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Energy Efficiency Evaluation, Measurement and Verification (EM&V) Final Report

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1 Executive Summary

For the City of Palo Alto Utilities (CPAU), TRC conducted evaluation, measurement, and verification (EM&V) of CPAU's Fiscal Year (FY) 2015 energy efficiency programs. This report presents the findings of that evaluation.

TRC developed first year net and gross savings estimates of demand (kW), energy (kWh) and natural gas (therm) savings, as well as lifecycle energy savings, for the following programs:

- The Commercial and Industrial Energy Efficiency Program (CIEEP), also known as the Enovity program
- RightLights Plus
- Commercial Advantage Program (CAP)
- Business New Construction
- Appliance Recycling

Overall, TRC verified programs representing 5.4 GWh of ex ante savings, or 75% of the total 8.2 GWh ex ante portfolio level energy savings. For each program evaluated, TRC achieved at least 90% confidence and 7% precision for first year energy (kWh) savings. For the programs where sampling was conducted, we provide detail on the statistical rigor achieved in the program-specific chapters.

1.1 Savings Summary

This section provides a summary of savings at the program and portfolio level.

1.1.1 First Year Demand (kW) and Energy (kWh)

Figure 1 shows gross first year savings for all programs, listed in descending order of ex ante energy (kWh) savings. The programs that TRC verified for FY 2015 are shown with an asterisk (*), and programs not evaluated (N.E.) do not have a realization rate.

As shown in Figure 1, the average first year kWh realization rate for the evaluated programs (weighted by ex post energy savings) was 93%. The energy savings adjustments resulted from the following, in order of descending significance. As shown, some of these adjustments decreased savings, while others increased savings.

- Adjustments to operating conditions based on trend data: Particularly for the CIEEP (Enovity) program, TRC found that some measures were not operating properly, or that schedules or set-points assumed by the program did not match current conditions. These generally decreased savings.
- Baseline adjustments: Particularly for some lighting measures, TRC assumed a baseline that met federal regulations for some measures (e.g., replacements of incandescent lamps), while the program assumed existing conditions for the baseline. These adjustments decreased savings.
- Corrections to calculation errors: For the one custom CAP project (responsible for the majority of CAP energy savings), TRC found a calculation error that resulted in an increase to energy savings.
- Adjustments to the number of measures installed, or to the efficiency of the measures installed. TRC found projects where the number of measures installed were lower than claimed (decreasing savings), and projects where the efficiency of measures were higher than claimed (increasing savings).

- Differences in energy savings assumed per unit: For the Appliance Recycling program, TRC used billing data from participants to develop a regression model to calculate energy savings per unit recycled. The calculated per-unit energy savings was lower than what the program assumed based on deemed savings values, which decreased savings.

The average kW realization rate for the evaluated programs was 80%. The primary reduction in demand (kW) savings was for lighting measures in the RightLights Plus program. The adjustment was because the program assumed demand savings from exterior lighting, while TRC did not (unless the measures were installed in an area where lighting would be used during peak hours, such as in a parking garage). In addition, the baseline adjustments to RightLights Plus measures that affected energy (kWh) savings also affected demand (kW) savings.

Figure 1. Gross 1st Year Demand and Energy Savings

	Ex Ante		Ex Post		
CPAU Program	**Demand (kW)**	**Energy Savings (kWh)**	**Demand (kW)**	**Energy Savings (kWh)**	**Realization Rate (% kWh)**
CIEEP (Enovity)*	422	2,222,800	412	1,969,000	89%
Home Energy Report	0	1,604,272	0	1,604,272	N.E.
RightLights Plus*	303	1,478,824	157	1,306,405	88%
CAP*	30	1,128,756	33	1,156,252	102%
Business New Construction*	0	473,100	0	473,100	100%
Res. Smart Energy	0	92,831	0	92,831	N.E.
Res. Energy Assistance (REAP) Low Income	0	69,409	0	69,409	N.E.
Appliance Recycling*	12	59,460	7.6	44,955	76%
Hospitality	60	44,209	60	44,209	N.E.
Res. New Construction	0	18,589	0	18,589	N.E.
Santa Clara Valley Water District (SCVWD)	0	91	0	91	N.E.
Total	**827**	**7,192,341**	**670**	**6,779,113**	**93%**

