Quantity	Ex Post Quantity	Notes
EEM 1 – Interior Lighting	1,170	1,170	Lighting technology and quantities match
EEM 2 – Exterior, High Mast Lights	231	231	Operation hours less than claimed in ex ante; all other parameters the same
EEM 3 – DHW Heaters	35	35	Quantity the same, units are: 14 X 399 kBtu/h units at 97.4% η, 1 X 750 kBtu/h unit @ 85% η, 20 X 300 kBtu/h unit @ 96% η, Assumptions for heater electric systems do not match

Source: DNV KEMA analysis

EEM 1- Interior Lighting

The 180 building facilities are identical modules with similar lighting fixture setups. Therefore, it was only necessary to verify lighting at one of the buildings and multiply the result by the number of housing units. Each building is composed of three pods of inmate cells, a mechanical room, a dining area, and under tier lights in front of the inmate cells. The lighting quantity was verified and matched perfectly with the analysis spreadsheet provided. The hours of operation were reasonable based on responses from the site contact. Lighting fixtures in the mechanical rooms would benefit from the installation of lighting data loggers but due to restrictions at the facility no data loggers were installed.

Energy savings were calculated using the same algorithm as the ex ante analysis. The energy savings for this measure is 441,058 and is identical to the ex ante results.

EEM 2 – Exterior, High Mast Lighting

DNV KEMA drove throughout the facility with the site contact to verify the installation of the high mast lights. With the help of a contractor's diagram of the light locations, DNV KEMA was able to verify the installation of all the lights. Additionally,

DNV KEMA inquired about the hours of operation for these lights and was informed that all the lights with the exception of the yard lights operated 12 hours per day. The yard lights make up 131 of the 231 lighting fixtures for this measure. The hours of operation vary but are typically on at the same time schedule as the other lights except when manually shut off from 12 a.m. to 4 a.m. Occasionally the lights will be turned on at these times during foggy conditions in order for the guards to see the yard from their post, but the frequency and duration is variable and cannot be established with certainty. DNV KEMA estimated that the yard lights are on 50 percent of the time during the 12 a.m. to 4 a.m. window resulting in a daily operation of 10 hours per day. Some uncertainty exists as to the actual hours of use for the yard lights but 50 percent represents an optimistic estimate in favor of higher program savings.

Energy savings were adjusted in light of this finding using the same algorithm as the ex ante analysis. The results show an energy savings of 258,353 kWh due to the revised hours of use.

EEM 3 – DHW Heaters

Installation of the DHW heaters was verified during the site visit. At the "180 unit" buildings, DNV KEMA verified two 399 kBtu/h units with a 97.4 percent thermal efficiency rating served each of seven "180 unit" buildings. These units were equipped with an internal circulation pump. DNV KEMA did not observe an externally located DHW circulation pump.

The eighth "180 unit" building, although identical in construction, had a different DHW heater system than the first seven. This system was similar to the preretrofit DHW heater system. DNV KEMA collected the nameplate of the DHW pump to verify the baseline calculation inputs. The DHW pump was much smaller than claimed and drew only 1.7 amps off of a 120 voltage source. The heating capacity of the current DHW heater was 750 kBtu/h and has a thermal efficiency of 85 percent.

At the twenty "270 unit" buildings, a 300 kBtu/h DHW heater with a 96 percent thermal efficiency was found serving each of the twenty building. The draft fan was rated at 1.7 amps using a 120 voltage source. The new DHW heaters were equipped with technology that recorded total elapse time since installation and total time the burners are turned on. These two values in effect provide the load factor for the DHW heaters. The load factor averaged 8.1 percent for all heaters examined.

Information from the site visit were inputted into the ex ante algorithms. The analysis included accounting for leaks in the pre-existing units. An adjusted energy savings of 58,411 kWh and 58,027 therms were calculated for this measure.

Savings Results

Considering the implementation of all three EEMS, this site saved 757,927 kWh and 58,027 therms of energy in its first year. Table E-43 breaks down the ex post energy savings by measure. The ex ante energy savings are also provided for comparison.

Discussion

EEM 1 – Interior Lighting

No discrepancies were found for the interior lighting counts or hours of use assumptions hence, this measure realized 100 percent of the ex ante savings.

EEM 2 – Exterior Lighting, High Mast Lights

Energy savings for this measure is 91 percent of the ex ante values reported in the ARRA status updates. Through interviewing the facility contact, DNV KEMA found that the lighting hours for a large number of the high mast lights were less than what was originally estimated. Based on the contact's response, 131 of the high mast yard lights operated four hours less per day than previously thought. The other 100 lights were on 4,380 hours per year operation. DNV KEMA used a total annual operation hours of 3,966 versus 4,380 when calculating the lighting savings and took into account a weighted average of all the lights. The estimates are optimistic in favor of program energy savings but actual energy savings for this measure may be potentially less depending on how often the yard high mast lights are turned on.

EEM 3 – Domestic Water Heaters

In the original ex ante calculations, the load factor for the DHW heater was estimated at 16.7 percent. However, data collected from the new boilers which records both the total time the burners are turned on along with the total time in service, show that the load factor was only 8 percent. This suggests that the original estimates overstated DHW needs at this facility. In addition, the energy calculations do not accurately capture the efficiency of the original and new DHW heaters (72.4 percent and 96-97.4 percent, respectively). In the calculations this was inputted as 61 percent and 92 percent for the original and new DHW heaters, respectively. For these reasons, the natural gas savings is much lower than the ex ante estimates.

The major source for the lower electrical energy savings for this measure comes from the assumptions used to calculate energy consumption for the DHW pumps. In the ex ante analysis, the pre-existing pumps were assumed as drawing 6.1 to 8.2 amps. However, during the site

visit, one of the existing DHW pump nameplate was examined and showed that the pump only drew 1.7 amps suggesting that baseline electrical energy usage due to the pumps were over estimated. The values were readjusted in DNV KEMA's calculations and resulted in an overall 34 percent realization rate for the electrical energy savings component of this measure.

In DNV KEMA's experience, electrical energy savings are not typically calculated for DHW boiler retrofits unless there is compelling reasons such as the removal of a large pump. There are no large pumps associated with this measure. For this measure, the typical pump only drew 205 Watts of power and would likely be replaced with a similar sized pump, either internal to the DHW heater or placed externally. Indeed for the 180 units, the new heaters were found to have an internal circulation pump in lieu of the externally located DHW pump.

There were also theoretical energy savings from the draft fans based on ex ante assumptions, but DNV KEMA notes that two systems with two draft fans are replacing one larger DHW heating system. It is highly questionable whether there is an actual efficiency improvement in equipment efficiency since one fan is being replaced by two, but it is not possible to prove this since the power draws of the new draft fan is not listed in the nameplate data or manufacturer's literature. It is also questionable how the power draws of the baseline system was determined. The draft fans are assumed to draw 10 to 11.2 amps in the ex ante analysis but a similar sized unit found on-site only drew 2.2 amps based on the nameplate data.

Although DNV KEMA is claiming an electric energy savings for this measure of 58,411 kWh, there is a high level of uncertainty associated with this value. This is because the values used in determining baseline and efficient case inputs in the calculation algorithms are unproven. The electric energy savings for this measure may be closer to zero.

Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

According to the site contact, the DHW heaters had exceeded its useful life and were in major disrepair so Baseline 1 is not used except for in the first year energy savings calculation. For subsequent years, a code standard thermal efficiency of 80 percent is used as the baseline, consistent with federal efficiency standards. There are no established standards for the site's exterior lighting so the existing conditions are used for the baseline in the life-cycle savings.

Table E-22 summarizes the energy savings and life-cycle parameters by measure used in the life-cycle savings calculations. EUL values come from the DEER.

Table E-22: Values Used in Life-cycle Savings Calculations by Measure

Measure	Baseline 1		Baseline 2		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
Interior Lighting	520,700	0	520,700	0	15	0
Exterior Lighting	258,353	0	258,353	0	15	0
Water Heaters	58,411	58,027	55,262	17,502	15	0

Source: DNV KEMA analysis

When only considering Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 12,561,960 kWh and 870,405 therms (Table E-23). However, if Baseline 2 is used, the life-cycle savings comes to 12,517,874 kWh and 303,055 therms. Table E-24 tabulate the energy savings by year starting with 2011 using Baseline 2.

Table E-23: Baseline 1 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	837,464	113	58,027
2	2012	837,464	113	58,027
3	2013	837,464	113	58,027
4	2014	837,464	113	58,027
5	2015	837,464	113	58,027
6	2016	837,464	113	58,027
7	2017	837,464	113	58,027
8	2018	837,464	113	58,027
9	2019	837,464	113	58,027
10	2020	837,464	113	58,027
11	2021	837,464	113	58,027

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
12	2022	837,464	113	58,027
13	2023	837,464	113	58,027
14	2024	837,464	113	58,027
15	2025	837,464	113	58,027
16	2026	0	0	0
Life-cycle	Total	12,561,960	1,6895	870,405

Source: DNV KEMA analysis

Table E-24: Dual Baseline Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	837,464	113	58,027
2	2012	834,315	113	17,502
3	2013	834,315	113	17,502
4	2014	834,315	113	17,502
5	2015	834,315	113	17,502
6	2016	834,315	113	17,502
7	2017	834,315	113	17,502
8	2018	834,315	113	17,502
9	2019	834,315	113	17,502
10	2020	834,315	113	17,502
11	2021	834,315	113	17,502
12	2022	834,315	113	17,502
13	2023	834,315	113	17,502
14	2024	834,315	113	17,502
15	2025	834,315	113	17,502
16	2026	0	0	0
Life-cycle	Total	12,517,874	1,695	303,055

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Substance Abuse Treatment Facility Retrofit

Site Summary

The Substance Abuse Treatment Facility (SATF), located in Corcoran, California, is a penitentiary serving thousands of inmates. The facility consists of housing blocks of various security levels and support areas such as kitchens, control offices, and workshops. The SATF implemented two EEMs that significantly reduced the prison's energy consumption: (EEM 1) EMS upgrades and programmable thermostat controls, and (EEM 2) efficient high mast exterior lighting with EMS scheduling controls.

Ex ante and ex post savings for the measures are presented in Table E-25.

Table E-25: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1: Control Upgrades	5,178,365	None Claimed	49,944	5,639,050	424.5	231,016	108.9%	462.5%
EEM 2: High Mast Lighting Retrofit	235,380	None Claimed	0.0	656,061	0.0	0.0	278.7%	N/A
Total	5,413,745	None Claimed	49,944	6,295,111	424.5	231,016	116.3%	462.5%

Source: DNV KEMA analysis

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the RUL of the pre-existing equipment is exceeded.

Table E-26: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	82,562,556	5,474.1	2,979,196
Baseline 2	82,562,556	5,474.1	2,979,196

Source: DNV KEMA analysis

Project Description

EEM 1:

EMS upgrades and programmable thermostats comprise the core components of EEM 1. Both measures serve the same function: reduce the operating hours of HVAC equipment distributed throughout the prison and allow for fixed programmable set points. Programmable thermostats were used if buildings could not be wired to the facility's EMS system. EMS or programmable thermostat based controls were implemented in a total of 84 buildings.

In some of the buildings outfitted with EMS controls, additional savings were derived from commissioning improvements including improved VFD fan logic and upgraded economizer controls.

EEM 2:

Sixty-two lighting poles consisting of 410 lamps illuminating the prison yards and all other exterior areas throughout the facility were retrofit. 1,000W metal halide fixtures were replaced with 750W Pulse Start Metal Halide fixtures in 366 cases, and 400W HPS fixtures were replaced with 320W Pulse Start Metal Halide fixtures in 44 instances. All new fixtures were placed on the facility's EMS system to allow for more refined scheduling. The schedules of 104 of the 750W PSMH lights were shortened by seven hours nightly relative to their pre-retrofit schedule.

Ex ante Savings

EEM 1 and EEM 2:

With the exception of commissioning savings, savings from the EMS and programmable thermostat measures were calculated in an identical fashion because both measures yielded identical results: reduced HVAC operating hours and raised cooling set points. An EFLH based calculation was used to evaluate measure savings.[17] Given the number of buildings affected by

17 The most recent version of the controls analysis, provided by the implementer, is titled "SATF Savings 17Jan12.xls". The older version, which the ex ante savings claims were based on, is titled was not provided for review.

these measures (84), it would not have been reasonable to assess savings using a more time intensive approach such as simulation modeling.

Presumably, EFLH for cooling, heating, and strip heating equipment were estimated using temperature dependent load profiles and binned weather data for Fresno. These EFLH values were then likely used to develop the load factors and duty cycle factors that ultimately appear in the ex ante analysis. There is some uncertainty because—unlike in the COR State Prison analysis conducted by the same contractor—the process used to develop the load factors and duty cycle factors was not presented.

Ultimately, the load and duty cycle factors were used in the context of the following equation to calculate scheduling adjustment savings for a given piece of equipment:

$$\mathrm{kWh_{saved}} = \mathrm{kW_{eq}} f_{dc} f_l \left(\mathrm{Hours_{pre}} - \mathrm{Hours_{Post}}\right)$$

Where,

$\mathrm{kWh_{saved}}$	= Annual energy savings for a given piece of equipment
$\mathrm{kW_{eq}}$	= Full load power draw of the equipment (kW)
$\mathrm{Hours_{pre}}$	= Operating hours before measure implementation (8,760)
$\mathrm{Hours_{Post}}$	= Operating hours following measure implementation (varies by equipment)
f_{dc}	= Duty cycle factor (fraction of scheduled time the equipment is on)
f_l	= Load factor (average equipment load fraction when operating)

Note that this approach is imperfect because the post-implementation schedules vary significantly from one building to the next, and thus the post-implementation duty cycle factors and load factors vary in practice as well. For instance, if a unit were scheduled to operate in the afternoon hours of 1 p.m. to 5 p.m., its air conditioning compressor would undoubtedly have greater duty cycle and load factors than if it were scheduled to operate between the hours of 5 a.m. and 8 a.m. This shortcoming was ultimately addressed in the ex post analysis and largely accounts for some of the difference between the ex ante and ex post savings claims.

In addition to calculating savings from operating schedule adjustments, savings were also claimed for programming fixed cooling set points. Before measure implementation, the pre-existing manual thermostats allowed prison staff to adjust cooling set points at their discretion, leading to excessive cooling in some cases.

Savings from implementing a 78°F fixed thermostat set point were estimated by first simulating a representative building in eQUEST. The savings derived from adjusting the set point from some unknown value to 78°F were determined to be 11 percent of the building's cooling and ventilation end uses. The eQUEST model used to develop these savings was not provided for review, so the validity of the results could not be assessed.

The savings factor (11 percent) determined from the eQUEST model runs was then applied to the cooling and ventilation equipment's energy consumption for the post-implementation period to estimate cooling set point adjustment savings. Note that not all buildings and equipment were subject to set point adjustments.

The commissioning savings from economizer controls improvements and VFD scheduling were calculated as an additional 4 percent of savings taken from the postretrofit period annual energy usage. As mentioned previously, these savings were only applied to certain buildings that underwent both EMS control upgrades and commissioning.

EEM 2:

The initial tracking savings calculation was based on the assumption that only the lighting controls would be upgraded, not the fixtures themselves.[18] As such, savings were simply calculated by assuming that the revised controls would lead to a 15 percent reduction in the pre-existing annual energy usage of the yard lights. The savings from this approach ultimately ended up in the tracking database, which largely explains the extremely high realization rate for this measure.

Later in the SATF project's life, the scope of this measure changed and the lights themselves were upgraded to more efficient lamps. The final ex ante savings estimates from the exterior prison lighting and lighting controls retrofit were calculated as:[19]

$$kWh_{saved} = \sum_i \left(kW_{pre}h_{i-pre} - kW_{post}h_{i-post}\right) kWh_{saved} = \sum_i \left(kW_{pre}h_{i-pre} - kW_{post}h_{i-post}\right)$$

Where,

kWh_{saved}	= Lighting energy savings [kWh]
kW_{pre}	= Fixture wattage of the pre-existing fixtures [kW]
kW_{post}	= Fixture wattage of the installed fixtures [kW]
h_{i-pre}	= Operating hours of fixture i pre-retrofit
h_{i-post}	= Operating hours of fixture i postretrofit

Project Evaluation

Given the number of buildings (84) and quantity of HVAC equipment (336 items) affected by this project, the focus of the evaluation was (1) verifying a sample of the installed equipment;

18 See the "Review Cals" tab of the spreadsheet titled "2K10039962 – 2010-12 CDCR-IOU Application Review. SATF EMS-v1.1.xls".

19 This exact document was passed through and used for the ex post savings calculation.

and (2) confirming that the installed equipment operates in the manner specified in the ex ante calculations.

The scope of the project also impacted the analysis approaches taken for EEM 1. Under normal circumstances, EEM 1 would be evaluated primarily using simulation tools such as eQuest. However, the number of buildings affected by this projected made it unreasonable to conduct the analysis in a simulation program. The evaluation team, therefore, leveraged the existing ex ante analysis and made modifications to improve the calculations. The site findings and analysis modifications are discussed subsequently.

EEM 1 and EEM 2:

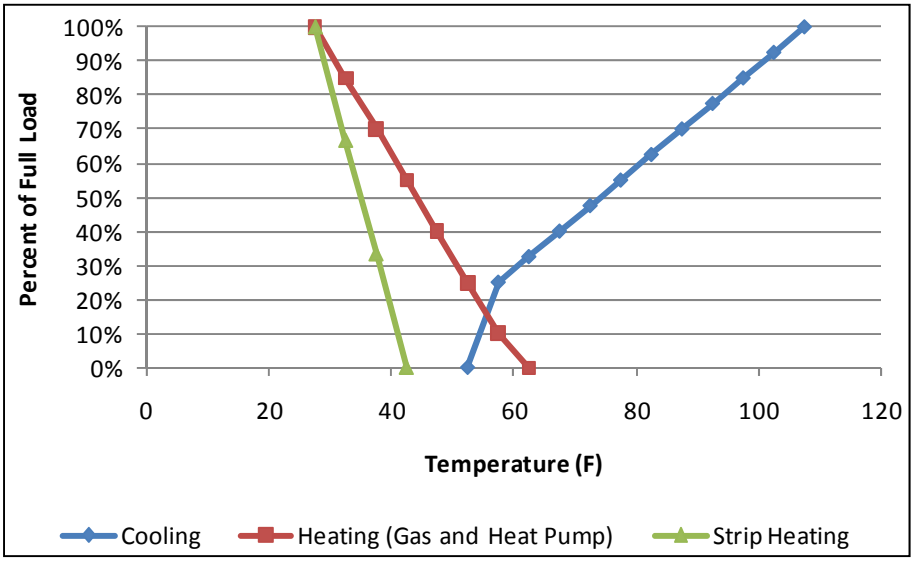
For the EMS and programmable thermostat controls measures, it was necessary to verify that the equipment affected by these measures was properly accounted for in the ex ante calculation. As such, HVAC equipment was verified in multiple buildings. Roughly 50 packaged and split systems controlled by programmable thermostats were verified. While minor errors were identified in the recorded model numbers for a few units, the equipment sizes and types were correct in all cases. More importantly, programmable thermostats were found in each case. The operating schedules corresponding to each unit were recorded.

In addition to verifying programmable thermostat controlled HVAC equipment, on-site time was also dedicated to observing the EMS system and verifying the operating schedules used for the EMS controlled units in the ex ante analysis. The site contact provided schedules for all equipment not projected to operate continuously.

Following the site work, the analysis began by using the newly collected scheduling data to revise the ex ante savings calculations. As mentioned previously, the ex ante approach was flawed in that it used constant duty cycle factors and load factors for all schedules. For the evaluation, this approach was modified by directly calculating EFLH for all equipment based on the 24 unique schedules identified during the site visit. This analysis required: (a) TMY3 data for Visalia, CA (the nearest weather station), (b) load profiles from which to develop EFLH estimates, and (c) the scheduling data collected during the site visit.

TMY3 data were readily available and scheduling data were collected on-site; the load profiles were ultimately appropriated from an identical analysis conducted for the COR State Prison project. Since the two facilities are adjacent to one another and consist of buildings with similar constructions, using the same load profiles was appropriate. Figure 4 below contains the temperature dependent load profiles used in this analysis.

Figure 4: Load Profiles for EFLH Analysis



Source: DNV KEMA analysis

For a given operating schedule, cooling EFLH were calculated according to the following formula:

$$EFLH_{cool} = \sum_{h=1}^{8,760} Load\%_h * Avail_h \; EFLH_{cool} = \sum_{h=1}^{8,760} Load\%_h * Avail_h$$

Where,

$EFLH_{cool}$	= Cooling EFLH
$Load\%_h$	= Cooling load fraction in hour h as determined from the ambient temperature and the trend in Figure 3.
$Avail_h$	= System availability in hour h as dictated by the operating schedule programmed in the EMS system or thermostat (for example, if a unit is on for 45 minutes during a given hour, then the availability is 45/60, or .75)

An identical approach was used to derive cooling, heating and strip heating ELFH values as necessary for each piece of equipment.

The revised EFLH values were used directly to calculate scheduling savings using the generalized formula,

$$kWh_{saved} = kW_{eq}(EFLH_{pre} - EFLH_{post})kWh_{saved} = kW_{eq}(EFLH_{pre} - EFLH_{post})$$

Where,

kWh_{saved} = Annual kWh saved by the project

kW_{eq} = Full load electrical demand of the equipment (kW)

$EFLH_{pre}$ = EFLH before measure implementation [h]

$EFLH_{post}$ = EFLH following measure implementation [h]

As in the ex ante analysis, cooling set point adjustment savings were calculated using the results of eQuest simulation models. However, because the model used in the ex ante analysis was not available, the 11 percent savings estimate was vetted against DEER prototypes. Three DEER prototypes—office, restaurant, and multi-family residence—were run to approximate the various prison buildings affected by this measure. In each case, the cooling set point was assumed to have shifted from 74°F—a temperature claimed to be typical of the pre-existing conditions by the site contacts— to 78°F. Table E-27 below summarizes the annual cooling load savings attributable to the set point adjustment by building type:

Table E-27: DEER Prototype Cooling Set Point Adjustment Savings Factors

DEER Building Prototype	Cooling Load Reduction Due To Set Point Adjustment	Types Of Spaces Applied To in Analysis
Restaurant	17%	Kitchens
Office	12%	Offices (Facility Support, Counselors Offices, Personnel Trailers, and so forth)
Multi-family Residential	24%	Housing Blocks

Source: DNV KEMA analysis

Since in all cases the DEER estimated cooling set point adjustment savings were greater than the 11 percent used in the ex ante calculations, the ex ante savings factor was deemed reasonable. Accordingly, the postretrofit energy use of all cooling equipment subject to cooling set point adjustments was reduced by 11 percent.

The VFD retrocommissioning portion of the commissioning savings was calculated using a measure specific analysis. The site contacts explained that before the retrofit, these units' fans operated at 100 percent speed at all times. During the retrofit, the fans were programmed to

operate at 100 percent speed in cooling mode and 60 percent speed in heating mode. Units are now set to remain in their current mode until there is a call for operation in the other mode. This means that if a unit were to receive a call for heat and then did not receive a call for cooling until many days later, the fan would remain at 60 percent speed whenever the unit was on for the duration of that time frame.

Since savings only occur when the VFD controlled fans are in heat mode, savings for a given fan were approximated as follows:

$$Savings_{VFD} = kW_{fan}(1-.6^3)Hours_{heat}Savings_{VFD} = kW_{fan}(1-.6^3)Hours_{heat}$$

Where,

$\text{Savings}_{\text{VFD}}$	= VFD fan scheduling savings
kW_{fan}	= Full load fan power draw
$\text{Hours}_{\text{heat}}$	= Hours of operation in heating mode
$.6^3$	= VFD power scale factor when unit operates at 60 percent speed

For housing units without VFD controlled units, the 4 percent commissioning savings used in the ex ante analysis were assumed reasonable since individual commissioning initiatives could not be looked into on a one by one basis. In vocational spaces (for example, the prison kitchens, auto shops, janitorial rooms, program rooms), commissioning savings were reduced to 1.6 percent. During the implementer's review of the controls programming for 10 randomly selected vocational units subject to commissioning, it was determined that 6 of the 10 units exhibited a commissioning issue.[20] Problems included units operating during off scheduled periods or cycling repeatedly between heating and cooling mode. Because commissioning issues were identified with 60 percent of this vocational sample, commissioning savings were cut to 40 percent of 4 percent, or 1.6 percent for units serving vocational areas.

Demand savings for EEM 1 were addressed by assessing which equipment had previously operated during the summer peak demand period,[21] but currently remains off due to the scheduling adjustments. In the event that a scheduling change resulted in partial operation during the peak demand period, savings were calculated by multiplying the fraction of the peak period during which the equipment no longer operates by its full load electrical demand. For instance, if an AC unit previously operated throughout the peak demand period (2 p.m. to 5 p.m.), but now only operates from (2 p.m. to 4 p.m.), demand savings were estimated as one third of the unit's full load power draw.

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20 The implementation site visit for Utility program verification of the same measures was conducted concurrently with the DGS evaluation site visit.

21 According to the CPUC, peak demand savings are defined as the average demand reduction occurring during the three consecutive hottest weekdays of the year between the hours of 2 p.m. and 5 p.m.

EEM 2:

Exterior lighting savings were verified in a few ways. First, the lighting schedules were verified in the EMS system. Second, an extra lamp of the installed type was observed. Third, the site visit was performed early enough in the morning for the evaluator to observe the new fixtures operating during the drive up the facility; since the new fixtures have a high color temperature, it was anecdotally confirmed that the new fixtures had been installed. Fourth, the site contact provided invoicing showing that more than the quantity of installed lamps had been purchased. Lastly, a helpful aerial Google Map™ image was provided by the implementer showing a clear layout of where the fixture masts were located throughout the facility. From this image it was possible to verify the mast and fixture counts claimed in the ex ante analysis.

Savings were ultimately calculated according to the same methodology used in the final ex ante analysis.

Savings Results

Relative to both the pre-existing equipment and expected replacement baselines, the SATF project saved 6,295,111 kWh and 231,016 therms annually, while reducing peak period electrical demand by 424.5 kW. EEM 1 savings are the same under both baselines because controls improvements are upgrade, not replacement, measures. Savings for EEM 2 are also equivalent relative to both baselines because the pre-existing lighting was standard practice for prison yard applications. Overall, the project achieved savings realization rates of 116.3 percent and 462.5 percent for kWh and therms respectively.

Discussion

The project saved considerably more energy than anticipated. The increase in EEM 1 savings is largely attributable to adjustments in the savings methodology. The load factor and duty cycle based analysis employed for the ex ante calculation significantly understated the energy use of cooling compressors and heating equipment. Since both the preretrofit and postretrofit energy usage estimates contained these factors, energy savings were linearly scaled as a function of those factors. Therefore, if either factor were incorrect, the results of the analysis shifted dramatically.

The evaluation analysis corrected this shortcoming by developing unique equivalent full load hour estimates (EFLH) for each piece of equipment based on its operating schedule. This process suggested that the savings estimates had been overly conservative and that equipment typically served greater loads than previously estimated. Since savings from the controls measure were largely derived from reducing operating hours, increased equipment loading actually helped to bolster energy savings. Gas savings in particular increased dramatically because the equipment loading had been grossly understated. In the ex ante analysis, the load-weighted average preretrofit and postretrofit EFLH values were 318 and 234 hours respectively for gas using equipment; in the ex post analysis, these same values increased to 1,979 and 1,456 hours respectively. Notice that not only did the magnitudes of the expected full load hours increase, but the differential between the pre- and post-period estimates increased as well. This change largely explains the dramatic increase in expected gas energy savings.

The savings for EEM 2 increased dramatically predominantly because the lighting calculation on which the tracking savings estimate was based came from an earlier iteration of this project that included only the controls upgrade, not the lighting retrofit. The ex ante values used in this report are consistent with the reported savings in the most recent (01-23-12) DGS status report. Since the lighting retrofit accounts for more than 56 percent of the realized savings for this measure, the ex post savings were understandable considerably greater than the ex ante savings.

Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

Table E-28: Values Used in Life-cycle Savings Calculations

Measure	Savings Relative To Pre-existing Equipment		Savings Relative To Expected Practice Equipment		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 1: Control Upgrades	5,639,050	231,016	5,639,050	231,016	12.90	0
EEM 2: High Mast Lighting Retrofit	656,061	0	656,061	0	15	0

Source: DNV KEMA analysis

Notice that in Table E-28, the EUL provide for EEM 1 is not a round number. Since EMS controls and programmable thermostats have EULS of 15 and 11 years respectively, it was necessary to calculate the savings-weighted average of the EUL for EEM 1 based on the EULs of the measure components.

Table E-29 provides life-cycle savings for the project relative to Baseline 1 and Baseline 2.

Table E-29: Life-cycle Savings Relative to Baseline 1 and Baseline 2

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	6,295,111	424	231,016
2	2012	6,295,111	424	231,016
3	2013	6,295,111	424	231,016
4	2014	6,295,111	424	231,016
5	2015	6,295,111	424	231,016
6	2016	6,295,111	424	231,016
7	2017	6,295,111	424	231,016
8	2018	6,295,111	424	231,016
9	2019	6,295,111	424	231,016
10	2020	6,295,111	424	231,016
11	2021	6,295,111	424	231,016
12	2022	6,295,111	424	231,016
13	2023	5,709,099	380	207,008
14	2024	656,061	-	-
15	2025	656,061	-	-
16	2026	-	-	-
Life-cycle	Total	82,562,553 kWh	5,474.1 kW-Years	2,979,200 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

California Correctional Institution Boiler Retrofit

Site Summary

The California Correctional Institution (Tehachapi) completed a central plant retrofit affecting cell blocks in Yards 4A and 4B. The project involved taking Yards 4A and 4B off of the primary boiler plant for the campus and installing local boiler plants at each yard. By doing so, Tehachapiwas able to eliminate more than three miles of underground pipe and 75 hp of pumps (net), thereby reducing both heat losses and pumping energy consumption. Additionally, the six new Fulton QT PHW-1400LE Pulse Boilers operate more efficiently (86 percent thermal efficiency) than the campus boilers (approximately 77 percent thermal efficiency), increasing the energy savings of the project further. Ex ante and ex post savings for the measure are presented in Table E-30.

Table E-30: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
Boiler Retrofit	430,116	None Claimed	345,322	440,303	50.3	428,250	102.4%	124.0%
Total	430,116	None Claimed	345,322	440,303	50.3	428,250	102.4%	124.0%

Source: DNV KEMA analysis

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the RUL of the pre-existing equipment is exceeded.

Even though the pre-existing equipment had exceeded its EUL (for example, had no RUL), one year of pre-existing equipment savings were granted under Baseline 2. These savings were

given under the assumption that the pre-existing equipment could have remained in operation for at least one more year even though it had exceeded its EUL.

Table E-31: Life-cycle Savings Summary

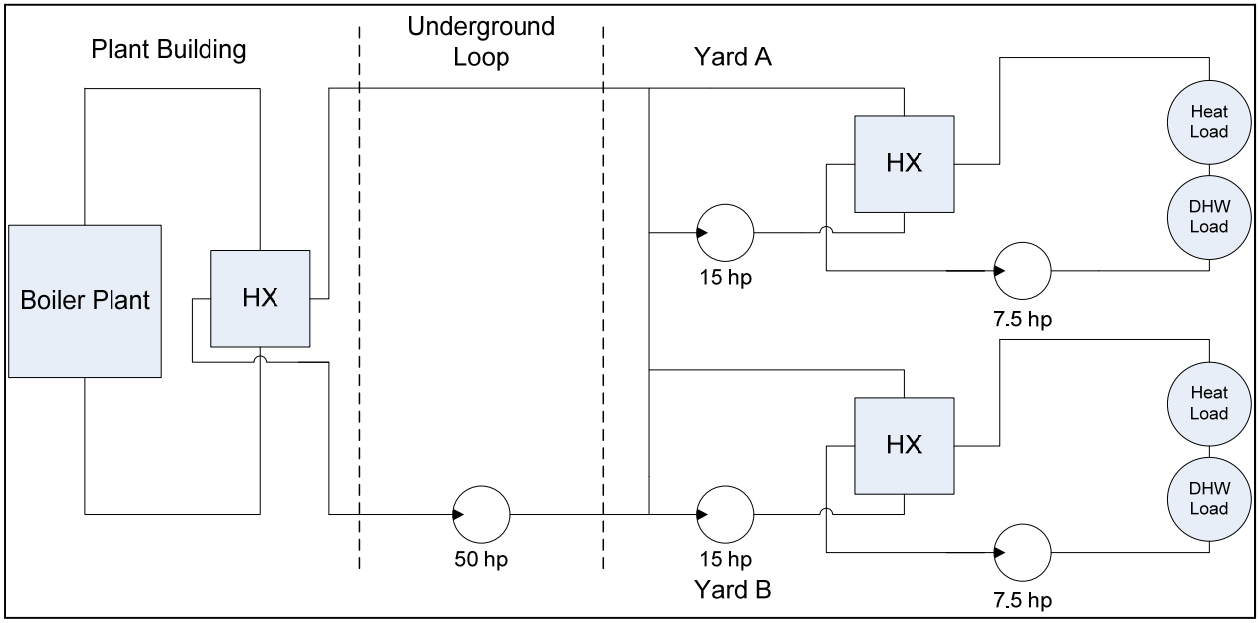
Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	8,806,051	1,005.3	8,565,000
Baseline 2	8,636,391	985.9	6,953,527

Source: DNV KEMA analysis

Project Description

This project consisted of an extensive retrofit of the hot water generation and distribution system for prison Yards 4A and 4B of the Tehachapi facility. Under the pre-existing arrangement, steam was generated in three high pressure boilers serving the entire campus. Some of the steam then passed through a heat exchanger, transferring thermal energy to a 3-mile long hot water distribution loop operating at supply temperatures between 200°F and 260°F. At each yard, a 15 hp pump then drew water off of this primary hot water loop into a secondary hot water loop. The high temperature water then passed through another heat exchanger to generate water at temperatures between 160°F and 180°F for space heating and DHW heating. The pre-existing hot water generation and distribution system for Yards 4A and 4B is displayed in Figure 5 below.

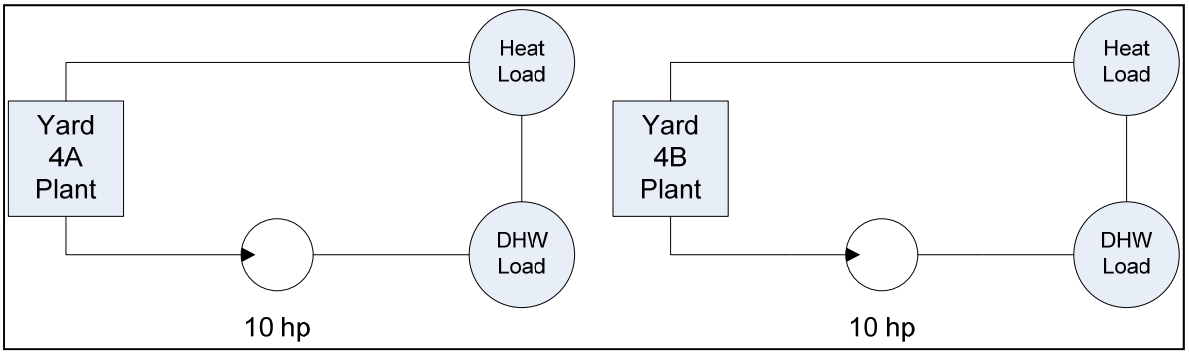
Figure 5: Pre-existing Plant Configuration



Source: DNV KEMA analysis

The new plant configuration completely removed the central boiler plant and the old heat exchangers from operation in Yards 4A and 4B. In their place, three Fulton QT PHW-1400LE Pulse Boilers were installed at each yard to generate hot water for space heating and DHW end uses. This plant retrofit completely removed the pipe leakage and heat losses associated with the underground loop, while increasing the hot water generation process efficiency. The installed plant configuration is presented in Figure 6 below.

Figure 6: Installed Plant Configuration



Source: DNV KEMA analysis

Ex Ante Savings

The project saved energy in three ways. First, and most importantly, it removed the 3-mile long underground hot water distribution system from operation. According to ex ante documentation,[22] this system leaked an average of 600 gallons of hot water per day. Furthermore, supply and return temperature data indicate that temperatures dropped an average of 15°F in the loop even in the unloaded state. These massive thermal loses were the primary driver of gas savings. The project saved electrical energy by removing one 50 hp pump, two 15 hp pumps, and two 7.5 hp pumps from constant operation and replacing the pumps with two 10 hp pumps. Lastly, the project saved energy by removing the three older, less efficient campus boilers from operation in Yards 4A and 4B and replacing the campus boilers with six efficient pulse boilers.

The core data used to estimate savings were the underground loop flow rate (estimated at a constant 372 GPM) and the supply and return water temperatures corresponding to that loop, which were recorded on an hourly basis for a full calendar year. These data were used both to estimate the loads at Yards 4A and 4B, as well as the distribution losses across the loop. Loop losses were estimated by evaluating the supply and return temperature differential during time periods with no loop load. In the months of June, July, August, and September, the average loop temperature drop was 15 degrees during the hour between 2 a.m. and 3 a.m. in the morning. During these warm months, there is little to no heating load, and DHW heating loads are completely non-existent. The fact that the early morning loop temperature drop remained consistent across these four hot months indicates that 15°F is a sound estimate of the no-load temperature drop through the loop. These losses were quantified on a monthly basis using the equation:

$$Q_{loss-pipe} = GPM * 8.337 * 60 * 24 * D_m * C_p * \Delta T_{loss} Q_{loss-pipe}$$
$$= GPM * 8.337 * 60 * 24 * D_m * C_p * \Delta T_{loss}$$

Where,

$Q_{loss-pipe}$	= Pipe heat loss for a given month (Btu)
GPM	= Loop flow rate (372 GPM)
8.337	= lbm/gallon
<	= Minutes/hour
	= hours/day
D_m	= Days in month m

22 Ex ante savings were calculated using the workbook "2K8#TBD Att 1 – Tehachapi Boiler Savings Estimate-NAM Rev071408.xls".

C_p = Specific heat capacity of water (1 Btu/lbm-F)

ΔT_{loss} = Temperature drop across the loop under unloaded conditions (15°F)

Additionally, the losses due to pipe leakages were quantified on a monthly basis as follows:

$$Q_{loss-leak} = GPD * 8.337 * 24 * D_m * C_p * (T_{return} - T_{makeup}) Q_{loss-leak} = GPD * 8.337 * 24 * D_m * C_p * (T_{return} - T_{makeup})$$

Where,

$Q_{loss-leak}$ = Monthly heat loss due to pipe leaks (Btu)

GPD = Average gallons lost each day to pipe leaks (600 GPD)

8.337 = lbm/gallon

= hours/day

D_m = Days in month m

C_p = Specific heat capacity of water (1 Btu/lbm-F)

T_{return} = Average return water temperature for a given month [F]

T_{makeup} = Make up water temperature based on location (55°F in Tehachapi)

After calculating losses, the actual monthly heat load at Yards 4A and 4B was effectively calculated as,

$$Q_{load} = GPM * 8.337 * 60 * 24 * D_m * C_p * (T_{supply} - T_{return} - \Delta T_{loss}) Q_{load} = GPM * 8.337 * 60 * 24 * D_m * C_p * (T_{supply} - T_{return} - \Delta T_{loss})$$

Where,

Q_{load} = Heat load for Yards 4A and 4B (Btu)

GPM = Loop flow rate (372 GPM)

8.337 = lbm/gallon

< = Minutes/hour

= Hours/day

D_m = Days in month m

C_p = Specific heat capacity of water (1 Btu/lbm-F)

T_{supply} = Average supply water temperature for a given month [F]

T_{return} = Average return water temperature for a given month [F]

ΔT_{loss} = Temperature drop across the loop under unloaded conditions (15°F)

The total load on the pre-existing plant was, therefore, $\frac{Q_{loss-pipe}+Q_{loss-leak}+Q_{load}}{\eta_{plant-pre}}$, where $\eta_{plant-pre}$ is the gas-to-steam efficiency of the pre-existing plant. In the ex ante calculation, however, the $Q_{loss-leak}$ term was effectively left out of the above equation ("effectively" is used here because the presentation of the analysis in the ex ante spreadsheet follows a slightly more complex—but ultimately equivalent—path).

For the installed case, the total gas energy use of the new systems should have been calculated as $\frac{Q_{load}}{\eta_{plant-inst}}$, where $\eta_{plant-inst}$ is the gas-to-steam efficiency of the new plant and Q_{load} is the same plant load term calculated for the pre-retrofit case. This value was slightly miscalculated in the ex ante analysis as well. The implementation team accidentally subtracted the above defined term, $Q_{loss-leak}$, from the plant load term, thereby reducing the post-case plant use. Since Q_{load} is the only boiler load for the postretrofit condition, terms relating to the pre-retrofit pipe distribution system are unnecessary. This mistake was not explicit in the ex ante analysis, but rather a consequence of a minor oversight in the implementation team's calculation methodology. Fortunately, relative to the pipe heat losses, the leakage losses were relatively minor, meaning that the aforementioned errors ultimately had a minimal effect on the results of the analysis.

The pre-existing plant efficiency, $\eta_{plant-pre}$, was not actually based on the pre-existing plant in the ex ante estimate. Instead, the efficiency was based on the minimum allowable efficiency specified in the SPC manual; this factor and its implications on the analysis are discussed later in this report. For the installed case, the plant efficiency term was pulled directly from the Fulton boiler cut sheet. This may not have been the most appropriate efficiency to use because the cut sheet thermal efficiency does not account for additional plant losses such as blow-down and boiler shell losses.

Electric energy savings were calculated on the basis of the saved pumping energy. Table E-32 below summarizes the pump specifications, loadings, and operating hours assumed for the pre-existing and installed cases. The pre-existing and installed pumping demand and energy consumption are presented as well.

Table E-32: Pre-existing and Installed Pump Data

	HP	Load Factor	Hrs	Motor Eff.	Demand (kW)	Annual kWh
Pre-existing Pumps						
P-3 Yard 4A	15	75%	8,760	91.0%	9.2	80,789
P-3 Yard 4B	15	75%	8,760	91.0%	9.2	80,789
P-1 Yard 4A	7.5	75%	8,760	88.5%	4.7	41,536
P-1 Yard 4B	7.5	75%	8,760	88.5%	4.7	41,536
P-5 Central Plant	50	85%	8,760	93.0%	34.1	298,641
Total (Pre-existing)			**8,760**		**62.0**	**543,291**
Installed Pumps						
New P-1 Yard 4A	10.0 (7.75*)	100%	8,760	89.5%	6.5	56,588
New P-1 Yard 4B	10.0 (7.75*)	100%	8,760	89.5%	6.5	56,588
Total (Installed)			**8,760**		**12.9**	**113,175**

Source: DNV KEMA analysis

Note the bracketed 7.75 hp listed for each of the newly installed pumps. These values—which were used as the basis of the ex ante kW and kWh calculations—correspond to the assumed operating point of the pumps, as specified by the intersection of the system and pump curves for the new boiler loops. Note that the load factors for these pumps were set to 100 percent to account for this modification to the calculation approach. Electrical energy and demand savings were taken simply as the difference between the pre-existing and installed case values.

Project Evaluation

Ex post energy savings were calculated using a nearly identical methodology to that employed in the ex ante analysis. This was done for the following reasons. First, and most importantly, the ex ante approach was generally robust and well thought out, excepting the few minor errors identified in the ex ante savings discussion. Additionally, the calculations made good use of the data available to conduct the analysis.

The second reason the analysis was left largely unchanged was a lack of new site data from which to significantly revise the analysis. In particular, the site was unable to provide boiler gas usage logs for the new boilers, and the old boilers' gas usage logs were recently found to be erroneous due to faulty gas meters.

Because new hard data were unavailable, an emphasis was made during the site visit to validate key savings inputs used in the analysis. First, the installed pumps and boilers were verified to match the specifications claimed in the ex ante documentation. Combustion analysis was next conducted on the boiler to verify the reasonableness of the claimed thermal efficiency (86 percent). Unfortunately, the combustion analyzer's thermistor failed before this site visit, meaning it was only possible to take exhaust gas composition readings. The excess oxygen reading (5.1 percent) was low enough to suggest that a thermal efficiency of 86 percent was *possible* if the net stack temperature (the difference between stack temperature and ambient temperature) was below ~180°F. Since this is possible (albeit not probable), the assumed thermal

efficiency of the installed boilers was left unmodified. However, boiler plants never actually operate at the boiler's rated efficiency, because "thermal efficiency" only takes into account combustion efficiency and boiler heat exchanger losses.[23] As such, it was necessary to modify the installed boilers' efficiencies to represent their gas-to-steam efficiencies as follows:

$$n_{plant-post} = n_{ther} - l_{rad} - l_{blowdown} n_{plant-post} = n_{ther} - l_{rad} - l_{blowdown}$$

Where,

$n_{plant-isnt}$	= Installed plant gas-to-steam efficiency (84 percent)
n_{ther}	= Installed plant thermal efficiency (86 percent)
l_{rad}	= Radiant and convective shell losses[24] (1 percent)
$l_{blowdown}$	= Blowdown losses (1 percent)

While on-site, spot measurements were taken off one of the installed pumps to validate the pump motor demand assumed in the ex ante analysis. The spot measured electrical demand of the installed pump was 6.39 kW, only slightly less than the 6.5 kW demand assumed in the ex ante calculation.

In addition to gathering information on the installed equipment, data were collected on the pre-existing boilers to assist in calculating savings relative to Baseline 1. In particular, combustion analysis data (excess oxygen, stack temperature) taken as part of boiler tuning tests were gathered and subsequently used to estimate the combustion efficiency of each of the primary plant boilers. These data were then averaged to determine a mean combustion efficiency of the whole plant. The combustion efficiency was then modified as follows to determine the estimated plant gas-to-steam efficiency:

$$\begin{aligned} n_{plant-pre} &= n_{comb} - l_{rad} - l_{blow} - l_{flash} - l_{da} n_{plant-pre} \\ &= n_{comb} - l_{rad} - l_{blow} - l_{flash} - l_{da} \end{aligned}$$

Where,

$n_{plant-pre}$	= Pre-existing plant gas-to-steam efficiency (63.0 percent)
n_{comb}	= Plant combustion efficiency (81.1 percent)
l_{rad}	= Radiant and convective shell losses (1.0 percent)

23 See the definition of Thermal Efficiency at http://cleanboiler.org/Eff_Improve/Primer/Boiler_Efficiency.asp.

24 Based on the Department of Energy's Best Practices End User Training document stating shell losses of well-maintained blowers typically average .1% to 2% (http://www1.eere.energy.gov/industry/pdfs/shellloss.pdf).

l_{blow} = Blowdown losses[25] (3.4 percent)

l_{flash} = Flash steam losses[26] (11.2 percent)

l_{da} = Deaerator losses[27] (2.5 percent)

Note that the last three loss terms were appropriated from the feasibility study conducted at the beginning of the project by Aircon Energy. While the assumed losses are liberal, data were not provided to either refute or deny these claims. As such, the losses were left unmodified for use in the evaluation analysis.

The final baseline modification investigated for use in the evaluation analysis was revising pump motor efficiencies. Unfortunately, with the exception of the 50 hp motor used in the underground loop, all other motors had been disposed of. Therefore, it was only possible to revise the motor efficiency for the one remaining pump motor; the others were left at the Title 24 minimums used in the ex ante calculation.

After revising the plant efficiencies and the pump data, savings were recalculated according to the methodology presented in the ex ante analysis section using Baseline 1. Savings were also calculated relative to Baseline 2, which used the standard practice plant efficiency (75 percent) and the Title 24 baseline pump motor efficiencies specified in the ex ante analysis. In both cases, the minor analysis errors related to the leakage losses identified in the ex ante analysis were corrected for the evaluation calculations.

Savings Results

Relative to Baseline 1, the project saved 428,250 therms annually, 440,303 kWh annually, and 49.1 kW in peak demand. These numbers significantly exceeded the ex ante project savings almost entirely because ex ante savings were calculated relative to what was in effect a standard practice baseline. When using Baseline 2, which was a standard practice baseline in this case (the pre-existing equipment had no RUL), the evaluated savings were nearly identical to the ex ante savings: 343,436 therms annually, 431,373 kWh annually, and 49.2 kW in peak demand savings (note that ex ante demand savings were not reported).

Discussion

The evaluation effectively corroborated the results of the ex ante analysis. The minor errors made in the ex ante analysis, as well as the adjustments made to the installed and pre-existing equipment efficiencies, had a negligible net impact. Relative to Baseline 2, the gas and electrical energy realization rates were 99.4 percent and 100.2 percent respectively. The increased

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25 Based on the Aircon Energy proposal provided in the "DGS Loan Fund Financing Application for California Correction Institute" document.

26 See note 4.

27 See note 4.

realization rates presented in Table E-43 above resulted nearly entirely from the pre-existing equipment efficiencies used as part of Baseline 1.

Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

Table E-33 below provides the annual energy savings estimates that fed into the life-cycle savings calculations, as well as the EUL for the installed measure.

Table E-33: Values Used in Life-cycle Savings Calculations

Measure	Savings Relative to Early Replacement Equipment		Savings Relative to Expected Replacement Equipment		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
Boiler Retrofit	440,303	428,250	431,373	343,436	20	0

Source: DNV KEMA analysis

Table E-34 provides life-cycle savings for the project relative to Baseline 1.

Table E-34: Life-cycle Savings Relative to Baseline 1

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	440,303	50.3	428,250
2	2012	440,303	50.3	428,250
3	2013	440,303	50.3	428,250
4	2014	440,303	50.3	428,250

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
5	2015	440,303	50.3	428,250
6	2016	440,303	50.3	428,250
7	2017	440,303	50.3	428,250
8	2018	440,303	50.3	428,250
9	2019	440,303	50.3	428,250
10	2020	440,303	50.3	428,250
11	2021	440,303	50.3	428,250
12	2022	440,303	50.3	428,250
13	2023	440,303	50.3	428,250
14	2024	440,303	50.3	428,250
15	2025	440,303	50.3	428,250
16	2026	440,303	50.3	428,250
17	2027	440,303	50.3	428,250
18	2028	440,303	50.3	428,250
19	2029	440,303	50.3	428,250
20	2030	440,303	50.3	428,250
21	2031	-	-	-
Life-cycle	Total	8,806,060 kWh	1,006 kW-Years	8,565,000 therms

Source: DNV KEMA analysis

Table E-35 provides life-cycle savings for the project relative to Baseline 2.

Table E-35: Life-cycle Savings Relative to Baseline 2

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	440,303	50.3	428,250
2	2012	431,373	49.2	343,436
3	2013	431,373	49.2	343,436
4	2014	431,373	49.2	343,436

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
5	2015	431,373	49.2	343,436
6	2016	431,373	49.2	343,436
7	2017	431,373	49.2	343,436
8	2018	431,373	49.2	343,436
9	2019	431,373	49.2	343,436
10	2020	431,373	49.2	343,436
11	2021	431,373	49.2	343,436
12	2022	431,373	49.2	343,436
13	2023	431,373	49.2	343,436
14	2024	431,373	49.2	343,436
15	2025	431,373	49.2	343,436
16	2026	431,373	49.2	343,436
17	2027	431,373	49.2	343,436
18	2028	431,373	49.2	343,436
19	2029	431,373	49.2	343,436
20	2030	431,373	49.2	343,436
21	2031	-	-	-
Life-cycle	Total	8,636,391 kWh	985 kW-Years	6,953,534 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Caltrans District 11 Chiller Plant Retrofit

Site Summary

The Caltrans District 11 building is the headquarters of Caltrans District 11 operations throughout San Diego and Imperial Counties. The building is located in the Mission Valley area of San Diego and consists of commercial office space and a small data center. In order to improve central plant efficiency, Caltrans District 11 replaced one pre-existing air-cooled screw chiller (102.6 ton) with a Turbocor, dual-compressor, centrifugal, water-cooled chiller (210 ton). Additionally, Caltrans District 11 retrofitted the pumps and cooling tower fans serving the other two plant chillers (500 tons each) with variable speed drives. Lastly, the entire plant was placed on Kiltech CPECS DDC controls to optimize operation of plant equipment to yield the lowest kW/ton efficiency possible at any time. Ex ante and ex post savings for the plant retrofit are presented in Table E-36.

Table E-36: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
Central Plant Retrofit	405,830	None Claimed	29,507	371,377	78.9	0	91.5%	0.0%
Total	405,830	None Claimed	29,507	371,377	78.9	0	91.5%	0.0%

Source: DNV KEMA analysis

The project saved slightly less electric energy than projected in the ex ante calculation. The savings discrepancy was the result of assumptions made in the ex ante calculation due to lack of available data. In particular, it was necessary to assume a plant load profile for use in a bin analysis. It was also necessary to predict a sequence of operations for the plant following the retrofit without foreknowledge of the final operating strategy. In light of these major unknowns, it is somewhat surprising that the ex ante and ex post electrical energy savings estimates came that close.

The ex ante therm savings estimate on the other hand appears unjustified. In neither the ex ante calculations nor the ex ante documentation[28] is there any mention of therm savings. Gas savings are only listed in DGS's project tracking spreadsheet. Since this project does not involve thermal heat recovery or any other mechanism that would result in gas savings, these savings were zeroed out for the ex post calculation.

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses minimally code compliant conditions or standard practice as the baseline once the RUL of the pre-existing equipment is exceeded.

Table E-37: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	7,427,543	1,578.9	0.0
Baseline 2	8,355,126	1,347.6	0.0

Source: DNV KEMA analysis

Project Description

This project involved a comprehensive central plant retrofit in which primary plant equipment was replaced, variable speed drives were added to multiple components, and new plant-optimizing DDC controls were installed. The first component of the retrofit consisted of replacing a 102.6-ton Carrier 30GXN air-cooled screw chiller and its constant speed 15-hp chilled water pump with a 210-ton water-cooled SMARDT WA.088 centrifugal chiller and its associated pumping equipment. The new chiller was supplied with a 15-hp VFD controlled chilled water pump and a 30-hp VFD controlled condenser water pump. The condenser water loop was piped to the pre-existing cooling tower.

In addition to installing a new chiller, the plant equipment associated with the other two chillers comprising the plant—two 500-ton Carrier 19XR chillers—was also upgraded. Before the retrofit, these chillers operated in a primary, variable-secondary chilled water loop configuration. Two 25-hp pumps served the primary loop, and two 75-hp pumps served the secondary loop. The condenser water loop consisted of two 50-hp constant speed pumps serving a cooling tower with two 30-hp constant speed fans. Following project implementation,

28 The document "Caltrans_DGS Chiller Project ARRA Overview.pdf" was provided for review.

all constant speed pumps and fans were converted to variable speed, and the chilled water loop configuration was changed to variable primary.

The final component of the plant retrofit was installed Kiltech CPECS DDC controls to optimize the operation of all three chillers and their associated plant equipment to yield the lowest possible plant kW/ton efficiency at any time.

Ex ante Savings

Ex ante savings were calculated using a spreadsheet bin analysis. This analysis was provided for evaluation review.[29] The analysis began with the construction of a linear load profile as a function of outdoor temperature. The load profile, as well as the hours associated with each load bin, are provided below for reference.

Table E-38: Ex Ante Load Bins

Dry Bulb Temperature	Bin Hours	Bin Load (tons)
97.0	2	629
92.0	6	551
87.0	25	486
82.0	94	421
77.0	324	389
72.0	774	356
67.0	972	259
62.0	895	194
57.0	462	130
52.0	150	97
47.0	59	65
42.0	7	65
37.0	3	65
Total	3,773	-

Source: DNV KEMA analysis

Note that a linear load profile was used between the temperatures of 97°F and 47°F, below which the load was assumed to remain constant due to the data center. The energy use of the pre-existing plant was then determined according to the following general sequence of operations:

29 See the spreadsheet titled "Cal Trans Dist 11 HQ CHW Analysis TMunoz_jdp0127'11 .xls".

(1) At loads less than the capacity of the air-cooled chiller (102.6 tons), only the air-cooled chiller operates. Additionally, the 15-hp chilled water pump dedicated to the air-cooled chiller operates.
(2) At loads above the capacity of the air-cooled chiller, the air-cooled chiller is base loaded. One of the 500-ton chillers then picks up the remainder of the load. One primary chilled water pump (25-hp) and one condenser water pump (50-hp) turn on with the 500-ton chiller.
(3) At loads greater than the capacity of the two operating chillers (602.6 tons), the third chiller (500-ton) also turns on. The other primary chilled water pump (25-hp) and the second condenser water pump (50-hp) turn on.
(4) Secondary chilled water loop flow is linearly proportional to load. At peak loads (629 tons), the secondary chilled water flow is 97 percent. At the minimum load point (65 tons), secondary loop flow is 10 percent. Both secondary pumps operate in parallel at identical drive frequencies.

Under the postretrofit scenario, the sequence of operations was changed as follows:

(1) The new 210-ton SMARDT chiller and its dedicated chilled and condenser water pumps operate alone until the plant load exceeds the chiller's capacity. Chilled water flow through the new VSD controlled chilled and condenser water pumps is linearly proportional to load.
(2) At loads in excess of 210 tons, the SMARDT chiller is base loaded. One of the 500-ton chillers serves the remainder of the plant load. One 25-hp chilled water pump (formerly the primary chilled water pump) and one 50-hp condenser water pump operate. Since these pumps are now VFD controlled, the chilled water flow is proportional to chiller load.
(3) The chilled water flow through the 75-hp chilled water pumps, which were formerly secondary chilled water pumps, is still proportional to the gross plant load. These pumps still operate in parallel at identical drive frequencies.

Savings were determined based on the differing energy consumptions of the base case and installed plants operating according to the above sequence of operations, while meeting the loads listed in Table E-38. The savings estimated using this methodology were greater than the savings claimed in the ex ante documentation. Ultimately, the contractor responsible for the calculation scaled the savings by a factor of 93 percent to arrive at a more conservative estimate.

Project Evaluation

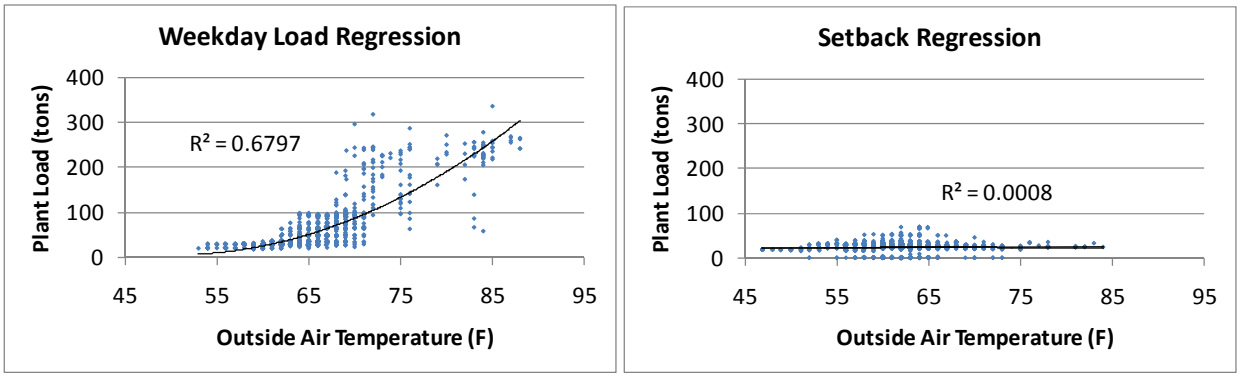
Due to schedule constraints, the site visit was planned when most but not all of the project was commissioned. At the time of the site visit, the new plant equipment was installed and operating with the exception of the Kiltech CPECS controls. These controls rely on an FTP communications link, which had not yet been established because the mechanical equipment

rooms were not hardwired for internet access. Commissioning was set to proceed quickly once this short term bottleneck was fixed.

Because the installed equipment was not yet operating according to its intended control strategy, metering plant equipment would not have provided any useful data. As such, the site visit was conducted primarily to verify equipment installation. The site visit revealed that all equipment had been installed as proposed in the ex ante documentation with one exception: the condenser water pump associated with the new chiller was found to be 30-hp, not 15-hp as initially claimed in ex ante documentation. During the site visit, the verifying engineer also had an opportunity to discuss the project with one of the engineers responsible for developing the project. This conversation proved beneficial, yielding a comprehensive set of pre-retrofit metered data and controls documentation indicating the finalized sequence of operations for the new CPECS controls.

Using the data collected on-site, a new bin savings analysis was conducted. First, 66 days' worth of 15-minute interval pre-monitoring data provided by the project engineer was processed to develop a new bin load profile. Since the interval data consisted of primary chilled water loop flow rate, supply water temperature, and return water temperature data, it was a straightforward matter to determine load at any timestamp from the metered data. This process revealed two things: first, the plant loads assumed in the ex ante analysis were considerably higher than the actual plants loads, and second, the plant remains in operation during setback periods to meet data center loads. Figure 7 below presents the load versus outdoor temperature trends for the daytime and setback periods.

Figure 7: Regression Load Profiles



Source: DNV KEMA analysis

Note that load is well correlated with ambient temperature during regular weekday business hours when the building's air handlers operate. However, during setback periods, when load is strictly from the data center, load is essentially uncorrelated with temperature. These results led to the development of the bin load profile presented in Table E-39.

Table E-39: Ex Post Load Bins

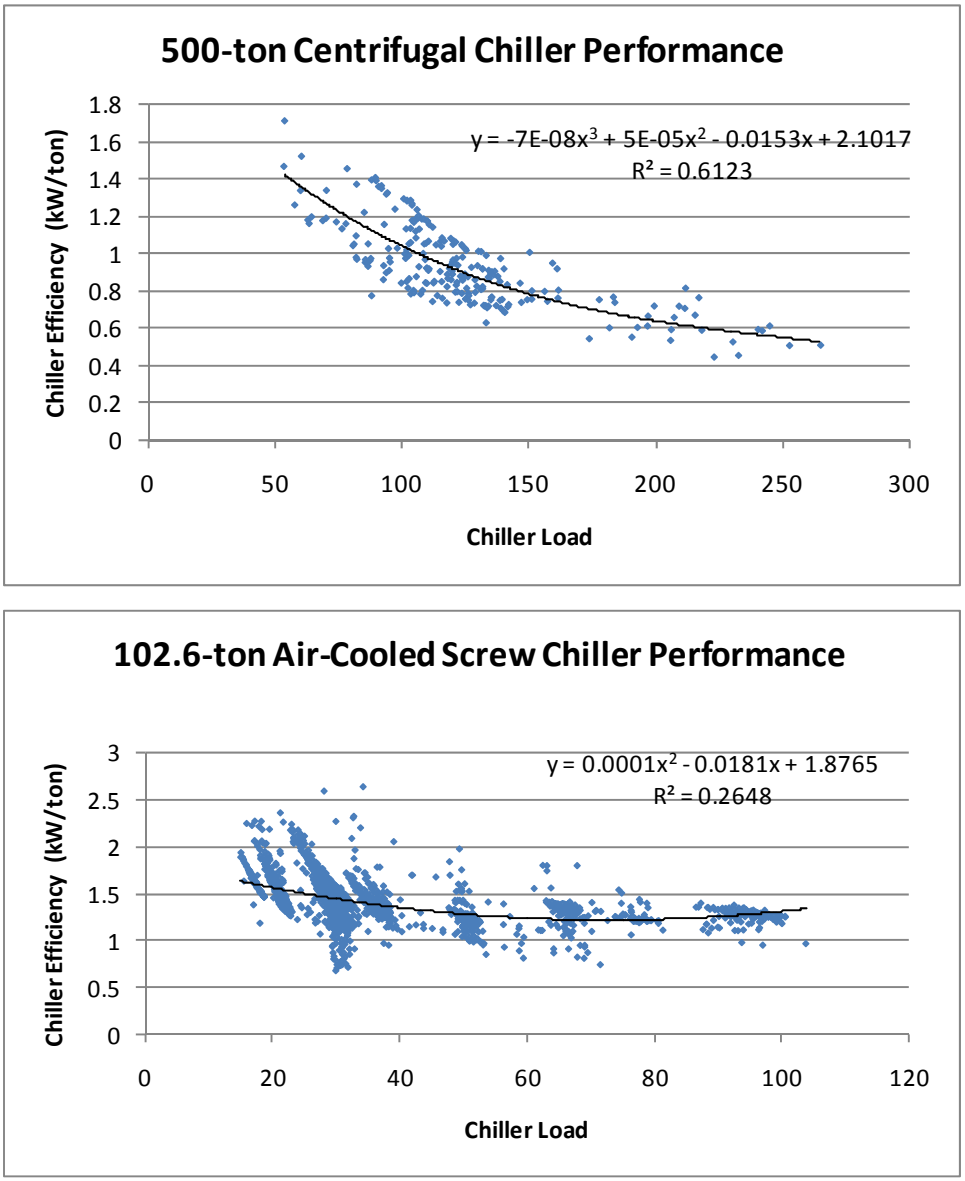
Dry Bulb Temperature	Bin Hours	Bin Load
88	1	290
86	5	247
84	23	220
82	46	195
80	49	174
78	64	154
76	172	137
74	233	118
72	273	100
70	300	83
68	436	64
66	285	48
64	320	37
62	229	28
60	97	22
58	99	20
56	50	20
54	39	20
52	16	20
50	9	20
48	2	20
46	1	20
44	1	20
Setback	6,010	24
Total	8,760	

Source: DNV KEMA analysis

The bin hours used in this profile were assigned based on TMY3 weather data for San Diego, CA. The setback hours were determined based on the building's typical schedule (as gleaned from the metered data).

After developing the bin-load profile, the metered data were next used to derive revised estimates of chiller efficiency for the three chillers operating in the pre-retrofit period. Using the chilled water flow, supply water temperature, return water temperature, and chiller power measurements, it was possible to determine each chiller's kW/ton efficiency at each time stamp. These values were then compared directly to chiller load to yield the chiller efficiency curves in Figure 8.

Figure 8: Preretrofit Chiller Performance Curves



Source: DNV KEMA analysis

Lastly, the metered data were used to revise the pre-existing plant sequence of operations assumed in the ex ante analysis. Note that this series of revisions is not based on plant logic, but rather strictly empirical conclusions arrived at via analysis on the metered plant data. This review yielded the following updated sequence of operations:

Chillers

(1) Base load the air-cooled chiller if the plant load is less than 102.6 tons.
(2) Base load one of the two 500-ton centrifugal chillers if the plant load is greater than 102.6 tons.

Pumps

(1) The 15-hp chilled water pump runs whenever the air-cooled chiller runs. Secondary chilled water pumps *do not* operate when the air-cooled chiller operates.
(2) If one of the 500-ton chillers operates, one of the two 25-hp primary chilled water pumps operates. If the plant load exceeds 150 tons, but is less than 220 tons, a second 25-hp primary chilled water pump operates roughly 50 percent of the time. If the plant load exceeds 220 tons, both 25-hp primary chilled water pumps operate.
(3) The secondary chilled water pumps are redundant; only one operates at any time. Whenever one or both of the primary chilled water pumps runs, then one of the two secondary chilled water pumps run.
(4) If one of the 500-ton chillers operates, the one of the 50-hp condenser water pumps operates. If the plant load exceeds 160 tons, but is less than 220 tons, then the other 50-hp condenser water pump also operates roughly 50 percent of the time. At plant loads in excess of 220 tons, both condenser water pumps operate.

Cooling Tower Fans

(1) If one of the 500-ton chillers operates, then one of the cooling tower fans operates. If the plant load exceeds 180 tons, but is less than 220 tons, then a second cooling tower fan operates roughly 50 percent of the time. If the plant load exceeds 220 tons, then both cooling tower fans operate.

With the pre-retrofit plant operations well defined, the next step in the analysis was reviewing the control schematics and sequence of operations for the Kiltech CPECS system to determine how the plant will operate once fully commissioned. These data were used to arrive at the following modeled sequence of plant operations:

Chillers

(1) The new SMARDT chiller will be base loaded when the outdoor air temperature is less than 75°F. At temperatures above 75°F, one of the pre-existing Carrier chillers will be base loaded.

Pumps

(1) When the SMARDT chiller operates, its dedicated chilled water pump (15 hp) and condenser water pump (30 hp) operate. The minimum chilled and condenser water flow rates are limited to 40 percent of their design values. Otherwise, the flow modulates as a function of loop load.
(2) When a Carrier chiller operates, one of the two 25-hp chilled water pumps operates. Additionally, one of the 75-hp chilled water pumps operates. Since these pumps now operate as part of the same loop (effectively in series, albeit one is located before the chiller and the other after), both pumps modulate flow as a function of load. The minimum chilled water flow rate is limited to 40 percent of its design value.
(3) A single 50-hp condenser water pump operates whenever one of the Carrier chillers operates. If the drive speed of the operating pump exceeds 80 percent of full speed, then the second condenser water pump turns on and both pumps track the same speed. The minimum condenser water flow rate is limited to 40 percent of its design value.

Tower Fans

(1) Cooling tower fan speed is dictated by condenser loop load and ambient wet bulb temperature. Cooling tower fan speed is not allowed to drop below 20 percent regardless of load. Both tower fans are anticipated to be required only if the plant load exceeds 480 tons.

The installed and pre-existing case operating sequences were used together with the load profile in Table E-39 and equipment efficiency data to estimate plant energy consumption under each scenario. Annual energy savings were simply calculated as the difference between the two scenarios. Peak demand savings were calculated based on the demand savings in the bins constituting the peak demand period. Since the peak period comprised three hours in the 84°F bin, five hours in the 82°F bin, and one hour in the 80°F bin, peak demand savings were calculated as the hour-weighted average of the demand savings in each of those three bins.

Savings were also calculated under an expected replacement scenario. Expected replacement is the minimally code compliant (or standard practice if no code applies) equipment that would be installed in the absence of the program, after the pre-retrofit equipment was determined to require replacement. Under the expected replacement scenario, the plant controls would have remained identical and VFDs would not have been installed throughout the plant. The chiller

would have been retrofit, however, albeit with a Title 24 minimum efficiency 210-ton centrifugal chiller. The plant sequence of operations would have been identical to the pre-existing case sequence of operations, but the new centrifugal chiller would have been base loaded until 210 tons as opposed to 102.6 tons.

Savings Results

Relative to the pre-existing equipment, the project saved 371,377 kWh and yielded 78.9 kW in peak demand savings. Relative to expected replacement equipment, the project saved 503,889 kWh and yielded 45.9 kW in peak demand savings. The project did not result in any therm savings. The central plant retrofit achieved kWh realization rates of 91.5 percent and 124.2 percent relative to the pre-existing and the expected replacement baselines respectively.

Discussion

In somewhat atypical fashion, this project saved more energy relative to the expected replacement baseline than the pre-existing equipment baseline. Usually the lower efficiency of the pre-retrofit equipment operating for more years results in more savings than the scenario where the pre-retrofit equipment is replaced at the end of its EUL. However, in this case the difference in the chiller replacement size, coupled with the pre-retrofit control scenario, increases the energy savings. The expected replacement chiller is assumed to be the same size as the chiller purchased (210 tons), which is roughly twice the size of the pre-existing chiller (102 tons). This increased project savings are due to the pre-existing plant sequence of operations — which would have remained in place under the expected replacement scenario as well — dictating that the small chiller serves as the base loaded machine up until it is fully loaded. Since the expected replacement chiller is considerably larger than the pre-existing chiller, this meant that many more annual hours were assigned to the small machine under the expected replacement scenario, reducing the hours assigned to the more efficient 500-ton chillers.

Relative to the pre-existing equipment baseline, ex post savings were less than ex ante savings primarily because of differences in the load profiles and operating sequences assumed in the analysis. The loads determined for the ex post analysis were drastically reduced from those assumed in the ex ante analysis; in fact, the peak load used in the ex post analysis was less than half that assumed in the ex ante analysis. Normally this would be cause for concern, but the ex post loads were vetted based on two months of metered data collected by the project design team.

The operating sequence assumed in the ex ante analysis was also found to differ enough from the actual operating sequence that it undoubtedly impacted the gross savings impact of the project significantly. In particular, the ex ante analysis assumed that the small chillers (for example, the 102.6-ton screw chiller in the pre-existing case and the 210-ton SMARDT chiller in the installed case) would be base loaded under all circumstances; metered data revealed that this was not the case in pre-existing scenario and controls schematics indicated that a different strategy was in place for the postretrofit period. Surprisingly, the net effect of the load profile and operating sequences changes was that the pre-existing equipment baseline savings dropped by only 8 percent relative to the ex ante claim.

Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have operated for the full EUL of the new equipment regardless if the existing equipment was at the end of its useful life. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the existing equipment's RUL. After the remaining useful-life period and up until the end of the EUL of the installed measure, an expected replacement baseline is used. This baseline considers minimally code compliant conditions or standard practice when no code is applicable.

Table E-40 below provides the annual energy savings estimates that fed into the life-cycle savings calculations, as well as the EUL for the installed measure.

Table E-40: Values Used in Life-cycle Savings Calculations

Measure	Early Replacement[30] / Pre-existing Equipment Baseline		Expected Replacement [31]Baseline		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
Central Plant Retrofit	371,377	0	503,889	0	20	13

Source: DNV KEMA analysis

Table E-41 provides life-cycle savings for the project relative to Baseline 1.

30 Early replacement is equipment replaced prior to the end of its useful life, because of the influence of the energy efficiency program.

31 Expected replacement is the minimally code compliant or typical operations equipment that would be installed in the absence of the program, after the pre-retrofit equipment was determined to require replacement.

Table E-41: Life-cycle Savings Relative to Baseline 1

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	371,377	78.9	-
2	2012	371,377	78.9	-
3	2013	371,377	78.9	-
4	2014	371,377	78.9	-
5	2015	371,377	78.9	-
6	2016	371,377	78.9	-
7	2017	371,377	78.9	-
8	2018	371,377	78.9	-
9	2019	371,377	78.9	-
10	2020	371,377	78.9	-
11	2021	371,377	78.9	-
12	2022	371,377	78.9	-
13	2023	371,377	78.9	-
14	2024	371,377	78.9	-
15	2025	371,377	78.9	-
16	2026	371,377	78.9	-
17	2027	371,377	78.9	-
18	2028	371,377	78.9	-
19	2029	371,377	78.9	-
20	2030	371,377	78.9	-
21	2031	-	-	-
Life-cycle	Total	7,427,540 kWh	1,578 kW-Years	0 therms

Source: DNV KEMA analysis

Table E-42 provides life-cycle savings for the project relative to Baseline 2.

Table E-42: Life-cycle Savings Relative to Baseline 2

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	371,377	78.9	-
2	2012	371,377	78.9	-
3	2013	371,377	78.9	-
4	2014	371,377	78.9	-
5	2015	371,377	78.9	-
6	2016	371,377	78.9	-
7	2017	371,377	78.9	-
8	2018	371,377	78.9	-
9	2019	371,377	78.9	-
10	2020	371,377	78.9	-
11	2021	371,377	78.9	-
12	2022	371,377	78.9	-
13	2023	371,377	78.9	-
14	2024	503,889	45.9	-
15	2025	503,889	45.9	-
16	2026	503,889	45.9	-
17	2027	503,889	45.9	-
18	2028	503,889	45.9	-
19	2029	503,889	45.9	-
20	2030	503,889	45.9	-
21	2031	-	-	-
Life-cycle	Total	8,335,124 kWh	1,347 kW-Years	0 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

California Energy Commission Building Retrofit

Site Summary

The California Energy Commission building is a four story office type building that contains approximately 121,000 square feet of conditioned space. The building is served by chilled water and hot steam piped in from a district plant located off site. Normal building hours are Monday through Friday from 8 a.m. to 6 p.m., but the building is partially occupied during other times.

Seven total EEMs were planned to be implemented at this site. These measures included: (EEM 1) delamping of perimeter lights, (EEM 2) air handler 4 (AH4) fan rescheduling, (EEM 3) hot water circulation pump rescheduling, (EEM 4) bathroom exhaust fan rescheduling, (EEM 5) supply fan 5 (SF5) rescheduling, (EEM 6) night purge routine, and (EEM 7) installation of occupancy sensors (OS) on T-8 fixture lighting in the open office areas. Table E-43 below summarizes the ex post and ex ante energy savings estimates by measure for this site.

Table E-43: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1 – Delamp Perimeter Lights	22,100	Not reported	0	0	0	0	0%	N/A
EEM 2 – AH4 Fan Reschedule	9,100	Not Reported	0	0	0	0	0%	N/A
EEM 3 – Hot Water Pump Reschedule	700	Not Reported	0	0	0	0	0%	N/A
EEM 4 – Exhaust Fan Reschedule	3,800	Not Reported	0	9,584	0	0	252%	N/A
EEM 5 – SF5 Reschedule	15,600	Not Reported	0	0	0	0	0%	N/A
EEM 6 – Night Purge	34,900	Not Reported	0	0	0	0	0%	N/A
EEM 7 – Occupancy Sensors	85,000	Not Reported	0	66,420	0	0	78%	N/A

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
Total	171,200	Not Reported	0	76,004	0	0	44%	N/A

Source: DNV KEMA analysis

Ex post energy savings estimates are considerably lower than what is claimed in the ex ante analysis[32] due chiefly to non-implementation for the majority of the measures. Ex post numbers are affected by computing zero savings for planned measures that were found to be not installed or not implemented at the time of the site visit. The evaluation used a combination of site observations, spot measurements, and on-site data loggers to measure energy consumption or time of use; utility bill or utility measured energy use was not included. A detailed look by measure is provided here:

- A combination of site observations, responses from the site contact, and the metered data collected on-site show that EEMs 1, 2, 3, 5 and 6 were either not implemented or turned off. Hence, there are no energy savings for these measures.
- Ex post energy savings for EEM 7 come from an actual fixture count, nameplate data, and time-of-use data while ex ante energy savings are from broad generalizations and assumptions on the building's light power density, square footage, and a controls savings factor. The low rigor in the ex ante savings method provided a rough estimate of potential energy savings, which were likely overstated.
- Ex post savings for EEM 4 were actually higher than ex ante estimates due to the fact that the fans were pulling a greater load than estimated in the retrocommissioning investigation report . This was supported by a spot power measurement of the exhaust fans, and documentation on the motor power rating. In addition, the operation of two fans were rescheduled but the ex ante calculations only accounted for one.

The overall results from Table E-43 yield a life-cycle energy savings of 675,117 kWh (Table E-44). Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full expected useful life (EUL) of the installed measures.
- Baseline 2, the dual baseline , uses minimally code compliant conditions or standard practice as the baseline once the RUL of the pre-existing equipment is exceeded. Since all

32 This document was part of the data files that was forwarded to DNV KEMA during the initial request for information. The analysis was done by Enovity.

these measures in this project are add-on measures, Baseline 1 and Baseline 2 are the same.

Table E-44: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Both Baseline 1 & Baseline 2	675,117	0	0

Source: DNV KEMA analysis

Project Description

This project was implemented at the Energy Commission building in Sacramento. The building is constructed from reinforced concrete and spans four stories. The total area of conditioned space is roughly 121,000 square feet. One governmental department occupies all four floors of the building. The building is served by built up air handling units on variable speed drive control. The air side delivery, however, acts like a constant volume system due to problems with the controls and aging/outdated equipment. Chilled water and steam are piped in from a district plant to provide the building's cooling and heating needs. There were seven measures planned to be implemented at this site. These measures are described in detail below.

EEM 1: Delamp perimeter lights – This measure was for delamping fixtures above desks in the perimeter areas where there is expected to be adequate day light.

EEM 2: AH 4 fan reschedule – This measure was to reschedule AH 4 to run based on occupancy instead of running constantly.

EEM 3: Hot water circulation pump reschedule – This measure was for the installation of a timer so the hot water circulation pump can be turned off automatically during off hours.

EEM 4: Bathroom exhaust fan reschedule – This measure was to reschedule two bathroom exhaust fans that can be automatically turned off during unoccupied hours.

EEM 5: SF 5 reschedule – This measure was to reschedule SF 5 to run based on occupancy instead of running constantly.

EEM 6: Night purge – This measure was to implement a night purge routine to pre-cool the building's thermal mass which theoretically would result in reduced cooling needs during the day time.

EEM 7: Occupancy sensors – This measure was to install occupancy sensor controls for overhead lights in the open office areas.

Ex Ante Savings

Enovity performed the savings analysis for all seven measures. While results of the calculations for four of the measures matched the status updates provided to DNV KEMA, three of the measures do not match (EEM 1, EEM 6, and EEM 7). The savings estimates for all measures used general assumptions to approximate energy savings. Details are provided here:

- EEM 1 – The analysis assumes 102 fixtures per floor were delamped. Each delamped fixture would save 26 Watts of demand. Hours of lighting operation were assumed as 2,736 hours per year. In the calculation workbook, the energy savings were calculated at 21,800 kWh, however, in the final status update this value is 22,100 kWh. It is not known why there was a change in the final value.
- EEM 2 – The calculation assumes the fan is on for only 50 hours per week in the efficient case and always on for the baseline case. Fan power draw is assumed at 1.49 kW.
- EEM 3 – The calculation assumes the pump is on for only 50 hours per week in the efficient case and always on for the baseline case. Pump power draw is assumed at 0.11 kW.
- EEM 4 – The calculation assumes the fan is on for only 50 hours per week in the efficient case and always on for the baseline case. Fan power draw is assumed at 0.68 kW. The calculated energy savings is for only one fan, although two were recommended for rescheduling.
- EEM 5 – The calculation assumes the fan is on for only 35 hours per week in the efficient case and always on for the baseline case. Fan power draw is assumed at 2.25 kW.
- EEM 6 – Simplified spreadsheet calculations along with weather data were used to estimate how much internal temperatures will drop if night venting was employed. The temperature drop from the night venting represents an amount of thermal energy removed from the building that will not need to be supplied by the chilled water system. The energy savings calculated in the spreadsheet is 54,800 kWh and is different from what is reported in the status updates (34,900 kWh). Energy savings will not be seen at the building but will appear at the district central plant.
- EEM 7 – The calculations do not count the number of fixtures affected by the occupancy sensors. Rather, the overall lighting demand of the open office areas was simplified using a 1.2 lighting power density and multiplied by the total area. This value is augmented by a 0.8 correction factor and a 0.15 reduction factor (the latter, presumably to describe how often the lights turned off). The estimated energy savings for the occupancy sensor was 42,835 kWh which differs from the 85,000 kWh reported in the status updates.

Project Evaluation

A DNV KEMA field engineer visited the project's site on June 17, 2011 to verify measure installation, install current transducer time-of-use loggers, and install time-of-use photocell data

loggers for determining hours of operation for a number of the end use equipment. In addition, spot power measurements were taken for the air handlers and pumps in order to establish the base power draw. Table E-45 summarizes the monitoring equipment that were installed at this site. Table E-46 below summarizes the most pertinent findings for this site followed by a more detailed explanation on the ex post savings analysis.

Table E-45: Monitoring Details.

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
DHW circulation pump	DENT CT TOU	On/Off (time-of-use)	Continuous	7 weeks
Supply fan 5	DENT CT TOU	On/Off (time-of-use)	Continuous	7 weeks
Air handler 4	DENT CT TOU	On/Off (time-of-use)	Continuous	7 weeks
Exhaust fan 1	DENT CT TOU	On/Off (time-of-use)	Continuous	7 weeks
6 Lighting fixtures (1st to 3rd floor)	DENT TOU Lighting Loggers	On/Off (time-of-use)	Continuous	7 weeks

Source: DNV KEMA analysis

Table E-46: Verification Summary

Equipment	Reported	Verified	Site Notes
EEM 1 – Open office perimeter lights, delamping	306	0	No delamping found
EEM 2 – Reschedule AH4 hours of operation	Off 118 hours/week	Not found	No rescheduling found
EEM 3 – Reschedule DHW circulation pump	Off 118 hours/week	Not found	Timer found on pump but being bypassed
EEM 4 – Reschedule exhaust fan hours of operation	Off 108 hours/week for 1 fan	Off 106 hours/week for 2 fans	Spot measurement taken to establish power draw
EEM 5 – Reschedule SF5 hours of operation	Off 135 hours/week	Not found	No rescheduling found
EEM 6 – Night purge routine	Implemented	Not Implemented	

Equipment	Reported	Verified	Site Notes
EEM 7 – Occupancy sensors	Not specified	1,039 fixtures	Total fixtures account for burnt out bulbs and nonfunctional circuits. OS on some circuits bypassed based on data and later confirmed with site contact.

Source: DNV KEMA analysis

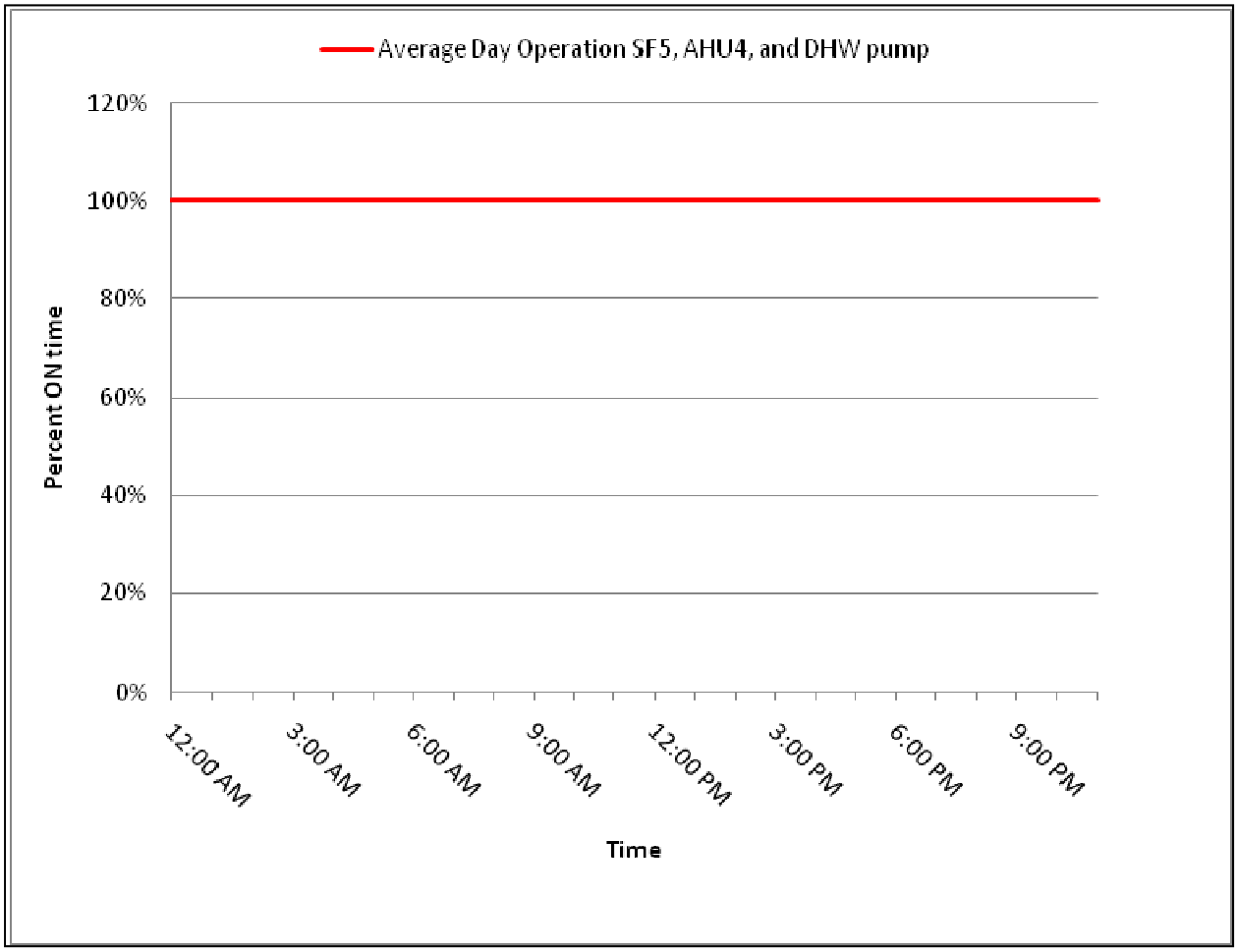
EEM 1 – Delamp Perimeter Lights

This measure claims energy savings for delamping of fixtures at office desks located at the perimeter where there is expected to be enough natural light for general office tasks. However, DNV KEMA did not find any evidence of systematic delamping at those locations despite careful inspection on all four floors. There was some delamping of about four fixtures seen in the interior of the building but is not likely part of the 102 delamped fixtures per floor described in the project files. If there was any delamping done, it was likely the bulbs were put back in place by the time of the evaluation site visit. The site contact was unaware of any delamping done at the perimeter. Hence, this measure receives zero savings.

EEM 2 – Air Handler 4 Reschedule

This measure was to turn off air handler 4 during unoccupied hours, but the facility operator stated that air handler 4 was manually controlled and ran at all hours. This statement is confirmed by time-of-use data collected on air handler 4 shown in Figure 9 below.

Figure 9: Average Day Time-of-use Profile for Supply Fan 5, Air Handler Unit 4, and DHW Circulation Pump



Source: DNV KEMA analysis

The data shows the unit always running for all hours of the day, seven days a week. Therefore, no energy savings are attributed to this measure since no evidence of rescheduling was found.

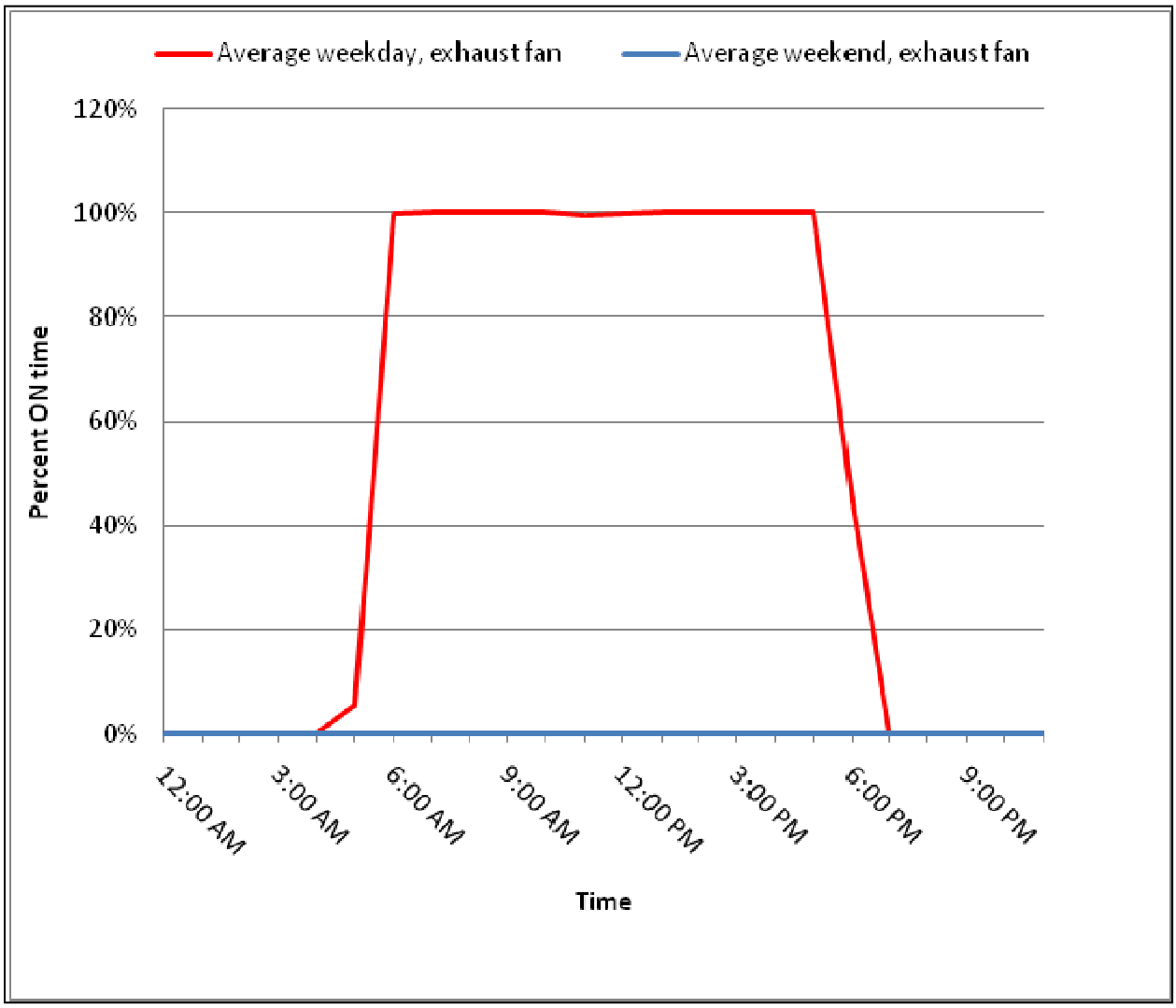
EEM 3 – Hot Water Circulation Pump Reschedule

While a time-clock was found installed at the hot water circulation pump, the controls appear to be bypassed by the operator during the monitoring interval for unknown reasons. The time-of-use profile is similar to air handler 4 shown in Figure 9. Since the controls are rendered ineffective, no energy savings are credited for this measure as well.