Figure 2 shows net first year savings. To calculate net savings, TRC multiplied the gross savings for each measure by the net-to-gross ratio (NTGR). TRC obtained the NTGR values for each measure from the Northern California Power Agency (NCPA) Energy Efficiency (EE) Reporting Tool based on the E3 calculator, which took NTGR values from the Database of Energy Efficiency Resources (DEER) 2014.

TRC used the same NTGR values as the program for the ex ante savings. TRC's adjustments to net ex ante savings came from adjustments to gross savings.

For programs not evaluated, TRC assumed the ex ante net savings values.

Figure 2. Net 1st Year Demand and Energy Savings

		Ex Ante		Ex Post	
CPAU Program	**Program Average NTGR**	**Peak Savings (kW)**	**Energy Savings (kWh)**	**Peak Savings (kW)**	**Energy Savings (kWh)**
CIEEP (Enovity)*	80%	338	1,778,240	330	1,575,200
Home Energy Report	100%	0	1,604,272	0	1,604,272
Right Lights Plus*	80%	243	1,183,059	126	1,045,124
CAP*	80%	24	903,005	26	925,002
Business New Construction*	85%	0	402,135	0	402,135
Res. Smart Energy	80%	0	74,265	0	74,265
REAP Low Income	80%	0	55,527	0	55,527
Appliance Recycling*	70%	8.4	47,568	5	31,468
Hospitality	85%	51	37,578	51	37,578
Res. New Construction	80%	0	14,871	0	14,871
SCVWD	80%	0	73	0	73
Total		**663**	**6,100,593**	**538**	**5,765,515**

*Programs evaluated by TRC.

1.1.2 Natural Gas (Therms) Savings

Figure 3 shows ex ante and ex post natural gas savings for the programs evaluated[1]. Only the CIEEP (Enovity) program generated natural gas savings among the programs evaluated. Three other programs resulted in *negative* natural gas savings due to interactive effects, as described below.

As shown in Figure 3, TRC presents findings for natural gas savings in multiple ways:

- **With and without interactive effects:** For the RightLights Plus, CAP, and Appliance Recycling program, the programs did not have ex ante natural gas savings. However, because these programs included interior lighting or appliances, building models predict that these measures would result in negative natural gas savings due to interactive effects. (Interactive effects refer to the increase in heating use, because efficient interior lighting and appliances release less waste heat.)
  - CPAU has historically not accounted for interactive effects, because they are the only California Publicly Owned Utility that provides natural gas, and because of the lack of supporting field data supporting interactive effects values. To align with this reporting precedent, TRC provides ex post savings values *without* interactive effects.
  - TRC also provides ex post natural gas savings *with* interactive effects, following the protocol set by the California Public Utilities Commission (CPUC) reporting procedures. To calculate the ex post therm savings from interactive effects, TRC identified the therm/kWh value based on the building type from the California Municipal Utilities Association Technical

[1] CPAU did not provide ex ante natural gas savings for the programs that TRC did not evaluate.

Reference Manual (referred to here are the "TRM")[1] for lighting measures or based on the appliance recycled from DEER 2014 for appliances. TRC then multiplied this therm/kWh by the ex post kWh value to calculate ex post natural gas savings.