EEM 4 – Bathroom Exhaust Fan Reschedule

Data for the bathroom exhaust fan do indeed show the fans turning off during unoccupied hours. These include all hours during the weekend days and weekdays from 5:30 p.m. to 5:00 a.m. as shown in Figure 10 below.

Figure 10: Average Day Time-of-use Profile for Restroom Exhaust Fan



Source: DNV KEMA analysis

A spot power measurement at the fan showed that the fan was drawing 852 Watts of power. Since the fan is constant speed, it is expected that the fan will draw the same amount of power whenever it is on. The building operator stated that before measure implementation, both exhaust fans operated 24 hours a day, 365 days a year. Energy savings for this measure occurs whenever the fan is scheduled off. DNV KEMA calculated the energy savings for this measure as the total off hours multiplied by the fan power draw and quantity. This measure saved 9,584 kWh per year and includes both exhaust fans.

EEM 5 – Supply Fan 5 Reschedule

The time-of-use profile for supply fan 5 is similar to the hot water circulation pump and air handler unit 4 shown in Figure 9. This unit serves both the 1st floor conference room and guard room which are right next to each other. The building operator stated that the measure was initially implemented. However, when the conference room was unoccupied, the guards would complain about inadequate cooling or heating. The controls were switched over to manual and the fan left on for all hours to address this problem. Data from the time-of-use loggers confirms the fan's 24 hours/7 days operation. Therefore, no savings are attributed to this measure since the controls were disabled. DNV KEMA has been informed that subsequent to the evaluation a new guard office was built.

EEM 6 – Night Purge Routine

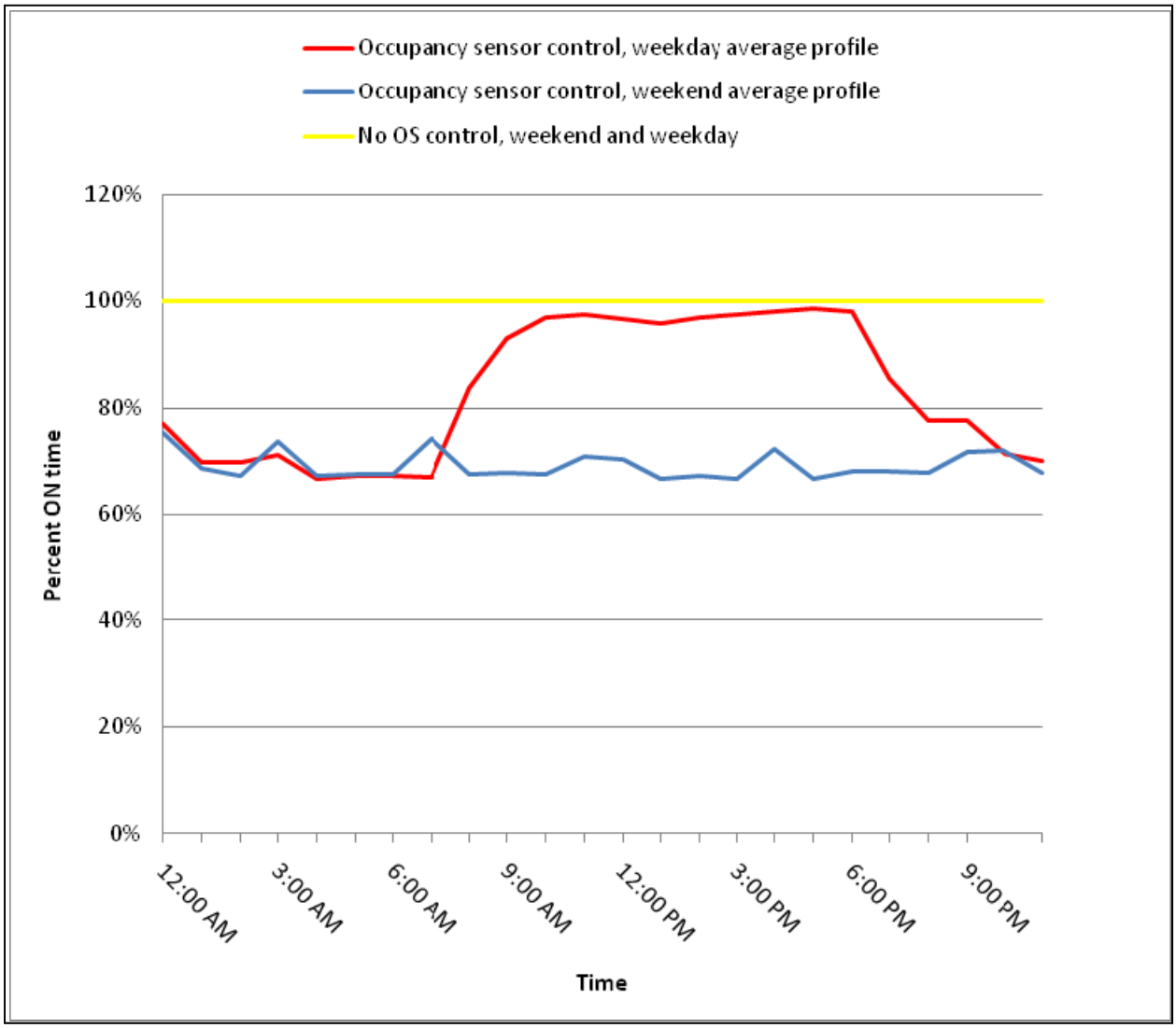
No evidence of a night purge routine was found at the site. The building operator stated that this measure was never implemented due to the inability to program the building automation system. There were also issues with non-functional actuators on the outside air dampers that made it not possible to control outside air flow. Inspection of the dampers shows that the motors had been removed. No energy savings are credited for this measure due to non-implementation.

EEM 7 – Occupancy Sensors (OS)

In order to assess energy savings from OS controls, DNV KEMA performed a manual count of the open office light fixtures that had an OS located close by. This was necessary because the project files did not contain enough information on the quantity of fixtures controlled by the sensors and this value is needed to calculate the measure's energy saving. The on-site lighting count included single lamp fixtures wired in tandem and dual lamp fixtures present throughout the open office spaces. Ballast nameplate for the dual lamp fixtures were inspected in order to estimate typical power draws for these fixtures. The single lamp fixtures had ballasts that were not accessible so the power draws were estimated based on the lamp wattage (32 Watts) observed instead.

Data from the photocell sensors installed at the fixtures show that lights without OS controls were kept on for all hours throughout the week. Interestingly, two out of the three monitored lighting fixtures presumed to have OS controls also show 24 hours /7 days of operation. This suggests that the OS were being bypassed rendering the sensors ineffective. However, one of the fixtures with an OS sensor do indeed cycle off during periods when occupancy is expected to be low suggesting that some circuits still have functional OS.

Figure 11: Average Weekend Day and Weekday Time-of-use Profile for Lighting Fixtures on Occupancy Sensor Controls



Source: DNV KEMA analysis

DNV KEMA used the average time-of-use profile for all three fixtures with occupancy sensors to establish typical hours of operation for fixtures with OS controls. The average profile includes both fixtures with functional OS and fixtures with bypassed OS controls. Energy savings for this measure is the total demand for all open office area lighting that was observed to have OS controls multiplied by the number of hours off due to the controls. Using this algorithm, energy savings for this measure is estimated at 66,420 kWh.

Savings Results

Total gross energy savings for this site for all seven measures is 76,004 kWh. There are no demand savings for this site because the energy savings for all implemented measures occur off

peak hours. Table E-43 at the beginning of this report categorizes the energy savings by measure. The ex ante savings estimates were taken from the program's monthly status reports and are also shown for comparison purposes.

Discussion

Measure 1 and Measure 6

Recommendations to delamp perimeter fixtures (EEM 1) and apply a night purge routine to pre-cool the building (EEM 6) were found not implemented. There is no evidence showing any actions were ever taken to realize energy savings for these two measures, hence the energy savings here is zero.

Measure 2 and Measure 5

The building operator claimed an attempt was made to re-schedule supply fan 5 (EEM 5) but due to complaints from a few occupants, the new schedule was dropped. In addition, the janitorial night shift was moved to the early morning (1 a.m. to 4 a.m.) and use of the air was required during those times. It became more convenient to leave the fans always on rather than adjusting the fans for changes in occupancy which may vary. However, this resulted in the fans always being left on, the same conditions as the baseline case. There were no attempts to reschedule AH4 (EEM 2). Therefore, these two measures are considered not implemented and receive zero energy savings.

Measure 3

A timer was indeed installed at the DHW pump. Metered data, however, show that the timer was being bypassed and the pump operated all the time. Even if the pumps were not being bypassed, actual hours off stated by the building operator (63 hours) are much less than what was used in the ex ante energy savings calculation (118 hours). Ultimately, data from the logger is used to assess energy savings and since the pump runs continuously, this measure also receives zero energy savings.

Measure 4

Data for the exhaust fans show the fans turn off during the weekends and 11.5 hours per weekday. Altogether, the fan turns off for a total of approximately 106 hours per week which is very similar to what was used in the ex ante calculations (108 hours). A review of the ex ante calculations show that the calculation only account for one fan instead two and that the average fan power draw (680 Watts) is estimated to be much less than what the fan was actually pulling (852 Watts). DNV KEMA accounted for the second exhaust fan's rescheduling and considered the actual fan operating load using a spot power measurement of the fan during normal operations. This provided additional energy savings to what was reported in the program's monthly status updates for this measure.

Measure 7

Ex ante energy savings for the occupancy sensors was calculated in a very imprecise way and serves only as a rough estimate of savings from the sensors. A lighting power density of 1.2 multiplied by the affected square footage was used to determine the overall demand. This value

was then multiplied by the annual hours of operation and multiplied again by lighting reduction factor of 15 percent. The source for the hours of operation is not known. Regardless, the resultant savings estimates do not actually match what is provided in the project updates so DNV KEMA cannot discern the source of the final energy savings for the ex ante estimates. Therefore, it is not possible to fully explain the discrepancy in energy savings for this measure at this time.

For this measure, the ex post savings estimates provided here by DNV KEMA contains a higher than expected uncertainty level primarily due to two factors:

- First, project documentation was unavailable to identify which lights are actually equipped with OS controls.
- Second, an unexpected finding that a portion of the lighting circuits believed to be on OS controls were being bypassed resulting in constant operation.

Regarding the first factor, DNV KEMA performed a thorough count of the lights believed to be on OS controls, but there is no guarantee as to how accurate that value is. DNV KEMA assumed the lights were on sensor controls if there existed a sensor in close proximity but this method may overestimate the number of fixtures with OS controls. The only accurate way to estimate this value is to review the bid documents or tenant improvement lighting diagrams which were not available during the site visit. A manual count based on visual inspection, however, was the next best method.

The finding of bypassed sensors also reduces the precision of the sampling approach and the accuracy of the savings estimate. DNV KEMA expected that the hours of operation would be identical since the affected lights served similar space types. Hence, only six total sensors were placed to establish both baseline and efficient case conditions. Conversation with the site contact after the data was reviewed confirmed that the majority of the lights were being bypassed but the magnitude was not known. It is likely the energy savings would be less than what is estimated in the ex post analysis if more sensors were used to estimate the hours of operation. Despite these uncertainties, the ex post analysis methodology is appropriate, since the algorithm is based on actual fixture counts, nameplate information, and measured hours of use.

Ex Post Life-cycle Savings

In essence, life-cycle savings is the sum of annual savings over the expected life of the measure. For replacement measures, the initial period considers the pre-existing conditions as the baseline for RUL, a so-called early replacement baseline or Baseline 1. After the remaining useful-life period and up until the end of the EUL of the installed measure, an expected replacement baseline is used. This baseline considers minimally code compliant conditions or standard practice where no code is applicable. The replacement measure which incorporates both early replacement and expected replacement baseline is called dual baseline or Baseline 2.

Since the only two measures installed at the Energy Commission building are add-on measures, both baselines are the same. EUL values for the two measures in Table E-47 come from DEER 2008.

Table E-47: Values Used in Life-cycle Savings Calculations by Measure

Measure	Early Replacement		Expected Replacement		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 4 – Exhaust Fan Reschedule	N/A	N/A	9,584	0	15	0
EEM 7 – Occupancy Sensors	N/A	N/A	66,420	0	8	0

Source: DNV KEMA analysis

The life-cycle savings for this site considering the EUL for the two measures implemented is calculated at 675,117 kWh. Table E-48 below shows the life-cycle savings by year for these measures.

Table E-48: Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	76,004	0	0
2	2012	76,004	0	0
3	2013	76,004	0	0
4	2014	76,004	0	0
5	2015	76,004	0	0
6	2016	76,004	0	0
7	2017	76,004	0	0
8	2018	76,004	0	0
9	2019	9,584	0	0
10	2020	9,584	0	0
11	2021	9,584	0	0
12	2022	9,584	0	0

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
13	2023	9,584	0	0
14	2024	9,584	0	0
15	2025	9,584	0	0
16	2026	0	0	0
Life-cycle	Total	675,120	0	0

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Office of Fleet Management, Parking Lots Lighting Retrofit

Site Summary

The Office of Fleet and Asset Management OFAM was awarded funds to retrofit outdoor lighting fixtures at five parking lots. The project consisted of lighting retrofits at Lots 8, 14, 38, 50, and 55. The existing outdoor fixtures consisted of either HPS or metal halide type lamps and were replaced with induction lamps equipped with bi-level controls.

Ex post energy savings were estimated at 661,318 kWh and represent 87 percent of the ex ante estimates (Table E-49). The lower energy savings are due to a more conservative estimate in lighting operation from the bi-level controls that is supported from metered power data at the OFAM, parking lots.

Table E-49: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
OFAM, parking lots lighting	Not reported	Not reported	0	511,041	49.3	0	N/A	N/A
OFAM, parking lots lighting Controls	Not reported	Not Reported	0	150,277	5.4	0	N/A	N/A
Total	761,436		0	661,318	54.7	0	87%	N/A

Source: DNV KEMA analysis

The overall results from Table E-49 yield a life-cycle energy savings of 8,867,827 (Table E-50). Life-cycle savings were calculated relative to the pre-existing condition for the full EUL of the fixtures and sensor controls.

Table E-50: Life-cycle Savings Summary

Measure	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Parking Lot Lighting	8,867,827	783.6	0

Source: DNV KEMA analysis

Project Description

This project was implemented at five of the OFAM parking lots spread throughout Sacramento and affected Lots 8, 14, 38, 50, and 55. Lot 8 and Lot 38 were outdoor parking lots with the lights operating for 12 hours a day. In contrast, Lots 14, 50, and 55 were enclosed parking lot structures with the lights operating to some extent 24 hours a day. The pre-existing fixtures were composed of 150 Watt (W) to 250 W HPS or metal halide lamps. This measure was to retrofit the pre-existing fixtures with induction lamp fixtures that are equipped with bi-level controls.

Ex Ante Savings

The ex ante savings used standard spreadsheet analysis. The algorithm included pre and post lighting fixture wattages, quantities, and estimates in hours of operation. In the postretrofit case, energy savings came from both a changeover of lighting technology and the use of bi-level controls. All new induction fixtures were assumed to be on the high bi-level setting for 25 percent of the time and the low bi-level setting for the rest of the time.

Project Evaluation

A DNV KEMA field engineer visited the project's sites on January 20, 2012 to verify measure installation and install data loggers to measure the power draw of the parking lot lights. Based on the energy savings magnitude and operation schedule, Lot 38 and Lot 55 were chosen for metering. Lot 38 represents typical operation on a 12 hour schedule while Lot 55 represents typical operation on a 24 hour schedule. Combined, these two lots represented almost 50 percent of the energy savings for this project. The other three lots were not metered but a fixture count was performed to verify measure implementation. A combination of DENT Elite Pro and Hobo Microstation loggers were used to measure power. Table E-51 summarizes the monitoring equipments that were installed at this site.

Table E-51: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
All OFAM parking lot lights, Lot 55	DENT Elite Pro	True power, amperage, voltage, power factor	5 minutes	18 days
All OFAM parking lot lights, Lot 38	Hobo Microstation with TRMS amperage module	Amperage, Power (when combined with spot measurements)	1 minute	18 days

Source: DNV KEMA analysis

Site Findings & Analysis

Bi-level induction lamps were found installed at the five OFAM parking lots during the site visit. At Lot 50, there were five more induction fixtures found than what was claimed while at Lot 14, there were six less fixtures. DNV KEMA found at Lot 14, the remaining six metal halide fixtures were still operating. Fixture counts were consistent for the other three lots. For the project overall, the minor difference in fixture counts found at two of the OFAM parking lots did not significantly impact the energy savings.

After removal of the data loggers on February 8th, the data was processed into average weekday and weekend day power draw profiles. The data showed that for the outdoor lots that are on 12 hour lighting operation, the schedule was consistent for all days. In contrast, at the 24 hour OFAM parking structures, there were two distinct operating profiles, one for weekdays and one for weekend days (Figure 9).

The next step was to determine the fixtures' proportion of time operating in the low versus high settings. This was done by calculating two theoretical power draw values. The first assumed all lights were on the high setting and the second assumed that all lights were on the low setting. This was performed using the fixture quantities found on-site and input power ratings of the fixtures. These two values were used to extrapolate the proportion of lights on the low versus high settings for each hour in the data. The following equation distills this process down mathematically:

$$N = (P_D - P_{min})/(P_{max} - P_{min})N = (P_D - P_{min})/(P_{max} - P_{min})$$

Where N is the percent of lights on the high bi-level setting, P is the power draw for the theoretical minimum (min), maximum (max), and hourly value from the data (d).

Results of the analysis yielded an average occupancy fraction of 24 percent for Lots 38, 65 percent for Lot 55 on weekdays, and 37 percent for Lot 55 on weekends (Table E-52). This fraction represents the fraction of the fixtures on the high bi-level setting.

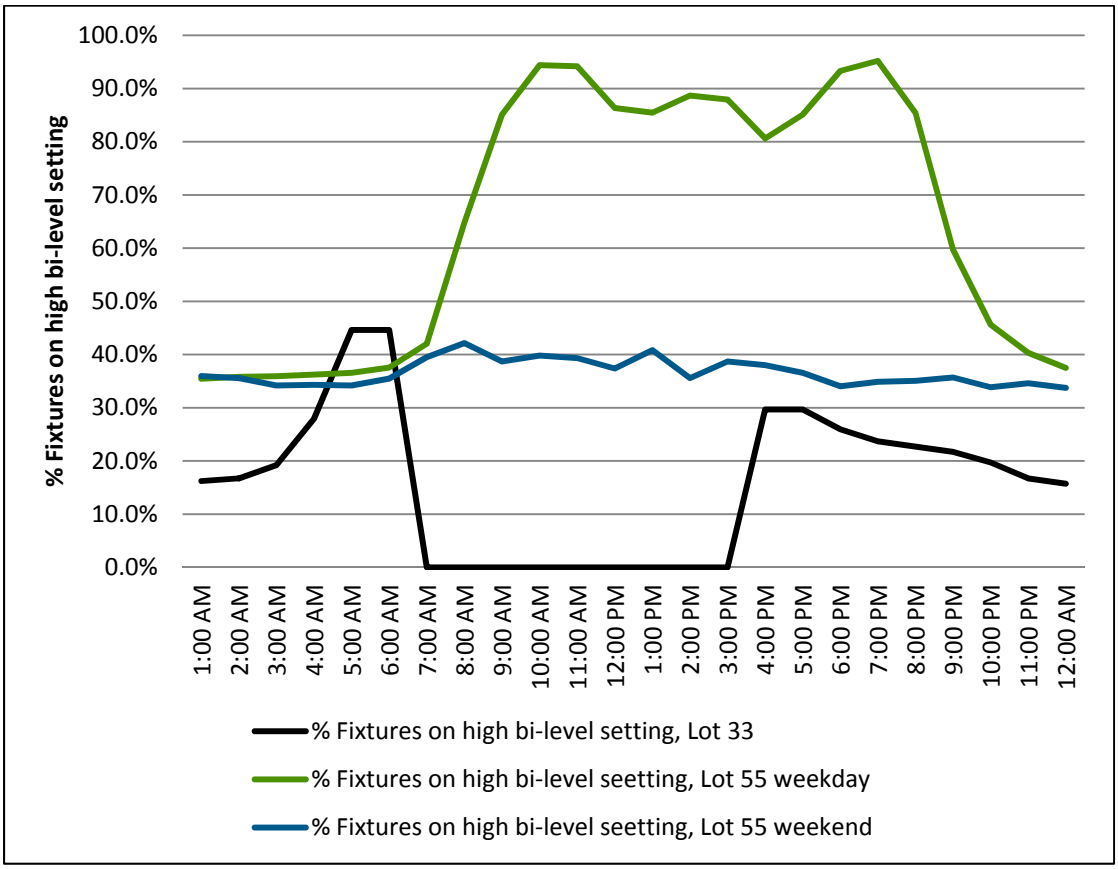
Table E-52: Average Percent of Fixtures on High Settings

Profile	% of Fixtures On High Setting
Lot 38	24%
Lot 55, weekday	65%
Lot 55, weekends	37%

Source: DNV KEMA analysis

A 24-hour profile for this result is also shown in Figure 12 below. The values derived from this analysis were used to inform the final energy savings calculations which takes into account fixture quantities, pre and postretrofit wattages, and hours of operation.

Figure 12: Percent of Lights on High Bi-level Settings for Lot 38 and Lot 55



Source: DNV KEMA analysis

Savings Results

Total energy savings for this site is 166,918 kWh and 63.9 kW of demand savings. The savings represent both the fixture change outs and bi-level controls.

Discussion

The energy savings for this project is 87 percent of the ex ante reported value and is a reflection of actual lighting operations due to the bi-level controls. The bi-level controls allow the fixtures to turn down the level of lighting based on occupancy. In the high setting, the fixtures operate at full capacity in response to inputs from a motion sensor. When no motion is detected for a period of time, the fixture reverts to a low setting by dimming the lights.

In the ex ante calculations, it was assumed that all parking spaces were occupied only 25 percent of the time, with similar lighting operation profiles. That is, for 25 percent of the time the lights are on the high setting due to occupancy sensor activity. According to the data, this is a fair assumption for the outdoor OFAM parking lots but was not true for the 24-hour parking lot structures which had the lighting fixtures operating on the higher bi-level setting for a significantly higher proportion of the time. On weekdays and weekend days, the lighting

fixtures at the 24-hour parking lot structures averaged 65 percent and 37 percent on the high settings, respectively. This is much more than the assumed 25 percent from the ex ante calculations and as a result, negatively impacts the energy savings for this measure.

Ex Post Life-cycle Savings

Typically, energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

In the case for parking lot light fixtures, there is no established standard practice so only the early replacement baseline is used to calculate life-cycle savings. Expected EUL values for outdoor lighting fixtures are 15 years while the sensor component is eight years according to DEER. The life-cycle savings calculations take into account both components of this measure. Details of this calculation are shown in Table E-53.

Table E-53: Values Used in Life-cycle Savings Calculations by Measure

Measure	Electric Energy (kWh)	Gas Energy (therms)	EUL	RUL
Outdoor light fixtures	511,041	0	15	N/A
Bi-level Occupancy Sensors	150,277	0	8	N/A

Source: DNV KEMA analysis

The life-cycle savings for this site considering the EUL is calculated at 8,867,827 kWh. Table E-54 below shows the life-cycle savings by year for these measures.

Table E-54: Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	661,318	55	0
2	2012	661,318	55	0
3	2013	661,318	55	0
4	2014	661,318	55	0
5	2015	661,318	55	0
6	2016	661,318	55	0
7	2017	661,318	55	0
8	2018	661,318	55	0
9	2019	511,041	49	0
10	2020	511,041	49	0
11	2021	511,041	49	0
12	2022	511,041	49	0
13	2023	511,041	49	0
14	2024	511,041	49	0
15	2025	511,041	49	0
16	2026	0	0	0
Life-cycle	Total	8,867,831	783.0	0

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Jesse Unruh Building Retrofit

Site Summary

The Jesse Unruh building in downtown Sacramento is a large governmental office building operating during standard business hours from Monday through Friday.

Four EEMs were implemented at the Jesse Unruh building with the assistance of Revolving Loan Fund Program financing. These measures included: (EEM 1) lighting occupancy sensors and timer based lighting controls, (EEM 2) low differential pressure air filters for air handlers (AHUs) 1 through 12, (EEM 3) coil cleaning services for AHUs 3 through 12, and (EEM 4) variable speed drive retrofits for AHU 3 through AHU 12. Ex ante and ex post savings for each of the four measures are presented below in Table E-55.

Table E-55: Energy Savings Summary

Measure	Ex Ante[33]			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1: Lighting – Occupancy Sensor and Timer Controls	206,180	None Claimed	N/A	7,097	1.7	N/A	3.4%	N/A
EEM 2: HVAC – Low Differential Pressure Air Filters	93,155	None Claimed	N/A	0	0	N/A	0.0%	N/A
EEM 3: HVAC – AHU Coil Cleaning Service	75,252	None Claimed	N/A	32,468	10.0	N/A	43.1%	N/A

33 Ex ante savings values for the individual measures were appropriated from a feasibility study produced by Cogent Energy (document titled "Feasibility Study – SOS, Bateson, Unruh.pdf"); these values were found to match the ex ante savings claimed for the Jesse Unruh building project in DGS's monthly project status update.

Measure	Ex Ante[33]			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 4: HVAC – AHU VFD Replacements	None Claimed	None Claimed	N/A	13,724	4.2	N/A	N/A	N/A
Total	374,587	None Claimed	N/A	53,289	16.0	N/A	14.2%	N/A

Source: DNV KEMA analysis

EEM 1 through EEM 3 did not save nearly as much energy as claimed for a variety of reasons. In the case of EEM 1, the ex ante savings calculations were based on rough assumptions regarding the proportion of building energy use attributable to lighting end uses and the savings potential of the measures themselves. These assumptions skewed the savings potential of the lighting controls measure and will be discussed later in this report. EEM 2 ultimately resulted in no energy savings because the building staff replaced the newly installed low differential pressure air filters with standard air filters when it came time to replace the first set of efficient filters. In the case of EEM 3, the ex ante savings methodology could not be deduced from the provided documentation; the reason(s) for the discrepancy between the ex ante and ex post savings estimates, therefore, remain unclear.

In contrast to EEM 1 through EEM 3, EEM 4 saves more energy than originally claimed. In fact, no ex ante savings were claimed for EEM 4 even though the measure was implemented through the Revolving Loan Fund Program. The monthly program status update bundles the VFD fan measure (EEM 4) and lighting controls measures (EEM 1) as one EEM, but the savings listed for that EEM only correspond to the lighting measure. Accordingly, only ex post energy savings are listed in Table E-43 for the VFD air handler measure.

The ex post energy savings reductions for EEM 1 through EEM 3 more than offset the newly claimed energy savings for EEM 4, resulting in a gross realization rate of 14.2 percent for energy savings for the entire project.

In addition to first year savings, project life-cycle savings were also assessed as part of this evaluation**.** Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses minimally code compliant conditions or standard practice as the baseline once the RUL of the pre-existing equipment is exceeded. Since all these measures in this project are add on measures, the Baseline 1 and Baseline 2 are the same.

For occupancy sensors and VFD fan measures, DEER provides EULs of 8 years and 15 years respectively. The EUL for EEM 2 was irrelevant since the measure was not retained. DEER does not report an EUL for evaporator coil cleaning measures; the closest proxy for evaporator coil cleaning in DEER is condenser coil cleaning, which has a three year EUL. The condenser coil cleaning EUL was appropriated in this case after performing secondary research that suggested even shorter periods (on the order of 6 months to 12 months) are the norm for evaporator coil cleaning services.[34]

Table E-56: Ex Post Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	360,038	107.2	0
Baseline 2	360,038	107.2	0

Source: DNV KEMA analysis

Project Description

The Jesse Unruh building is a five-story (six if including the basement), 162,000 square foot office building constructed in 1922. The building operates Monday through Friday with typical occupancy between the hours of 8 a.m. and 5 p.m. Building HVAC turns on at 5 a.m. to ensure that set points are met by 8 a.m., and it shuts off at 6 p.m. HVAC equipment is completely off during night and weekend periods.

Measure 1:

EEM 1 consisted of two lighting controls components. The first portion was "smart breaker" panels. Unlike conventional breakers, which can only be flipped locally, smart breakers can be integrated into the building's EMS system and controlled remotely via timer schedules. Once integrated into the EMS system, building management can limit usage of lights to certain periods of the day.

The second portion of EEM 1 consisted of installing wall mounted occupancy sensors throughout the building's office spaces. The number of sensors was not specified explicitly in the application materials, but 101 sensors were ultimately installed.

34 http://www.bbjenviro.com/cm_hvacmaint.asp.

Measure 2:

EEM 2 consisted of installing low differential pressure air filters in AHU 1 through AHU 12. Installing these filters effectively reduces the static pressure loss across each AHU's filter bank by roughly .5" WG, thereby reducing the power demands on the fan motors for an equivalent amount of air flow.

Measure 3:

The third EEM implemented at the Jesse Unruh building was evaporator coil cleaning for AHU 3 through AHU 12. Like EEM 2, evaporator coil cleaning generates energy savings by reducing the static pressure that AHU supply fans have to work against.

Measure 4:

EEM 4 consisted of replacing pre-existing VFDs on AHU 3 through AHU 12 with new VFDs. Whereas each air handler's supply and return fans had previously been fed from a single VFD, the new configuration provides each fan with its own VFD. Furthermore, two of the pre-existing VFDs (those on AHU 3 and AHU 10) had failed, leaving the fans to operate in bypass mode (full speed) at all times.

Ex ante Savings

According to the project documentation reviewed, Cogent Energy calculated ex ante savings for each of the EEMs using spreadsheet analyses. EEM 1 savings were calculated from a year's worth of facility electricity billing data by employing the following set of assumptions:

- Lighting end uses represent one-third of total facility energy use.
- Occupancy sensors reduce total lighting energy use by 30 percent.
- The smart breaker controls will reduce lighting energy use by 2.5 percent.

Savings were, therefore, calculated as $\mathrm{kWh}_{\mathrm{annual}}\left(\frac{1}{3}\right)\left(\frac{30+2.5}{100}\right)$. This overly simplified calculation grossly overestimated lighting energy savings.

Ex ante energy savings for EEM 2 were calculated using a spreadsheet model. The values output from this spreadsheet, however, do not match the ex ante savings claimed in the Energy Commission's monthly status reports, so it is unclear if this approach was ultimately used for the final savings claims.

Limited documentation was provided for EEM 3, making the implementer's analysis procedure impossible to decipher. According to the Energy Commission, savings claims of 4 percent relative to pre-retrofit fan usage are typically allowed for coil cleaning measures. Based on the pre-existing AHU energy use predicted as part of the evaluation, this rule would have resulted in a saving claim of only 4,420 kWh. Either fan energy use was dramatically overestimated for the ex ante calculations, or a different approach was used for this coil cleaning measure.

Since EEM 4 savings were not claimed, there were no supporting calculations.

Project Evaluation

A DNV KEMA engineer visited the facility on July 19, 2011 to verify the installation of each measure, install data logging equipment, and gather facility operating data to assist in assessing energy savings. Table E-57 below contains a summary of all monitoring equipment that was installed during the initial site visit.

Table E-57: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
AHU-7 Supply Fan	Dent ElitePro	V, A, PF, True Power	5 Minute	49 Days
AHU-7 Return Fan	Dent ElitePro	V, A, PF, True Power	15 Minute	49 Days
AHU-11 Supply Fan	Dent ElitePro	V, A, PF, True Power	5 Minute	49 Days
AHU-11 Return Fan	Dent ElitePro	V, A, PF, True Power	15 Minute	49 Days
Office 432 lighting (4th Floor)	Dent Lighting*logger*	On/Off Records	N/A	49 Days
Office 339 lighting (3rd Floor)	Dent Lighting*logger*	On/Off Records	N/A	49 Days
Office 1P lighting (Basement)	Dent Lighting*logger*	On/Off Records	N/A	49 Days
Office 351 lighting (3rd Floor)	Dent Lighting*logger*	On/Off Records	N/A	49 Days
1st Floor Break Room	Dent Lighting*logger*	On/Off Records	N/A	49 Days

Source: DNV KEMA analysis

Following 49 days of metering, the DNV KEMA engineer returned to the facility to retrieve the data loggers and complete verification activities begun during the initial site visit. This section details the verification activities, monitoring results, and analysis procedures on a measure by measure basis.

Measure 1 – Smart Breaker Panels and Occupancy Sensors

On-site verification activities confirmed that the smart breaker panels were installed as intended. The smart breakers, however, had not been integrated into the building's EMS system, so the smart breakers did not have any additional functionality relative to the pre-existing breakers. The site contacts indicated that the control wiring is unlikely to be installed

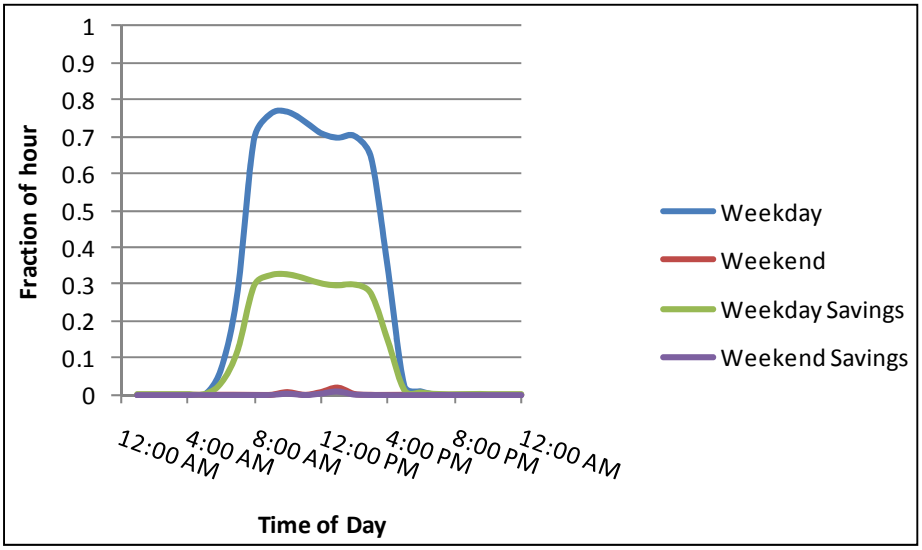
until the building's aged EMS system is replaced. While the building engineer could say that talks were underway regarding a potential EMS system replacement, no plans to replace the EMS system had yet been finalized. The smart breaker portion of this measure, therefore, will not save any energy for the foreseeable future.

Hypothetically, if the smart breakers had been wired to a capable EMS systems, savings would have been assessed based on the reduction of operating hours introduced by controlling light use at the breaker level. Select circuits would have been monitored to observe smart breaker operation. Interview data would have been used to inform the pre-retrofit operating conditions before smart breaker installation. Under ideal circumstances, pre- and post-circuit monitoring could be performed to directly assess the change in lighting usage.

For the occupancy sensor component of the measure, one of the site contacts was able to provide a contractor's building floor plan layout indicating where 124 new occupancy sensors had been installed. This list did not indicate the types, wattages, and quantities of fixtures had been connected to the sensors, so it was necessary to both verify the existence of each of the claimed sensors and record general information about the fixture types controlled by the sensors. Since there were ultimately 101 sensors to verify (23 of those claimed in the contractor's layout were not installed as proposed) and 264 associated fixtures to identify, it was only reasonable to record basic fixture characteristics, including: type (FT, CFL, Inc., and so forth), lamp quantities, and lamp length. For incandescent and CFL fixtures, the rated lamp wattages were also recorded if visible. The room type served by each sensor was also recorded.

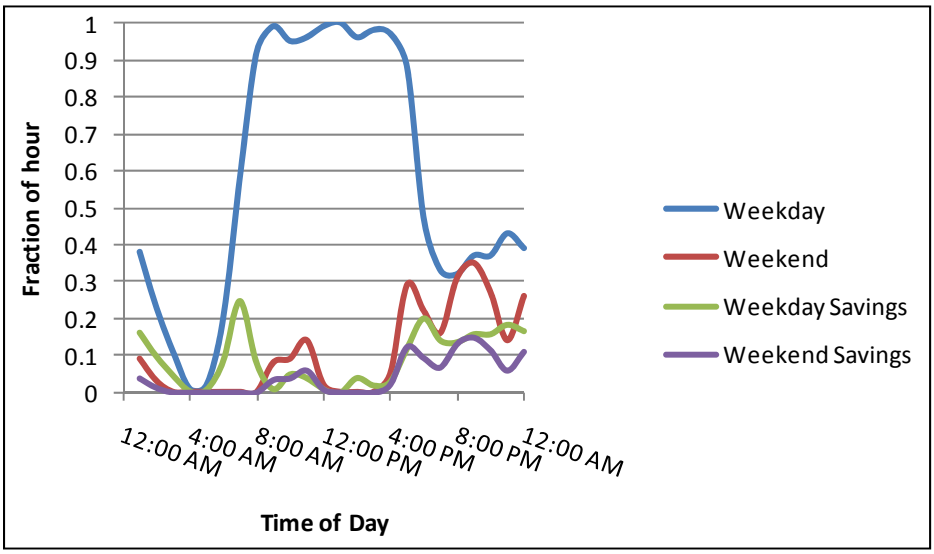
While verifying the sensor installations, five time-of-use ON/OFF lighting data loggers were installed in four randomly selected offices (the predominant space type served by the new sensors) and one break room. Figure 13 and Figure 14 below exhibit the average weekend and weekday usage and savings profiles for the office loggers and the break room logger respectively. Note that the office usage profile represents the average of the four loggers installed in office spaces.

Figure 13: Office Weekday and Weekend Lighting Usage and Savings Profiles



Source: DNV KEMA analysis

Figure 14: Break Room Weekday and Weekend Lighting Usage and Savings Profiles



Source: DNV KEMA analysis

Notice that Figure 13 and Figure 14 also display the time-of-use savings for each data logger. The time-of-use savings presented in Figure 13 and Figure 14 were calculated based on the assumption that occupancy sensors yield time-of-use reductions of roughly 30 percent relative

to the baseline lighting usage.[35] As such, for each hour, the time-of-use (TOU) reduction was calculated as $\frac{\mathrm{TOU_{metered}}}{.7} - \mathrm{TOU_{metered}}$. For hours during which the metered usage was greater than 70 percent, the time-of-use reduction was calculated as $1 - TOU_{metered} 1 - TOU_{metered}$ because the standard formula would yield greater than 100 percent usage for a given hour.

The hourly time-of-use reductions were then summed to develop full-day weekday and weekend time-of-use reduction estimates for each day type. These daily schedules were then scaled to annual TOU reduction profiles that were then applied to the gross connected loads (kW) from each space type. These gross connected load estimates were derived by matching observed fixture types with wattage values provided in the *2011 Table of Standard Fixture Wattages.*[36]

For space types other than those that were metered (for example, restrooms, conference rooms, halls, and storage rooms), assumptions regarding operating hours were made in order to inform the TOU reduction savings analysis. These assumptions were made based on building operating hours and usage characteristics observed over the course of two sites visits. In general, the time-of-use assumptions, which are provided in Table E-58 below, were made liberally to avoid shortchanging the project of any potential savings.

Table E-58: TOU Reduction Estimates for Unmonitored Space Types

Space Type	Estimated Weekday Operating Hours	Estimated Weekend Operating Hours	Estimated Daily TOU Reduction Weekday (h)	Estimated Daily TOU Reduction Weekend (h)
Closet	2	0	0.6	0.0
Conference Room	9	0	2.7	0.0
Fan/Mechanical Room	2	0	0.6	0.0
Hall	13	5	3.9	1.5
Restroom	13	5	3.9	1.5
Storage	2	0	0.6	0.0

Source: DNV KEMA analysis

35 *NEEP Mid-Atlantic Technical Reference Manual Version 1.1, pg. 83, October 2010.*

36 http://www.sce.com/business/ems/customized-solutions/tools-resources.htm, Appendix B.

Measure 2 – Low Differential Pressure Air Filters

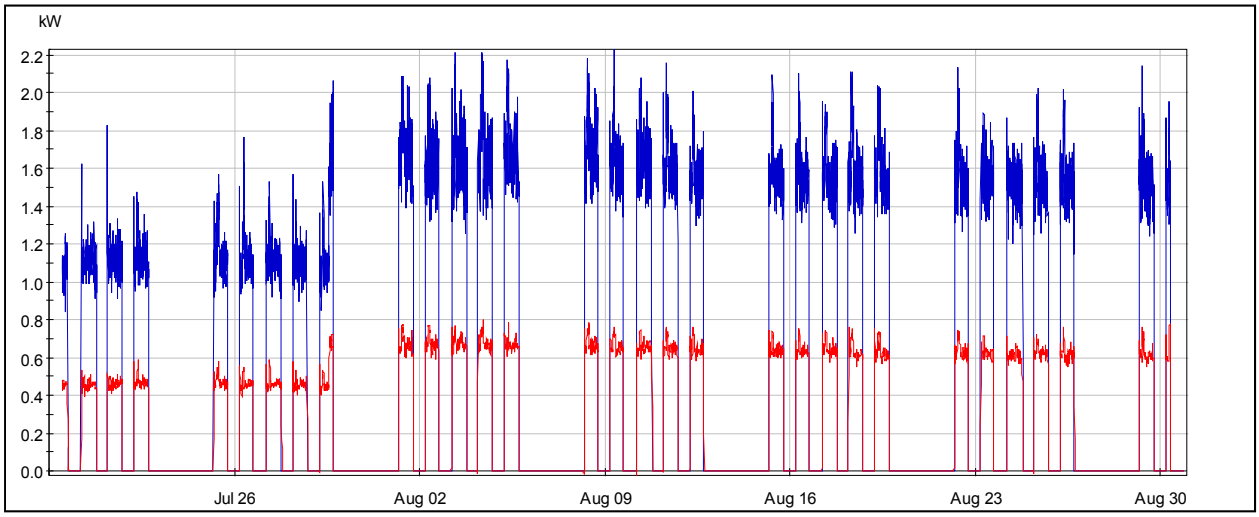
The newly installed low differential pressure (DP) air filters had already been replaced with the baseline air filters by the time of the initial verification site visit. According to the building engineer, the building reverted to the old filter type because the low DP filters were repeatedly collapsing inside the filter slots. Since the new filters were not functioning properly, the building staff chose not to continue using the low DP filters. No savings were, therefore, derived from this EEM.

Measure 3 – Coil Cleaning

During the facility visit, the site contact confirmed that the coils in AHU 3 through AHU 12 had been cleaned as claimed. In addition, the DNV KEMA auditor briefly looked inside an air handler and was able to observe that the coils appeared clean.

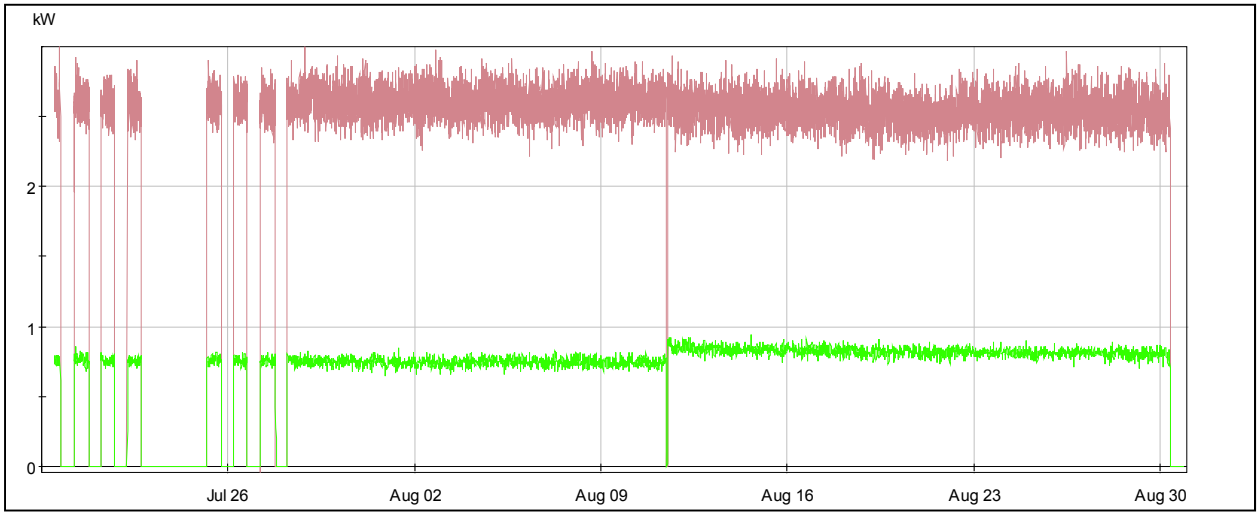
To assist in developing energy savings estimates for each air handler, true power data loggers were installed on the supply and return fans of AHU 7, which serves the 5th floor's east half, and AHU 11, which serves the 4th floor's west half. The trends captured from AHU 11 and AHU 7 over the course of the monitoring period are presented in Figure 15 and Figure 16 below.

Figure 15: AHU11 Metered Profile: Supply Fan (Blue) and Return Fan (Red)



Source: DNV KEMA analysis

Figure 16: AHU7 Metered Profile: Supply Fan (Purple) and Return Fan (Green)



Source: DNV KEMA analysis

Figure 15 and Figure 16 indicate that the fans operate at relatively constant speeds irrespective of load. When the building engineers were asked to explain this trend, the building engineers first noted that the EMS system is set to maintain a constant supply static pressure. Furthermore, since there are not VAV boxes or dampers for individual zone control, a constant air flow is required at all times to maintain the static pressure set point. In essence, the VFDs primarily function to reduce the output of oversized fans and motors. Note that the return fans also maintain a constant output since the return fans are controlled to maintain the same output frequency as the supply fans.

After addressing the constant load trend, the building engineer was also asked to explain why AHU7 remained in constant operation from July 28th onward even though the fans are supposed to remain off during nights and weekends. He explained that control system failures had required him to switch certain air handlers over into "hand" (manual) operating mode. As a result, the fans were essentially disconnected for the control system and operated manually at a frequency of his choosing from July 28th onward. Under normal circumstances, the fans in Figure 16 would follow an identical on/off schedule to that exhibited by the fans in Figure 15. As such, savings were subsequently calculated as if the fans operated according to the intended schedules.

For the purposes of the ex post analysis, the metered data were used to estimate load factors for the motors driving each of the fans. The supply and return fan motor load factors were then averaged independently and applied to each of the remaining supply and return fan motors in the building. This approach was deemed appropriate given that each fan in the building operates at nearly the same frequency, which indicates relatively equivalent motor loading across each of the 10 affected AHUs.

Using data from the building's mechanical schedules (design airflow and design total static pressure when available) in conjunction with the motor loading data, estimates of the operating static pressures for each of the building's AHUs were then derived for clean-coil conditions. These static pressures were subsequently modified to mimic dirty-coil conditions in accordance with the following assumptions:

- Coils typically represent roughly 25 percent of all static pressure losses in commercial HVAC systems.[37]
- Evaporator coils foul enough to double the static pressure loss across the coil in roughly 7.5 years.[38] Since the Jesse Unruh building coils had not been professionally cleaned within that time frame, it is safe to assume that the coil static pressure drop had at least doubled relative to the design condition.

These two rules of thumb were implemented in the context of a spreadsheet analysis by effectively assuming that the pressure drop across the supply fans was 25 percent higher under dirty coil conditions than clean coil conditions. The energy consumption of the fans under dirty-coil conditions was adjusted from the clean-coil case by shifting the fan curve operating point (as defined by the ratio of flow^2/pressure [CFM^2/In.WG], which holds constant for a given point on the fan curve irrespective of motor frequency), and then scaling the frequency of VFD operation to maintain the proper flow rate. This procedure is represented graphically in Figure 17 below for AHU 3. Fan efficiency reductions caused by the shift in fan's operating point under fouled coil conditions were also addressed in the analysis. Because actual fan curves for the building were not available (and rarely are available), representative fan curves were appropriated from the Mechanical Engineering Reference Manual for backward-inclined centrifugal fans.[39]

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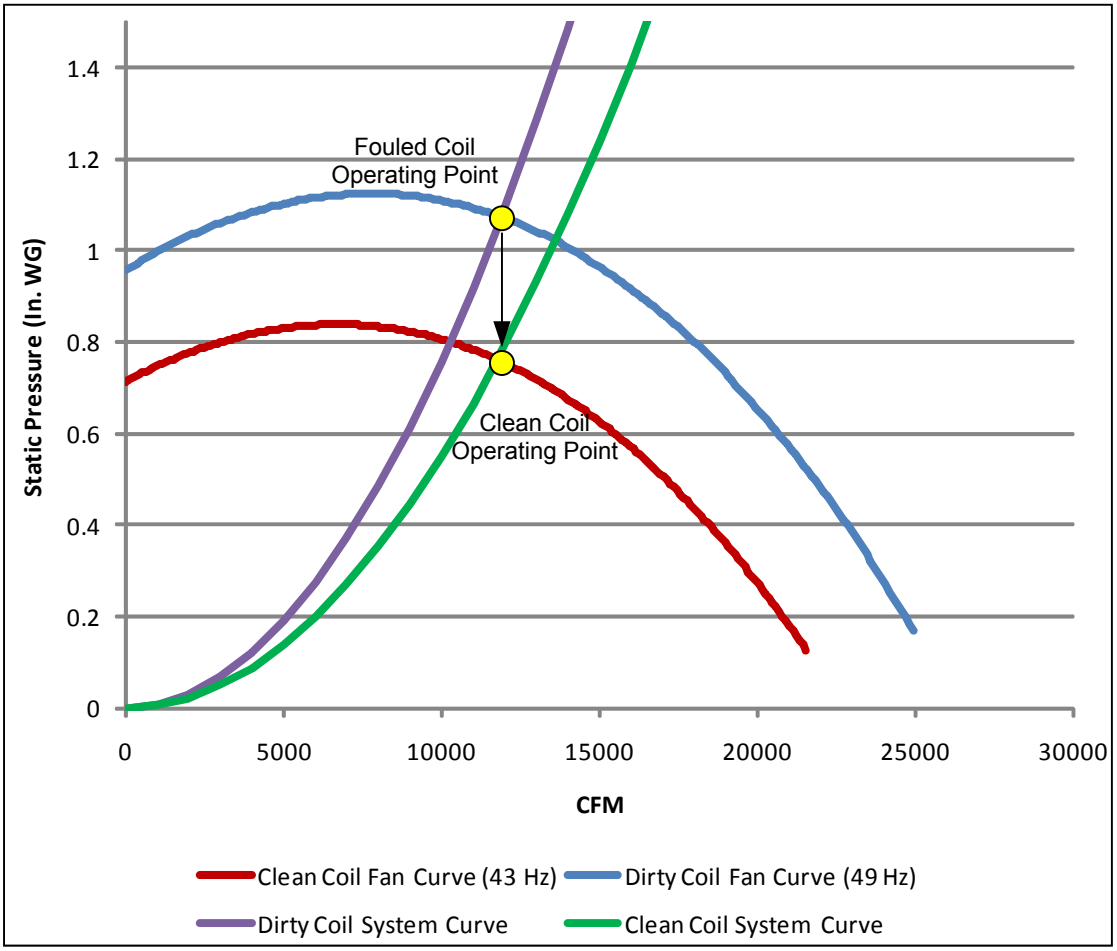
37 Siegel, Jeffrey Alexander, Particle Fouling of HVAC Heat Exchangers, 2002.

38 Siegel, Jeffrey Alexander, Dirty Air Conditioners: Energy Implications of Coil Fouling.

39 Lindeburg, Michael R., Mechanical Engineering Reference Manual, 2006.

Figure 17: AHU3 Operating Point Shift



Source: DNV KEMA analysis

Savings for each fan were determined by multiplying the demand savings resulting from the coil cleaning as determined from the above analysis (for example, $kW_{dirty} - kW_{clean}$) by annual operating hours as determined from the metered data in Figure 15.

Measure 4 – VFD Fan Retrofit

The site engineer verified that the supply and return fans in AHU 3 through AHU 12 had each been retrofit with new VFDs. In the cases of all AHUs with the exceptions of AHU 3 and AHU 10, this measure did not result in energy savings. The remaining eight AHUs had each previously been controlled by a single functioning VFD connected to both the supply and return fans. In the installed case, the supply and return fans were each supplied with VFDs. This approach could result in energy savings *if* the supply and return fans were operated at different frequencies. However, after the retrofit, the return fans VFDs were set to track the frequency of the supply fans, effectively negating any energy savings that could be obtained by independently controlling the two fans.

AHU 3 and AHU 10 did however achieve savings because the VFDs had failed before the retrofit. As a result, the supply and return fans in both AHUs were running at full speed (60 Hz) unnecessarily. The base case power draw for these two fans was, therefore, the full load power draw of the fans running at 60 Hz under dirty coil conditions. The installed case was taken as the power draw of the VFD controlled fans under dirty coil conditions as determined using the analysis for EEM 3. It was necessary to assume dirty coil conditions in the analysis to avoid double counting the coil cleaning savings achieved by EEM 3.

Savings were calculated by multiplying the annual operating hours of the effected AHUs by the preretrofit and postretrofit case demand differentials.

Savings Results

Taking into account all four EEMs, the Jesse Unruh building project resulted in 53,289 kWh in gross energy savings. Demand savings of 16.0 kW were estimated in accordance the CPUC's peak period definition.[40] A breakdown of savings by individual measure is presented at the beginning of this report in Table E-43. The ex ante savings estimates, which were acquired from the program's monthly status reports, are also provided as a point of reference.

Discussion

As Table E-43 indicates, this project did not achieve its ex ante energy savings claims. The discrepancies between the ex ante and ex post savings results are addressed below on a measure-by-measure basis.

Measure 1 –- Smart Breaker Panels and Occupancy Sensors

This measure did not achieve its ex ante savings claim for two reasons. First, and most significantly, the ex ante savings estimation approach was highly oversimplified. In particular, there was no realistic basis for the implementer to assume that lighting represented 33.3 percent of building's total billed electricity use. Furthermore, it was not practical to assume that installing occupancy sensors on a fraction of the building's lighting fixtures would results in 30 percent energy usage reduction for *all* of the building's lighting. To put these assumptions into perspective, the gross connected lighting load affected by this measure was approximately 12.7 kW. Therefore, if the lights operated 8,760 hours per year, the lights would use 111,112 kWh, providing the opportunity for 33,334 kWh in energy savings from occupancy sensors (assuming a 30 percent reduction). By contrast, the ex ante methodology projected 634,400 kWh of baseline energy use by the lights affected by this measure and 190,320 kWh in energy savings (not including the smart breaker panel contribution to energy savings). As these figures illustrate, the assumptions inherent in the ex ante analysis were the reason for the discrepancy between the achieved and claimed savings.

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40 According to the CPUC, peak demand savings are defined as the average demand reduction occurring during the three consecutive hottest weekdays of the year between the hours of 2 p.m. and 5 p.m.

Savings were also reduced to a small degree because the smart breaker panels have not been connected to the building's antiquated EMS system and there are no plans to do so in the near future. The smart breakers will not generate any savings, until wired to an EMS and controlled.

Measure 2 – Low Differential Pressure Air Filters

As discussed previously, this measure did not achieve any measurable energy savings because the low-differential pressure filters were removed from service and replaced with the baseline equipment.

Measure 3 – Coil Cleaning

Insufficient ex ante documentation was provided for EEM 3 to reproduce the energy savings. As a result, the reasons for the discrepancy between the ex ante and ex post estimates are unknown.

Measure 4 – VFD Fan Retrofit

Ex ante savings were not claimed for this measure. The ex post savings that were achieved helped bolster the overall realization rate for the entire project.

Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

Since all the four measures installed at the Jesse Unruh building are add-on measures, both baselines are the same.

Table E-59 below provides the annual energy savings estimates that fed into the life-cycle savings calculations (same as those in Table E-35), as well as the EULs for each of the four measures.

Table E-59: Values Used in Life-cycle Savings Calculations by Measure

Measure	Early Replacement		Expected Replacement		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 1 – Smart Breaker Panels & Occupancy Sensors	N/A	N/A	7,097	0	8	N/A
EEM 2 – Low Differential Pressure Air Filters	N/A	N/A	0	0	0.5	0
EEM 3 – Coil Cleaning	N/A	N/A	32,468	0	3	0
EEM 4 – VFD Fan Retrofit	N/A	N/A	13,724	0	15	0

Source: DNV KEMA analysis

Table E-60 provides life-cycle savings for the project on a year-by-year basis through the EUL of the longest lived measure.

Table E-60: Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	53,289	16.0	-
2	2012	53,289	16.0	-
3	2013	53,289	16.0	-
4	2014	20,821	6.0	-
5	2015	20,821	6.0	-
6	2016	20,821	6.0	-
7	2017	20,821	6.0	-
8	2018	20,821	6.0	-
9	2019	13,724	4.2	-
10	2020	13,724	4.2	-
11	2021	13,724	4.2	-
12	2022	13,724	4.2	-
13	2023	13,724	4.2	-
14	2024	13,724	4.2	-
15	2025	13,724	4.2	-

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
16	2026	-	-	-
Life-cycle	Total	360,040 kWh	107.4 kW-Years	0.0 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Secretary of State Building Retrofit

Site Summary

The Secretary of State building is a 460,000 square foot multi-use building in the Capitol District of Downtown Sacramento. The building houses the offices of the Secretary of State, the California State archives and associated office spaces, a museum, and a day care facility. Typical operating hours for the Secretary of State building are 6 a.m. to 6 p.m. Monday through Friday; the California State archives offices generally operate between 7 a.m. and 5 p.m. Monday through Friday, and 9 a.m. to 5 p.m. on Saturdays. The museum operates from 10 a.m. to 5 p.m. Monday through Saturday, and 12 p.m. – 5 p.m. Sunday; the day care facilities operate during normal business hours Monday through Friday.

The Secretary of State building underwent a five part retrofit implemented through the Revolving Loan Fund Program. Implemented measures included: (EEM 1) smart breaker panels and lighting occupancy sensors, (EEM 2) low differential pressure filter retrofits in all air handlers, (EEM 3) coil cleaning service for all air handlers, (EEM 4) a chiller compressor retrofit, and (EEM 5) DART Federspeil controls for optimal control of space temperatures in the IT office's server room. Table E-61 below summarizes the ex post and ex ante savings estimates for each measure.

Table E-61: Energy Savings Summary

Measure	Ex Post			Ex Ante[41]			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1 – Smart Breakers and Lighting Occupancy Sensors	8,363	1.6	0.0	297,528	None Claimed	0.0	2.8%	N/A
EEM 2 – Air Filter Replacement	-	0.0	0.0	230,035	None Claimed	0.0	0.0%	N/A
EEM 3 – Coil Cleaning	209,965	41.5	0.0	110,697	None Claimed	0.0	189.7%	N/A
EEM 4 – Chiller Retrofit	227,000	25.6	0.0	377,735	None Claimed	0.0	60.1%	N/A
EEM 5 – DART Federspeil Controls	53,567	6.1	0.0	None Claimed	None Claimed	0.0	N/A	N/A
Total	498,895	74.8	0.0	1,015,995	None Claimed	0.0	49.1%	N/A

Source: DNV KEMA analysis

Project savings were considerably less than estimated in the ex ante calculations. At the measure level, discrepancies ranged from incomplete, ineffectual, and non-persistent implementation of the measures, to incorrect assumptions in the ex ante savings calculation methodologies.

- Savings for EEM 1 were reduced dramatically primarily because the ex ante calculation estimated the savings potential of the lighting occupancy sensor measure without actually giving consideration to where or how many occupancy sensors would be installed. Furthermore, the smart breaker panels have not been connected to the

41 Ex ante savings values for the individual measures were appropriated from a feasibility study produced by Cogent Energy (document titled "Feasibility Study – SOS, Bateson, Unruh.pdf"); these values were found to match the ex ante savings claimed for the Secretary of State project in DGS's monthly project status update.

building's EMS system. Therefore, the smart breaker panels do not perform any function beyond that of the pre-existing breakers.

- EEM 2 savings were non-existent because the low differential pressure air filters were replaced with the pre-existing air filters after the first set needed replacement.
- It was not possible to assess why EEM 3 saved more energy than projected because the ex ante documents provided for review were inadequate to assess the ex ante savings analysis approach.
- EEM 4 saved less energy than projected because the chiller performance curves and building load curves used in the ex post analysis differed from those used in the ex ante analysis.
- Savings for EEM 5 were not claimed as part of the ex ante analysis even though the project was implemented through the Revolving Loan Fund Program.

In spite of the previously unclaimed savings from EEM 5, the project saved considerably less than projected because the EEM 3 did not save any energy, the impact of EEM 1 was highly overstated, and EEM 4 impacts were not fully realized.

In addition to first year savings, project life-cycle savings were also assessed as part of the evaluation. Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses minimally code compliant conditions or standard practice as the baseline once the RUL of the pre-existing equipment is exceeded. Since all these measures in this project are add on measures, Baseline 1 and Baseline 2 are the same.

For occupancy sensors (EEM 1), DEER provides an EUL of eight years. The EUL for EEM 2 was irrelevant since the measure was not retained. DEER does not report an EUL for evaporator coil cleaning measures (EEM 3); the closest proxy for evaporator coil cleaning in DEER is condenser coil cleaning, which has a three year EUL. The condenser coil cleaning EUL was appropriated in this case after performing secondary research that suggested even shorter periods (on the order of 6 months to 12 months) are the norm for evaporator coil cleaning services.[42] Lastly, DEER provides EULs of 20 years and 15 years respectively for chillers (EEM 4) and VFDs (the primary component of EEM 5).

42 http://www.bbjenviro.com/cm_hvacmaint.asp.

Table E-62: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	6,040,299	741.4	0.0
Baseline 2	6,040,299	741.4	0.0

Source: DNV KEMA analysis

Project Description

The Secretary of State building is a complex six story multi-use building. The building is logically divided into two halves: the Secretary of State side and the archives side. The Secretary of State side houses the offices of the Secretary of State, as well as a number of other governmental departments. The Secretary of State side is, therefore, composed primarily of office spaces. The other half of the building houses six floors of archives, a two story museum, support offices and other areas related to the archives and museum. The Archive side of the building is unique in that the archives require precise cooling and humidification at all times. These services are provided for the archives (as well as the server room on the Secretary of State side) by on-site chillers and electric boilers, whereas the rest of the building uses district cooling and heating.

Measure 1:

EEM 1 consisted of two lighting controls components. The first portion was "smart breaker" panels. Unlike conventional breakers, which can only be flipped locally, smart breakers can be integrated into the building's EMS system and controlled remotely via timer schedules. Once integrated into the EMS system, building management can limit usage of lights to certain periods of the day.

The second portion of EEM 1 consisted of installing wall mounted occupancy sensors throughout the building's office spaces. The number of sensors was not specified explicitly in the application materials, but 166 sensors were ultimately installed.

Measure 2:

EEM 2 consisted of installing low differential pressure air filters in all of the building's air handlers (AHUs 1-12 and AHUs 20-23). Installing these filters effectively reduces the static pressure losses in each AHU's duct work by roughly .5" WG, thereby reducing the power demands on the fan motors for an equivalent amount of air flow.

Measure 3:

The third EEM implemented at the Secretary of State building was evaporator coil cleanings for all AHUs (AHUs 1-12 and AHUs 20-23). Like EEM 2, evaporator coil cleaning generates energy savings by reducing the static pressure that AHU supply fans have to work against.

Measure 4:

EEM 4 consisted of replacing the four pre-existing reciprocating compressors on a McQuay WHR-210D water-cooled chiller with two Turbocor TT350 frictionless centrifugal compressors. The remainder of the central plant was left unchanged.

Measure 5:

Discharge Air Regulation Technique (DART) Federspeil Controls were installed in conjunction with variable speed drives on five computer room air conditioning (CRAC) unit supply fans. The Federspeil controls wirelessly monitor temperature and relative humidity conditions locally at the server racks in the data center and relay data to the CRAC unit controls, which then modulate the supply fan VFDs speeds to maintain space conditions. Before installing the DART controls and associated VFDs, the fans serving the server room ran at full speed during all hours.

Ex Ante Savings

Cogent Energy calculated ex ante savings on a measure-by-measure basis using spreadsheet approaches. EEM 1 savings were calculated from a year's worth of facility electricity billing data by employing the following set of assumptions:

- Lighting end uses represent one-third of total facility energy use.
- Occupancy sensors reduce total lighting energy use by 30 percent.
- The smart breaker controls reduce lighting energy use by 2.5 percent.

Savings were, therefore, calculated as $\mathrm{kWh}_{\mathrm{annual}}\left(\frac{1}{3}\right)\left(\frac{30+2.5}{100}\right)$. This overly simplified calculation highly overestimated lighting energy savings.

EEM 2 savings were calculated using a spreadsheet model that was not provided for review.

EEM 3 savings were projected based on the assumption that coil cleaning would yield a 4 percent reduction in total fan energy usage. Neither the source of this assumption, nor the method used to derive the baseline fan energy use, was provided for review.

Chiller compressor retrofit (EEM 4) savings were calculated using a spreadsheet model based on a linear load profile with a zero load condition assumed at 50^0 F and a full load condition at 101°F. Base case and installed case chiller performance was differentiated with unique performance curves. For the pre-existing equipment, standard DOE2 curves for reciprocating chillers were used; the installed case was approximated using custom curves of unknown origin.

Savings for EEM 5 were not claimed for this project even though the Federspeil controls were implemented through the Revolving Loan Fund Program.

Project Evaluation

A DNV KEMA engineer visited the facility on August 31, 2011 to verify the installation of each measure, install data logging equipment, and gather facility operating data to assist in assessing energy savings. Table E-63 below contains a summary of all monitoring equipment that was installed during the initial site visit.

Table E-63: Monitoring Details.

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
Retrofit Turbocor Chiller	Dent ELITEPro	True Power, Voltage, Amperage, Power Factor	5 Minutes	37 Days
AHU1 – Museum Air Handler	Hobo Microstation with TRMS Amperage Module	Amperage	1 Minute	37 Days
AHU4 – Office Air Handler	Hobo Microstation with TRMS Amperage Module	Amperage	1 Minute	37 Days
2nd Floor Conference Room Lighting	Dent Lighting*logger*	On/Off Records	N/A	37 Days
4th Floor Conference Room Lighting	Dent Lighting*logger*	On/Off Records	N/A	37 Days
4th Floor Office Lighting	Dent Lighting*logger*	On/Off Records	N/A	37 Days
5th Floor Office Lighting	Dent Lighting*logger*	On/Off Records	N/A	37 Days
2nd Floor Classroom	Dent Lighting*logger*	On/Off Records	N/A	37 Days
3rd Floor Storage	Dent Lighting*logger*	On/Off Records	N/A	37 Days
4th Floor Restroom	Dent Lighting*logger*	On/Off Records	N/A	37 Days
3rd Floor Electrical Closet	Dent Lighting*logger*	On/Off Records	N/A	37 Days

Source: DNV KEMA analysis

Measure 1 – Smart Breaker Panels and Occupancy Sensors

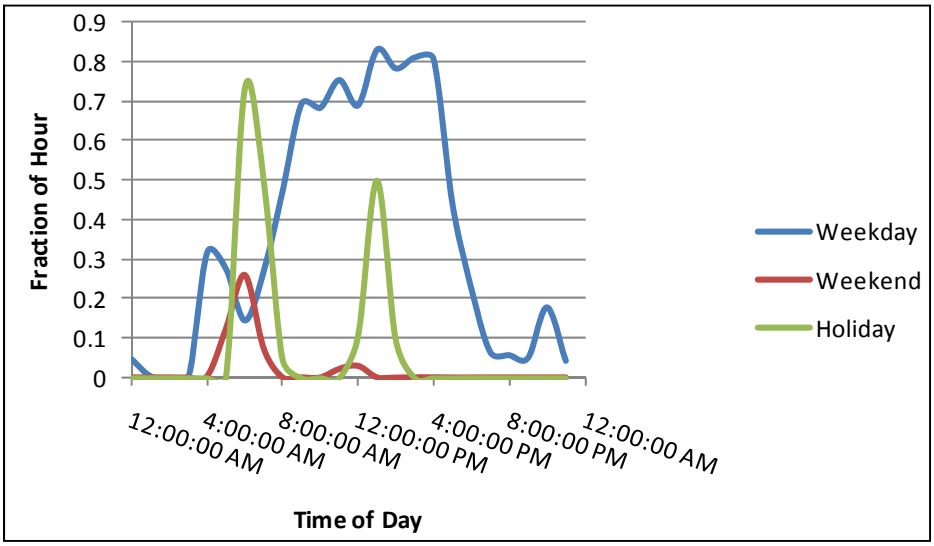
On-site verification activities confirmed that the smart breaker panels were installed as intended. The smart breakers, however, have not been integrated into the building's EMS system, and currently do not have any additional functionality relative to the pre-existing breakers. The site contacts did not know if or when the wiring would be completed. The site

contacts stated that there were no immediate plans to compete the wiring. The smart breaker portion of this measure, therefore, will not save any energy for the foreseeable future.

For the occupancy sensor component of the measure, one of the site contacts was able to provide a building floor plan layout indicating where the sensors had been installed. This list did not indicate the types, wattages, and quantities of fixtures had been connected to the sensors, so it was necessary to both verify the existence of each of the claimed sensors and record general information about the fixture types controlled by the sensors. Since there were ultimately 166 sensors to verify and 543 associated fixtures to identify, it was only reasonable to record basic fixture characteristics, including: type (FT, CFL, Inc., and so forth), lamp quantities, and lamp length. For incandescent and CFL fixtures, the rated lamp wattages were also recorded if visible. The room type served by each sensor was also recorded.

While verifying the sensor installations, eight time-of-use ON/OFF lighting data loggers were installed in eight randomly selected rooms and closets to assist in developing usage profiles. While the individual rooms were randomly selected, an effort was made to sample a range of space types served by the new occupancy sensors. Loggers were ultimately installed in two conference rooms, two personal offices, one large classroom, a storage room, an electrical closet, and a restroom. For illustrative purposes, the average weekday, weekend, and holiday profiles for the two monitored offices are presented in Figure 18. Note that the office usage profiles reflect the average of the two loggers installed in office spaces.

Figure 18: Office Lighting Usage Profiles



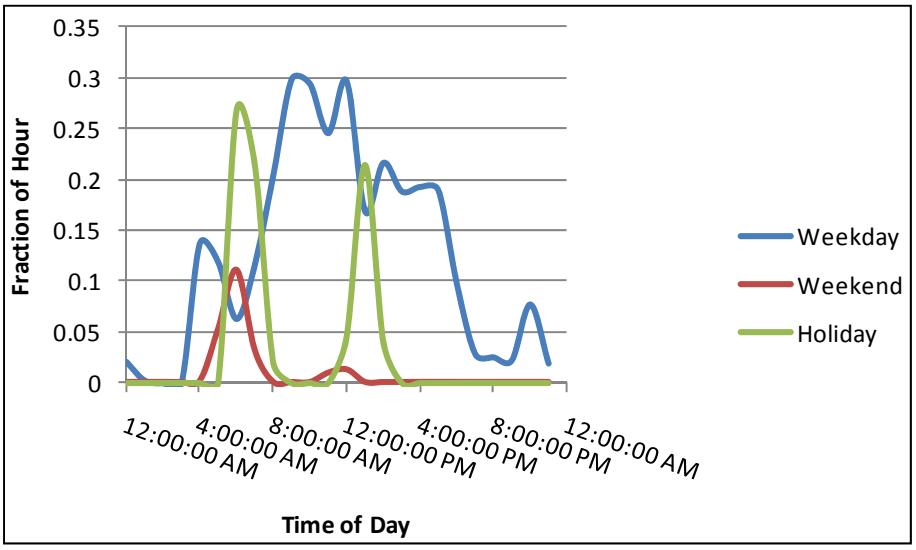
Source: DNV KEMA analysis

The monitored usage profiles were subsequently used to extract the savings provided by the occupancy sensors. This calculation relied on the assumption that occupancy sensors yield time-

of-use reductions of roughly 30 percent relative to the baseline lighting usage.[43] As such, for each hour, the time-of-use (TOU) reduction was calculated as $\frac{TOU_{metered}}{.7} - TOU_{metered}$ $\frac{TOU_{metered}}{.7} - TOU_{metered}$. For hours during which the metered usage was greater than 70 percent, the time-of-use reduction was calculated as $1\text{-}TOU_{metered}$ because the standard formula would yield greater than 100 percent usage.

The hourly time-of-use reductions were then summed to develop full-day weekday, weekend and holiday time-of-use reduction estimates for each day type. A representative set of time-of-use savings profiles for office spaces is provided in Figure 19 below. Similar time-of-use savings profiles were generated using the same methodology for the five other monitored space types (conference rooms, classrooms, storage rooms, electrical closets, and restrooms). These daily time savings schedules were scaled to annual TOU reduction profiles that were then applied to the gross connected loads (kW) from each space type. These gross connected load estimates were derived by matching observed fixture types with wattage values provided in the *2011 Table of Standard Fixture Wattages*.[44]

Figure 19: Office Lighting Time-of-use Savings Profiles



Source: DNV KEMA analysis

For space types other than those that were metered (for example, hallways and elevator lobbies), it was necessary to make assumptions regarding operating hours in order to inform

43 N*EEP Mid-Atlantic Technical Reference Manual Version 1.1, pg. 83, October 2010.*

44 http://www.sce.com/business/ems/customized-solutions/tools-resources.htm, Appendix B.

the TOU reduction savings analysis. These assumptions were made either based on building operating hours and usage characteristics observed over the course of two sites visits or the assumptions were provided by site contacts. In general, the time-of-use assumptions, which are provided in Table E-64 below, were made liberally to avoid shortchanging the project of any potential savings.

Table E-64: TOU Reduction Estimates for Unmonitored Space Types

Space Type	Estimated Weekday Operating Hours	Estimated Weekend Operating Hours	Estimated Holiday Operating Hours	Estimated Daily TOU Reduction Weekday (h)	Estimated Daily TOU Reduction Weekend (h)	Estimated Daily TOU Reduction Holiday (h)
Freight Elevator Lobby	2	.5	0	0.86	0.21	0.0
Service Hallway	4	1	0	1.71	0.43	0.0
Art Storage Room	2	0	0	0.86	0	0

Source: DNV KEMA analysis

Measure 2 – Low Differential Pressure Air Filters

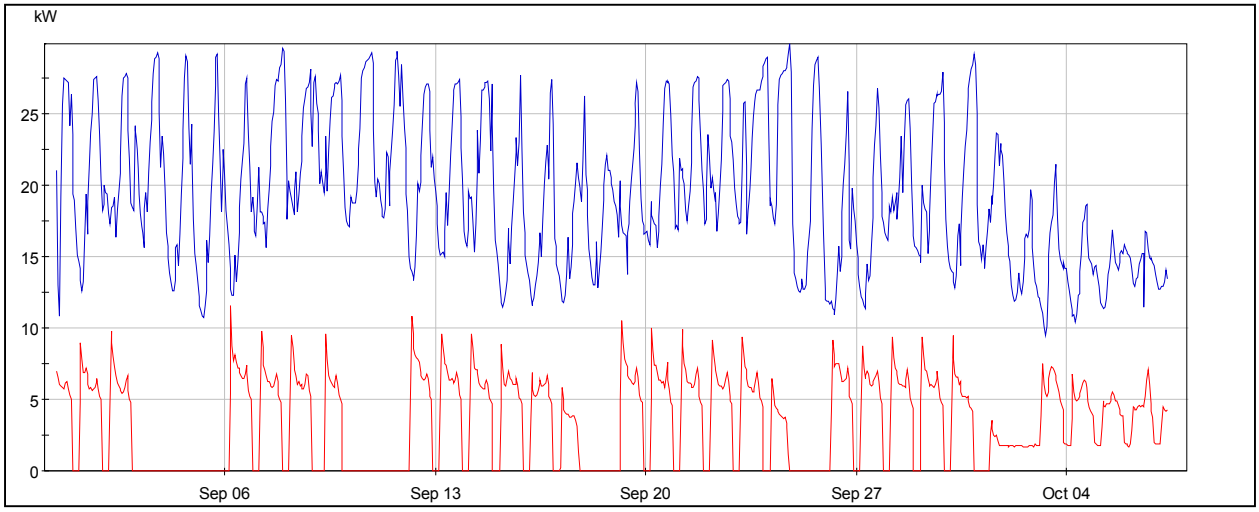
The newly installed low differential pressure (DP) air filters had already been replaced with the baseline air filters by the time of the initial verification site visit. According to the facility engineer, the building reverted to the old filter type because the low DP filters were repeatedly collapsing inside the filter slots. Since the new filters were not functioning properly, the building staff chose not to continue using the low DP filters. Therefore, no savings were derived from this EEM.

Measure 3 – Coil Cleaning

During the facility visit, the site contact confirmed that the coils in AHU 1 through AHU 12 and AHU 20 through AHU 23 had been cleaned as claimed. In addition, the DNV KEMA auditor briefly looked inside an air handler and was able to observe that the coils appeared clean.

To assist in developing energy savings estimates for each air handler, amperage data loggers were installed on the supply fans of AHU1, which serves the Archive side museum on the first and second floors, and AHU4, which serves portions of the Secretary of State side on the second, third and fourth floors. The trends captured from the supply fans of AHU 1 and AHU 4 over the course of the monitoring period are presented in Figure 20 below.

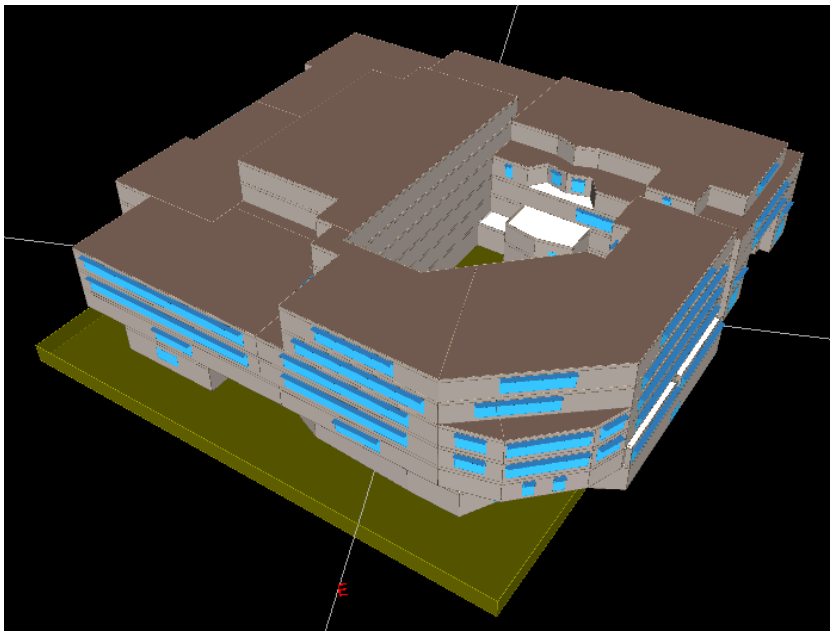
Figure 20: AHU 1 (Blue) and AHU 4 (Red) Metered Supply Fan Profiles



Source: DNV KEMA analysis

These metered data were ultimately used to calibrate a simulation model of the building developed using the DOE2 modeling software eQUEST. It was deemed appropriate to conduct the coil cleaning savings analysis in eQUEST due to the diversity of the fan usage profiles in the Secretary of State building: four of the air handlers (AHU 20 through AHU 23) operate constantly to maintain tight archive dead band requirements; one air handler operates constantly to meet museum requirements; one air handler serves a cafeteria on the Secretary of State side of the building; and the remaining eleven air handlers are distributed across the Archive and Secretary of State office sides of the building. To account for the unique schedules and load profiles of each air handler, an eQUEST model was developed using data gathered from building plans, interviews with building engineers, and walkthroughs of the building.

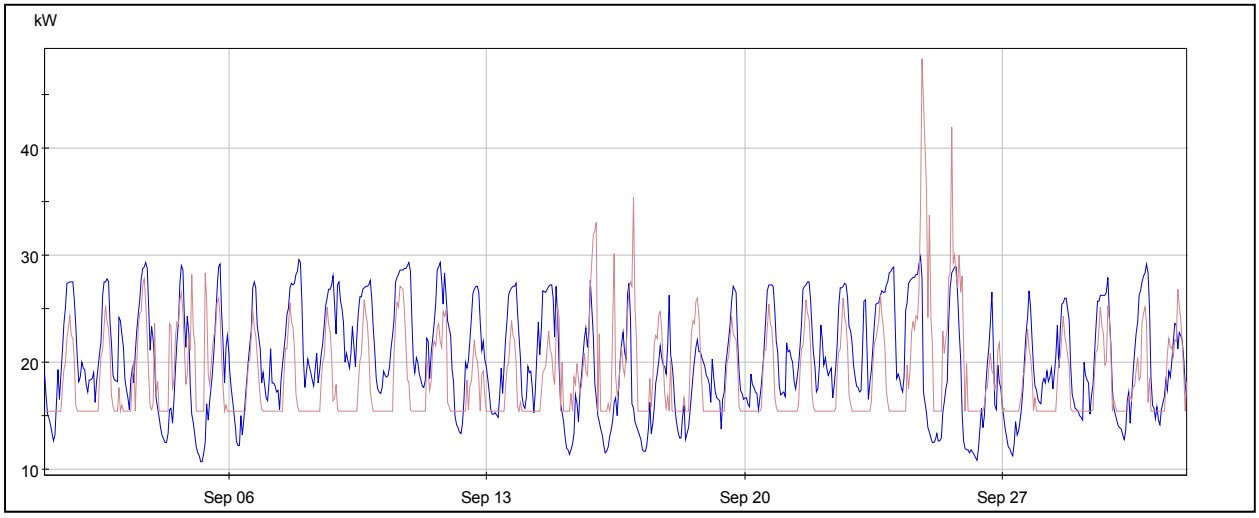
Figure 21: eQUEST Simulation Model Shell



Source: DNV KEMA analysis

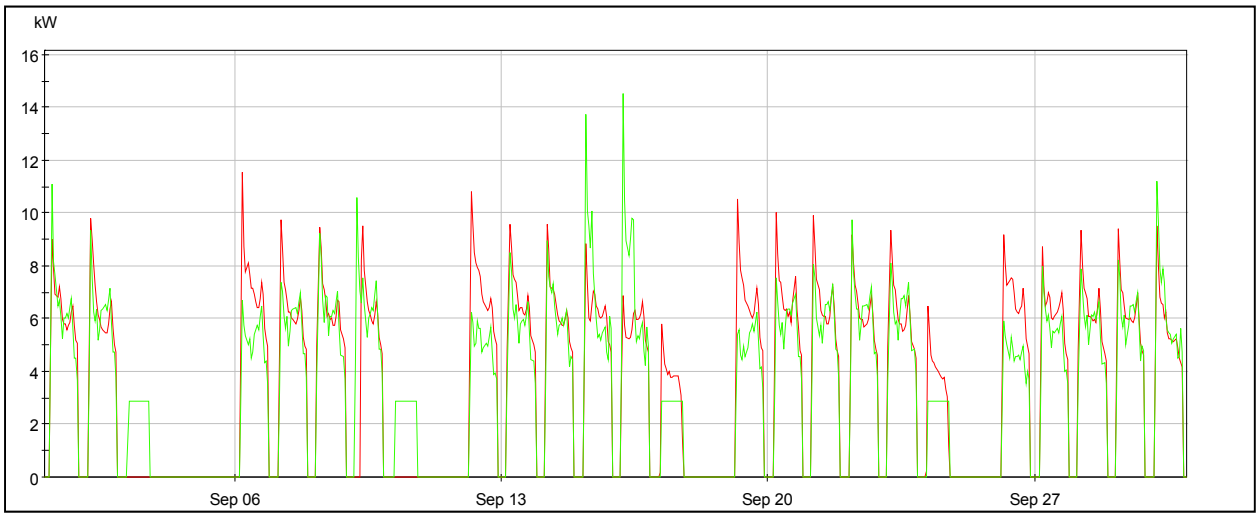
After constructing the model, the modeled end-use profiles of the two metered AHU supply fans were calibrated by adjusting the space loads in the two monitored areas until the mean bias error was reduced to within the allowable tolerance. The calibration profiles are presented in Figure 22 and Figure 23 below. Ultimately, it was possible to calibrate AHU 4 to a MBE of 0 percent and CV of RMSE of 35 percent. AHU 4 was calibrated to an MBE of 0 percent and CV of RMSE of 51 percent. It was not possible to achieve a lower CV for AHU 4 because of inconsistent Saturday operations that vary according to tenant requirements. After calibrating the two monitored areas, equivalent loads (W/Sq. ft.) to those used in the calibration process for AHU 4—which serves office spaces—were applied to the remaining office areas in the building to approximate the internal heat gains experienced by the building in practice. It was unnecessary to calibrate the fans serving the archives because the fans operate at constant speed at all hours. As such, coil cleaning savings are essentially *independent* of space loads for the archives.

Figure 22: AHU 1 September Supply Fan Calibration (Pink) and Metered (Blue) Profiles



Source: DNV KEMA analysis

Figure 23: AHU 4 September Supply Fan Calibration (Green) and Metered (Red) Profiles



Source: DNV KEMA analysis

After calibrating the as-operating building, it was next necessary to generate the base case building by adding additional static head for the fans to overcome. The total static pressure seen by each fan was modified in the model to mimic dirty-coil conditions in accordance with the following assumptions:

- Coils typically represent roughly 25 percent of all static pressure losses in commercial HVAC systems.[45]
- Evaporator coils foul enough to double the static pressure loss across the coil in roughly 7.5 years.[46] Since the Secretary of State building coils had not been professionally cleaned within that time frame, it is safe to assume that the coil static pressure drop had at least doubled relative to the design condition.

These two rules of thumb were implemented in the context of the simulation model by effectively assuming that the pressure drop across the supply fans was 25 percent higher under dirty coil conditions than clean coil conditions. Savings were assessed by running the base case (dirty coil) and retrofit case (clean coil) models using TMY3 data for the Sacramento area and taking the difference between the base case and retrofit case fan end use energy consumption.

Measure 4 – Chiller Retrofit

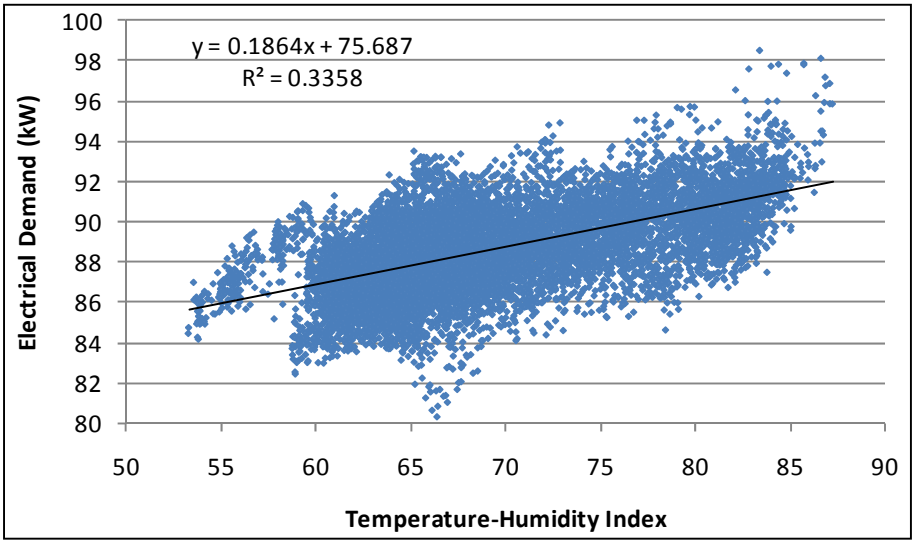
The installation of the two new Turbocor compressors was verified during the site visit. Subsequently, a Dent ELITEPro data logger was installed on the chiller to monitor its energy consumption over the course of a month. Following 37 days of data logging, the logger was retrieved and regression trends were investigated to relate chiller electrical demand (kW) to outdoor conditions. Fits to outdoor temperature, relative humidity, and Temperature-Humidity Index[47] (THI, which accounts for both sensible and latent conditions) were considered. Ultimately the THI fit was used because it minimized the coefficient of determination value relative to the other two options. Figure 24 below presents the metered data cloud and the corresponding regression fit.

45 Siegel, Jeffrey Alexander, Particle Fouling of HVAC Heat Exchangers, 2002.

46 Siegel, Jeffrey Alexander, Dirty Air Conditioners: Energy Implications of Coil Fouling.

47 Defined as $(.5)$ x $T_{\text{dry bulb}} + (.3)$ x $T_{\text{dew point}} + 15$ $(.5)$ x $T_{\text{dry bulb}} + (.3)$ x $T_{\text{dew point}} + 15$ in accordance with the New England ISO definition.

Figure 24: Chiller Metered Data Regression Fit



Source: DNV KEMA analysis

A review of the metered data and the regression results yielded two important conclusions. First, the chiller remains in operation at all times because the server room provides a sufficient base load for the chiller. Second, the space loads are only mildly driven by outdoor conditions, as evidenced by the minimal slope of the regression trend.

Using the regression trend in Figure 24 and weather data from the TMY3 file for Sacramento, an annual profile of the installed case chiller's demand was generated. Using the part load efficiency curve for the new compressor, the chiller load (tons) corresponding to each hourly demand projection was then calculated. Finally, the base case compressor's electrical demand was then projected using performance data provided by McQuay for the chiller as it was originally constructed with reciprocating compressors. Savings during each hour were then calculated on the basis of the difference between the Turbocor and base case compressors' electrical demand.

DNV KEMA investigated the possibility that the compressor savings extended beyond the chiller to the cooling tower and condenser pump. It was immediately obvious that the compressor retrofit did not generate condenser water pump savings because the pump operates at a single speed. The cooling tower fans, on the other hand, can operate at two speeds and, therefore, would yield savings if the additional heat rejection load of the base case chiller ever caused the fans to switch into high speed when the fans would have remained in low speed for the retrofit case. The analysis, however, revealed that the cooling tower is never more than 40 percent loaded in *either* the base case or the installed case and, therefore, would never switch over into high speed fan mode under either scenario. Furthermore, the additional heat load of the base case compressors is so minimal relative to the space heat rejection load that the impact

of the retrofit on cooling tower energy consumption would be negligible even if the tower were often loaded at or above 50 percent.