- **Under a natural gas NTGR of 100%, and under the program-specific NTGR assumed for electricity savings**. CPAU has historically assumed a 100% NTGR for natural gas savings. The rationale is that natural gas equipment is typically capital intensive, and natural gas is relatively inexpensive. Both of these should decrease the likelihood that the participant would have installed the same equipment in the absence of the program, making free ridership very low or nonexistent. However, for FY 2015, the equipment that produced natural gas savings also produced electricity savings. The two measures that generated natural gas savings were for retrofitting air handling unit supply fans with variable frequency drivers, and installing economizers on air handling units. Both measures reduced cooling (electricity) and heating (natural gas) use. It is unknown whether the customer was motivated by electricity savings, heating savings, or a combination of both. Consequently:
  - TRC provides net natural gas savings using a 100% NTGR, which would reflect a participant decision motivated primarily by natural gas savings.
  - TRC provides net natural gas savings using a 80% NTGR[2], which would reflect a participant decision motivated primarily by electricity savings.

Figure 3. Gross and Net Annual Natural Gas Savings

	Ex Ante		Ex Post		
CPAU Program	**Gross Savings (Therms)**	**Net Savings (Therms)**	**Gross Savings (Therms)**	**Net Savings: 100% NTG (Therms)**	**Net savings: 80% NTG (Therms)**
CIEEP (Enovity)	30,320	24,256	21,280	21,280	17,024
Right Lights Plus	0	0	(7,823)	(7,823)	(6,259)
CAP	0	0	(251)	(251)	(201)
Business New Construction	0	0	0	0	0
Appliance Recycling	0	-	(742)	(742)	(520)
Total without interactive Effects	**30,320**	**24,256**	**21,280**	**21,280**	**17,024**
Total with Interactive Effects	**N.A.**	**N.A.**	**12,463**	**12,463**	**10,045**

As shown in Figure 3, for the one program with natural gas savings (Enovity – CIEEP), TRC calculated a natural gas realization rate of 70%. The adjustments to natural gas savings were primarily because:

- Project 1301, EEM-2: TRC found an error in the calculation, which resulted in an *increase* in natural gas savings for this project.

[1] Energy and Resource Solutions, "Savings Estimation Technical Reference Manual for the California Municipal Utilities Association", 2014.

[2] For all programs except the Appliance Recycling program, for which the NTGR is 70%.

- Project 1384, EEM-3: TRC found that the actual HVAC runtimes differed compared to the runtimes in the ex ante calculations. In particular, there was one Air Handling Unit (AHU) found to operate continuously (8760 hours per year), rather than at 4,486 hours per year as assumed in the ex ante calculation. This increased night-time heating needs, which *reduced* natural gas savings.
- Project 1384, EEM-5: TRC found that some of the economizers installed through the program were not correctly operating. Two were stuck at fully or partially opened conditions. During times when heating was needed, the open economizers led to additional heating loads, *reducing* natural gas savings.

TRC provides more detail on these adjustments in Section 3.4.

1.1.3 Lifecycle Savings

Figure 4 shows gross and net lifecycle savings. To calculate lifecycle savings for the programs evaluated, TRC multiplied the annual savings for each measure by the measure Effective Useful Life (EUL). TRC obtained the EUL values for each measure from the Northern California Power Agency (NCPA) Energy Efficiency Reporting Tool. TRC also confirmed these EUL values using DEER 2014.

For programs not evaluated, TRC assumed the ex ante lifecycle savings.