Measure 5 – DART Federspeil Controls

During the initial site visit, the installation of the proposed wireless DART wireless sensors and controllers, as well as the associated VFDs, was verified. The Manager of the Infrastructure Section of the Secretary of State office (effectively the data center manager) was asked about server room operations during the second site visit. He stated that following installation of the new controls, the CRAC units have been consistently operating at the minimum fan speed/motor speed of 30 Hz. He subsequently provided EMS system screen captures and log files proving that the units had remained operating at 30 Hz over the course of a full week. Since the server room is completely isolated from outdoor conditions (for example, bounded on all exterior surfaces by conditioned space) and the servers operate constantly, server room load should remain relatively constant. As a result, the monitored behavior of the AHU fans should be indicative of annual operating conditions. DNV KEMA calculated savings by multiplying 8,760 hours by the demand reduction caused by reducing the CRAC units' fan motor speeds from 60 Hz to 30 Hz.

Savings Results

Taking into account all five EEMs, the Secretary of State project resulted in 498,895 kWh in gross energy savings. Demand savings of 74.8 kW were estimated in accordance the CPUC's peak period definition.[48] A breakdown of savings by individual measure is presented at the beginning of this report in Table E-43. The ex ante savings estimates, which were acquired from the program's monthly status reports, are also provided as a point of reference.

Discussion

Measure 1 —- Smart Breaker Panels and Occupancy Sensors

This measure did not achieve its ex ante savings claim for two reasons. First, and most significantly, the ex ante savings estimation approach was grossly oversimplified. In particular, there was no realistic basis for the implementer to assume that lighting represented 33.3 percent of building's total billed electricity use. Furthermore, it was not practical to assume that installing occupancy sensors on a fraction of the building's lighting fixtures would results in a 30 percent energy usage reduction for *all* of the building's lighting. To put these assumptions into perspective, the total connected lighting load affected by this measure was approximately 22.3 kW. Therefore, if the lights operated 8,760 hours per year, the lights would use 195,707 kWh, providing the opportunity for 58,712 kWh in energy savings from occupancy sensors (assuming a 30 percent reduction). By contrast, the ex ante methodology projected 915,471 kWh of baseline energy use by the lights affected by this measure and 274,641 kWh in energy savings (not including the smart breaker panel contribution to energy savings). As these figures

48 According to the CPUC, peak demand savings are defined as the average demand reduction occurring during the three consecutive hottest weekdays of the year between the hours of 2 p.m. and 5 p.m.

illustrate, the assumptions inherent in the ex ante analysis were the reason for the discrepancy between the achieved and claimed savings.

To a small degree, savings were also reduced because the smart breaker panels have not been connected to the building's EMS system and there are no plans to do so in the near future.

Measure 2 – Low Differential Pressure Air Filters

As discussed previously, this measure did not achieve any measurable energy savings because the low-differential pressure filters were removed from service and replaced with the baseline standard air filters.

Measure 3 – Coil Cleaning

Insufficient ex ante documentation was provided for EEM 3 to reproduce the energy savings. As a result, the reasons for the discrepancy between the ex ante and ex post estimates are unknown.

Measure 4 – Chiller Retrofit

The discrepancy between the ex ante and ex post chiller retrofit savings results from differences in the analysis methodology, as well as changing assumptions regarding chiller load. In the ex ante analysis, the pre-existing chiller was assigned a generic performance curve from DOE2 as opposed to a model-specific performance curve; in the ex post analysis, a performance curve for the pre-existing chiller was appropriated from the manufacturer's technical data. The ex ante analysis was also limited because metering data were not available (as in the ex post analysis) from which to develop a building load versus outdoor conditions regression profile. Instead, the ex ante analysis relied on an estimated linear load profile interpolated between the design day temperature and an assumed no-load temperature. Changes to the load profile and the underlying chiller performance curves in the ex post analysis caused the reduction in savings relative to the ex ante values.

Measure 5 – DART Federspeil Controls

Ex ante savings were not claimed for this measure even though it was implemented through the Revolving Loan Fund Program. The ex post savings that were achieved helped bolster the overall realization rate for the entire project.

Ex Post Life-cycle Savings

Energy savings were calculated relative to two established baselines referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have operated for the full EUL of the new equipment regardless if the existing equipment was at the end of its useful life. In contrast, Baseline 2 uses the pre-existing equipment as the measure baseline until the end of the existing equipment's RUL. After the remaining useful-life period and up until the end of the EUL of the installed measure, an expected replacement baseline is used. This baseline considers minimally code compliant conditions or standard practice where no code is applicable.

Since all the measures installed at the Secretary of State building are add-on measures, both baselines are the same.

Table E-65 below provides the annual energy savings estimates that fed into the life-cycle savings calculations (same as those in Table 1), as well as the EULs for each of the four measures.

Table E-65: Values Used in Life-cycle Savings Calculations by Measure

Measure	Early Replacement		Expected Replacement		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 1 – Smart Breaker Panels & Occupancy Sensors	N/A	N/A	8,363	0.0	8	0
EEM 2 – Low Differential Pressure Air Filters	N/A	N/A	0.0	0.0	0.5	0
EEM 3 – Coil Cleaning	N/A	N/A	209,965	0.0	3	0
EEM 4 – Chiller Retrofit	N/A	N/A	227,000	0.0	20	0
EEM 5 – Dart Federspeil Controls	N/A	N/A	53,567	0.0	15	0

Source: DNV KEMA analysis

Table E-66 provides life-cycle savings for the project on a year-by-year basis through the EUL of the longest lived measure.

Table E-66: Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	498,895	74.8	-
2	2012	498,895	74.8	-
3	2013	498,895	74.8	-
4	2014	288,930	33.3	-
5	2015	288,930	33.3	-
6	2016	288,930	33.3	-

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
7	2017	288,930	33.3	-
8	2018	288,930	33.3	-
9	2019	280,567	31.8	-
10	2020	280,567	31.8	-
11	2021	280,567	31.8	-
12	2022	280,567	31.8	-
13	2023	280,567	31.8	-
14	2024	280,567	31.8	-
15	2025	280,567	31.8	-
16	2026	227,000	25.6	-
17	2027	227,000	25.6	-
18	2028	227,000	25.6	-
19	2029	227,000	25.6	-
20	2030	227,000	25.6	-
21	2031	-	0.0	-
Life-cycle	Total	6,040,304 kWh	741.45 kW-Years	0.0 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

Gold Camp Data Center HVAC and Lighting Retrofit

Site Summary

The Gold Camp data center was awarded loan funds to implement four EEMs at its facilities. EEM 1 is for the upgrade of the CRAC air handling units to include variable speed drive (VSD) controls. EEM 2 is to retrofit the central plant chillers with variable speed drives to improve the chiller part load efficiency. EEM 3 is to add a heat exchanger to the cooling tower in order to enable the use of a water-side economizer control. EEM 4 is a building wide lighting retrofit which replaced the existing first generation T-8 system with a fifth generation T-8 lighting system.

Ex post energy savings were estimated at 2,572,269 kWh. This represent 83 percent of the ex ante electric energy savings (Table E-43). The following contributed to the energy savings difference:

- The current operation of the VSD CRAC units drew more power than originally anticipated resulting in less energy savings.
- The waterside economizer did not allow the chiller to completely turn off. Rather, it allowed the chiller to operate at a more favorable part load efficiency level but energy savings are significantly less than what was presumed. Ex post analysis also considered interactive effects with the chiller measure which decreased energy savings.
- Typical time-of-use for key lighting fixtures for certain zones was much higher than estimated. The time-of-use data showed these zones operate 24 hours a day, 7 days a week. The baseline for these zones was readjusted to show 8,760 hours of operation and resulted in a higher energy savings for this measure.
- Data collected for the chiller showed that it was operating under a more favorable efficiency curve than anticipated resulting in moderately higher energy savings for this measure. The ex ante analysis methodology was also highly simplified and did not capture the weather effects associated with this measure.

The combination of these factors lowered the electric energy savings to 83 percent of ex ante estimates.

Table E-67: Energy Savings Summary

Measure	Ex Ante[49]			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1 – CRAC Units Upgrade	1,535,264	Not reported	0	1,277,445	145.6	0	83%	N/A
EEM 2 – Chiller VSD	725,088	Not reported	0	852,808	172.9	0	118%	N/A
EEM 3 – Waterside Economizer	618,025	Not reported	0	122,444	0.0	0	20%	N/A
EEM 4 – Lighting retrofit	213,857	Not reported	0	319,572	46.2	0	149%	N/A
Total	3,092,234	Not reported	0	2,572,269	365	0	83%	N/A

Source: DNV KEMA analysis

The results from Table E-68 yield a life-cycle energy savings of 38,584,035 kWh. Life-cycle savings were calculated relative to the pre-existing condition for the full EUL of each measure.

Table E-68: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	38,584,035	5,470.5	0

Source: DNV KEMA analysis

Project Description

This project was implemented at the Gold Camp data center. Energy savings come from upgrading the building's interior lighting system, adding VSD controls to the data center CRAC

49 Ex ante values taken from an update from DGS provided to DNV KEMA during the request for a site visit and are not from the monthly status reports.

units, and various control measures employed at the central plant. There are four distinct EEMs for this project.

EEM 1 – The focus of EEM 1 is to reduce the fan energy from the data center CRAC units. There were 29 CRAC units with air handlers that operated at full speed 24 hours a day. These units were retrofitted with VSDs along with an overarching control system that allowed cooling to be directed to hot spots throughout the data center rather than supply cold air to areas that did not need it.

EEM 2 – This measure is for addition of a VSD on the compressor units of the central plant chillers. The chillers operate under part load most of the time and the VSDs are anticipated to improve the chiller's part load efficiency.

EEM 3 – This measure is for addition of a waterside economizer to the existing chilled water system. Energy savings are achieved when the waterside economizer takes over during colder time periods and allows the chillers to shut down.

EEM 4 – This is a building wide retrofit of the existing first generation T8 fixtures with higher efficiency light-emitting diode (LED) fixtures. Some fixtures were also retrofitted with occupancy sensors. For these units, energy savings come from an assumed 20 percent reduction in hours of operation in addition to the reduced power draw from the new technology.

Ex Ante Savings

EEM 1 – CRAC Units Upgrade

The analysis for this measure took nameplate information for the fans at full speed and multiplied this value by 8,760 hours to establish the baseline energy consumption. For the efficient case, all fans were assumed to operate at 80 percent speed which resulted in a 62 percent drop in power draw. The power draw in the efficient case appears to come from the manufacturer's estimates. Energy savings was calculated as the difference of energy consumption under these two conditions and can be summarized by the following equation:

EEM 1 – CRAC Units Upgrade

$Savings = (kW_{100\%} - kW_{80\%}) \times 8760$Where *Savings* is the energy savings in kWh and *kW* is the power draw of the fans at 100 percent and 80 percent speed.

EEM 2 – Chiller VSD

Building load is approximated at 515 tons for all hours throughout the year regardless of outside air temperatures. Assumptions were made for the baseline and VSD chiller efficiencies at full load and part load. The algorithm can be summed up using this equation:

$$Savings = (\eta_1 \times cooling\ load) \times 8736 - (\eta_2 \times cooling\ load_2 + \eta_3 \times cooling\ load_3) \times 8736$$

$Savings = (\eta_1 \times cooling\ load) \times 8736 - (\eta_2 \times cooling\ load_2 + \eta_3 \times cooling\ load_3) \times 8736$
Where Savings is the energy savings in kWh, η is the chiller efficiency at either full capacity (1 subscript) or at improved part load capacities (2 and 3 subscripts) in kW/ton, and cooling load is

the respective cooling load for each chiller in tons. The analysis is highly simplified and does not account for weather conditions.

EEM 3 – Waterside economizer

The baseline chiller energy consumption is generalized by multiplying a 0.60 kW/ton efficiency, 515-ton load, and 8,736 hours of operation. Energy savings were calculated by reducing the hours of operation by 2,000 hours.

EEM 4 – Lighting retrofit

Lighting energy savings used the pre and postretrofit wattages, quantities, and assumed a typical fixture time-of-use. Details of the analysis, however, are not available for review. In addition the LED fixtures were not implemented. Fifth generation T8 fixtures were found on-site instead.

Project Evaluation

A DNV KEMA field engineer visited the project's site on February 28, 2012 to perform a site audit, install data loggers, and trend various central plant parameters.

Data Monitoring

Two power data loggers were installed at the CRAC units. The first logger measured power for one unit only while the second was installed at the panel which measured a total of nine other units. Spot power measurements were also taken at the CRAC units individually with the speed ramped up to 100 percent in order to determine typical baseline power draw.

For the lighting measure, data loggers were placed at fixtures that were anticipated to contribute the bulk of the energy savings for the lighting measure. Using five data loggers, the DNV KEMA engineer chose fixture groups that were responsible for 55 percent of the total lighting energy savings.

The Gold Camp data center had trending capabilities that allowed the monitoring of various central plant parameters. The DNV KEMA engineer set up 15 minute data trends for the following parameters available on the EMS: outside air, water side economizer status, chiller power, chilled water return and supply temperatures, and chilled water flow rate. The trend data was used as the basis for the evaluation energy calculations. Table E-69 summarizes the pre-retrofit monitoring equipments and data trending that were set up at this site.

Table E-69: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
CRAC air handler (10 units)	DENT Elite Pro	True power, amperage, voltage, power factor	15 minutes	3 weeks
5 Light fixtures	DENT TOU	ON time	Continuous	3 weeks
Central plant values (CHWR & CHWS temps, CHW flow rate, chiller power, outside air temp, water side economizer status)	Building EMS	Temperature, % Power, °F, GPM, or status	15 minute	3 weeks

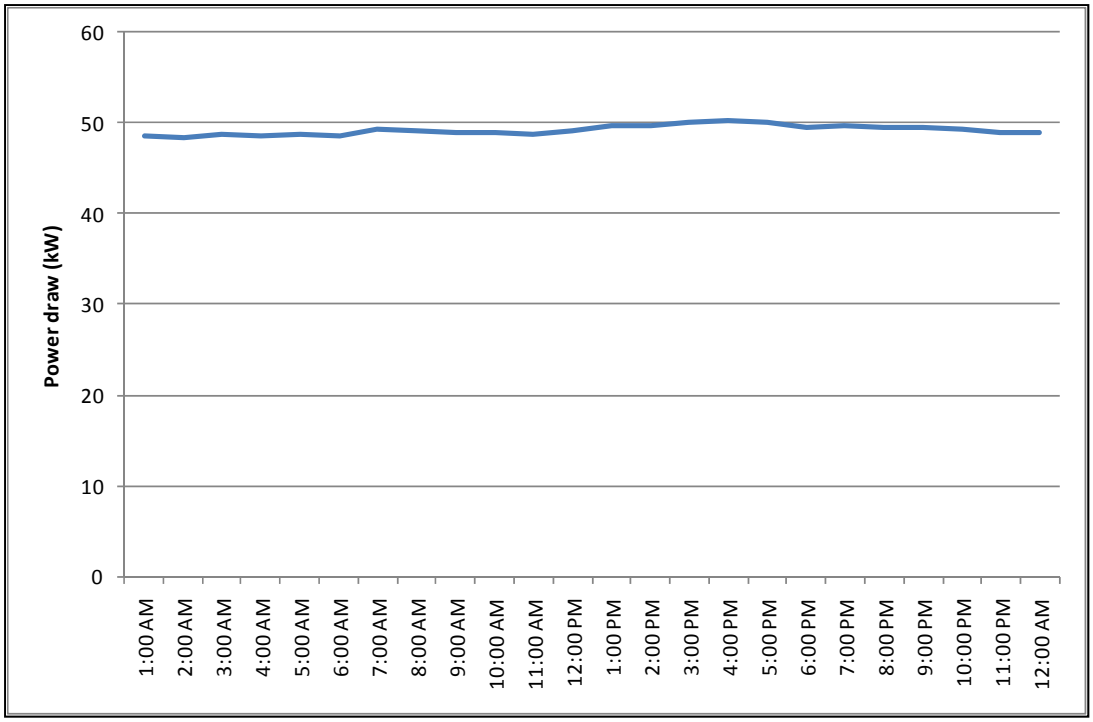
Source: DNV KEMA analysis

EEM 1 – CRAC Unit Upgrade Analysis

The power data from the monitoring effort showed that the energy consumption of CRAC fans varied from hour to hour and day to day without any recognizable patterns. This was expected due to the unpredictable nature of the data center loads. However, the single unit that was monitored showed a constant power draw of around 9.8 kW for the majority of the time with limited modulation control throughout the monitoring period. Many of the units were observed to be off at the time of the site visit, while a select few were either at 60 percent speed or 100 percent speed. This suggests that the fan speed programming is much more complicated than presumed in the ex ante assumptions where all fans were assumed to operate at 80 percent speed. DNV KEMA observed that out of 33 fans, 16 were off, 10 ran at 100 percent, and the rest ran at 60 percent speed. Based on conversations with the technician, it is likely the control logic leaves these units on at this speed for a prolonged time to control the hot spots at the data center.

To simplify the analysis, the 10 units that were monitored were assumed to be representative of all the units as a whole. Figure 25 below shows that the 10 CRAC units draw a consistent amount of power throughout the day.

Figure 25: Typical Daily Power Draw of 10 CRAC Units



Source: DNV KEMA analysis

When the full amount is divided by the total number of CRAC units monitored, the average power draw for one CRAC unit is around 4.92 kW.

To establish the baseline, the DNV KEMA engineer measured the power of one of the CRAC units at full speed. This value is de-rated (reduced) by about 3 percent to account for the extra power consumed by the VSD. The energy savings calculation uses a similar algorithm as the ex ante's except that the power draw values are derived from actual power data with the fans operating under real conditions. Below is a table for the values used in the energy calculations for this measure.

Table E-70: EEM 1, VSD CRAC Unit Calculation Detail

Parameter	Value		Notes
Baseline Calculation			
CRAC unit quantity	33	units	From site survey
Hours of operation	8,760	hours	
Baseline power at 100% speed	9.34	kW	From spot power (value is adjusted downwards for 3% VSD power)
Baseline energy consumption, one unit	81,810	kWh	
Total baseline fan energy, all units	2,699,718	kWh	
Efficient Case, VSD Calculation			
CRAC unit quantity	33	units	
Hours of operation	8,760	hours	
Average power (VSD and other control settings)	4.92	kW	From logged data of 10 CRAC units
Fan energy consumption, one unit	43,099	kWh	
Total fan energy, all units	1,422,274	kWh	
Demand Savings, all units	145.8	kW	
Fan energy savings, all units	1,277,445	kWh	

Source: DNV KEMA analysis

EEM 2 – Chiller VSD Analysis

Analysis for the VSD chiller requires three steps performed in this order: determine chiller loads, determine the performance curves under real operating conditions, and perform an 8,760 analysis based on climate zone weather data. Trend data was used for these purposes.

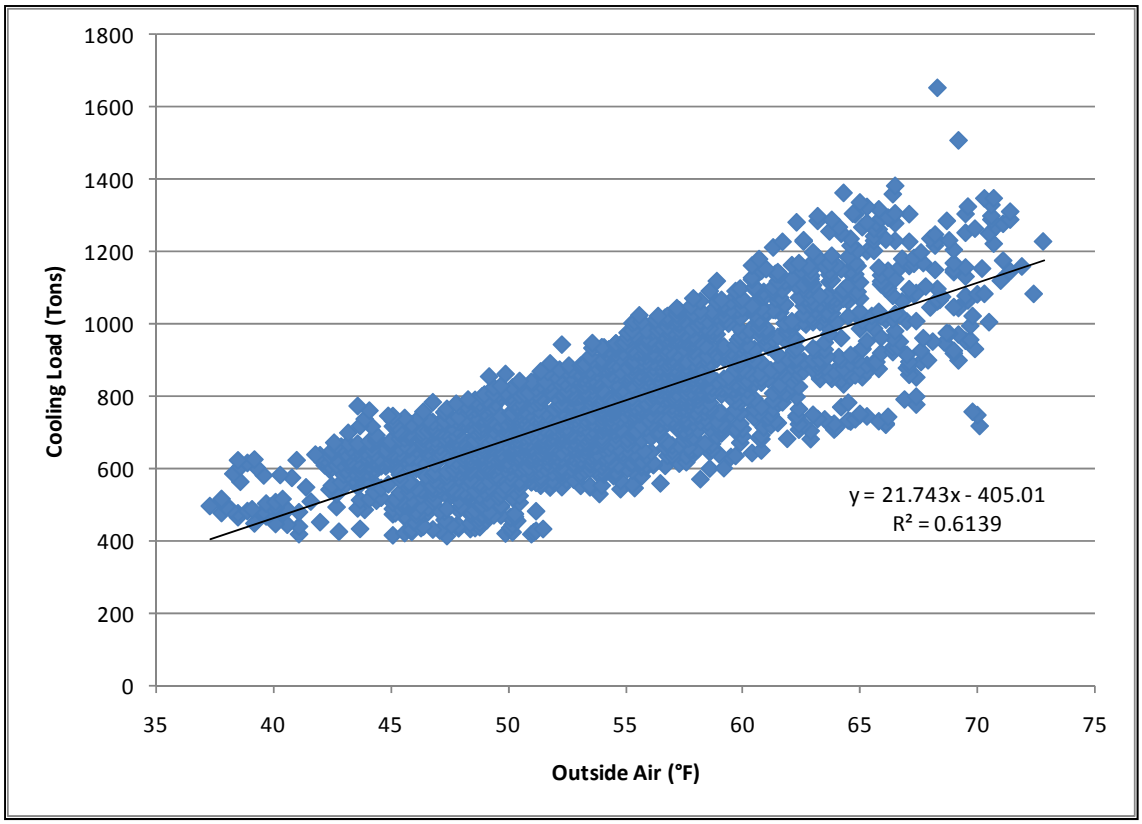
For step one, the chiller loads were estimated using the chilled water supply and return temperatures, and the chilled water flow rate for each 15 minute time step. The chiller load is estimated using the following standard equation:

$$Cooling\ Load = (CHW\ flow\ rate\ \times 500\ \times \Delta T)/12{,}000$$

$Cooling\ Load = (CHW\ flow\ rate\ \times 500\ \times \Delta T)/12{,}000$Where *Cooling Load* is the building cooling load, *CHW flow rate* is the chilled water flow rate and ΔT is the temperature differential of the supply and return chilled water.

A regression was performed with the outside air dry bulb temperature in order to predict building load at various outside air temperatures throughout the year.

Figure 26: Regression of Building Load to Outside Air Temperature



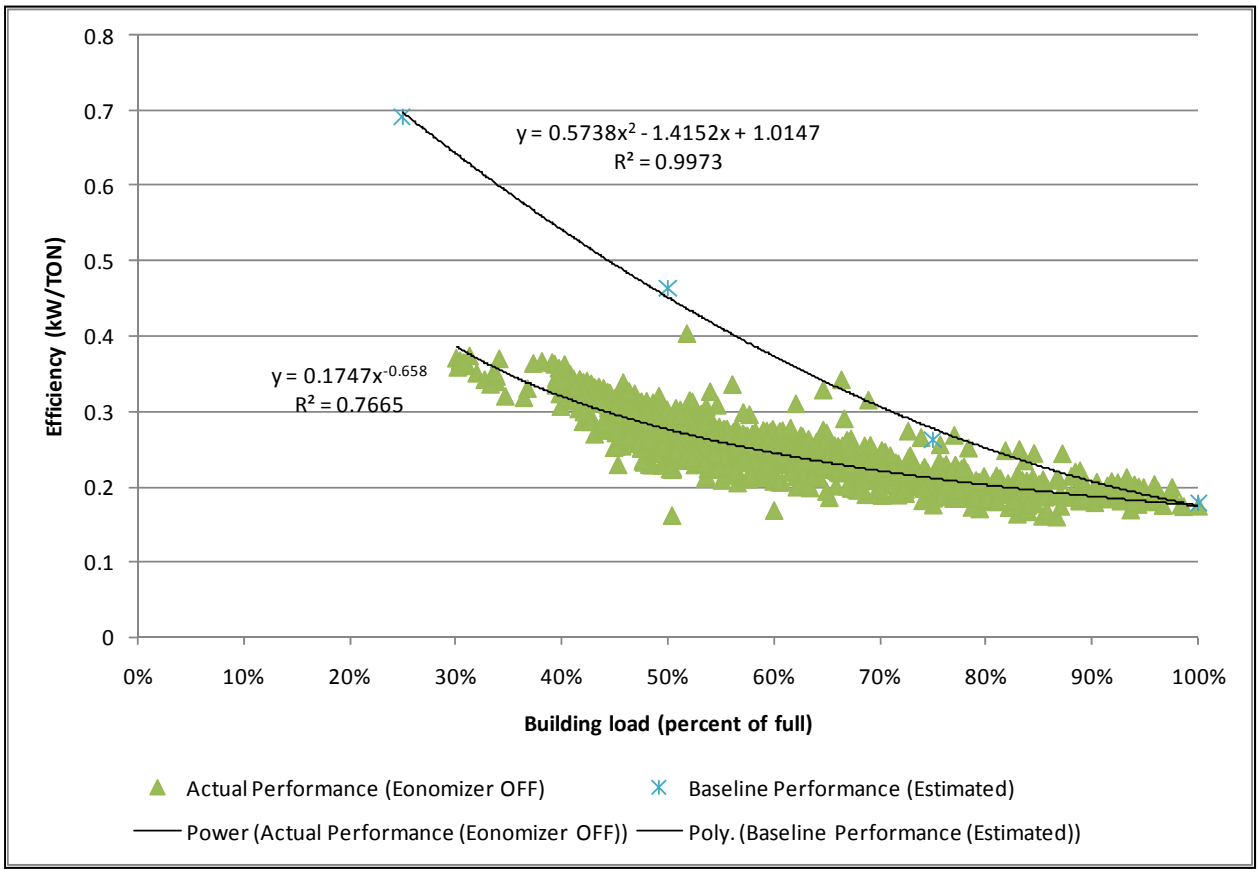
Source: DNV KEMA analysis

For the entire monitoring interval, only one chiller was ever on. The chiller's capacity is rated at 575 tons although the estimated cooling load, which is based on chilled water flow rate, reaches 1,400 tons in Figure 26. The building load is obviously overestimated and is likely due to the EMS flow sensor for the chilled water flow rate, which is not an uncommon problem. This, however, should not affect estimates on chiller power as long as the efficiency curve uses the same building load parameter consistently in determining the chiller efficiency and throughout the energy calculations.[50] The important value to consider is the EMS readings for chiller power which was indeed accurate as verified through a spot power of the chiller during the site visit.

50 Note that the chiller performance profile derived from this analysis may not match the technical specifications due to issues with the flow sensor, although it is also not expected to match due to real operating conditions versus rated, test conditions.

For step two, construction of the chiller performance profile as seen under real conditions. To perform this, the chiller power, building load, and building load maximum needs to be known at different points throughout the day. All this data was available from EMS trend records. When this was plotted, the chiller showed the following performance curve (Figure 27).

Figure 27: VSD Chiller Performance Curve under Real Conditions



Source: DNV KEMA analysis

To establish the baseline performance curve shown in Figure 27, DNV KEMA requested the efficiency specifications for the original chiller without a VSD and the same chiller with a VSD. The curve contains chiller efficiencies at four load points. The percent efficiency differences between the two chillers were calculated at these four points. Using the performance curve established in Figure 27, a baseline performance curve was constructed by adjusting the efficiency of the chiller at those four points. A best fit trend line using those points was created to establish the baseline performance profile. Results of the performance curve are also tabulated in Table E-71 below.

Table E-71: Chiller Performance Profile

From Chiller Specification Data Sheet				Performance Curve Used in Analysis		
	VSD Chiller Efficiency	Chiller Efficiency, No VSD		VSD Chiller Efficiency (Actual)	Chiller Efficiency, No VSD (Estimated)	
Load	kW/ton	kW/Ton	% Difference	kW/ton	kW/ton	% Difference
100%	0.546	0.556	2%	0.175	0.178	2%
75%	0.421	0.523	24%	0.211	0.262	24%
50%	0.336	0.566	68%	0.276	0.464	68%
25%	0.460	0.732	59%	0.435	0.692	59%

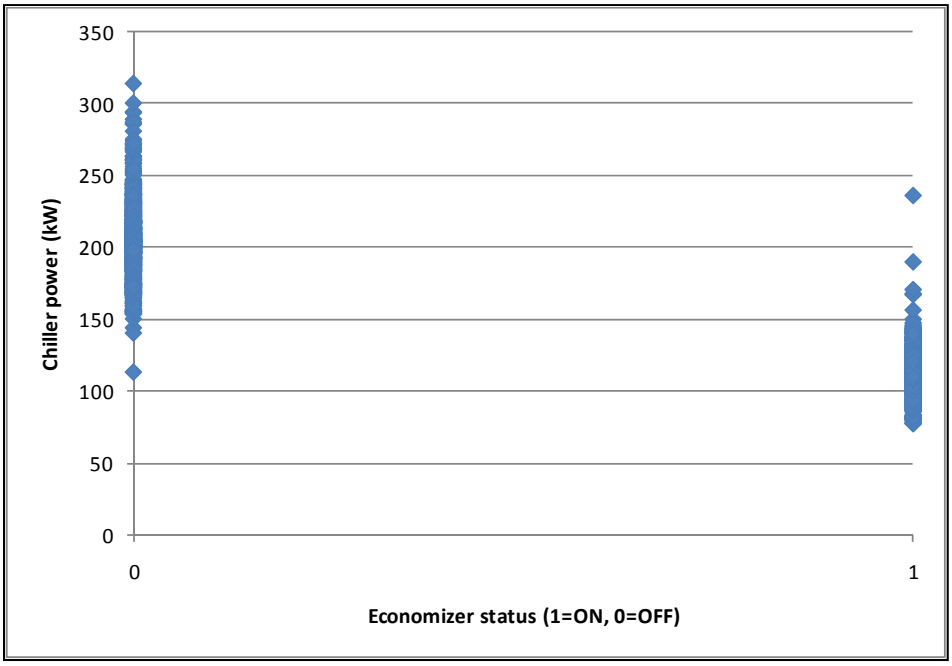
Source: DNV KEMA analysis

The last step to determine energy savings is the 8,760 hourly analysis which uses the performance curve and load regression from the previous two steps. Climate zone 12 data was used to determine the building load throughout the year using the regression equations in step 1. Next, the baseline and chiller efficiencies were determined based on the calculated building load. With these two values, the chiller power can be estimated for each hour throughout the year. Energy saved from the chiller retrofit using this methodology is 852,808 kWh.

EEM 3 – Water Side Economizer Analysis

Data from the EMS system shows that the chiller never shuts down even though the central plant was under the water economizer mode (Figure 28). Note that the chiller power never goes below 75 kW.

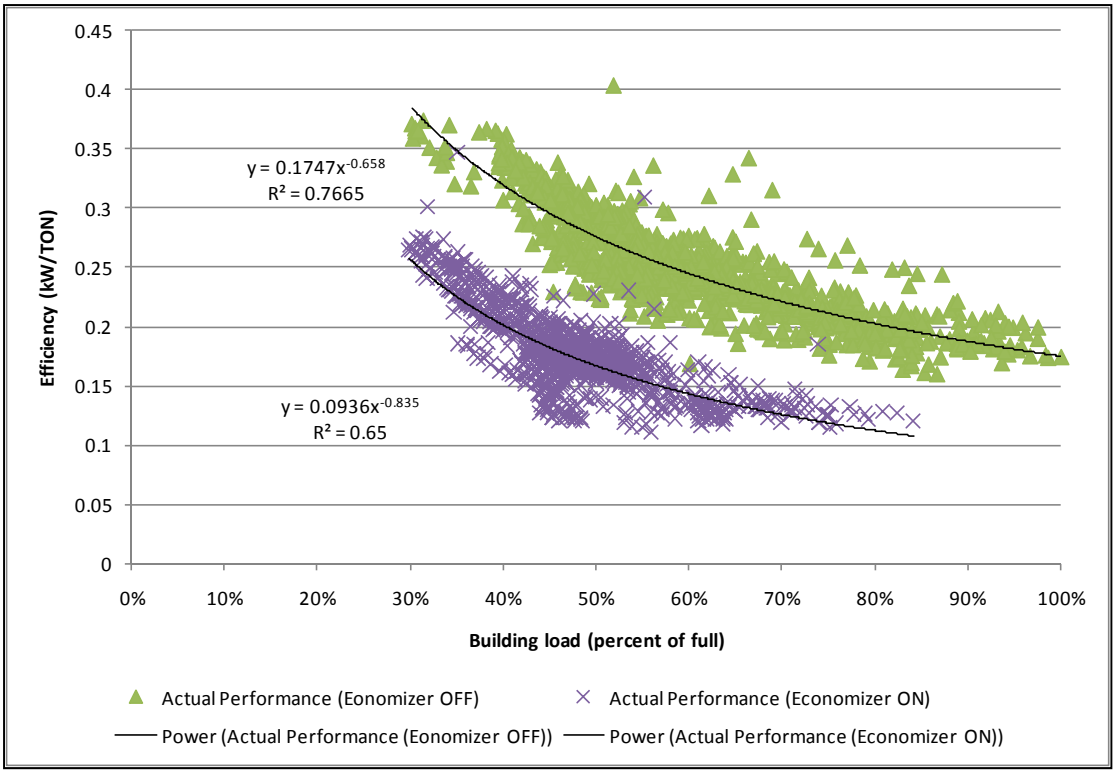
Figure 28: Chiller Power and Economizer Status



Source: DNV KEMA analysis

A closer look at the data shows that although the chiller doesn't shut off, the efficiency of the chiller improves a great deal when the water side economizer is running (Figure 29).

Figure 29: Chiller Performance with and without Water Side Economizer



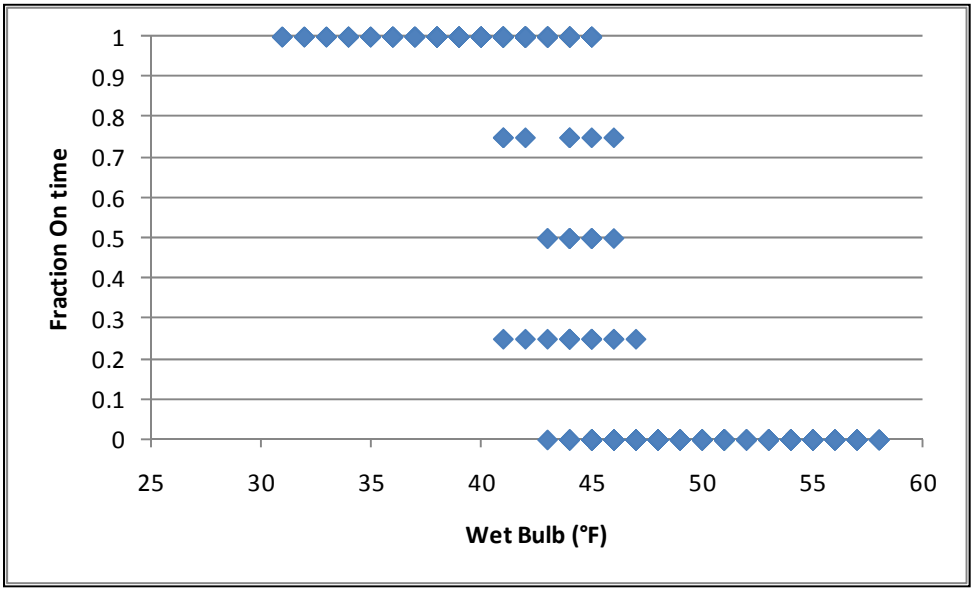
Source: DNV KEMA analysis

This suggests that at times when the outside air is cold enough, the chilled water return is diverted to the heat exchanger before going to the chiller. The result is that the chiller does not have to work as hard to produce the 45°F chilled water supply required to cool the data center.

Due to the current setup of the chilled water system, the chiller will not shut off unless the condenser water return temperature goes below 40°F. According to the data, although the outside wet bulb reached as low as 31°F, the chilled water return cannot be cooled below the 40°F low point required to turn off the chiller, most likely due to limitations on the heat exchanger capacity. Hence, the chiller never turned off during the monitoring interval despite the cold weather. As a result, the chiller must always be on providing part load cooling that cannot be satisfied by the economizer.

Energy savings calculated for this measure was performed similar to EEM 2. The baseline used the chiller performance (with the new VSD compressors) without economizer controls while the efficient case used the chiller performance with economizer controls (Figure 29). To determine when the economizer control applied, the hourly fraction when the economizer mode was enabled is plotted at different outside wet bulb temperatures yielding the following figure.

Figure 30: Fraction of Time Economizer Mode is Enabled versus Wet Bulb Temperature



Source: DNV KEMA analysis

Based on Figure 30, the ex post analysis assumed the economizer will turn on below a wet bulb of 45°F. Note that when this occurs, the chiller efficiency performance changes from the new efficiency curve due to the VSD measure in EEM 2 to the improved efficiency curve from the economizer shown in Figure 29 (rather than having the chiller shut down). Since the three-week monitoring is limited to wet bulb temperatures at or above 31°F, DNV KEMA gave this measure the benefit of the doubt and assumed at lower temperatures, the chiller is able to turn off completely.

When the analysis was normalized by the climate zone weather, energy savings for this measure was calculated at 122,444 kWh.

EEM 4 – Lighting Retrofit Analysis

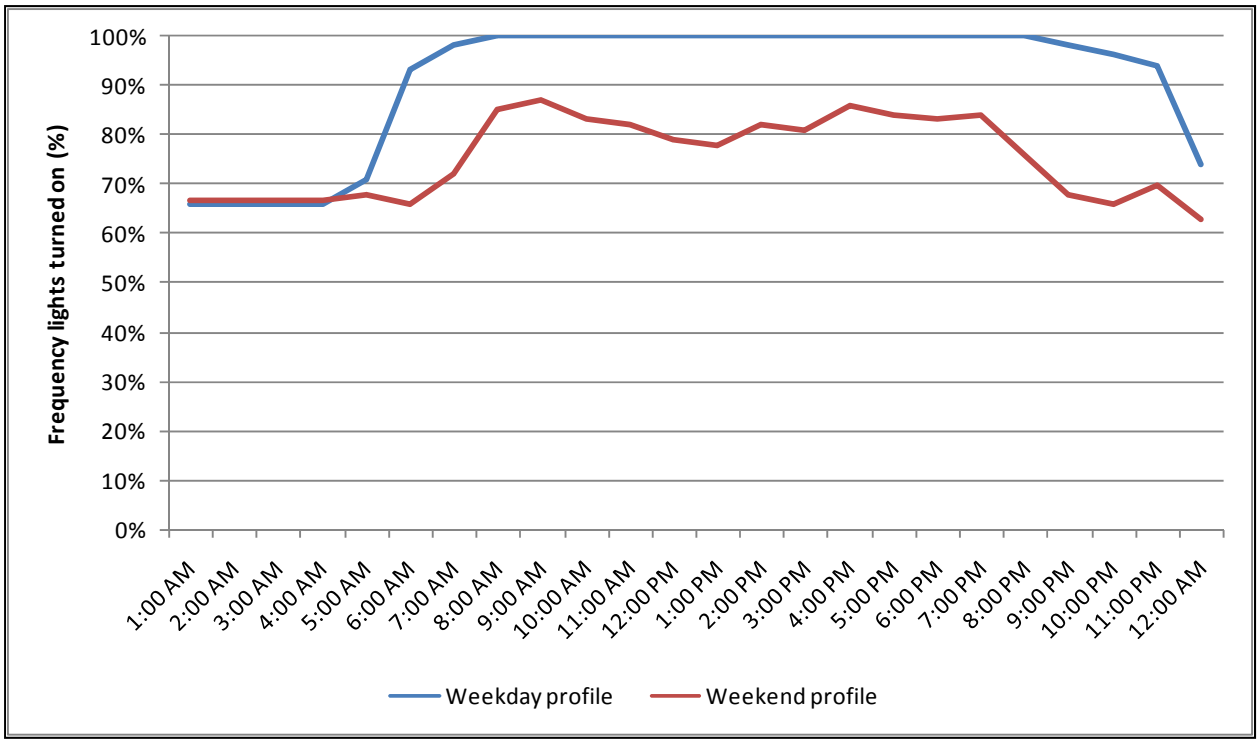
The original lighting energy savings reported in the ARRA status updates were for a building wide lighting fixture conversion to LED which was not implemented. Instead the existing system was converted to a 5th generation T8 system but the energy savings were never updated to show this.

DNV KEMA obtained the new list which showed the fixture quantities along with the pre and postretrofit fixture wattages associated with each line item.[51] Visual counts were verified on-site and no major discrepancies were found with the list provided. A three-week monitoring of the

51 Provided by DGS.

fixtures which contributed the most to the energy savings yielded the following time-of-use profile for the open office areas.

Figure 31: Time-of-use Profile for Open Area Fixtures During Weekdays and Weekends



Source: DNV KEMA analysis

This profile equates to 7,590 hours per year of operation. The baseline for these fixtures were adjusted to show 8,760 hours of operation since the space that these fixtures illuminate were expected to be kept on at all times throughout the year. The hours for the other fixtures were not monitored due to privacy restrictions, but the hours assumed in the analysis appear reasonable for an office space setting and were, therefore, kept unchanged.

Ex post energy savings were calculated similar to the ex ante algorithm except that the open office area hours of use were updated to reflect the hours of use from the data loggers. Ex post energy savings are calculated at 319,572 kWh with a demand reduction of 46.2 kW.

Savings Results

The four EEMs for this site resulted in 2,572,269 kWh and 365 kW of demand savings. Demand savings were estimated in accordance with the CPUC's peak period definition.[52] A breakdown of savings by individual measure is presented at the beginning of this report in Table E-43. The ex ante savings estimates, which were acquired from the DGS site contact, are also provided as a point of reference.

Discussion

The ex post electric energy savings overall for this project was 83 percent of the ex ante claims, respectively. Discrepancies between the two savings estimates are addressed below by measure.

EEM 1 – CRAC Units Upgrade

Power data from 10 of the CRAC units show that the average power draw from these units under VSD controls were slightly higher than initially assumed. The postretrofit CRAC unit fans were assumed to draw 4.12 kW in the ex ante calculations. However, the monitored data shows an average power draw of 4.92 kW, 20 percent higher than presumed. In addition, a spot power measurement of the CRAC fans at 100 percent speed support a baseline power draw that is also lower (9.34 kW versus 10.18 kW). The combination of these two items reduced the energy savings by close to 40 percent of the ex ante estimates. However, because more units were affected (33 versus 29) by this measure, the energy savings were buoyed up to 1,277,445 kWh or 83 percent of the ex ante estimates.

EEM 2 – Chiller VSD

The ex post energy savings for this measure was 852,808 kWh. This represents 118 percent of the ex ante electric energy savings. Discrepancy between the ex ante and ex post are due to differences in the analysis methodology. Ex ante methodology in calculating energy savings for this measure was simplified and did not account for weather factors associated with the chiller VSD retrofit, observed building loads, or in situ performance of the chillers. These factors were taken into account in the ex post analysis using data extracted from the site's EMS. Despite these differences, the conservative estimates in the ex ante methodology yielded relatively similar results to the ex post analysis. Because actual chiller plant data was used in the ex post analysis, the results are expected to be more accurate than the assumptions found in the ex ante calculation algorithms.

EEM 3 – Water Side Economizer

Ex post energy savings for this measure was 122,444 kWh and represented only 20 percent of ex ante estimates. Differing analysis methodologies are partly responsible for the low realization rate but there are two other major factors that contribute significantly to the lower realization rate.

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52 According to the CPUC, peak demand savings are defined as the average demand reduction occurring during the three consecutive hottest weekdays of the year between the hours of 2 p.m. and 5 p.m.

First, the economizer controls as found are not expected to shut down the chiller as frequently as assumed. In the ex ante analysis, the chillers were expected to shut down for 2,000 hours a year. However, the data shows that even at very low wet bulb temperatures (approaching 31°F), the chillers remain on because the heat exchanger is unable to cool the return water temperature low enough to shut off the chiller. The current set up has the chiller shutting down when the chilled water return can reach below 40°F. With the current setup, even at 31°F low outside wet bulb, the best the heat exchanger can do is lower the chilled water return to 48°F.

Although the chiller does not shut down, there is an improved chiller part load efficiency due to the diversion of the chilled water return to the heat exchanger before returning it to the chiller. The energy savings for this control sequence, however, result in less energy savings than if the chiller had shut off completely. The conclusion is that the high base load from the data center along with an undersized heat exchanger prevents the chilled water return from reaching chiller shutoff set point.

The second factor comes from how the baseline is treated in the ex ante analysis. In the ex ante analysis, the baseline is assumed to use the pre-existing chiller power before applying EEM 2. However, the application of EEM 2 should first be applied before calculating energy savings for the waterside economizer since the two measures are interactive with each other and cannot be ignored. By calculating the energy savings independently, the ex ante analysis treats the site as though it has two separate chiller plants when in fact it only has one.

EEM 4 – Lighting Retrofit

Energy savings for this measure is grossly different because the ex post values are being compared to values derived from a different project that was not implemented. The energy savings value of 213,857 kWh reported in the documents provided by personnel from DGS appear to be for an LED project that was not implemented due to high first costs. The project that was eventually implemented was for a building wide upgrade to a 5th generation fluorescent lighting system. DNV KEMA obtained a list of the proposed fixtures which were found to be installed in place of the LED fixtures described in the project files. Hence, energy savings for this measure is expected to be different.

In addition, data collected for open area fixtures were found to be on continuously and as a result drives up the energy savings due to higher hours of use.

Ex Post Life-cycle Savings

Typically, energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement

baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

The lighting system for this site was approximately six years old but without DGS funds, it would have remained in place indefinitely. Therefore, only Baseline 1 (considering the existing equipment) is used in the life-cycle savings calculation.

All of the other measures are add on measures to the existing equipment. The baseline for add on measures is the existing conditions (for example, without VSDs or economizer controls). Baseline 2 is not applicable for any of the measures for this site.

The EUL is 15 years for all the measures implemented at this site, according to DEER. Details of this calculation are shown in Table E-72.