Figure 4. Gross and Net Lifecycle Energy Savings

	Ex Ante Lifecycle		Input Values for Ex Post Lifecycle		Ex Post Lifecycle		
CPAU Program	**Gross Savings (kWh)**	**Net Savings (kWh)**	**Ex Post 1st Year Gross Savings (kWh)**	**Average Measure Life (Yr)**	**Gross Savings (kWh)**	**Net Savings (kWh)**	**Gross Realization Rate (%)**
CIEEP (Enovity)*	30,825,400	24,660,320	1,969,000	12.1	23,899,000	19,119,200	78%
Home Energy Report	1,604,272	1,604,272	1,604,272	N.E.	1,604,272	1,604,272	100%
RightLights Plus*	22,182,361	17,745,889	1,306,405	7.0[1]	8,576,613	6,861,290	39%
CAP*	9,217,183	7,373,746	1,156,252	5.5[2]	6,169,482	4,935,585	67%
Business New Construction*	5,677,200	4,825,620	473,100	12.7	6,008,370	5,107,115	106%
Res. Smart Energy	1,054,909	843,927	92,831	N.E.	1,054,909	843,927	100%
REAP Low Income	805,610	644,488	69,409	N.E.	805,610	644,488	100%
Appliance Recycling*	297,300	237,840	44,955	4.8	217,058	151,940	73%
Hospitality	530,508	450,932	44,209	N.E.	530,508	450,932	100%
Res. New Construction	223,068	178,454	18,589	N.E.	223,068	178,454	100%
SCVWD	1,001	801	91	N.E.	1,001	801	100%
Total	**72,418,812**	**58,566,290**	**6,779,113**		**49,089,891**	**39,898,005**	**68%**

*Programs evaluated by TRC

As shown in Figure 4, TRC calculated a much lower lifecycle savings than the ex ante calculations showed for RightLights Plus and (to a lesser extent) CAP. Furthermore, TRC's lifecycle kWh savings realization rates were lower than first year kWh savings realization rates for these programs. The reasons for the adjustments for lifecycle savings were the following, in descending order of significance:

1. **Adjustments to lighting measure Effective Useful Life (EUL) based on operating hours.** For the ex ante lifecycle savings estimate for lighting measures, the RightLights Plus and CAP program (or program implementer) assumed the measure EUL without adjusting for the operating hours of where the measures was installed. For example, for LED lamps, the programs generally assumed 15 years, regardless of where the LEDs were installed. For the ex post lifecycle savings

[1] Based on projects sampled. Average measure life for program multiplied by first-year savings (kWh) does not equal lifecycle savings (kWh) because of sampling weights, and because of dual baseline measures.

[2] Based on projects sampled. Average measure life for program multiplied by first-year savings (kWh) does not equal lifecycle savings (kWh) because of sampling weights.

estimate, TRC adjusted the EUL based on the operating hours, according to DEER assumptions for building type and space type. For example, for an LED installed in an area for which DEER assumes 4,350 hours per year, TRC divided 20,000 hours (the rated lifetime of an LED lamp[1]) by 4,350 to estimate a measure life of 4.6 years. As described in Section 8.2, TRC's adjustment to lighting EUL based on operating hours aligns with TRM guidance and with the precedent set by California Public Utility Commission (CPUC) lighting impact evaluations. The majority of the lifecycle savings reductions for RightLights Plus and CAP were because of this adjustment.

2. **Adjustments to first year savings.** All of TRC's adjustments to first year kWh savings also affected lifecycle kWh savings. In particular for the RightLights Plus program, TRC adjusted baseline conditions for some lamp types (e.g., replacement of incandescent lamps) to meet current federal or state regulations, rather than existing conditions. These first year savings adjustments compounded the adjustments specific to lifecycle savings.
3. **Accounting for dual baseline.** The RightLights Plus program included several T12 early replacement projects, for which the ex ante program calculations assumed existing conditions for the entire EUL. For the ex post lifecycle calculations, TRC assumed a dual baseline for T12 early replacement projects, under which savings for the first one-third of the EUL was calculated assuming existing conditions, and the last two-thirds of the EUL was calculated assuming code-compliant conditions. This did not affect first year savings, but reduced lifecycle savings. Because T12 replacements comprised a small fraction of program savings, this was a relatively small fraction of the lifecycle savings adjustments for the RightLights Plus program.