Table E-72: Values Used in Life-cycle Savings Calculations by Measure

Measure	Electric Energy (kWh)	Gas Energy (therms)	EUL	RUL
EEM 1 – CRAC Units Upgrade	1,277,445	N/A	15	N/A
EEM 2 – Chiller VSD	852,808	N/A	15	N/A
EEM 3 – Waterside Economizer	122,444	N/A	15	N/A
EEM 4 – Lighting retrofit	319,572	N/A	15	N/A

Source: DNV KEMA analysis

The life-cycle savings for this site considering the EUL is calculated at 38,584,035 kWh. Table E-73 below shows the life-cycle savings by year for these measures.

Table E-73: Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	2,572,269	365	0
2	2012	2,572,269	365	0
3	2013	2,572,269	365	0
4	2014	2,572,269	365	0
5	2015	2,572,269	365	0

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
6	2016	2,572,269	365	0
7	2017	2,572,269	365	0
8	2018	2,572,269	365	0
9	2019	2,572,269	365	0
10	2020	2,572,269	365	0
11	2021	2,572,269	365	0
12	2022	2,572,269	365	0
13	2023	2,572,269	365	0
14	2024	2,572,269	365	0
15	2025	2,572,269	365	0
16	2026	0	0	0
Life-cycle	Total	38,584,035	5,475	0

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

CHP Oakland Area Retrofit

Site Summary

The Oakland area California Highway Patrol (CHP) facility consists of two single-story office buildings which together amount to 13,880 square feet of office space. Comprehensive lighting retrofits including new fixtures and occupancy sensors were completed in both buildings. New fixtures were also installed in the outdoor parking lot and two unconditioned and generally unoccupied sheds.

The bulk of the retrofit consisted of replacing antiquated T12 fixtures with new low-wattage (25W/lamp) T8 fixtures. Wall and ceiling-mounted occupancy sensors were the other primary component. In total, 284 lighting fixtures were retrofitted, 116 of which were placed on occupancy sensors.

The project did not save nearly as much energy as claimed in the ex ante analysis. Savings were not realized primarily because the operating schedules used in the ex ante analysis greatly overestimated the annual operating hours for the majority of the affected lighting. Furthermore, many of the occupancy sensors slated for installation were not installed, which further reduced the energy savings potential of the project. Lastly, the total number of retrofit fixtures was reduced to 284 fixtures from the 311 fixtures claimed in the ex ante documentation.

Ex ante and ex post savings for the lighting retrofit are provided in Table E-74 below. DGS's monthly status update was the source for ex ante savings. These values were corroborated by the savings listed in the implementer's ex ante analysis.

Table E-74: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1—Lighting Retrofit	119,777	None Claimed	0	35,394	6.0	0	29.6%	N/A

Source: DNV KEMA analysis

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the (RUL of the pre-existing equipment is exceeded.

In this case, both baselines are the same. This retrofit does not trigger Title 24 lighting power density requirements for wattage in a given space because the luminaires were not replaced.

Table E-75: Ex Post Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	492,108	81.6	0
Baseline 2	492,108	81.6	0

Source: DNV KEMA analysis

Project Description

Measure 1:

The Oakland area CHP office completed a comprehensive lighting retrofit of the Oakland area CHP office building as well as the adjoining radio shop. According to ex ante documentation, the original plan was to retrofit 311 fixtures and install 35 wall and ceiling mounted occupancy sensors. 197 of the retrofit fixtures were projected to be occupancy sensor controlled. Of the 311 fixtures, 289 were interior fixtures and 21 were exterior lights for the parking lot and building facades.

Ex ante Savings

Johnson Controls conducted the ex ante savings analysis using a spreadsheet calculation.[53] In general, for any group of fixtures, savings were calculated as:

$$kWh_{saved} = \frac{n}{1000}(W_{bl}h_{bl} - W_{ins}h_{ins})kWh_{saved} = \frac{n}{1000}(W_{bl}h_{bl} - W_{ins}h_{ins})$$

53 See the Johnson Controls spreadsheet titled "CHP Lighting.xls" for the detailed calculation used in the ex ante analysis.

Where,

n	= Number of affected fixtures
W_{bl}	= Baseline Fixture Wattage [W]
h_{bl}	= Baseline Operating Hours [h]
W_{ins}	= Installed Fixture Wattage [W]
h_{ins}	= Installed Operating Hours (potentially adjusted for occupancy sensors) [h]
1,000	= [W/kW]

Savings from all affected fixture groups were then summed to estimate gross project savings.

Project Evaluation

A DNV KEMA engineer visited the facility on August 10, 2011 to verify the installation of each lighting fixture and occupancy sensor, install time-of-use data loggers, and gather facility lighting schedule data to assist in assessing energy savings. During verification, a total of 284 new fixtures were identified, of which 116 were controlled by occupancy sensors; these numbers were reduced from the 311 total fixtures and 197 controlled fixtures identified in the ex ante spreadsheet.

A total of 14 time-of- use data loggers were installed during the initial site visit to establish lighting schedules. Table E-76 below contains a summary of all monitoring equipment that was installed during the initial site visit.

Table E-76: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
Sergeant's Office Lighting (Switch A)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Sergeant's Office Lighting (Switch B)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Briefing Room (Switch A)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Briefing Room (Switch B)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Hallway (Switch A)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Hallway (Switch B)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Administrative Office	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Lobby (Switch A)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Lobby (Switch B)	Dent Lighting*logger*	On/Off Records	N/A	55 Days

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
Radio Shop	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Weight Room	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Men's Locker Room (Switch A)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Men's Locker Room (Switch B)	Dent Lighting*logger*	On/Off Records	N/A	55 Days
Carport/Garage	Dent Lighting*logger*	On/Off Records	N/A	55 Days

Source: DNV KEMA analysis

After 55 days of monitoring, the data loggers were retrieved. Table E-77 below presents (1) a summary of the average monitored operating schedules for each logger by day type; (2) an estimate of annual operating hours for each monitored lighting group; and (3) monitored peak coincidence factors for the lights monitored by each logger.

Table E-77: Metered Operating Schedules

Monitored Lighting Group	Hours per Weekday	Hours per Weekend Day	Hours per Holiday	Annual Operating Hours	Peak Coincidence Factor
Sergeant's Office Lighting (Switch A)	16.8	16.5	18.7	6,115	0.71
Sergeant's Office Lighting (Switch B)	12.7	17.1	19.2	5,168	0.54
Briefing Room (Switch A)	13.5	16.2	24.0	5,317	0.56
Briefing Room (Switch B)	8.2	5.9	0.0	2,664	0.19
Hallway (Switch A)	23.5	22.5	24.0	8,474	1.00
Hallway (Switch B)	0.1	0.0	0.0	25	0.00
Administrative Office	10.1	2.9	1.2	2,831	0.97
Lobby (Switch A)	12.4	7.5	6.6	3,960	0.99
Lobby (Switch B)	4.0	0.9	0.0	1,088	0.33
Radio Shop	5.1	3.2	0.0	1,611	0.37
Weight Room	1.7	2.7	0.8	713	0.14
Men's Locker Room (Switch A)	0.0	0.0	0.0	0	0.00

Monitored Lighting Group	Hours per Weekday	Hours per Weekend Day	Hours per Holiday	Annual Operating Hours	Peak Coincidence Factor
Men's Locker Room (Switch B)	13.6	12.0	0.0	4,643	0.56
Carport/Garage	4.5	5.2	2.0	1,697	0.00

Source: DNV KEMA analysis

In instances where one half of the lights in a given area were controlled with one switch, and the other half were controlled with another (for example, the sergeant's office or the briefing room), the simple average of the two schedules was taken and used to estimate the schedule for all lights in those areas.

Some of the schedules provided in Table E-77 implicitly included the impact of occupancy sensors. Therefore, in order to approximate lighting usage under base case conditions, it was necessary to scale the operating hours by a factor of $\frac{1}{(1-.3)}$, which follows from the standard practice assumption that occupancy sensors yield a 30 percent reduction in lighting time-of-use.[54] Schedules from monitored areas were applied to unmonitored areas if reasonably applicable. For instance, the men's locker room schedule was applied to the women's locker room lighting as well. In instances where monitored schedules could not be used, the schedules used in the implementer's analysis were retained unless sufficient evidence was obtained during the site visits—either from interviews with facility staff regarding lighting usage or anecdotally observed usage— to make adjustments.

Savings with respect to the pre-existing equipment baseline were calculated using the same general methodology as the ex ante analysis.

Savings Results

The project achieved annual energy savings of 35,394 kWh and 6.0 kW in demand savings relative to the Energy Commission's baseline.

Discussion

This project saved markedly less energy than estimated in the ex ante analysis for a few key reasons. First, the lighting operating hours assumed in the ex ante analysis far exceeded the hours observed in the metered data sets. Second, the observed number of fixtures controlled by occupancy sensors was considerably fewer than estimated in the ex ante analysis. As a result of these two factors, the load-weighted average operating hours shifted dramatically from the ex ante analysis to the ex post analysis. In the ex ante analysis, the load weighted average annual operating hours were 5,299 and 4,180 for the base and installed cases respectively; in the ex post

54 *NEEP Mid-Atlantic Technical Reference Manual Version 1.1, pg. 83, October 2010.*

analysis, these same metrics were reduced to 2,927 hours and 2,557 hours. Not only did the averages decrease dramatically, but the differential between the base case and installed cases (induced by the reduced number of installed occupancy sensors) also decreased. These two changes greatly reduced the savings potential of the project. Realized energy savings were also mitigated somewhat because only 284 lighting fixture retrofits were completed, as opposed to the 311 claimed in the ex ante analysis.

Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

Table E-78 below provides the annual energy savings estimates, EULs, and RULs that fed into the life-cycle savings calculations. Note that the project was broken down into two subcomponents since the new fixtures and occupancy sensors have different EULs.

Table E-78: Values Used in Ex Post Life-cycle Savings Calculations by Measure

Measure	Early Replacement		Expected Replacement		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 1 – Lighting Retrofit Component	29,851	0	12,062	0	15	0
EEM 1 – Occupancy Sensor Component	5,543	0	5,543	0	8	0

Source: DNV KEMA analysis

Table E-79 provides life-cycle savings for the project relative to Baseline 1 and Baseline 2.

Table E-79: Baseline 1 and Baseline 2 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	35,394	6.0	0
2	2012	35,394	6.0	0
3	2013	35,394	6.0	0
4	2014	35,394	6.0	0
5	2015	35,394	6.0	0
6	2016	35,394	6.0	0
7	2017	35,394	6.0	0
8	2018	35,394	6.0	0
9	2019	29,851	4.8	0
10	2020	29,851	4.8	0
11	2021	29,851	4.8	0
12	2022	29,851	4.8	0
13	2023	29,851	4.8	0
14	2024	29,851	4.8	0
15	2025	29,851	4.8	0
16	2026	0	0.0	0
Life-cycle	Total	492,109 kWh	81.6 kW-years	0 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

CHP South Los Angeles Area Retrofit

Site Summary

The South Los Angeles area CHP facility consists of two single-story buildings. The first building is a typical 8,900 square foot CHP facility composed primarily of office space. The second building is a 6,500 square foot vehicle depot comprised mostly of low-bay garage space. Comprehensive lighting retrofits including new lamps, ballasts, and occupancy sensors were completed in both buildings. New parking lot flood lights and exterior wall wash fixtures were also installed as part of the retrofit.

The bulk of the retrofit consisted of retrofitting antiquated T12 fixtures with new low-wattage (25W/lamp) T8 lamp and ballast combinations. Wall and ceiling-mounted occupancy sensors were the other primary component. In total, 323 fixtures were retrofitted, 75 of which were placed on occupancy sensors.

The project did not save nearly as much energy as claimed in the ex ante analysis. Savings were not realized primarily because the operating schedules used in the ex ante analysis greatly overestimated annual operating hours for the majority of the affected lighting. Furthermore, many of the occupancy sensors slated for installation were not installed, which further reduced the energy savings potential of the project. Lastly, the total number of retrofit fixtures was reduced minimally from the 324 claimed in the ex ante documentation to 323.

Ex ante and ex post savings relative to Baseline 1 for the lighting retrofit are provided in Table E-80 below. Baseline 1 considers the existing conditions found before the EEM implementation. Ex ante savings were appropriated from DGS's monthly status update and were corroborated by the savings listed in the implementer's ex ante analysis.

Table E-80: Energy Savings Summary

Measure	Ex Post			Ex Ante			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1– Lighting Retrofit	84,629	13.24	0	137,410	None Claimed	0	61.6%	N/A

Source: DNV KEMA analysis

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the RUL of the pre-existing equipment is exceeded.

Table E-81 below summarizes the life-cycle savings relative to each of these baselines.

Table E-81: Ex Post Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	1,244,213	195.1	0
Baseline 2	1,244,213	195.1	0

Source: DNV KEMA analysis

***Note that life-cycle savings are equivalent relative to both baselines because only lamps and ballasts were replaced. Because the fixture casings were not removed, Title 24 was not triggered for Baseline 2 and the expected replacement equipment remained the pre-existing lamps and ballasts.*

Project Description

Measure 1:

The South Los Angeles area CHP facility underwent a comprehensive lighting retrofit of its office building as well as the adjoining vehicle depot. According to ex ante documentation, the original plan was to retrofit 324 fixtures and install 43 wall and ceiling mounted occupancy sensors. 237 of the retrofit fixtures were projected to be occupancy sensor controlled. Of the 324 fixtures, 227 were to be in the main building, 85 were to be in the vehicle depot, and 12 were to be exterior lights for the parking lot and building facades.

Ex Ante Savings

Johnson Controls conducted the ex ante savings analysis using a spreadsheet calculation.[55] In general, for any group of fixtures, savings were calculated as:

$$kWh_{saved} = \frac{n}{1000}(W_{bl}h_{bl} - W_{ins}h_{ins})kWh_{saved} = \frac{n}{1000}(W_{bl}h_{bl} - W_{ins}h_{ins})$$

Where,

n	= Number of affected fixtures
W_{bl}	= Baseline Fixture Wattage [W]
h_{bl}	= Baseline Operating Hours [h]
W_{ins}	= Installed Fixture Wattage [W]
h_{ins}	= Installed Operating Hours (potentially adjusted for occupancy sensors) [h]
1,000	= [W/kW]

Savings from all affected fixture groups were then summed to estimate gross project savings.

Project Evaluation

A DNV KEMA engineer visited the facility on September 1, 2011 to verify the fixture retrofits and occupancy sensor installations, install time-of-use data loggers, and gather facility lighting schedule data to assist in assessing energy savings. During verification, a total of 323 retrofit fixtures were identified, of which 75 were controlled by occupancy sensors; these numbers were reduced from the 324 total fixtures and 232 controlled fixtures projected in the ex ante spreadsheet.

A total of 11 time-of-use data loggers were installed during the initial site visit to establish lighting schedules. Table E-82 below contains a summary of all monitoring equipment that was installed during the initial site visit.

Table E-82: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
CHP Office: Main Office	Dent Lighting*logger*	On/Off Records	N/A	28 Days
CHP Office: Lobby	Dent Lighting*logger*	On/Off Records	N/A	28 Days

55 See the Johnson Controls spreadsheet titled "CHP Lighting.xls" for the detailed calculation used in the ex ante analysis.

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
CHP Office: Main Hallway (Secondary Circuit)	Dent Lighting*logger*	On/Off Records	N/A	28 Days
CHP Office: Lieutenant's Office	Dent Lighting*logger*	On/Off Records	N/A	28 Days
CHP Office: Sergeant's Office	Dent Lighting*logger*	On/Off Records	N/A	28 Days
CHP Office: Debrief Area	Dent Lighting*logger*	On/Off Records	N/A	28 Days
CHP Office: Men's Locker Room	Dent Lighting*logger*	On/Off Records	N/A	28 Days
CHP Office: Vehicle Canopy	Dent Lighting*logger*	On/Off Records	N/A	28 Days
Vehicle Depot: Stall 1	Dent Lighting*logger*	On/Off Records	N/A	28 Days
Vehicle Depot: Stall 3	Dent Lighting*logger*	On/Off Records	N/A	28 Days
Vehicle Depot: Shop Perimeter Lights	Dent Lighting*logger*	On/Off Records	N/A	28 Days

Source: DNV KEMA analysis

After 28 days of monitoring, the data loggers were retrieved. Table E-83 below presents (1) a summary of the average monitored operating schedules for each logger by day type; (2) an estimate of annual operating hours for each monitored lighting group; and (3) peak coincidence factors for the fixtures monitored by each logger.

Table E-83: Metered Operating Schedules

Monitored Lighting Group	Hours per Weekday	Hours per Weekend Day	Hours per Holiday	Annual Operating Hours	Peak Coincidence Factor
CHP Office: Main Office	16.6	11.6	24.0	5,620	0.95
CHP Office: Lobby	9.5	1.0	0.0	2,475	0.89
CHP Office: Main Hallway (Secondary Circuit)	0.0	0.0	0.0	0	0.00

Monitored Lighting Group	Hours per Weekday	Hours per Weekend Day	Hours per Holiday	Annual Operating Hours	Peak Coincidence Factor
CHP Office: Lieutenant's Office	3.8	0.6	6.1	1,094	0.55
CHP Office: Sergeant's Office	18.9	19.1	21.7	6,949	0.88
CHP Office: Debrief Area	13.0	15.5	23.7	5,128	0.65
CHP Office: Men's Locker Room	23.8	23.0	24.0	8,603	0.97
CHP Office: Vehicle Canopy	6.4	3.8	0.0	1,978	0.03
Vehicle Depot: Stall 1	8.7	0.0	0.0	2,173	0.70
Vehicle Depot: Stall 3	5.9	0.0	0.0	1,480	0.41
Vehicle Depot: Shop Perimeter Lights	0.1	0.0	0.0	20	0.00

Source: DNV KEMA analysis

The debrief area schedule provided in Table E-77 implicitly included the impact of occupancy sensors. Therefore, in order to approximate lighting usage under base case conditions, it was necessary to scale the operating hours by a factor of $\frac{1}{(1-.3)}$, which followed from the standard practice assumption that occupancy sensors yield a 30 percent reduction in lighting time-of-use.[56] The remainder of the schedules in Table E-77 corresponded to areas that were not controlled by occupancy sensors.

Schedules from monitored areas were applied to unmonitored areas if reasonably applicable. For instance, the men's locker room schedule was applied to the women's locker room lighting as well. In instances where monitored schedules could not be used, the schedules used in the implementer's analysis were retained unless sufficient evidence was obtained during the site visits—either from interviews with facility staff regarding lighting usage or anecdotally observed usage— to make adjustments.

56 NEEP Mid-Atlantic Technical Reference Manual Version 1.1, pg. 83, October 2010.

After assigning schedules to each group of retrofit lights, energy savings with respect to Baseline 1 were calculated using the same general methodology used in the ex ante analysis. Baseline 2 savings were identical to Baseline 1 savings because the project did not trigger Title 24. The project would have only required Title 24 compliance if the entire fixture assemblies had been replaced as opposed to just the lamps and ballasts.

Savings Results

The project achieved annual energy savings of 84,629 kWh and 13.24 kW in demand savings relative to the Baseline 1 and Baseline 2.

Discussion

This project saved markedly less energy than estimated in the ex ante analysis for a few key reasons. First, the lighting operating hours assumed in the ex ante analysis far exceeded the hours observed in the metered data sets. Second, the observed number of fixtures controlled by occupancy sensors was considerably fewer than estimated in the ex ante analysis. As a result of these two factors, the load-weighted average operating hours shifted dramatically from the ex ante analysis to the ex post analysis. In the ex ante analysis, the load weighted average annual operating hours were 4,585 and 3,530 for the base and installed cases respectively; in the ex post analysis, these same metrics were reduced to 3,696 hours and 3,549 hours. Not only did the averages decrease dramatically, but the differential between the base case and installed cases (induced by the reduced number of installed occupancy sensors) also decreased. These two changes greatly reduced the savings potential of the project.

Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable. In this case, standard practice would have entailed replacing the pre-existing lamps and ballasts with equivalents components as the pre-existing units died out.

Table E-84 below provides the annual energy savings estimates, EULs, and RULs that fed into the life-cycle savings calculations. Note that the project was broken down into two subcomponents since the new fixtures and occupancy sensors have different EULs.

Table E-84: Values Used in Ex Post Life-cycle Savings Calculations by Measure

Measure	Relative to Pre-existing Equipment		Relative to Expected Replacement Equipment		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 1 – Lighting Retrofit Component	81,026	0	81,026	0	15	0
EEM 1 – Occupancy Sensor Component	3,603	0	3,603	0	8	0

Source: DNV KEMA analysis

Table E-85 provides life-cycle savings for the project relative to Baseline 1 and Baseline 2 on a year-by-year basis through the EUL of the longest lived measure. Life-cycle savings are equivalent relative to both baselines because the pre-existing equipment represents standard practice.

Table E-85: Baseline 1 and Baseline 2 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	84,629	13.2	-
2	2012	84,629	13.2	-
3	2013	84,629	13.2	-
4	2014	84,629	13.2	-
5	2015	84,629	13.2	-
6	2016	84,629	13.2	-
7	2017	84,629	13.2	-
8	2018	84,629	13.2	-
9	2019	81,026	12.7	-
10	2020	81,026	12.7	-
11	2021	81,026	12.7	-
12	2022	81,026	12.7	-
13	2023	81,026	12.7	-
14	2024	81,026	12.7	-
15	2025	81,026	12.7	-

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
16	2026	-	-	-
Life-cycle	Total	1,244,214 kWh	194.5 kW-years	0 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

CHP Coalinga Building Retrofit

Site Summary

The CHP building in Coalinga is an approximately 4,500 square feet, one story office type building served by direct expansion (DX) split-system air conditioning units, heat pumps and gas-fired furnaces. Two EEMs were implemented at the site. The first EEM is for a lighting retrofit which included the replacement of the existing ballast and lamps with higher efficiency ballasts and lamps. Occupancy sensor controls were also included as part of the measure. The second EEM is for the replacement of the split DX units along with a reduction in fan usage overnight.

The evaluators performed a site visit to verify implementation of these measures and installed monitoring equipment on the DX units and lighting fixtures for a period of four weeks to determine energy savings. The analysis using this data yielded an overall electric energy savings of 140 percent when compared to the ex ante estimates. Details of the energy savings by measure are provided in Table E-86.

Table E-86: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
Lighting	32,697	Not reported	0	42,205	3.83	0	129%	N/A
HVAC	12,706	Not Reported	0	21,532	8.35	0	169%	N/A
Total	45,403	Not Reported	0	63,737	12.19	0	140%	N/A

Source: DNV KEMA analysis

More energy savings for the lighting measure is seen due to a higher cycling rate from the occupancy sensor controls. Energy savings from the HVAC units are also greater due to the installation of higher efficiency units relative to what was claimed in the project files. The higher efficiency units would have generated more energy savings for the HVAC portion of this

project; however, this is masked slightly in the final ex post values because no reduction in fan usage overnight is seen.

Table E-87 below shows the life-cycle energy savings for this site. Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses minimally code compliant conditions or standard practice as the baseline once the RUL of the pre-existing equipment is exceeded.

The overall results from Table E-87 yields a life-cycle energy savings of 878,305 kWh when using Baseline 1, whereas the life-cycle energy savings of 579,264 kWh are estimated when using Baseline 2.

Table E-87: Ex Post Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	878,305	182.8	0
Baseline 2	579,264	94.6	0

Source: DNV KEMA analysis

Project Description

This project was implemented at the CHP building in Coalinga, California. The building is a one-story office-type building with approximately 4,500 square feet of conditioned space that is served by direct expansion (DX) split-system air conditioning units and gas-fired furnaces. Two office zones and the break room are served by heat pumps. The building is in use 24 hours a day but the lobby is opened for business 8 a.m. to 5 p.m., Monday through Friday. The project consists of two measures.

Measure 1: Lighting Retrofit— This lighting measure was a fixture-for-fixture replacement of the pre-existing T-12 linear fluorescent lighting system with next generation T8 lamps and electronic ballasts. New occupancy controls were also installed on the lighting fixtures as part of this measure. A total of 105 lighting fixtures were installed at this site for an estimated ex ante energy savings of 32,697 kWh.

Measure 2: HVAC Retrofit—This measure was for the replacement of one four-ton and two five-ton split-system HVAC units with high efficiency DX and ductless split units. The units were replaced with one to four ton systems totaling 14 tons of cooling capacity. There is also a

claim for energy savings from turning off the supply fan at night. The estimated ex ante energy savings for this measure is 12,706 kWh.

Ex Ante Savings

Johnson Controls with the help of Cogent Energy prepared the energy savings reported in the monthly status updates. A building energy modeling application, eQuest, was used to estimate the energy savings for the HVAC measure. The savings estimate used pre- minus post-modeled end use energy usage from the following main inputs:

- The air conditioning system efficiency was modeled as 7.03 EER (EIR of 0.4260) in the preretrofit model and 10.1 EER (EIR of 0.2843) in the postretrofit model.
- The postretrofit model included a reduced fan schedule that turned on only from a.m. to 5 p.m.

The values that are reported here were taken from the actual eQuest models, not the report that was provided to DNV KEMA. While the energy savings for the HVAC measure in the report also matches the model, the actual HVAC EER parameters presented in the report were inconsistent with what was actually used in the models.

There is also a parametric run for the lighting savings in Johnson Control's model, but the energy savings from that run is not the same as the values reported in the monthly status updates. Along the same vein, DNV KEMA obtained a lighting calculation spreadsheet from the DGS which accurately documented the lighting changes for various CHP and department of motor vehicle buildings.[57] However, the lighting energy savings also do not match the values reported in the monthly status updates for the CHP office building in Coalinga. It remains unclear where the final energy savings value for the lighting retrofit came from.

Project Evaluation

A DNV KEMA field engineer visited the project's site on July 14, 2011 to verify measure installation, install true power data loggers on three of the AC units, install time-of-use photocell data loggers for determining lighting hours of operation, and to corroborate other modeling inputs (temperature set points, building dimensions, and so forth). Additionally, a temporary weather station measuring the dry-bulb and wet-bulb temperatures was deployed at the site. Table E-45 summarizes the monitoring equipment details.

The engineer returned on August 12, 2011 to retrieve the data loggers and the weather station. Figure 32 below shows a seven-day snapshot of the data for the three HVAC units' power draw (total 11 tons metered) and outside air temperature conditions. Data for the entire monitoring period were used in the analysis.

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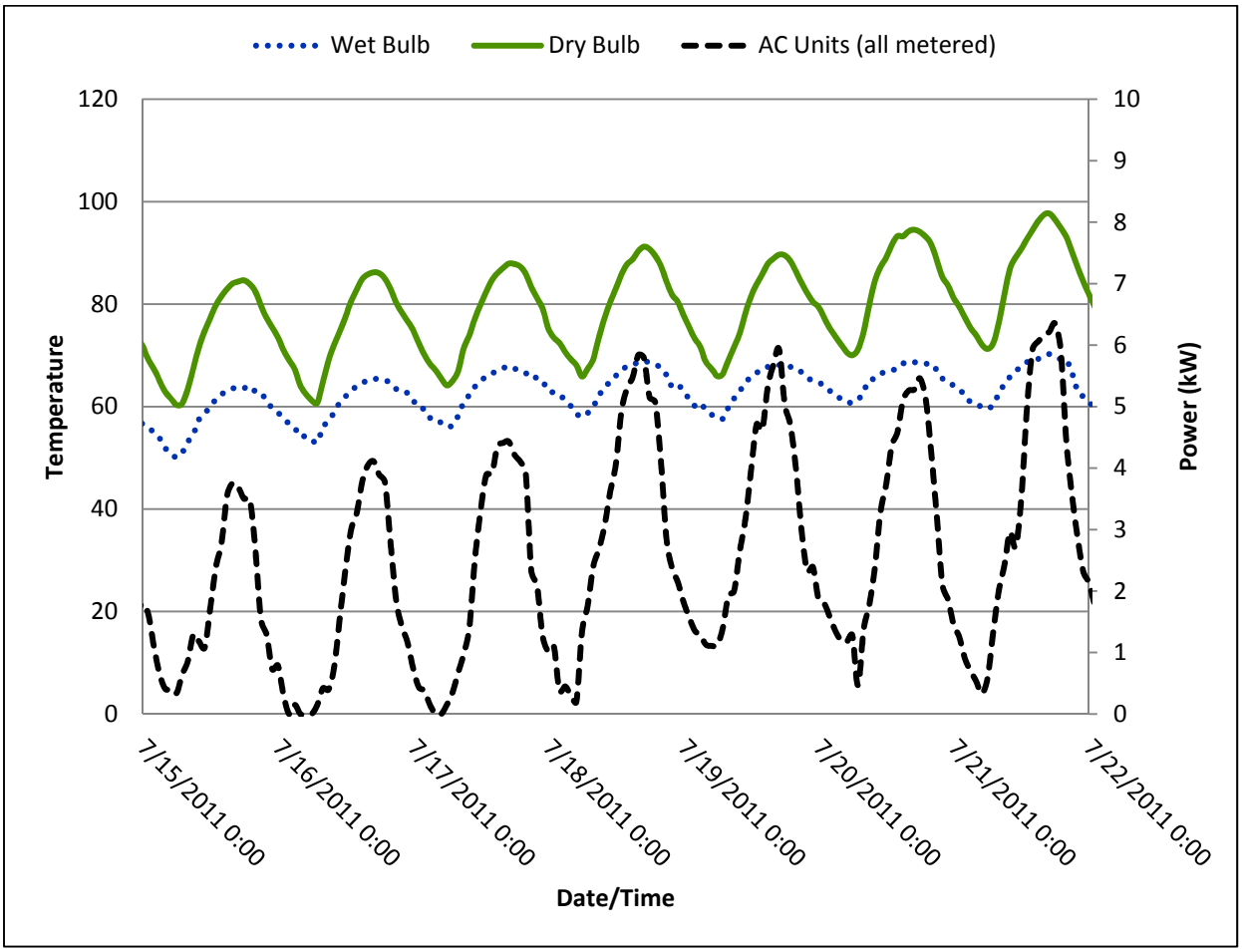
57 The document was part of the data files that was forwarded to DNV KEMA during the initial request for information. This particular document does not list the author.

Table E-88: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
2 Four-ton condenser unit	Wattnode, Microstation	Pulse output (kW)	20 seconds	4 weeks
1 Three-ton condenser unit	Wattnode, Microstation	Pulse output (kW)	20 seconds	4 weeks
6 Light fixtures	DENT TOU lighting loggers	On/Off (time-of-use)	Continuous	4 weeks
1 Outside Air	Microstation with temp/RH sensor	Dry bulb and wet bulb temperature	1 minute	4 weeks

Source: DNV KEMA analysis

Figure 32: Hourly Power for DX AC Units and Outside Air Temperature, Seven-day Snapshot



Source: DNV KEMA analysis

Table E-89: Verification Summary

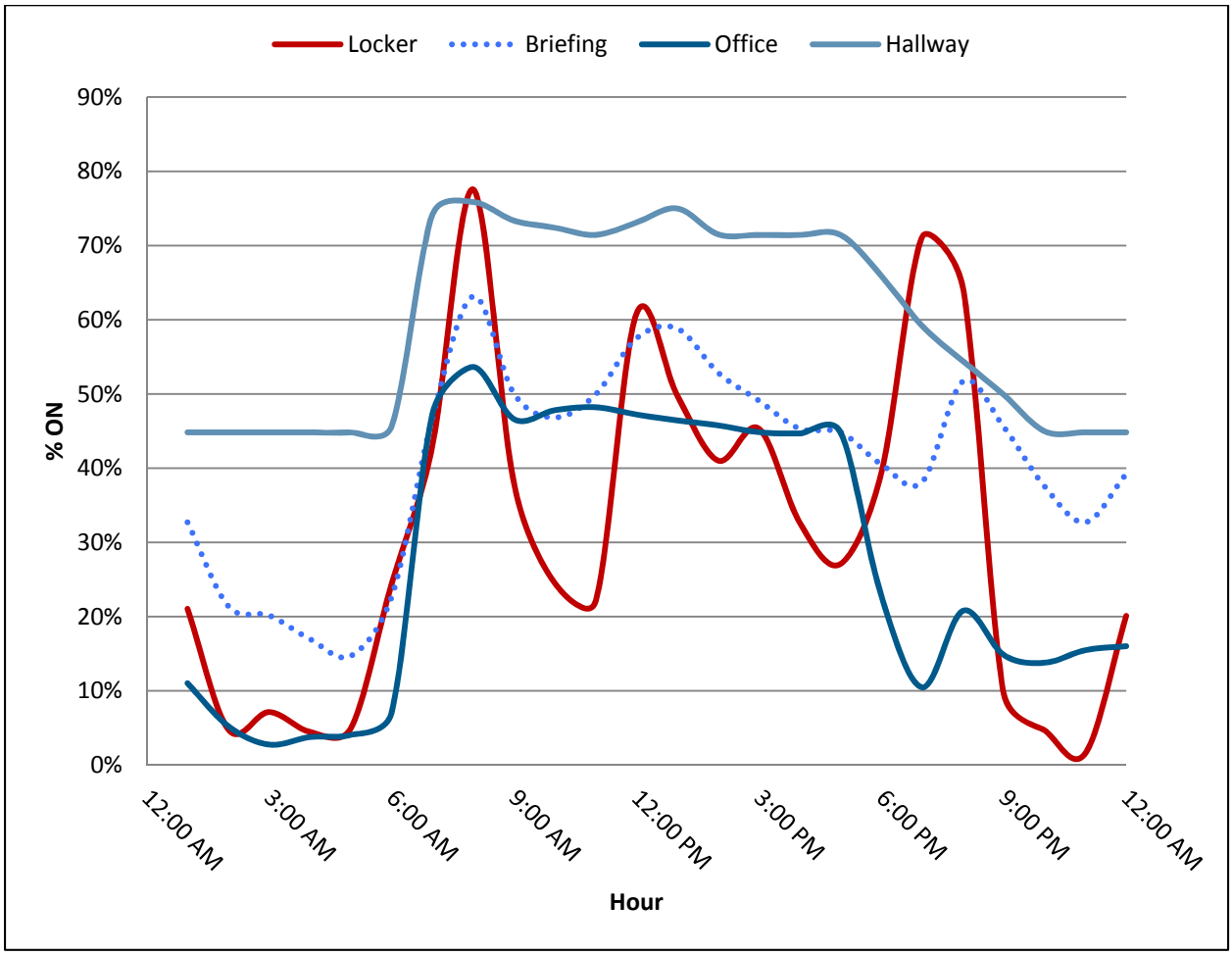
Equipment	Reported	Verified	Site Notes
T8 Fixtures with electronic ballasts and occupancy sensors	105	105	Consistent with lighting spreadsheet provided. Occupancy sensors found at all circuits specified in spreadsheet.
Direct expansion (DX) cooling and gas-fired furnaces	6	6	Nameplate indicates 2 four-ton units at SEER 17, 1 three-ton unit at SEER 18.5, 3 one-ton heat pumps at SEER 20.5 and 10 HSPF

Source: DNV KEMA analysis

Measure 1 – Lighting

The ex post savings estimate for the lighting retrofit was generated with a spreadsheet analysis using time-of-use data from the photocell data loggers. The data yielded four typical use profiles for the building which were used to estimate the annual operation hours for each major space type. Figure 33 below shows the lighting time-of-use profiles for the locker room areas, briefing room, general offices, and hallways which comprise the majority of the energy savings for this measure. All metered fixtures were equipped with occupancy sensor control; hence, the total hours estimated reflects the use of the sensors. Fixture types were also verified and found to be consistent with what was recorded in the spreadsheet from the project files.

Figure 33: Lighting Time-of-use Profiles



Source: DNV KEMA analysis

Figure 33 translates to 2,693 annual hours of operation for the locker type spaces, 3,567 hours for the briefing/conference room spaces, 2,411 hours for office type spaces, and 5,216 hours for the

hallway spaces. Energy savings were calculated using the following equation supplemented with the hours from the data loggers:

$$Energy\ Savings = Quantity \times Annual\ Hours \times (kW_{Pre} - kW_{Post}) Energy\ Savings = Quantity \times Annual\ Hours \times (kW_{Pre} - kW_{Post})$$

Where,

Energy Savings is the annual energy savings for all fixtures covered by the measure in kWh,

Quantity is the total number of affected fixtures

kW is the pre and postinstallation fixture wattages in kW,

and *Annual Hours* are the estimated hours using data from the loggers.

DNV KEMA reverted to the estimated hours from the original spreadsheet for spaces that do not fit these descriptions, particularly for the low use rooms such as the shower areas and janitor rooms but these make up a small fraction of the total energy savings for this measure.

Once the energy savings for the interior lighting was established, this value was placed into eQuest by adjusting the lighting power density and lighting schedules in the pre and post models such that the lighting energy savings component of eQuest matches the spreadsheet calculations. The lighting inputs were run along with the HVAC parametric runs. This final step was necessary to establish the HVAC interactive effects associated with the lighting reduction. The analysis yielded a total energy savings of 42,205 kWh.

Measure 2 – HVAC

Ex post savings for the HVAC retrofit were estimated using pre- and post-eQuest models built from data collected on-site. Energy savings were calculated by varying specific parameters in eQuest that is designed to mirror the energy efficiency component of the measure. The SEER value of the old and new units were determined either by looking up the model numbers in the Preston Guide or through using the manufacturer's literature. The post eQuest model outputs were compared to metered data to ensure the results are in line with reality and are consistent with IPMVP Option D protocol. This method represents the highest level of rigor possible for an energy model. DNV KEMA started with the Johnson Controls-Cogent Energy's eQuest model and modified the shell to reflect dimensions and zones recorded at the site visit along with these major modeling parameters:

Table E-90: Modeling Parameters

	Pre	Source (Pre)	Post	Source (Post)
Total cooling capacity (kBtu/h)	168	Assumed similar to installed capacity	168	Nameplate
Cooling efficiency	9.38 SEER (EIR of 0.3629)	Composite SEER research using model numbers available from project files	SEER 17.5 or 20.5, depending on unit (EIR of 0.1444 or 0.1760)	Composite SEER value normalized by tons from nameplate
Heating efficiency of heat pump	2.7 COP	Assumed from DEER using vintage, climate zone, and building type	10 HSPF	Nameplate
Heat pump capacity	3 Tons	Assumed similar to installed capacity	3 Tons	Nameplate

Source: DNV KEMA analysis

Internal loads and hours of operations were adjusted in the pre and post models to calibrate the model AC usage with data obtained on-site, which also included the site specific weather data (Figure 32). The AC units in DNV KEMA's pre and post models were allowed to operate 24 hours per day which are consistent with the results from the metered data (in contrast to turning off the units from 5 p.m. to 8 a.m. in the postretrofit case assumed in the ex ante analysis). Hourly results from the model were well in line with data from the metering interval showing a mean bias error of 1 percent and a coefficient of variation (CV) of the root mean square of 20 percent (Table E-91).

Table E-91: Calibration Summary

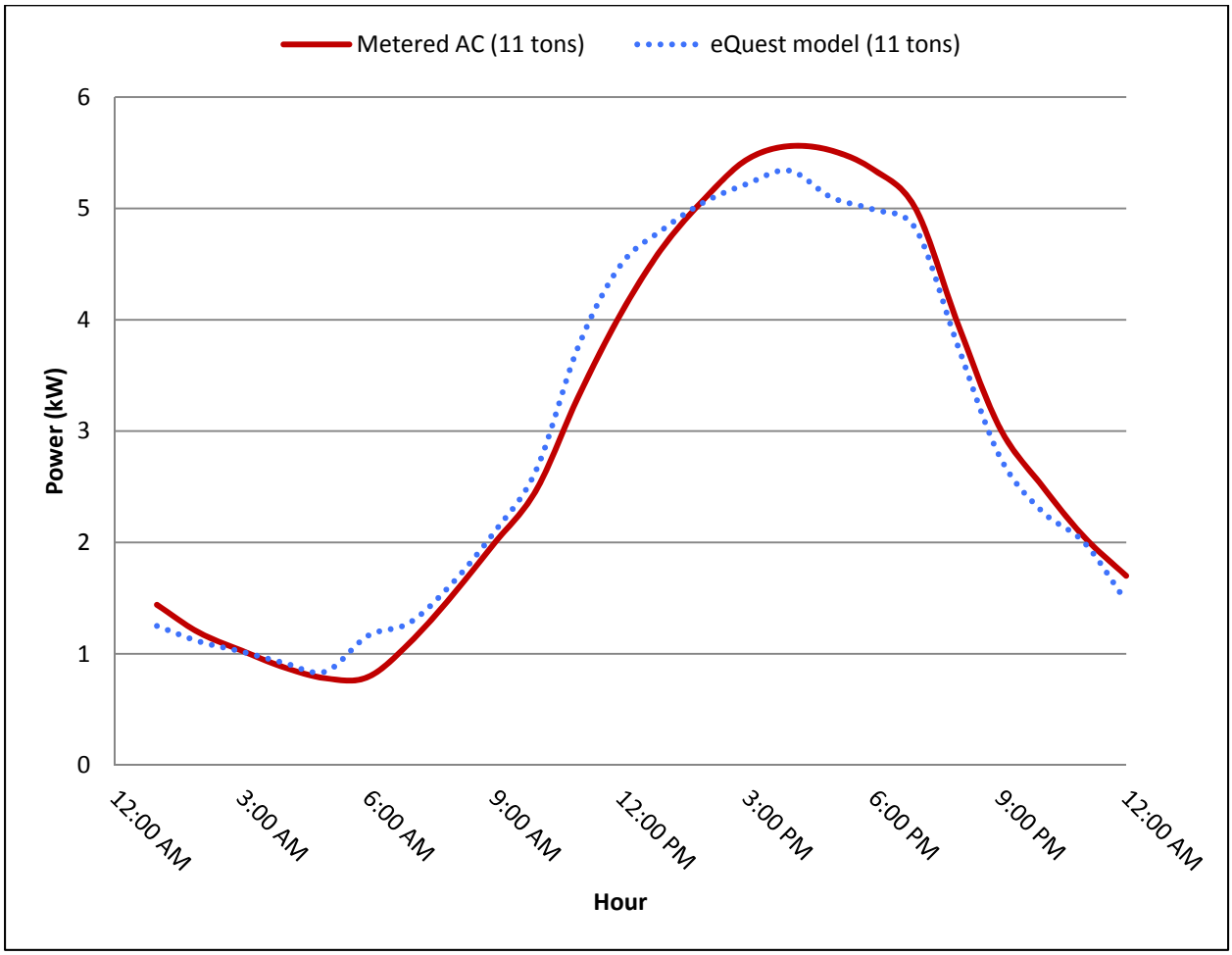
	Mean Bias Error (MBE)	Coefficient of Variation (CV)
3 total units with combined 11-ton capacity	1%	20%
Target	≤10%	≤30%

Source: DNV KEMA analysis

Note that the calibration is an hour-for-hour comparison of the power draw for three of the larger condenser units with a combined capacity of 11 tons. The three one-ton heat pumps were not metered and, therefore, not calibrated, but the power profile is expected to be similar to the larger units.

Figure 34 graphically illustrates the comparison between metered energy usage and the calibrated model's energy usage. The close match indicates the ex post model is an excellent predictor of overall AC usage as seen from the daily power draw profile.

Figure 34: Metered versus Modeled Average Weekday Power Draw in HVAC Energy Savings Analysis



Source: DNV KEMA analysis

A final eQuest simulation run was performed using the local weather data to establish the HVAC energy savings for this site which comes to 21,532 kWh.

Note that the pre-eQuest model efficiency was not de-rated for degradation and the energy savings for this measure represents a conservative estimate. Due to the small energy savings of the HVAC relative to the whole project, a degradation of 10 percent is not expected to significantly impact the overall project energy savings. Furthermore, it is impractical and

difficult to accurately measure the level degradation of the units in situ and any estimate is a blind guess. Hence, a conservative estimate is chosen to calculate energy savings.

Savings Results

The annual energy savings is the sum of hourly savings over all hours of the year, as predicted by the evaluation's eQuest postretrofit and baseline models. Based on the evaluation's eQuest analysis, total energy savings for this site is 63,737 kWh taking into account the separate lighting spreadsheet analysis performed prior. The savings include interior and exterior lighting, HVAC, and associated interactive effects. Table E-43 at the beginning of this report categorizes the energy savings by measure. The savings reported in the status update are also shown for comparison purposes.

Discussion

The higher energy savings result presented here likely come from a higher cycling rate of the light fixtures due to the new occupancy sensors. Undoubtedly, the sensors are very active based on the time-of-use data seen on multiple fixtures. This building was a good candidate for occupancy sensors since the many of the spaces are sporadically occupied throughout the day and night. However, since DNV KEMA does not have access to the ex ante final lighting calculations the reason for differences in energy savings for this measure remain unknown.

Energy savings were also boosted due to the new DX units which showed a much higher rated operational efficiency (17 SEER to 20.5 SEER) than what was claimed in the project files (10.1 EER or 11.3 SEER equivalent). The ex ante's efficiency value is likely a data entry error. The modeler may have intended to enter an 11.3 EER but entered an 11.3 SEER instead resulting in lower energy savings predicted in the ex ante analysis. Although DNV KEMA used a high efficiency rating for the baseline, energy savings were not significantly impacted since the new units found on-site had a much higher efficiency rating than anticipated.

There is no evidence of a reduction in time-of-use of the air handler fans as shown by the DX unit's operation which shows intermittent use at all hours. It is unlikely the fans are scheduled to be off during the night time when the condenser units are active. Thus no credit is given for this component of the HVAC measure.

Ex Post Life-cycle Savings

In essence, life-cycle savings is the sum of annual savings over the expected life of the measure. For replacement measures, the initial period considers the pre-existing conditions as the baseline for RUL, a so-called early replacement baseline or Baseline 1. After the remaining useful-life period and up until the end of the expected useful life (EUL) of the installed measure, an expected replacement baseline is used. This baseline considers minimally code compliant conditions or standard practice where no code is applicable. The replacement measure which incorporates both early replacement and expected replacement baseline is called dual baseline or Baseline 2.

EUL for both HVAC and lighting systems is 15 years while the occupancy sensor portion of the lighting system is eight years, according to DEER.

The Baseline 1 found on-site was an LPD of 1.32 and HVAC efficiencies of 9.38 SEER. But, the expected replacement baseline using code standard will use an LPD of 1.1 and HVAC efficiencies of 13 SEER.

Both the pre-existing lighting and HVAC units at Coalinga are more than 15 years old. Using the definition described above, both systems have no RUL left. However, energy savings for the first year are calculated using the Baseline 1 as default for this program. DNV KEMA will use the expected replacement baseline for the last 14 years.

The lighting measure includes the installation of occupancy sensors, an add-on measure with a EUL of eight years. For add on measures only the expected replacement baseline (no occupancy sensor) will be used for the entire EUL.

Table E-92 summarizes the energy savings by measure component used in the life-cycle savings calculations.

Table E-92: Values Used in Life-cycle Savings Calculations by Measure and Measure Subcomponent

Measure	Early Replacement		Expected Replacement		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
Lighting – fixtures only	31,098	0	22,782	0	15	0
Lighting – occupancy sensors	11,107	0	11,107	0	8	0
HVAC	21,532	0	8,488	0	15	0

Source: DNV KEMA analysis

When only considering the Baseline 1 first year baseline over the entire life of the measure, this project yields an estimated energy savings of 878,305 kWh (Table E-93). However, if the Baseline 2 is used, the life-cycle savings comes to 579,264 kWh.

The life-cycle savings for this considering the EUL for the two measures implemented is calculated at 675,117 kWh. Table E-93 below shows the life-cycle savings by year for these measures.

Table E-93 tabulates the energy savings by year starting with 2011 using this Baseline 2.

Table E-93: Baseline 1 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	63,737	12.19	0
2	2012	63,737	12.19	0
3	2013	63,737	12.19	0
4	2014	63,737	12.19	0
5	2015	63,737	12.19	0
6	2016	63,737	12.19	0
7	2017	63,737	12.19	0
8	2018	63,737	12.19	0
9	2019	52,630	12.19	0
10	2020	52,630	12.19	0
11	2021	52,630	12.19	0
12	2022	52,630	12.19	0
13	2023	52,630	12.19	0
14	2024	52,630	12.19	0
15	2025	52,630	12.19	0
16	2026	0	0	0
Life-cycle	Total	878,306 kWh	183 kW-years	0 therms

Source: DNV KEMA analysis

Table E-94: Baseline 2 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	63,737	12.19	0
2	2012	42,377	5.89	0
3	2013	42,377	5.89	0
4	2014	42,377	5.89	0
5	2015	42,377	5.89	0
6	2016	42,377	5.89	0
7	2017	42,377	5.89	0
8	2018	42,377	5.89	0
9	2019	31,270	5.89	0
10	2020	31,270	5.89	0
11	2021	31,270	5.89	0
12	2022	31,270	5.89	0
13	2023	31,270	5.89	0
14	2024	31,270	5.89	0
15	2025	31,270	5.89	0
16	2026	0	0	0
Life-cycle	Total	579,266 kWh	94.7 kW years	0 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

DMV Oakland Coliseum Field Office Retrofit

Site Summary

The Oakland Coliseum DMV field office is housed in a 14,510 square foot, single story building. A comprehensive lighting retrofit including new lamps, ballasts, and occupancy sensors was completed at the facility. All interior areas of the facility, as well as the parking lot, were retrofitted with new lamps and ballasts.

The bulk of the interior retrofit consisted of retrofitting legacy 32W/lamp T8 fixtures with new low wattage (25W/lamp) T8 lamps and high efficiency electronic ballasts. Wall-switch occupancy sensors were the other primary interior component of the retrofit. In total, 148 interior fixtures were retrofit, 17 of which were placed on occupancy sensors. In addition, 36 exterior lights, which had previously been metal halide and high-pressure sodium fixtures, were replaced with induction fixtures.

The project saved slightly more energy than claimed in the ex ante analysis. The ex ante savings projections were exceeded primarily because most of the lighting in the facility operates for more hours annually than estimated in the ex ante analysis. Aside from this discrepancy, there were minor differences between the proposed scope of work and the completed scope of work. In particular, the evaluation identified a total of 148 retrofit interior fixtures as opposed to the 150 claimed in the ex ante calculations. In addition, only 17 fixtures were identified as occupancy sensor controlled during the on-site verification as opposed to the 55 claimed in the ex ante analysis.

Ex ante and ex post savings for the lighting retrofit are provided in Table E-43 below. DGS's monthly status update was the source for ex ante savings. These were corroborated by the savings listed in the implementer's ex ante analysis.

Table E-95: Energy Savings Summary

Measure	Ex Post			Ex Ante			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1– Lighting Retrofit	41,115	4.5	0	37,350	None Claimed	0	110.1%	N/A

Source: DNV KEMA analysis

Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline, uses *minimally code-compliant* conditions or *standard practice* as the baseline once the RUL of the pre-existing equipment, is exceeded.

Table E-96: Ex Post Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	608,892	67.0	0
Baseline 2	608,892	67.0	0

Source: DNV KEMA analysis

Note that savings relative to both baselines were equivalent because only lamps and ballasts were replaced, as opposed to whole fixtures. Since the fixture assemblies were not replaced, Title 24 was not triggered. As such, standard practice would have been to replace the existing lamps and ballasts with equivalent components as those components failed.

Project Description

Measure 1: The Oakland Coliseum DMV field office completed a comprehensive lighting retrofit of the DMV building, as well as the associated parking lot. According to ex ante documentation, the original plan was to retrofit 150 interior fixtures and 36 exterior fixtures, and install 16 wall switch occupancy sensors. The wall switch occupancy sensor controls were intended to control 55 of the retrofitted interior fixtures.

Ex Ante Savings

Johnson Controls conducted the ex ante savings analysis using a spreadsheet calculation.[58] In general, for any group of fixtures, savings were calculated as:

$$kWh_{saved} = \frac{n}{1000}(W_{bl}h_{bl} - W_{ins}h_{ins})$$

Where,

n	= Number of affected fixtures
W_{bl}	= Baseline Fixture Wattage [W]
h_{bl}	= Baseline Operating Hours [h]
W_{ins}	= Installed Fixture Wattage [W]
h_{ins}	= Installed Operating Hours (potentially adjusted for occupancy sensors) [h]
1,000	= [W/kW]

Savings from all affected fixture groups were then summed to estimate gross project savings.

Project Evaluation

A DNV KEMA engineer visited the facility on August 9, 2011 to verify the fixture retrofits and occupancy sensor installations, install time-of-use data loggers, and gather facility lighting schedule data to assist in assessing energy savings. During verification, a total of 148 retrofit interior fixtures were identified, of which 17 were controlled by occupancy sensors. In addition, 30 exterior induction lights were identified. Relative to the ex ante claims, the number of interior retrofit fixtures was reduced by two and the number of occupancy-sensor controlled lights was reduced by 38.

There were ten time-of-use data loggers installed during the initial site visit to establish lighting schedules. Five of the loggers were placed throughout the main floor of the DMV building where 90 of the 148 retrofit lights were located; the remaining loggers were distributed throughout other interior spaces with large quantities of affected fixtures. Table E-45 below contains a summary of all monitoring equipment that was installed during the initial site visit.

58 See the Johnson Controls spreadsheet titled "DMV Lighting.xls" for the detailed calculation used in the ex ante analysis.

Table E-97: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
Main Floor (A)	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Main Floor (B)	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Main Floor (C)	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Main Floor (D)	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Main Floor (E)	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Conference Room	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Break Room	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Break Area Hall	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Storage	Dent Lighting*logger*	On/Off Records	N/A	37 Days
Restroom	Dent Lighting*logger*	On/Off Records	N/A	37 Days

Source: DNV KEMA analysis

After 37 days of monitoring, the data loggers were retrieved. Table E-77 below presents (1) a summary of the average monitored operating schedules for each logger by day type; (2) an estimate of annual operating hours for each monitored lighting group; and (3) peak coincidence factors for the lights monitored by each logger.[59]

59 Peak coincidence factors were calculated using the CPUC defined 2-5 p.m. weekday peak time frame for non-weather dependent measures.

Table E-98: Metered Operating Schedules

Monitored Lighting Group	Hours per Weekday	Hours per Weekend Day	Hours per Holiday	Annual Operating Hours	Peak Coincidence Factor
Main Floor *(Average of five loggers)	16.4	8.6	14.4	5,168	1.00
Conference Room	3.7	0.0	0.1	918	0.34
Break Room	19.4	4.8	0.0	5,348	1.00
Break Room Hall	24.0	24.0	24.0	8,758	1.00
Storage Room	11.1	0.0	0.0	2,781	1.00
Restroom	7.8	0.0	0.0	1,947	0.74

Source: DNV KEMA analysis

In the case of the main floor lights, the simple average of the five recorded schedules was taken to arrive at the operating hour estimates presented in Table E-77.

Some of the schedules presented in Table E-77 implicitly include the impact of occupancy sensors, while others do not. Therefore, in order to make the monitored schedules applicable to other spaces in the facility that were not monitored, as well as to define the base case for occupancy sensor-monitored areas, it was necessary to derive both "occupancy-sensor controlled" and "uncontrolled" schedules from the monitored schedules. In order to derive occupancy-sensor controlled schedules from the metered schedules for uncontrolled areas (all monitored spaces besides the restroom), the annual operating hours were simply multiplied by .7. This approach follows from the standard practice assumption that occupancy sensors yield a 30 percent reduction in time-of-use.[60]

The reverse approach (that is, generating uncontrolled schedules from metered occupancy sensor controlled schedules) was slightly more complicated for the restroom data logger. The complication arose from the fact that it is possible for the reverse approach to yield greater than 8,760 hours of operation. For instance, if the restroom logger had recorded a schedule amounting to 7,000 annual operating hours, then the assumed uncontrolled schedule would be $\frac{7,000}{.7}$, or 10,000 hours. Since this is clearly not possible, the analysis approach was refined by looking at the hourly schedules for each of the day types in Table E-77. For a given hour, the equivalent uncontrolled usage was calculated as $\frac{TOU_{hour}}{.7}$, where time-of-use (TOU) represents the fraction of the hour the lights were in use. If this value exceeded 1.0, the baseline usage in that hour was simply assumed to be 60 minutes. Usage estimates from all hours were then

60 *Mid-Atlantic Technical Reference Manual Version 1.1, pg. 83, October 2010.*

summed to arrive at revised "uncontrolled" lighting usage estimates by day type. These values were then scaled to an annual schedule to yield the final "uncontrolled" lighting usage projections for the restroom space.

The original and modified schedules were then applied to unmonitored lighting groups in the facility according to their anticipated usage. For instance, the one monitored restroom schedule was also applied to the five other restrooms in the building. Similarly, the break area hallway schedule was applied to the other hall way in the building. In the few instances where the monitored schedules were not applicable to certain space types (such as the exterior lights), the implementer's schedules were retained unless there was sufficient evidence—either from interviews with site contacts or observed usage during the site visits—to change the schedules.

After assigning schedules to each group of retrofit lights, energy savings with respect to Baseline 1 (called the "existing conditions" baseline) were calculated using the same general methodology used in the ex ante analysis. Savings relative to Baseline 2, the standard practice baseline, were identical to savings relative to Baseline 1 because the DMV did not completely replace the existing fixtures, opting instead to only replace lamps and ballasts. If the entire fixture assemblies had instead been replaced, Title 24 would have been triggered and served as the measure baseline. Instead, standard practice dictates that the DMV would have simply replaced the lamps and ballasts with equivalent components as existing units failed.

Savings Results

The project achieved annual energy savings of 41,115 kWh and 4.5 kW in demand savings relative to the Baseline 1 and Baseline 2.

Discussion

The project saved slightly more energy than projected in the ex ante analysis primarily because the operating hours observed during evaluation monitoring exceeded the operating hours estimated in the ex ante calculation. In the ex ante analysis, the connected load weighted average operating hours for the base and installed cases were 3,306 hours and 2,994 hours respectively; in the ex post analysis, these same parameters increased to 4,105 hours and 4,073 hours. While these figures help explain the increase in energy savings, the figures also reveal why energy savings did not increase more substantially. Note that even though the total operating hours increased for both the base case and installed case, the *differential* between the base case and installed case operating hours decreased from 312 hours in the ex ante analysis to 32 hours in the ex post analysis. This shift, which indicates a reduction in savings potential for the project, was caused by the fact that fewer occupancy sensors were installed than originally planned. As a result, only 17 lights in the facility realized reduced operating hours relative to the base case, as opposed to the 55 projected in the ex ante analysis. On the whole, this factor was more than offset by the overall increase in operating hours, which in turn explains the 110.1 percent realization rate.

Ex Post Life-cycle Savings

Energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable. In this case, standard practice would have entailed replacing failing lamps and ballasts with equivalent components. As such, life-cycle savings were equal relative to both Baseline 1 and Baseline 2.

Table E-92 below provides the annual energy savings estimates, EULs, and RULs that fed into the life-cycle savings calculations. Note that the project was broken down into two subcomponents since the new fixtures and occupancy sensors have different EULs.

Table E-99: Values Used in Life-cycle Savings Calculations by Measure

Measure	Relative to Pre-existing Equipment		Relative to Expected Replacement Equipment		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
EEM 1 – Lighting Retrofit Component	39,996	0	39,996	0	15	0
EEM 1 – Occupancy Sensor Component	1,119	0	1,119	0	8	0

Source: DNV KEMA analysis

Table E-12 provides life-cycle savings for the project relative to Baseline 1 and Baseline 2.

Table E-100: Baseline 1 and Baseline 2 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	41,115	4.5	0
2	2012	41,115	4.5	0
3	2013	41,115	4.5	0
4	2014	41,115	4.5	0
5	2015	41,115	4.5	0
6	2016	41,115	4.5	0
7	2017	41,115	4.5	0
8	2018	41,115	4.5	0
9	2019	39,996	4.4	0
10	2020	39,996	4.4	0
11	2021	39,996	4.4	0
12	2022	39,996	4.4	0
13	2023	39,996	4.4	0
14	2024	39,996	4.4	0
15	2025	39,996	4.4	0
16	2026	0	0.0	0
Life-cycle	Total	608,892 kWh	67.0 kW-years	0 therms

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

DDS Sonoma Campus Retrofit

Site Summary

The Sonoma DDS campus was awarded loan funds to implement three main EEMs. The first EEM is a campus-wide interior lighting retrofit. The second and third EEMs are for the installation of variable speed drives (VSD) to the air handling units in the Nelson and EJOR buildings (Johnson-Ordahl, Emparan-Regamy).

Before the retrofit, campus-wide interior lighting was predominately of the T12 fluorescent or incandescent types. These were replaced with either compact fluorescent fixtures or 5th generation T8 linear fluorescent fixtures. As for the HVAC existing conditions, the air handling units at the Nelson and EJOR buildings were constant volume fans that operated 24 hours a day.

Ex post energy savings were estimated at 1,612,994 kWh and 51,955 therms. This represent 75 percent and 144 percent of the ex ante electric and gas energy savings (Table E-43). The following contributed to the energy savings difference:

- Preretrofit data monitoring showed lower fan energy consumption relative to the ex ante eQuest baseline. This is true for both the Nelson and EJOR buildings. The ex post baseline model was revised to reflect this.
- Postretrofit data monitoring at the Johnson-Ordahl building supports a fan energy consumption that were higher than estimated in the ex ante eQuest model. The ex post VSD model was also revised to reflect this.

The combination of these two factors lowered the electric energy savings.

On the other hand, DNV KEMA cannot explain the higher ex post therms savings. Based on ante eQuest files provided, the gas savings value claimed in the report is not the same as the values from the ex ante simulation runs, and most likely represents a data entry error.

Table E-101: Energy Savings Summary

Measure	Ex Ante			Ex Post			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
EEM 1 – Interior Lighting	865,790	Not reported	0	862,258	361.5	0	100%	N/A
EEM 2 – VFD fans (Nelson)	520,202	Not reported	27,778	419,567	39.8	27,203	81%	98%
EEM 3 – VFD fans (EJOR)	774,723	Not reported	8,336	331,168	39.1	24,752	43%	297%
Total	2,160,715	Not reported	36,114	1,612,993	440	51,955	75%	144%

Source: DNV KEMA analysis

The overall results from Table E-101 yield a life-cycle energy savings of 24,194,903 kWh and 779,325 therms (Table E-102). Life-cycle savings were calculated relative to the pre-existing condition for the full EUL of each measure.

Table E-102: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	24,194,910	6,600	779,325

Source: DNV KEMA analysis

Project Description

This project was implemented at the Sonoma DDS campus and focused on upgrading the interior lighting system campus-wide along with retrofitting the air handler units with VSD controls on select buildings. The buildings chosen for the air handler retrofit included the EJOR (two buildings) and Nelson buildings. At the two EJOR buildings, the airside system consists of three sets of supply and return fans for a total of 12 fans. At the Nelson building, the airside system is divided into eight zones each with a set of supply, return, and exhaust fans for a total of 24 fans. The fans operated at constant volume and were replaced with VSD controls. The lighting upgrade consists primarily of changing out the existing T12 lighting system with 5th

generation T8 linear fluorescent fixtures. Some incandescent fixtures as well as occupancy sensors were included as part of the retrofit.

Ex Ante Savings

EEM 1 – Interior Lighting Retrofit

The final lighting analysis was not available for review. However, based on an earlier version of the analysis, the energy savings were calculated using a spreadsheet that contained information on the pre and post lighting wattages and quantities. Hours of operations were assumed at either 2,080 hours or 8,760 hours, depending on where the fixtures were located. Fixtures with occupancy sensors were given a 25 percent reduction in operating hours in the proposed case.

EEM 2/EEM 3 – VSD fans

Energy savings were calculated using an un-calibrated eQuest model. The fan operating parameters such as overall efficiency and static pressure were estimated. To model the VSD fans in the efficient case, the fan control was changed from constant volume to variable speed operation and the minimum fan ratio at the zonal level was revised from 100 percent to 50 percent. This resulted in substantial electric and gas savings from fan turndown and interactive effects from the central plant.

Project Evaluation

A DNV KEMA field engineer visited the project's site on July 12, 2011 to perform pre-retrofit metering and again on February 7, 2012 to perform postretrofit metering.

Data Monitoring

During the pre-retrofit metering effort, all three supply fans at the Johnson-Ordahl building were monitored along with two of the supply fans at the Nelson building for a total of five units. When the equipment was retrieved 10 weeks later, it was discovered that the contractor threw out three of the five data loggers (two at Johnson-Ordahl and one at Nelson) when the VSDs were installed. Fortunately, spot power measurements were taken at the time of the logger installation and since the fans ran 24 hours a day at constant speed, the loss of some of the data did not invalidate the pre-retrofit monitoring effort. Table E-103 summarizes the pre-retrofit monitoring of equipment that was installed at this site.

Table E-103: Pre-retrofit Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
3 Supply fans at Johnson-Ordahl building	DENT Elite Pro	True power, amperage, voltage, power factor	15 minutes	10 weeks[61]
2 Supply fans at Nelson building	DENT Elite Pro	True power, amperage, voltage, power factor	15 minutes	10 weeks
Weather dry bulb	Hobo Microstation with Temp sensor	Temperature	1 minute	10 weeks

Source: DNV KEMA analysis

For the postretrofit metering effort, the same fans at the Johnson-Ordahl and Nelson buildings were monitored along with the outside air temperature. Spot power measurements were taken for all the fans at the Nelson building where safe access was available and included four of the eight largest airside systems.

Lighting time-of-use loggers were also installed at four buildings to measure time-of-use. The selection for fixture locations was limited to fixtures under 10 feet high (due to limitations on accessibility) and the fixture's completion status.[62] Table E-104 summarizes the postretrofit monitoring equipments that were installed at this site.

61 Left in longer to minimize number of site visits.

62 Only 4 buildings were completed at the time of the site visit. The majority of the retrofit had not yet been completed. DNV KEMA decided to move forward with the postretrofit site visit despite this, since DNV KEMA did not expect substantial deviation from the final lighting retrofit plans (obtained from the contractor), a complete census of the lighting retrofit was not possible due to size of the project, and time-of-use logging for the high impact fixtures were not possible due to access issues (fixtures are high bay or greater than 10 feet high).

Table E-104: Postretrofit Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
3 Supply fans at Johnson-Ordahl building	DENT Elite Pro	True power, amperage, voltage, power factor	5 minutes	3 weeks
2 Supply and return fans at Nelson building	DENT Elite Pro or Microstation amp logger	True power, amperage, voltage, power factor	5 minutes	3 weeks
Weather dry bulb	Hobo Microstation with Temp sensor	Temperature	1 minute	3 weeks
(14) Lighting fixtures at various buildings	Dent TOU	On time	Continuous	3 weeks

Source: DNV KEMA analysis

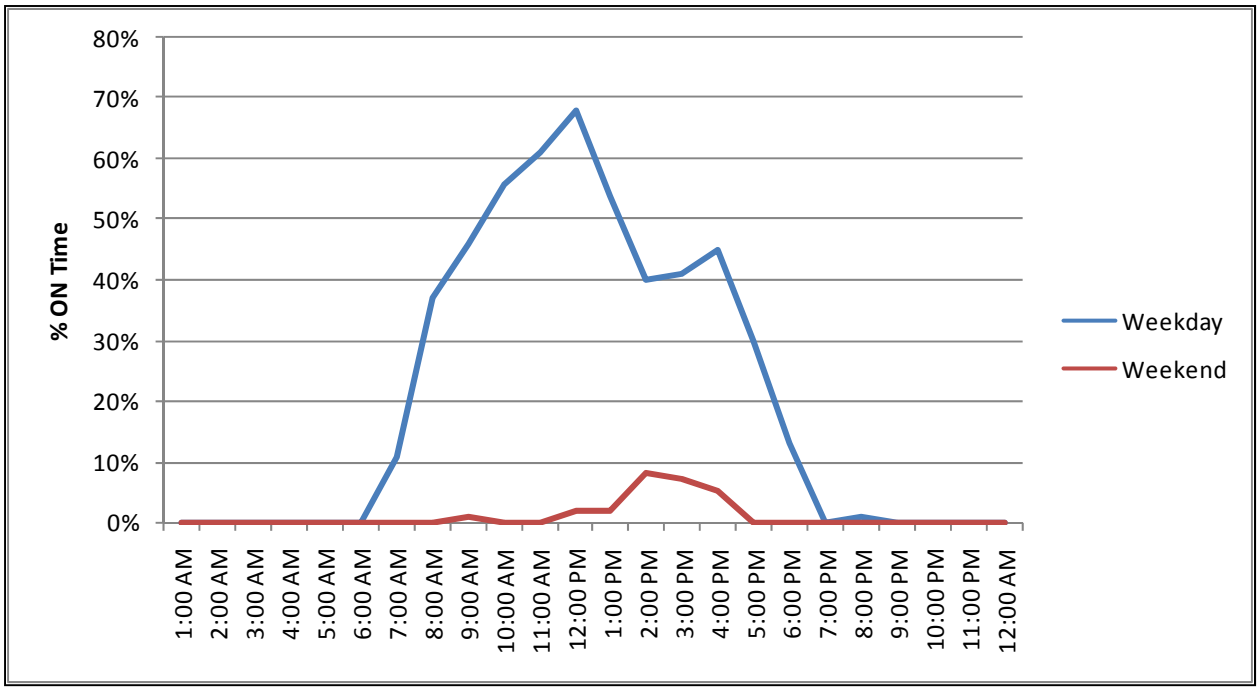
EEM 1 – Interior Lighting Retrofit Analysis

Verification of the lighting retrofit was only verified at buildings where the project had been completed. At the time of the site visit only the Slater, Turner, Van Horn, and Farrell buildings were completed. The police station was completed on the return trip and was verified when the loggers were collected. In general, the proposed fixtures matched the fixtures described in the spreadsheet provided to DNV KEMA with only minor discrepancies. These discrepancies included a few fixtures that did not exist and some mismatch to the number of lamps per fixtures. These values were revised in the calculation spreadsheet but did not impact the overall energy savings much because their contribution was small relative to the total number of fixtures surveyed.

For the analysis, DNV KEMA started with the initial spreadsheet calculations provided by Johnson Controls. This version claimed a total of 930,957 kWh were saved from the lighting retrofit and had not been updated to reflect changes made to the lighting scope. To calculate ex post energy savings for this measure, a number of entries were eliminated due to scope changes. These included the fixtures at the Roadtruck, Credit Union, L, Rectangle, Bentley, and Brent buildings. The remaining 9,067 fixtures were reconciled with a list provided by Johnson Controls. Further steps described below were performed to determine the energy savings from the lighting retrofit and incorporated the time-of-use data collected on-site along with a quality check on the calculation algorithm.

Analysis of the data loggers placed in the Turner, Van Horn, and Farrell buildings yielded the following time-of-use profile for the main room lights which are responsible for 75 percent of the energy savings for these buildings (Figure 35).

Figure 35: Typical Weekday and Weekend Day Fixture Lighting ON Time



Source: DNV KEMA analysis

This profile equates to 1,334 annual hours of use. The respective fixture hours of operation were revised based on the lighting logger data in the spreadsheet. Only fixtures for the Turner, Van Horn, Farrell, and Slater buildings were revised. There were no changes to the hours of operation for the other buildings where the retrofit had not yet been performed. This is because one building's lighting fixture hours of use cannot be assumed for the other buildings since the operation from building to building varied so much. For example, data from the Slater building only yielded a total of 246 annual hours of use versus the 1,334 found at the Turner building cluster. For buildings where no data loggers were placed, DNV KEMA reverted to the ex ante assumptions of 2,080 hours or 8,760 hours which are considered reasonable based on the operation hours of the campus and functions of the space.

Finally, the ex ante lighting survey and calculation algorithms were examined for consistency. DNV KEMA compared the fixture type descriptions with the SPC fixture demand and found that a large number of these values were incorrectly inputted. Table E-105 below summarizes the corrections made to the lighting spreadsheet and the total quantity of affected fixtures.

Table E-105: Corrected Fixture Input Values

Lamp/fix	Lamp Type	Quantity	SPC CODE	KEMA (kW)	Implementer (kW)
2	26W CFL SI	18		0.052	0.026
2	28W 4' T8	1	F44ILL-R	0.042	0.084
2	28W 4' T8	25	F41ILL-R	0.042	0.021
4	28W 4' T8	51	F41ILL-R	0.084	0.021
4	28W 4' T8	99	F42WLL-R	0.084	0.042
4	28W 4' T8	26	F43ILL-R	0.084	0.063
2	ELMDT13	65		0.026	0.013
3	ELMDT13	3		0.039	0.013
2	F25T8TL841AL TO	18	F31ILL-R	0.046	0.023

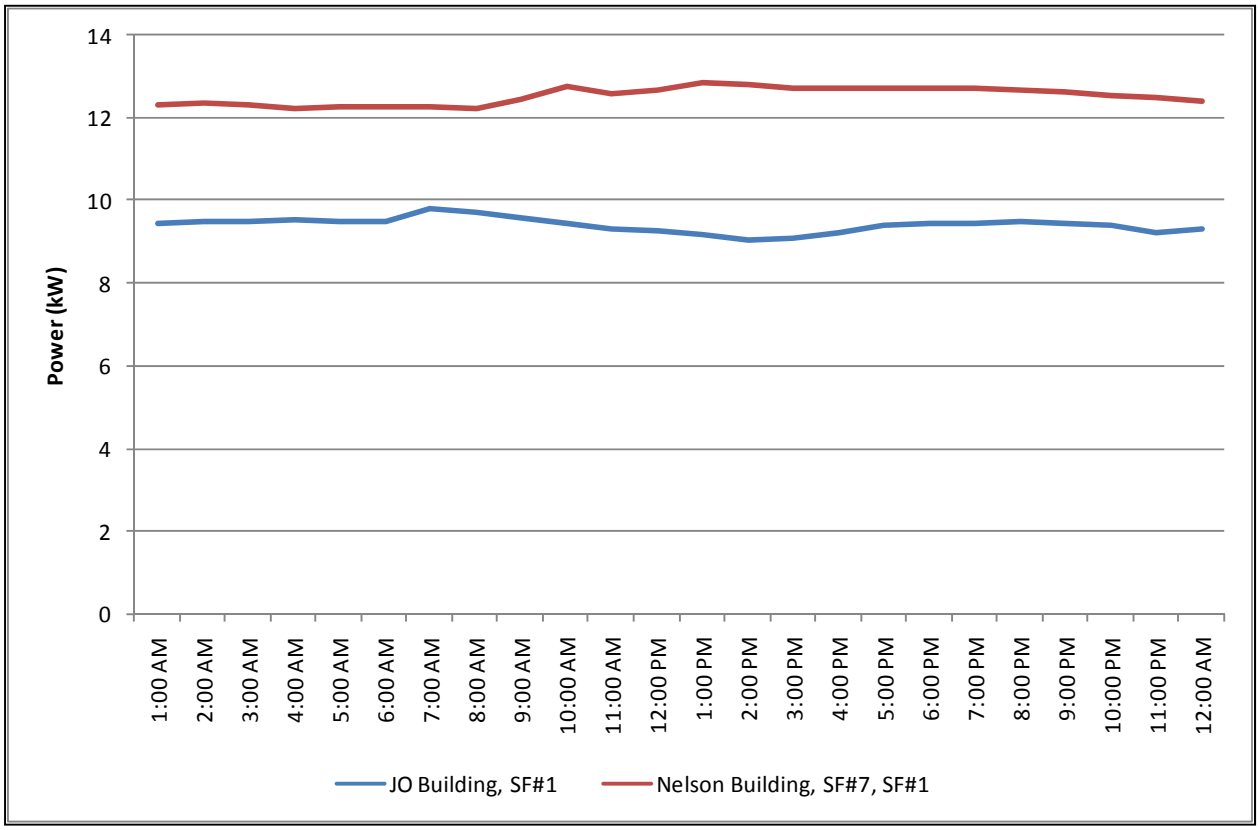
Source: DNV KEMA analysis

The total energy savings for the lighting retrofit were calculated using pre and postretrofit fixture wattages and quantities and yielded an ex post energy savings of 862,258 kWh. This value assumes that all fixtures scheduled to be retrofitted will be performed according to specifications. Based on the audit for the buildings that have already been retrofitted, there is no reason to suspect a significant deviation from the plan.

EEM 2/3 – VSD fans

Preretrofit data from the supply fans logged more than 10 weeks at the Johnson-Ordahl and Nelson buildings yielded the following daily power draw profile:

Figure 36: Average Day Supply Fan Power Draw Profiles at the Johnson-Ordahl (JO) and Nelson Buildings

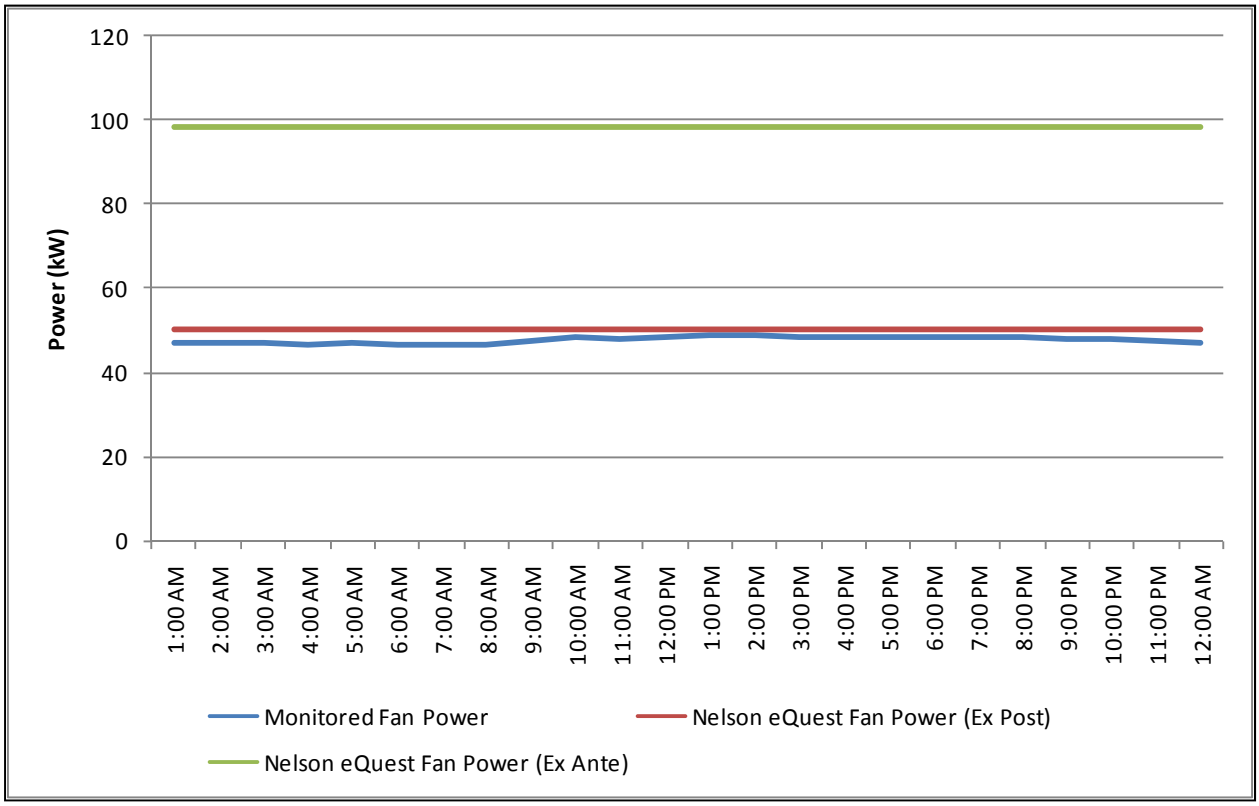


Source: DNV KEMA analysis

As expected, the constant speed fans have a consistent power draw profile throughout the day. To determine the total fan energy for each building, the profiles in Figure 26 were scaled up relative to the spot power measurements of all the fans. For example, at the Nelson building, a total spot power of 50.3 kW was recorded for all the fans. The fans that were monitored included supply and return fan #7 and fan #1 with a total spot power of 13.2 kW. The scale up factor for fan power at this building is a 50.3/13.2 factor or a 3.81 factor. This scale up factor is necessary to account for the fans that were not monitored.

Next, the baseline eQuest model was simulated and the fan energy output was compared to the monitored data. The ex ante eQuest model's fan power overestimated the baseline fan power by a factor of two. Adjustments to the fan power parameters in eQuest were necessary in order to reduce the fan power estimate to reasonable levels. This included the reduction of the static head from a 3 inch water column to a 2.25 inch water column and increasing the total fan efficiency from 0.48 to 0.765. As shown in Figure 37, when these adjustments were made, the fan power draw profile more closely match the data collected during the preretrofit conditions.

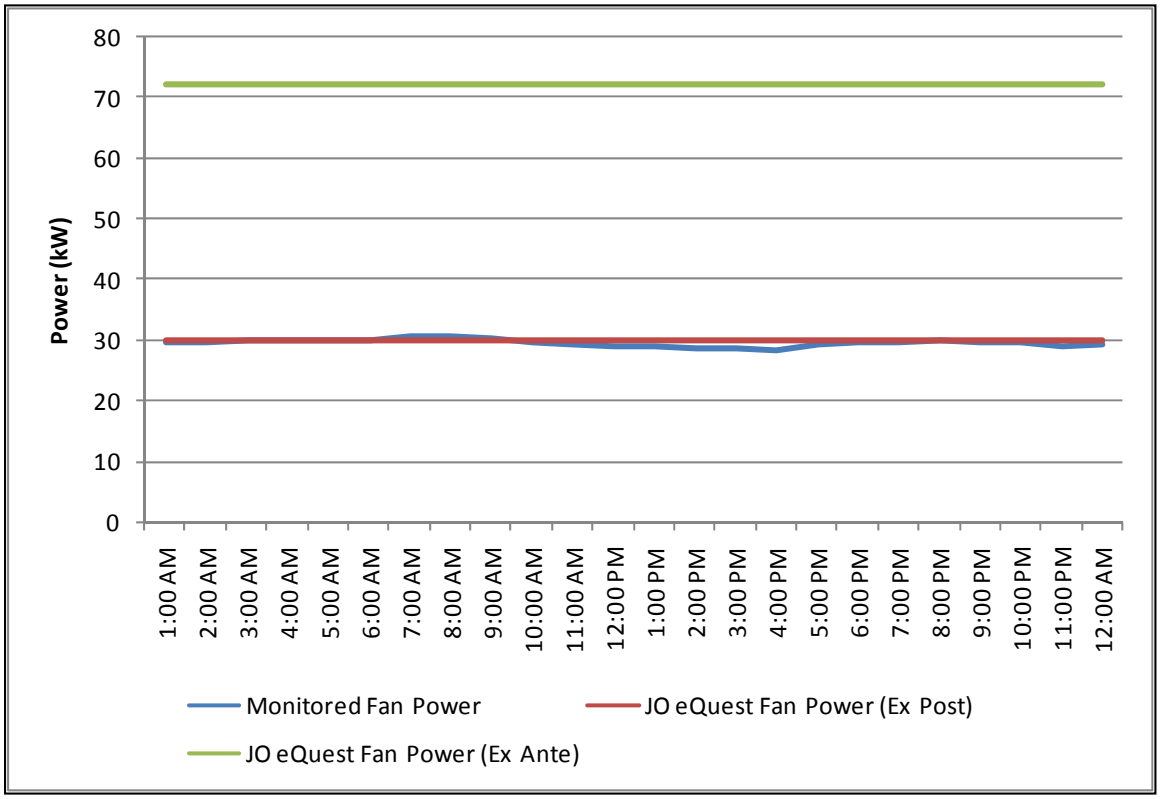
Figure 37: Nelson Building Fan Power Pre-retrofit Conditions Compared to Ex Post and Ex Ante eQuest Fan Power Outputs



Source: DNV KEMA analysis

Similar adjustments were required for the Johnson-Ordahl building baseline. The fan's static head was reduced from 3.0 inches of water column to 2.7 inches of water column and total fan efficiency was increased from 0.53 to 0.765. The baseline ex post and ex ante fan power draw profiles are compared with the preretrofit data for the Johnson-Ordahl building in Figure 38 (below), and shows that the ex ante eQuest model overestimates the fan power by almost 2.5 times.

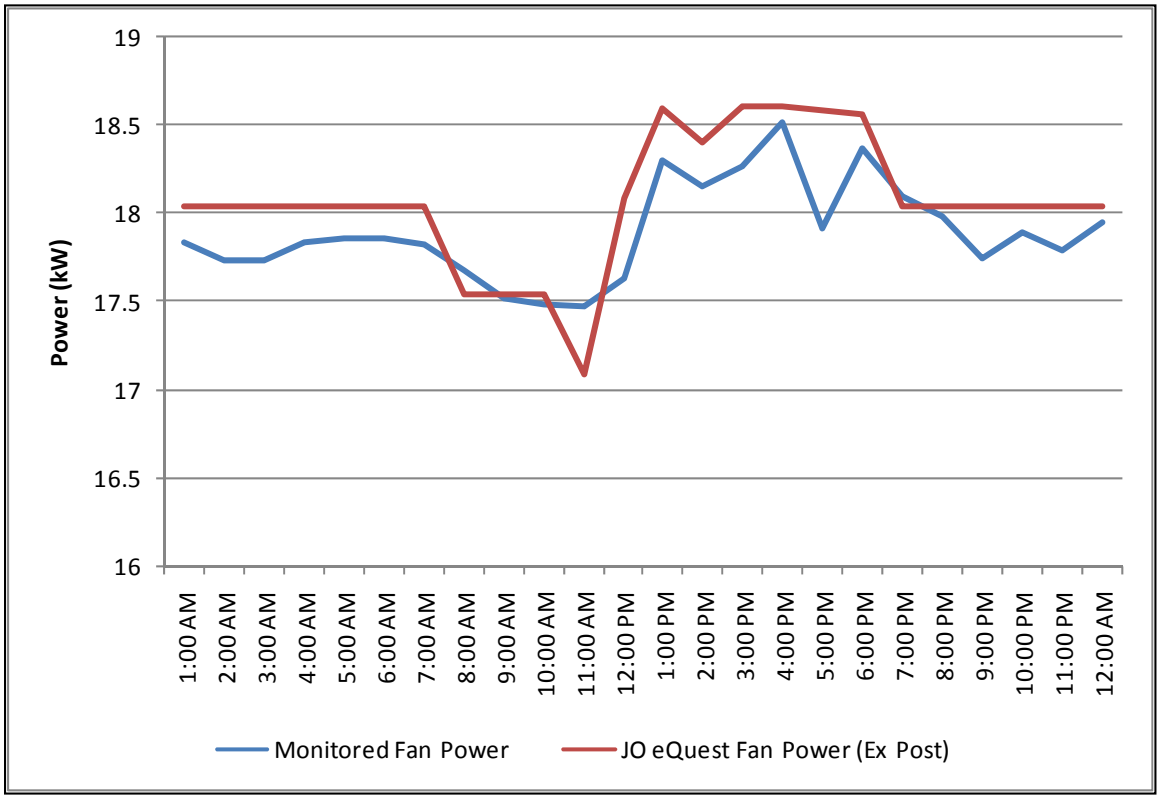
Figure 38: Johnson-Ordahl (JO) Building Fan Power Preretrofit Conditions Compared to Ex Post and Ex Ante eQuest Fan Power Outputs



Source: DNV KEMA analysis

Next, to determine energy savings for the VSD retrofit at the Johnson-Ordahl building, the fan controls were switched to variable speed drive, the minimum flow ratio was revised to 80 percent, and the total fan efficiency was revised upwards to 0.79 percent to account for the premium efficiency motors. The fan energy was compared to the postretrofit fan data collected on-site which matched reasonably well (Figure 39).

Figure 39: Johnson-Ordahl (JO) Building Postretrofit Fan Power Compared to Ex Post and Ex Ante eQuest Outputs



Source: DNV KEMA analysis

Total energy savings were computed by taking the difference of the annual energy consumption of the baseline case (constant speed fan control) and efficient case (VSD fan control). For the Johnson Ordahl building, the eQuest outputs show a total energy savings of 165,584 kWh and 12,376 therms. The results were multiplied by two to account for the Emparan-Regamy building, which is identical to the Johnson Ordahl building. The total energy savings for EEM 3 is, therefore, 331,168 kWh and 24,752 therms.

A similar analysis was planned for the postretrofit case at the Nelson building. However, examination of the data shows that although VSDs were indeed installed, the units still ran at 100 percent speed. A follow-up conversation with the building engineer revealed that the contractors did not finish commissioning of the Nelson building even though the VSDs had been installed for more than six months. The contractor plans to return and finish the commissioning sometime later this year.

Since the Nelson building had not yet been commissioned, the postretrofit data for this building is not useful for the calibration of the eQuest model. DNV KEMA, therefore, reverted to the ex ante assumptions for the postretrofit case. The fan control strategy was changed to variable speed controls and the minimum flow ratio was revised down to 50 percent in the eQuest

model. The ex post energy savings for the Nelson building (EEM 2) is estimated at 419,567 kWh and 27,203 therms. This energy savings estimate has more uncertainty because of the lack of post commissioning data.

Note that fan power data was used to calibrate both the pre and post eQuest model. Table E-106 shows the calibration statistics for fan power and indicates the ex post models are excellent predictors of fan power both in the pre and postretrofit conditions. Acceptable mean bias error and coefficient of variation (CV) are 10 percent and 30 percent, respectively, which are levels that are often very difficult to achieve.

Table E-106: Calibration Statistics

eQuest Model	Mean Bias Error	CV of RMSE
EJOR, pre model	2%	5%
EJOR, post model	1%	4%
Nelson, pre model	6%	9%
Nelson post model	Not calibrated due to lack of data	

Source: DNV KEMA analysis

Savings Results

The three EEMs for this site resulted in 1,612,994 kWh, 51,955 therms and 63.9 kW of demand savings. Demand savings were estimated in accordance with the CPUC's peak period definition.[63] A breakdown of savings by individual measure is presented at the beginning of this report in Table E-43. The ex ante savings estimates, which were acquired from the program's monthly status reports, are also provided as a point of reference.

Discussion

The ex post electric and gas energy savings overall for this project was 75 percent and 144 percent of the ex ante claims, respectively. Discrepancies between the two savings estimates are addressed below by measure.

EEM 1 – Interior Lighting Retrofit

Ex post energy savings for the lighting retrofit were close to 100 percent of the ex ante estimates even though there were some significant adjustments made to many of the postretrofit fixture input wattages mentioned in the previous sections. These adjustments reduced the initial

63 According to the CPUC, peak demand savings are defined as the average demand reduction occurring during the three consecutive hottest weekdays of the year between the hours of 2 p.m. and 5 p.m.

energy savings estimate of 930,957 kWh to 862,258 kWh. It is possible that the updated energy savings value in the status reports were updated to correct the same errors found by DNV KEMA, but without that spreadsheet DNV KEMA cannot confirm this. The adjusted lighting hours for four of the buildings reduced the energy savings slightly but did not impact the measure as a whole since the overall energy savings for those buildings were small relative to the scope of the measure.

EEM 2 – VFD fans (Nelson)

The energy savings for this measure was 419,567 kWh. This represents 81 percent of the ex ante electric energy savings. There is less energy savings for this measure because the baseline fan energy was overestimated. Figure 27 shows that the actual baseline fan power from the preretrofit monitoring effort was only about 50 kW while the ex ante eQuest model estimated this at 98 kW. This suggests that the fan energy savings potential was much higher than originally estimated. When this value was corrected in the baseline model, the energy savings was reduced to 81 percent of the ex ante estimates and was chiefly due to a reduction in baseline fan energy. Gas energy savings for the Nelson building was in line with the ex ante estimates at 27,203 therms.

EEM 3 – VFD fans (EJOR)

This measure suffered from the same issues as EEM 3. In this case, the baseline fan energy was overestimated by almost 2.5 times the actual amount (29 kW actual versus 72 kW modeled). Furthermore, the minimum flow ratio after the VSDs were installed did not match what was observed in the data. This ratio was estimated at 50 percent whereas postretrofit fan power showed a minimum flow ratio closer to 80 percent. The combination of these two factors narrowed the fan energy savings band for this measure and resulted in an electric energy savings of 331,168 kWh which was only 43 percent of the ex ante estimates.