1.2 Key Findings

Based on our evaluation results, the realization rate for energy savings was fairly high: 93% of total ex ante first year energy (kWh), 80% of demand (kW), and 70% of natural gas (therms)[2] for the programs evaluated. TRC provides more detail in each program chapter, and summarizes the first year savings adjustments here:

- CIEEP (Enovity): Changes to operating conditions based on trend data – e.g., supply temperature, fan flow operation, economizer operation, or operating hours that reduced energy (kWh) and natural gas (therm) savings overall compared to the operating condition assumed in the ex ante calculation.
- RightLights Plus: Increases to the baseline energy efficiency assumptions for some lighting measures that reduced the energy (kWh) savings, and removal of demand (kW) savings for exterior lighting which reduced demand savings.
- CAP: Correction to a calculation resulting which increased energy savings, reductions in the number of efficiency measures installed which reduced energy savings, and increases to the efficiency of the measure installed which increased energy savings, for an overall increase in energy (kWh) and demand (kW) savings.

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[1] California Public Utilities Commission (CPUC), 2014. "EUL-RUL Calculating DEER Values for Lighting 2014-02-05".

[2] This realization rate excludes interactive effects. The natural gas realization rate including interactive effects is 41%.

- Business New Construction: No adjustments
- Appliance Recycling: Reduction in deemed energy (kWh) savings claimed based on results of participant billing analysis.

TRC made larger adjustments to lifecycle savings compared with first year savings, primarily to account for operating hours in the measure life for lighting projects.

TRC provides the program recommendations based on the evaluation findings in Section 9.

2 Introduction

The objective of this project was to verify FY 2015 demand, energy, and natural gas savings claims. To meet this goal, TRC verified annual and lifecycle gross and net impacts.

The primary purpose of this project was to meet CPAU's reporting requirements to the CEC. In addition, CPAU will use the findings for internal tracking purposes and to make improvements to programs going forward.

2.1 Overview of Programs Evaluated

TRC evaluated five programs in FY 2015. TRC collaborated with CPAU staff to identify programs for evaluation at the annual planning meeting on July 20, 2015. In general, TRC and CPAU prioritized a program for evaluation if it:

- Had high ex ante savings. TRC evaluated four of the five programs with the highest ex ante savings. TRC did not evaluate the Home Energy Report program, although this had the second highest ex ante savings in the portfolio, because there was no control group with which to conduct billing analysis.
- Had not been evaluated for several years. For example, RightLights Plus had not been evaluated since FY 2012, and Appliance Recycling had not been evaluated since before FY 2012. For the Appliance Recycling program, CPAU staff also questioned whether the deemed savings values in the TRM were accurate for their program.

Section 10.1 in the Appendix provides a more detailed description of why TRC and CPAU did or did not select each program for evaluation in FY 2015.

Below, TRC provides a summary of each program evaluated.

- **CIEEP (Enovity)** provides energy assessments and incentives for custom efficiency projects to large customers. CIEEP is available to customers with buildings larger than 30,000 square feet and/or with a maximum electric demand greater than 50 kilowatts (kW). Incentives are calculated based on installed and verified energy savings. One third party vendor, Enovity, implemented the program in FY 2015. In FY 2015, there were seven participating projects implemented at six sites.
- **CAP** provides CPAU commercial and industrial customers with incentives for energy saving appliances, lighting, and custom retrofits. Projects can apply for either deemed rebates or custom incentives. In FY 2015, twelve projects participated in the program.
- **RightLights Plus** provides small and medium businesses with incentives for lighting, vending, HVAC, and controls upgrades, as well as technical assistance. Program participants receive an energy audit, through which energy upgrades are identified. A program trade ally – i.e., a participating contractor – installs the recommended upgrades and receives the program rebates. RightLights Plus is implemented by a third party, Ecology Action. In FY 2015, 23 projects participated in the program.
- **The Business New Construction program** provides incentives and technical assistance for new construction nonresidential projects that exceed the required energy efficiency standards. The program sets a minimum eligibility requirement of 20% above Title 24 for incentives but provides tiered incentives for buildings modeled with energy savings higher than 20%. In FY 2015, one project participated in the Business New Construction program.