On the other hand, gas energy savings were 24,752 therms versus the 8,336 therms claimed in the project files. It is unclear why 8,336 therms were claimed in the project files and status update since the eQuest model provided to DNV KEMA clearly did not report such a small number. Given the similar HVAC system type, EEM type, and building size of one of the EJOR buildings to the Nelson building the energy savings should be more in line with the Nelson building estimates. The value reported in the status updates and project files is likely due to a data entry error.

Ex Post Life-cycle Savings

Typically, energy savings for this program are calculated relative to two established baselines, referred to as Baseline 1 and Baseline 2. Baseline 1 considers the existing conditions found before the EEM implementation and takes into account the equipment's operating efficiency along with the control strategies found at that time. Life-cycle savings for Baseline 1 assumes the pre-existing equipment would have continued to operate indefinitely, up to the EUL of the new equipment. In contrast, Baseline 2 uses the pre-existing equipment as the measure's baseline until the end of the existing equipment's RUL. After the remaining useful-life period, and up until the end of the EUL of the installed measure, the measure's expected-replacement

baseline is used. This baseline considers either minimally code compliant conditions or standard practice when no code is applicable.

The lighting system for this site was more than 45 years old but without DGS funds, it would have remained in place indefinitely. Therefore, Baseline 1 (considering the existing equipment) is used in the life-cycle savings calculation. For the VSD measures, the baseline is simply the fans operating without the new controls. Baseline 2 is not applicable for any of the measures for this site.

The EUL for both VSDs on supply fans and indoor lighting fixtures is 15 years according to DEER. Details of this calculation are shown in Table E-107.

Table E-107: Values Used in Life-cycle Savings Calculations by Measure

Measure	Electric Energy (kWh)	Gas Energy (therms)	EUL	RUL
EEM 1 – Interior Lighting	862,258	0	15	N/A
EEM 2 – VFD fans (Nelson)	419,567	27,203	15	N/A
EEM 3 – VFD fans (EJOR)	331,168	24,752	15	N/A

Source: DNV KEMA analysis

The life-cycle savings for this site considering the EUL is calculated at 24,194,903 kWh and 779,325 therms. Table E-108 below shows the life-cycle savings by year for these measures.

Table E-108: Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	1,612,994	440	51,955
2	2012	1,612,994	440	51,955
3	2013	1,612,994	440	51,955
4	2014	1,612,994	440	51,955
5	2015	1,612,994	440	51,955
6	2016	1,612,994	440	51,955
7	2017	1,612,994	440	51,955

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
8	2018	1,612,994	440	51,955
9	2019	1,612,994	440	51,955
10	2020	1,612,994	440	51,955
11	2021	1,612,994	440	51,955
12	2022	1,612,994	440	51,955
13	2023	1,612,994	440	51,955
14	2024	1,612,994	440	51,955
15	2025	1,612,994	440	51,955
16	2026	0	0	0
Life-cycle	Total	24,194,910	6,600	779,325

Source: DNV KEMA analysis

ON-SITE EVALUATION REPORT
Energy Efficient State Property Revolving Loan Fund Program

DMV Yuba City Building Retrofit

Site Summary

The DMV in Yuba City is a small office type building served by direct expansion (DX) split-system air conditioning units and gas-fired furnaces. Two EEMs were implemented at the site. The first measure is for a lighting retrofit which included the replacement of the existing ballast and lamps with higher efficiency units. The second is for the replacement of the cooling and heating system and also considers efficiency gains from upgrading the economizer, adjusting the heating schedule, and installing optimal start and stop controls.

The evaluators performed a site visit to verify installation and installed monitoring equipment for a period of four weeks. The analysis using this data yielded an overall electric energy savings of 120 percent and natural gas savings of 48 percent when compared to the ex ante estimates. Details by measure are provided in Table E-109.

Table E-109: Energy Savings Summary

Measure	Ex Post			Ex Ante			Realization Rate	
	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric Energy (kWh)	Demand (kW)	Gas Energy (therms)	Electric	Gas
Lighting	21,332	2.7	-130	20,391	Not reported	Not reported	105%	N/A
HVAC	33,490	24.7	469	25,416	Not Reported	713	132%	66%
Total	54,821	27.4	339	45,807	Not Reported	713	120%	48%

Source: DNV KEMA analysis

Higher energy savings are estimated due to longer hours of use for the HVAC units in addition to a heat island effect accounted for in the modeling. The reduced natural gas savings is due to the absence of the optimal stop/start controls, which could not be confirmed by the site contacts. Additional support for the removal of the optimal stop/start control in the postretrofit eQuest model is supported by a comparison of the metered data and eQuest power output predictions if these controls were employed, which do not match.

Table E-110 below shows the life-cycle energy savings for this site. Life-cycle savings were calculated relative to two baselines:

- Baseline 1 uses the pre-existing condition as the baseline for the full EUL of the installed measures.
- Baseline 2, the dual baseline uses minimally code compliant conditions or standard practice as the baseline once the RUL of the pre-existing equipment is exceeded.

The overall results from Table E-110 yields a life-cycle energy savings of 796,634 kWh and 3,180 therms when using Baseline 1, whereas the life-cycle energy savings of 378,093 kWh and 2,986 therms are estimated when using Baseline 2.

Table E-110: Life-cycle Savings Summary

Baseline Type	Electrical Energy Savings (kWh)	Electrical Demand Savings (kW-years)	Natural Gas Energy Savings (therms)
Baseline 1	796,634	411.6	3,180
Baseline 2	378,093	40.9	2,986

Source: DNV KEMA analysis

Project Description

This project was implemented at the state's DMV branch in Yuba City. The building is a one-story office-type building with approximately 9,800 square feet of conditioned space that is served by direct expansion (DX) split-system air conditioning units and gas-fired furnaces. The project consists of two measures.

Measure 1: Lighting Retrofit—This measure was a fixture-for-fixture replacement from the pre-existing T-8 linear fluorescent lighting system with next generation T8 lamps and electronic ballasts. New occupancy controls were also installed as part of this measure. A total of 122 fixtures (including occupancy sensors) were installed at this site for an estimated ex ante energy savings of 20,391 kWh.

Measure 2: HVAC Retrofit—This measure was for the replacement of the pre-existing split-system HVAC units with new seasonal energy efficiency ratio (SEER) 13 units. A total of seven new units (four 48 kBtu/h and three 60 kBtu/h) replaced the pre-existing cooling system. Similarly, the heating system was replaced with four 80 kBtu/h and three 100 kBtu/h furnaces rated at 97-97.5 AFUE. A temperature-based economizer and heating optimization scheduling were also included in the retrofit. In addition, there is a claim for the implementation of optimal

stop and optimal start controls for the HVAC system. The estimated ex ante energy savings for this measure is 25,416 kWh and 713 therms.

The energy savings for all measures are summarized in Table E-43.

Ex Ante Savings

Johnson Controls (JCI) and Nexant prepared the savings reported in the status update on July 19, 2011 and were assumed to be estimated using eQuest, a building energy modeling application, which uses the DOE 2.2 simulation engine. The savings estimates uses pre- minus post-modeled energy usage from the following main inputs:

- The air conditioning system efficiency was modeled as a 5.4 energy efficiency ratio (EER) system in the pre-retrofit model and 9.35 EER in the postretrofit model. There was an attempt to model an increase in the furnace's efficiency but was inputted incorrectly in the parametric descriptions and resulted in no gas savings for this portion of the retrofit.
- A fixed outside air percentage was modeled in the pre-retrofit model, while economizers with dry-bulb temperature controls were modeled in the postretrofit case.
- The postretrofit model included an optimal start/stop control for the HVAC system along with a revised heating schedule which was not employed in the pre-retrofit model.
- Lighting power density was modeled as 0.73 Watts per square foot (W/sf) in the pre-model and 0.49 W/sf in the postretrofit model.

DNV KEMA notes that the lighting savings reported in eQuest do not match with what is reported in the monthly status updates for the lighting measure (8,082 kWh versus 20,391 kWh). It is not known where the final lighting energy savings reported to the Energy Commission came from. Review of the eQuest models also show that the electric energy savings (26,753 kWh) do not match what is reported in the monthly updates (25,416 kWh). Gas savings, however, do match.

Project Evaluation

A DNV KEMA field engineer visited the project's site on June 16, 2011 to verify measure installation. This visit also included installing true power data loggers on two of the AC units, installing time-of-use photocell data loggers for determining lighting hours of operation, and to corroborate other modeling inputs (temperature set points, building dimensions, and so forth). Additionally, a temporary weather station measuring the dry-bulb and wet-bulb temperatures was deployed at the site. Table E-111 summarizes the monitoring equipment details for this site.

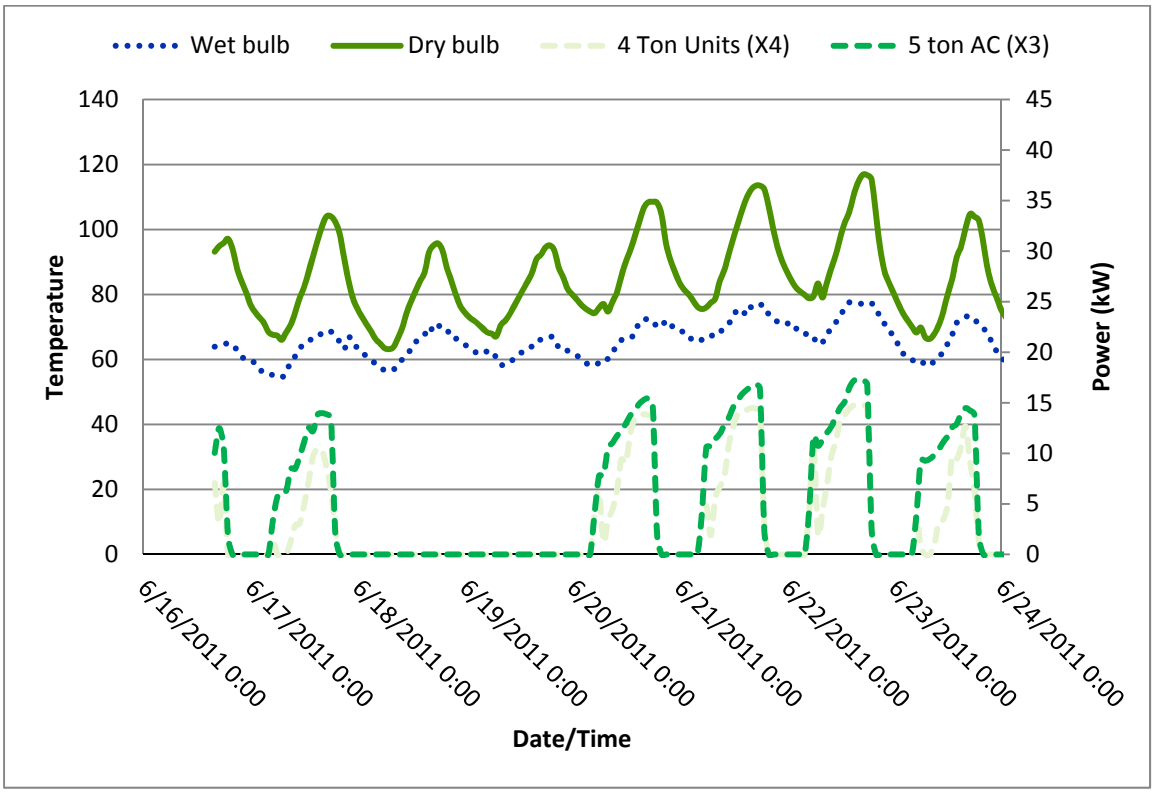
Table E-111: Monitoring Details

Monitored Equipment	Logger Type	Measurement Type	Measurement Interval	Duration
1 Four-ton condenser unit	Wattnode, Microstation	Pulse output (kW)	20 seconds	4 weeks
1 Five-ton condenser unit	Wattnode, Microstation	Pulse output (kW)	20 seconds	4 weeks
5 Light fixtures	DENT TOU lighting loggers	On/Off (time-of-use)	Continuous	4 weeks
1 Outside Air	Microstation with temp/RH sensor	Dry bulb and wet bulb temperature	1 minute	4 weeks

Source: DNV KEMA analysis

The engineer returned on July 15, 2011 to retrieve the data loggers and the weather station. Figure 40 below shows an eight day snapshot of the data for illustrative purposes only (the data for the entire monitoring period were used in the analysis). The power data for the 48 kBtu/h condenser unit were multiplied by four to represent all 48 kBtu/h rated units seen at the site. Likewise, the 60 kBtu/h unit was multiplied by three to represent similarly rated units at the site.

Figure 40: Hourly Power for DX AC Units and Outside Air Temperature, Eight Day Snapshot



Source: DNV KEMA analysis

All visible measure components were verified as summarized in Table E-112. The start/stop control is not visible and can be determined only through inspection of HVAC usage data.

Table E-112: Verification Summary

Equipment	Reported	Verified	Site Notes
T8 Fixtures with electronic ballasts and occupancy sensors	122	122	122 fixtures (including occupancy sensors) were identified. Ballasts model and lamp wattages were checked. Over 95% of the fixtures used 25 Watt bulbs. Rated amperage draw for a two lamp fixture was 0.33 amps at 120 V.
Direct expansion (DX) cooling and gas-fired furnaces	6	7	Nameplate indicates 4 48-kBtu/h and 3 60-kBtu/h units. Cooling units are all SEER 13. The associated furnaces are 4 80-kBtu/h capacity at 97.5% AFUE and 3 100-kBtu/h capacity at 97% AFUE.

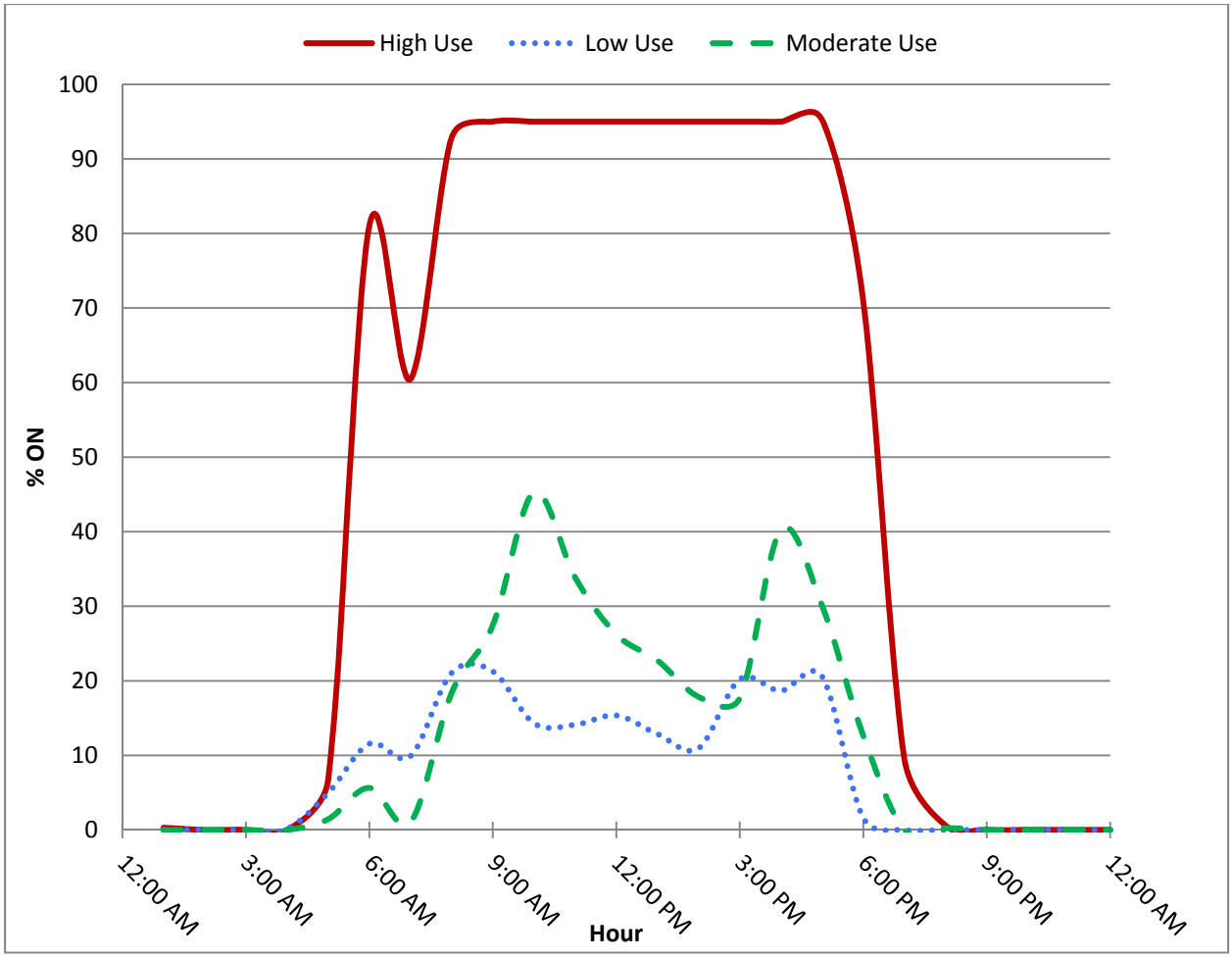
Equipment	Reported	Verified	Site Notes
Economizers	Yes	Yes	Economizer observed to be closed but expected to be in working order. Cannot verify it is temperature or enthalpy based. Assuming temperature based per implementer's eQuest.
Optimum start/stop controls and optimized heating set point	Yes	Not observable	Thermostats were centrally controlled and not available for inspection

Source: DNV KEMA analysis

Measure 1 – Lighting

The ex post savings estimate for the lighting retrofit was generated with a spreadsheet analysis using time-of-use data from the photocell data loggers. The data yielded three typical use profiles as expected, high, moderate, and low (Figure 41 below) for a typical weekday, which represents lighting from the lobby, office, and storage areas, respectively. The figure below illustrates how often the lights are on during a typical weekday.

Figure 41: Lighting Time-of-use Profiles



Source: DNV KEMA analysis

Lighting hours of operation were extrapolated out to a whole year using the time-of-use data for a typical day for all day types (Monday through Sunday). Based on this data, the annual hours of operation varies from 562 hrs/yr for the low use fixtures, 835 hrs/yr for the medium use fixtures, and 3,309 hrs/yr for the high use fixtures.

Energy savings were calculated using the pre and post fixture wattages and quantities from the project lighting spreadsheet. Note that the quantities and fixture wattages were verified during the site visit. Once the energy savings for the interior lighting was established, this value was placed into eQuest by adjusting the lighting power density and lighting schedules in the pre and post models such that the lighting energy savings component of eQuest matches the spreadsheet calculations. This final step was necessary to establish the HVAC interactive effects associated with the lighting reduction. A total energy savings of 21,332 kWh and gas penalty of 130 therms were calculated for this measure.

Measure 2 – HVAC

Ex post savings for the HVAC retrofit were estimated using pre- and post-eQuest models built from data collected on-site. Energy savings are calculated by varying specific parameters in eQuest that is designed to mirror the energy efficiency component of the measure. The outputs are compared to metered data to ensure the results are in line with reality. This method represents the highest level of rigor possible for an energy model. DNV KEMA started with the ex ante eQuest model and made adjustments to the shell to reflect the data collected on-site. In addition, the following main eQuest input parameters were used in the evaluation analysis and best represents the energy efficiency equipment and changes made at the facility:

Table E-113: Modeling Parameters

	Pre	Source (Pre)	Post	Source (Post)
Total cooling capacity (kBtu/h)	372	Assumed similar to installed capacity	372	Nameplate
Cooling efficiency	7.4 SEER	Composite efficiency normalized by unit tonnage from model number recorded by in project files	13 SEER	Nameplate
Total heating capacity (kBtu/h)	620	Assumed similar to installed capacity	620	Nameplate
Heating efficiency (AFUE)	78	Assumed from vintage of units	97-97.5	Nameplate
Economizer	None or fixed depending on unit	Field notes from project files	Temperature Based	Site findings and deferred to ex ante assumptions for economizer type
Heating schedule	74°F from 7 a.m. – 6 p.m.	Deferred to ex ante assumptions	70°F from 7 a.m. – 6 p.m.	Deferred to ex ante assumptions
Optimal start/stop	None	Deferred to ex ante assumptions	None	Comparison of metered data versus eQuest outputs that include an optimal start/stop control

Source: DNV KEMA analysis

Internal loads and hours of operations were adjusted in the pre and post models to calibrate the model AC usage with data obtained on-site, which also included the site specific weather data. The AC units in DNV KEMA's model were allowed to operate from 5 a.m. to 8 p.m. which are consistent with the results from the metered data (in contrast to the 7 a.m. to 6 p.m. operation in the ex ante case). Hourly results from the model were well in line with data from the metering interval showing a mean bias error of less than 10 percent (Table E-114).

Table E-114: Calibration Summary

	Mean Bias Error (MBE)	Coefficient of Variation (CV)
4 AC 4-Ton Units	7%	62%
3 AC 5-Ton Units	9%	24%
Target	≤10%	≤30%

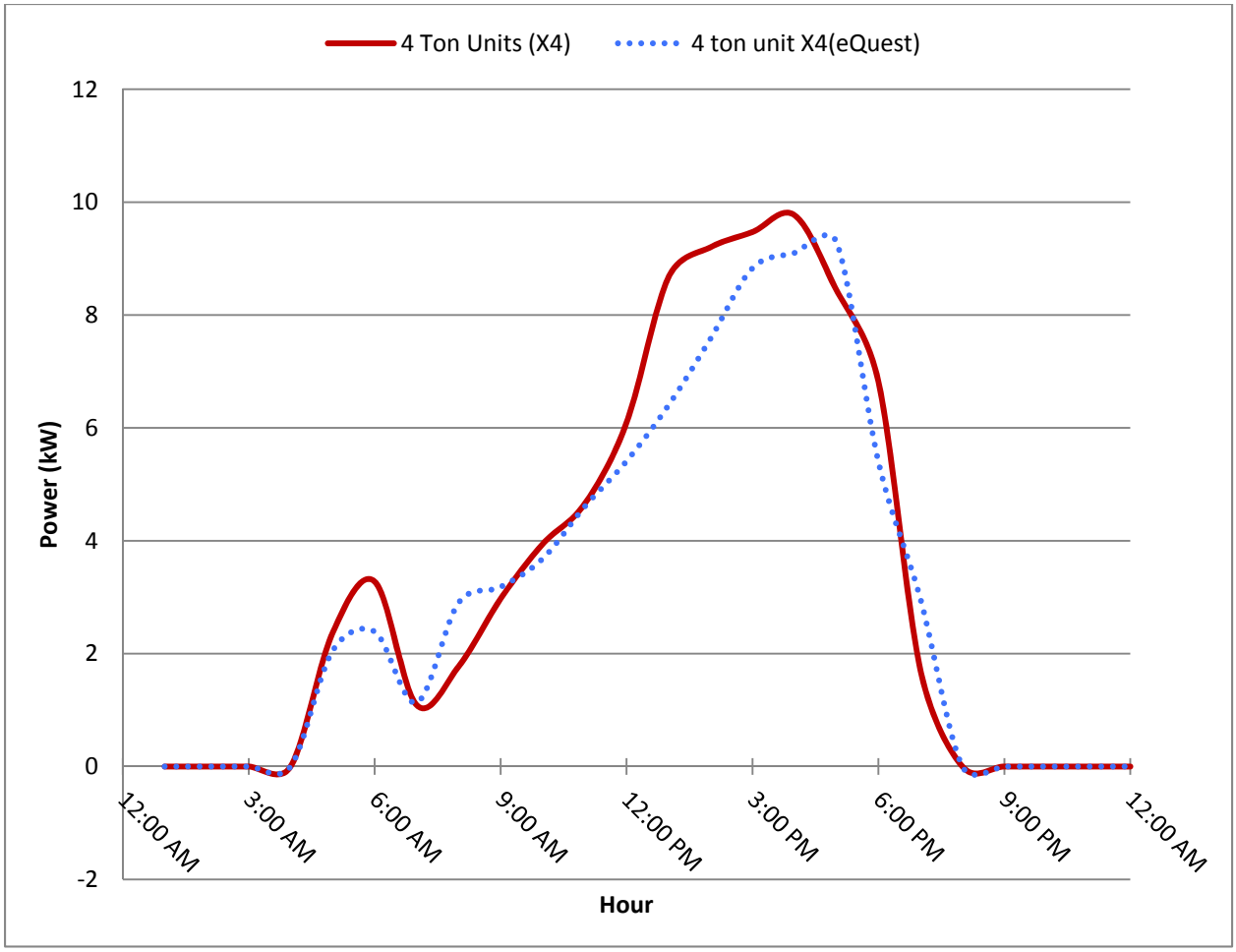
Source: DNV KEMA analysis

Note the four-ton unit could not be calibrated to the target CV. In this case, there are several possible factors that confound the CV calibration, which is the indicator of "closeness of fit", between modeled and real cooling system data and all could be present in this case. One factor is that there was a significant drop in temperature during one of the weeks which decreased the need for air conditioning. While the model correctly predicted a decreased usage during those days and the cumulative energy usage during that time, it is not possible to get precise power draw predictions of the units especially during hours of low use. In these situations, any small absolute difference in predicted versus metered values translates to large percentage differences which will drive the CV up substantially. For example, during most afternoon hours, eQuest predicts the air conditioners to draw about 9 kW whereas the metered data shows about 10 kW for an absolute difference of 1 kW. Overall this represents only a 10 percent difference which is well within calibration targets. However, if there is a 1 kW absolute difference between a predicted and metered value of 0.5 kW and 1.5 kW, respectively, the overall difference represent 66 percent of the metered value, and will drive up the CV.

Additionally, the metered data show some air conditioning usage during one Sunday afternoon which is not expected to represent typical hours of operation. This was (correctly) not modeled but as a result pushes the CV beyond the target calibration value.

Figure 42 graphically illustrates the relationship between metered energy usage and the calibrated model's energy usage. The close match indicates the ex post model is a good predictor of overall AC usage as seen from the daily power draw profile and a 7 percent MBE despite the inability of the four-ton unit to calibrate to its target CV.

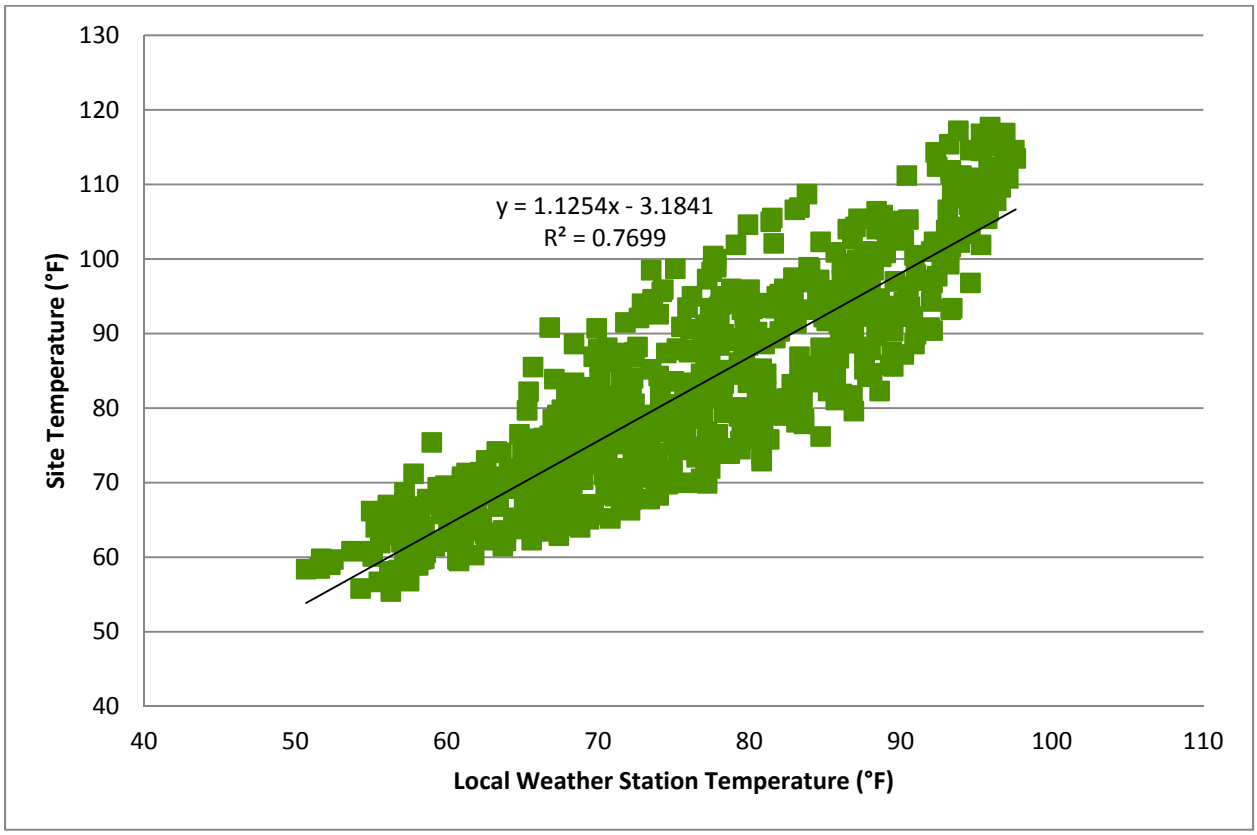
Figure 42: Metered versus Modeled Average Weekday Power Draw for Four-ton Units



Source: DNV KEMA analysis

A comparison of temperature data shows that the outside air temperature data collected at the site were higher than temperatures found from a nearby weather station. DNV KEMA recognizes that large temperature differences, especially as high as 16°F during peak hours between these two sources are unusual. However, the result is not uncommon and likely represents a local heat island effect rather than inaccurate measurements. In order to account for this effect, a plot of the average hourly temperatures collected on-site was compared to the values from a nearby weather station for that same hour, and a simple regression was done to relate site specific temperature to temperatures from that weather station. The linear regression equation that came from this relationship (Figure 43) was used to modify the site's TMY weather file in order to predict actual temperatures at the site. This addresses the heat island effect observed in the temperature data and essentially normalizes the standard TMY weather files so that it includes the site's heat island effect.

Figure 43: Site Ambient Temperature versus Marysville Weather Station Data



Source: DNV KEMA analysis

A final eQuest simulation run was performed using the modified TMY weather data to establish the HVAC energy savings for this site which comes to 33,490 kWh and 469 therms.

Ex Post Savings Results

The annual energy savings (kWh and therms) is the sum of hourly savings over all hours of the year, as predicted by the evaluation's eQuest postretrofit and baseline models. Based on the evaluation's eQuest analysis, total energy savings for this site is 54,821 kWh and 339 therms. The savings include interior and exterior lighting, HVAC, and associated interactive effects. Table E-43 categorizes the energy savings by measure. The savings reported in the status update are also shown for comparison purposes.

Discussion

Measure 1 – Lighting

For lighting energy savings, the evaluation's estimate is about 105 percent of the tracking, but this is likely similar only by chance. The evaluation used the lighting fixture inventory provided to DNV KEMA by the Energy Commission as the basis for the analysis along with data from the

metering effort.[64] However, a detailed comparison of the ex post and ex ante lighting values cannot be done because the final ex ante calculations are not available for review.

Measure 2 – HVAC

The difference in energy savings for the HVAC upgrade as shown in Table E-43 represents a 132 percent realization rate for that measure alone.

The source for this discrepancy come from two major adjustments made to the model: the hours the fans are allowed to turn on and the modified climate zone data. In the evaluation model, the HVAC hours were allowed to turn on from 5 a.m. to 8 p.m. in contrast to the settings used in the ex ante model (7 a.m. to 6 p.m.). This is a more realistic schedule of the HVAC units based on data seen in Figure 34 which shows the unit turning on much earlier than 7 a.m. and still cycling even after 6 p.m. Changes in these settings resulted in longer hours of operation for the HVAC units which in turn provided larger energy savings.

In conjunction with the naturally hot climate zone, which tend to keep the building temperatures elevated, there is a fair amount of heat gain past normal business hours which the HVAC units need to reject. Along the same line of reasoning, the weather file used to calculate savings was adjusted to take into account the heat island effect and will raise building internal loads at all hours of the day. The result is a greater usage of the HVAC in both the pre and postretrofit cases and which explains the higher energy savings in the evaluation models.

Additional issues – Stop/start Algorithm

The ex ante analysis included an optimum stop and optimum start control to the modeled HVAC system, but the available metering data showed no evidence of this control. When the optimum start/stop algorithm was included in the ex post eQuest model, the model erroneously predicted the start times much later in the day and stop times much earlier than what was shown in the metered data. Therefore, either the current optimum stop/start algorithms were not working as planned, or there was no specific stop/start control algorithm for this system.

By examining the day-to-day power draw of the DX units at different outside air temperatures and times of the day, the metering data suggest that the stop/start times were dictated by internal building temperatures and a fixed schedule, rather than an optimal stop/start control algorithm that would show different start and stop times (Figure 44). In Figure 44, a comparison of all 48 kBtu/h air conditioning units under different control schemes (temperature based and optimal stop/start) are shown against metered data. Note the temperature based control scheme predicts power draws in-line with the metered data particularly during the early morning and late afternoon hours. The interval is a five-day snapshot which is representative for the entire four-week monitoring period. In light of this result, no stop/start controls were simulated in the final evaluation eQuest model.

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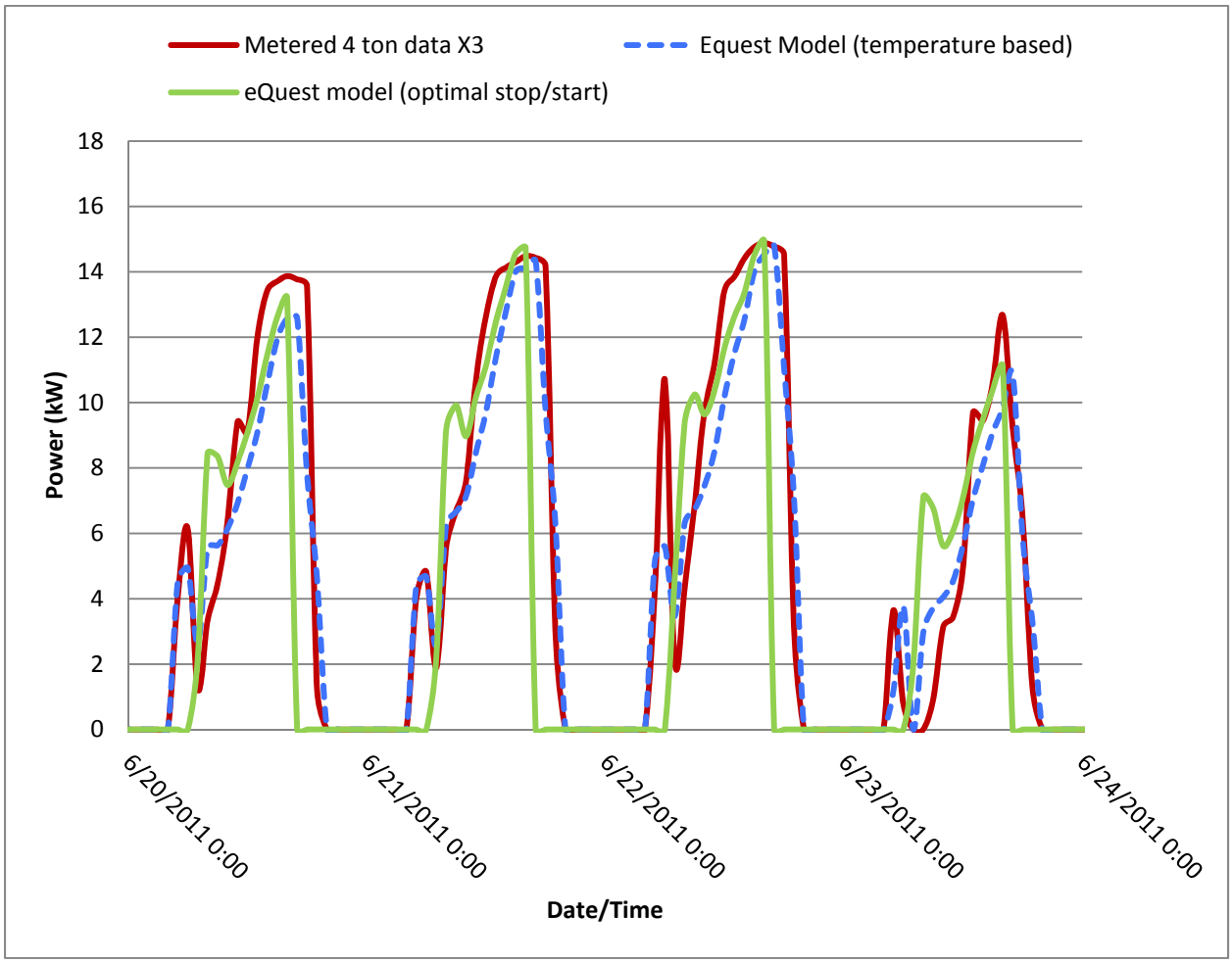
64 This document was part of the data files that was forwarded to DNV KEMA during the initial request for information. This particular document does not list the author.

Figure 44: Comparison of Modeled Control Strategy Compared with Monitored Data



Source: DNV KEMA analysis

The absence of stop/start control is the reason contributing to the difference in gas energy savings. Without the optimal start/stop algorithm controls in the evaluation's model, heating is assumed also to start at a fixed time instead of being capable of being turned off. The gas savings in the ex post model comes from improvements in the efficiency rating of the furnace, and are not due to the stop/start controls. As mentioned in an earlier section, improvement in operating efficiency of the furnace were also considered in the ex ante model but the settings were incorrectly inputted into eQuest and generated zero savings for this particular parametric run.

Additional issues –Baseline Efficiency

DNV KEMA did not use the baseline efficiency provided in the ex ante's eQuest model because the values could not be supported by the information provided. Instead, DNV KEMA sought

out additional sources to track down the efficiency of the pre-retrofit air conditioning units, based on the nameplate provided in the project files.[65] This model was determined to be a 7.4 SEER unit (equivalent to a 7.2 EER), which is greater than the assumed ex ante value of 5.4 EER but less than typical EER for this vintage as presented in the DEER database (8.9 EER).

The reason for the low efficiency in the ex ante estimate is not known. Possibly an adjustment was made to account for degradation, although no basis is provided. Standard practice does not consider degradation in estimating the existing unit's efficiency when evaluating energy efficiency savings for measures related to air conditioner replacements.

DNV KEMA assessed studies on HVAC degradation, and found a lack of data on in-situ units. A review by the Davis Energy Group found that unit degradation is not something that can easily be measured in-situ and the results often have a high level of uncertainty.[66] Claims that coil cleaning, refrigerant charge, and duct sealing increase the efficiency of the unit have largely been put into question in light of recent large scale studies because, in part, of uncertainties in measuring the unit's EER in-situ. There are some older studies that estimate degradation rates in the laboratory based on various criteria (for example, refrigerant overcharge/undercharge, reduction in airflow, restricted refrigerant lines) but these do not capture typical in-situ conditions and the studies do not report what a typical overall degradation factor is.[67] In addition, lab studies do not mirror what actually does occur in-situ and is compounded by various factors such as number of unknown faults in the system causing degradation, measurement accuracy, and lack of statistical significance with one time EER measurements to name a few.

In conclusion, this site yielded 54,821 kWh and 339 therms of energy savings for realization rates of 120 percent for electric and 48 percent for gas due chiefly to more hours of use.

Ex Post Life-cycle Savings

In essence, life-cycle savings is the sum of annual savings over the expected life of the measure. For replacement measures, the initial period considers the pre-existing conditions as the baseline for RUL, a so-called early replacement baseline or Baseline 1. After the remaining useful-life period and up until the end of the expected useful life (EUL) of the installed measure, an expected replacement baseline is used. This baseline considers minimally code compliant conditions or standard practice where no code is applicable. The replacement measure which incorporates both early replacement and expected replacement baseline is called dual baseline or Baseline 2.

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65 Preston's Guide – This guide has a list of air conditioning units built from 1960 to 2005 and has efficiency ratings based on the model number and manufacture year.

66 HVAC Energy Efficiency Maintenance Study, 2010.

67 Monitoring the Performance of Residential Central Air Conditioner under Degraded Conditions on a Test Bench, 1992.

The pre-existing Yuba City DMV HVAC and lighting systems were assumed to be more than 20 years old based on the site contact's responses and notes on the unit's nameplate. This would likely mean that DMV HVAC and lighting systems were at the end of their useful lives. In these cases, only the first year's savings would use the Baseline 1. From the second year until the end of expected EULs of the installed measures (15 years for the HVAC efficiency component, 10 years for the economizer, and 15 years for lighting per DEER 2008), a replacement baseline model using code minimums would be used to calculate the savings.

For the lighting measure, the lighting power density of the pre-existing lighting system was better than the current code maximum for this occupancy, so there was no adjustment made to the normal replacement baseline. Thus, the savings are calculated as the first year savings multiplied by the useful life, which in this case is 15 years. In contrast, code minimum for the cooling unit is SEER 13, the same as the units currently installed. This has the effect of negating the energy savings from the cooling efficiency component of the new split-DX units and also reducing energy savings from economizer and heating schedule subcomponent due to interactive effects. Table E-115 summarizes the energy savings by measure component used in the life-cycle savings calculations.

Table E-115: Values Used in Life-cycle Savings Calculations by Measure and Measure Subcomponent

Measure	Early Replacement		Expected Replacement		EUL (years)	RUL (years)
	Electric Energy (kWh)	Gas Energy (therms)	Electric Energy (kWh)	Gas Energy (therms)		
Lighting	21,332	-130	21,332	-130	15	1
HVAC – high efficiency	28,352	88	0	78	15	1
HVAC – economizer and optimal heating schedule	5,137	381	2,737	375	10	1

Source: DNV KEMA analysis

If only considering the Baseline 1 over the entire life of the measure, this project yields an estimated energy savings of 796,634 kWh and 3,180 therms (Table E-116). However, if the Baseline 2 is used, the life-cycle savings comes to 378,093 kWh and 2,986 therms. Source: DNV KEMA analysis

Table E-117

Table E-116: Baseline 1 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	54,821	27.4	339
2	2012	54,821	27.4	339
3	2013	54,821	27.4	339
4	2014	54,821	27.4	339
5	2015	54,821	27.4	339
6	2016	54,821	27.4	339
7	2017	54,821	27.4	339
8	2018	54,821	27.4	339
9	2019	54,821	27.4	339
10	2020	54,821	27.4	339
11	2021	49,684	27.4	-42
12	2022	49,684	27.4	-42
13	2023	49,684	27.4	-42
14	2024	49,684	27.4	-42
15	2025	49,684	27.4	-42
16	2026	0	0	0
Life-cycle	Total	796,630 kWh	411 kW-years	3,180 therms

Source: DNV KEMA analysis

Table E-117: Baseline 2 Life-cycle Savings

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
1	2011	54,821	27.4	339
2	2012	24,068	2.73	323
3	2013	24,068	2.73	323
4	2014	24,068	2.73	323
5	2015	24,068	2.73	323
6	2016	24,068	2.73	323
7	2017	24,068	2.73	323

	Year	Electric Energy Savings (kWh/yr)	Electrical Demand (kW)	Natural Gas Energy Savings (therms/yr)
8	2018	24,068	2.73	323
9	2019	24,068	2.73	323
10	2020	24,068	2.73	323
11	2021	21,332	2.73	-52
12	2022	21,332	2.73	-52
13	2023	21,332	2.73	-52
14	2024	21,332	2.73	-52
15	2025	21,332	2.73	-52
16	2026	0	0	0
Life-cycle	Total	378,093 kWh	65.9 kW-years	2,986 therms

Source: DNV KEMA analysis

Glossary

ARRA	American Recovery and Reinvestment Act of 2009
Baseline 1	Comparison to existing conditions found before the installation of the energy efficiency measure
Baseline 2	Comparison to current code or common practice conditions for a given energy efficiency measure
Caltrans	California Department of Transportation
CDCR	California Department of Corrections and Rehabilitation
CCI	California Correctional Institution
CEC	California Energy Commission (Energy Commission)
CHP	California Highway Patrol
COR	California Correctional Institution
CRAC	computer room air conditioning
CTF	Correctional Training Facility
CV	Constant Volume
DDC	direct digital controls
DDS	Department of Developmental Services
DOE	United States Department of Energy
DEER	Database for Energy Efficient Resources
DGS	Department of General Services
DHW	domestic hot water
DMV	Department of Motor Vehicles
DNV KEMA	DNV KEMA Energy & Sustainability
DOE2	Building Simulation Model
DOE	U.S. Department of Energy
EEM	energy efficiency measures
EFLH	estimated full load hours
EMS	energy management system
Energy Commission	California Energy Commission
EUL	effective useful life
ex ante	energy savings estimates for an energy efficiency measure developed by the site or the program implementers

ex post	energy savings estimates for an energy efficiency measure developed by the evaluation team
HPS	high pressure sodium
HVAC	heating, ventilation, and air conditioning
IOU	investor-owned utility
IPMVP	International Performance Measurement and Verification Protocol
kBtu	kilo British thermal unit
kW	
kWh	kilowatt-hour
lbs	pounds
LED	light-emitting diode
Loan Fund Program	Energy Efficient State Property Revolving Loan Fund Program
M&V	measurement and verification
Measure	At an end use energy consumer facility, an installed piece of equipment or system; a strategy intended to affect consumer energy use behaviors, or modification of equipment, systems or operations that reduces energy that would otherwise have been used to deliver an equivalent or improved level of end-use service.
NRC	Norco Rehabilitation Center
OCIO	Office of the Chief Information Officer
OFAM	Office of Fleet Management
Project	An activity or course of action involving one or multiple efficiency measures at a single facility or site.
Retrocommissioning	Retrocommissioning is the process of optimizing the existing building systems and operations to improve energy performance.
RUL	remaining useful life
SATF	Substance Abuse Treatment Facility
SPC	Standard Performance Contract
TMY	typical meteorological year
VAV	variable air volume
VFD	variable frequency drive
VSP	Valley State Prison