- **The Appliance Recycling program** provides rebates to consumers for the pick-up of their old, inefficient, but operable refrigerator or freezer. Recycled appliances can be primary or secondary units. The old appliances are sent to a recycling center and permanently removed from further use. A third party contractor, JACO Environmental, operated the program in FY 2015. There were eighty-four refrigerators and twelve freezers recycled through the program in FY 2015.

2.2 Methodology overview

Figure 5 shows the total number of projects verified for each program evaluated, and TRC's overall approach to verifying each program. TRC provides more detail below this figure, and in the program specific sections.

Figure 5. Number of Projects Verified by Program

CPAU Program	Total Projects in FY 2015	Verified On-site	Verified by Desktop Review only	Verified by Billing Analysis	Total Projects Verified
CIEEP (Enovity)	7	6	1		7
RightLights Plus	23	5	5		10
CAP	12	4	3		7
Business New Construction	1	1	0		1
Appliance Recycling	96	0	0	69[1]	69
Total	**139**	**16**	**9**	**69**	**94**

To conduct EM&V for FY2015, TRC used the following overall methodologies:

- For a census of projects in the CIEEP (Enovity) and Business New Construction programs, as well as for the one custom project in CAP, TRC used the following process:
  - Conducted on-site verifications[2], in which we compared the number, efficiency, and location of the measures installed versus the claimed values.
  - Reviewed trend data and compared actual operating conditions to the operating conditions assumed in the ex ante calculations.
  - Verified, or adjusted as-necessary, the baseline energy efficiency assumption.
- For a sample of the deemed savings projects in RightLights Plus and CAP, TRC used the following process:
  - Reviewed the savings algorithm and assumptions for a sample of projects, including the baseline energy use assumptions.
  - Conducted on-site verifications for a sub-sample of projects, in which we compared the number, efficiency, and location of the measures installed versus the claimed values.

[1] The TRC team attempted to use all participating projects, but removed some because of insufficient billing data.

[2] For one Enovity project that was equipment optimization only, TRC did not conduct an on-site verification, because there was no equipment installation to verify.

    - Used project documentation, including invoices and work orders, to verify the number of measures installed and the efficiency of those measures, for projects not chosen for on-site verification.

- For the Appliance Recycling program, TRC and its team member Klos Energy Consulting calculated gross energy savings for refrigerators through statistical billing analysis. Due to the lack of freezers with useable data for analysis, the TRC team could not perform similar billing analysis for freezers. Instead, TRC used the TRM deemed savings values.

The program-specific chapters provide more detail.

3 CIEEP (ENOVITY)

3.1 Program Overview

The Commercial and Industrial Energy Efficiency Program (CIEEP) provides energy assessments and incentives for custom efficiency projects to large customers. CIEEP is available to customers with buildings larger than 30,000 square feet and/or with a maximum electric demand greater than 50 kW. Incentives are calculated based on installed and verified energy savings, typically at a rate of $0.10 per kWh and $1.00 per therm saved over one year.

In FY 2015, there were seven participating projects implemented at six sites. One third party vendor, Enovity, implemented the program in FY 2015. For each project, the implementer conducted an audit, developed a report to identify potential savings, and developed a final report showing the savings from the projects as installed, based on custom calculations.

3.2 EM&V Approach

Because this program accounted for the largest savings in the CPAU FY 2015 portfolio, had a small number of participants, and used custom savings calculations, TRC verified a census of projects – i.e., verified savings from all seven participating projects.

TRC conducted on-site verifications for six of the seven projects. The seventh project did not include equipment installation (i.e., optimization-only project); consequently, TRC reviewed trend data only for this project, since field verification was not needed.

Prior to the site visits, TRC reviewed the project investigation and verification reports and calculations (e.g., Excel spreadsheets, eQUEST energy models) to become familiar with project scope, calculation methodology, and savings for each of the implemented measures. During the on-site field visits, TRC:

- Conducted brief staff interviews to determine any major operational or occupancy changes since measure implementation;
- Visually verified lighting and equipment installation quantity, make, and model;
- Review Energy Management System (EMS) schedules and settings; and
- Obtained or requested EMS trend data, screenshots, and equipment performance, specification product submittals, and as-built plan sets.

For the ex post savings, TRC used the data we collected to verify calculation and model inputs and to make the necessary changes to revise the savings to reflect current operating conditions.

As part of our verification, TRC reviewed the baseline assumptions used in the ex ante savings calculation and made adjustments where necessary. In general, TRC:

- Assumed existing conditions as the baseline for optimization projects, because these projects were not triggered by code. The ex ante savings calculations were also developed using existing conditions, so TRC generally did not make baseline adjustments for optimization projects.

- Assumed code-compliant equipment as the baseline for installation / replacement of large equipment, because this activity would have triggered Title 24[1]. The program included a few instances where Title 24 would not have been triggered (e.g., an economizer was installed on existing equipment); TRC assumed existing conditions for such cases. The ex ante savings calculations were developed using existing conditions for most equipment installations, but in some cases, the existing equipment met Title 24-2008. Consequently, TRC adjusted savings due to baseline changes for one project.

These adjustments and others are discussed in more details in this chapter.

3.3 Overview of Program EM&V Results

Figure 6 provides first year ex ante and ex post gross savings for each project.

Overall, TRC calculated a gross realization rate of 89% kWh savings compared with ex ante claims. TRC's kWh adjustments were primarily because of:

- Differences in operating conditions – e.g., supply temperature, fan flow operation, economizer operation, or operating hours assumed in the ex ante calculation did not match current conditions, based on TRC's analysis of trend data.
- Changes in the baseline conditions for one project.

TRC's adjustments also reduced natural gas savings from 30,320 therms to 21,280 therms, for a program realization rate of 70% for natural gas. The adjustments in natural gas savings were because:

- Project 1301, EEM-2: TRC found an error in the calculation, which resulted in an *increase* in natural gas savings for this project, described in more detail in Section 3.4.3.
- Project 1384, EEM-3: TRC found that the actual HVAC runtimes differed compared to the runtimes in the ex ante calculations - some increased, while one increased substantially. On balance, there was a net increase of equipment runtime which translated into a reduction of savings. A change in schedule for Air Handling Unit (AHU)-5 in particular, from 4,486 hours per year to continuous use, resulted in an increase in natural gas use – i.e., a *reduction* in natural gas savings. (Note that, while this is shown as a negative natural gas savings, it does not reflect interactive effects.)
- Project 1384, EEM-5: TRC found that some of the economizers installed through the program were not correctly operating. Two were stuck at fully or partially opened conditions. During times when heating was needed, the open economizers led to additional heating loads, *reducing* natural gas savings.

Section 3.4 provides more detail on TRC's findings and adjustments for each project.

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[1] Based on permitting dates, Title 24-2008 was the applicable version of Title 24 for all projects where code would have been triggered.

Figure 6. CIEEP (Enovity) Results: First Year Gross Savings

Project	Measure	Description	Ex Ante 1st Year Gross Savings			Ex Post 1st Year Gross Savings			Realization Rate (% kWh)
			kW	kWh	Therms	kW	kWh	Therms	
1067	EEM-1	Condenser Plant Upgrades	-	218,100	-		153,400		70%
	EEM-2	Optimizer Chiller Staging	-	249,500	-		249,500		100%
1270	EEM-15	Install Variable Frequency Drive (VFD) Chiller with Efficiency over T24		165,600	-		114,900		69%
1301	EEM-1	Chiller Plant Upgrade	53.0	277,000	-	52.6	258,000	-	93%
	EEM-2	Retrofit Air Handler Unit (AHU) Supply Fans with VFDs	19.0	120,900	6,670	19.4	120,900	12,030	100%
1304	EEM-1	Optimize economizer operation for AHU ST-4	13.0	96,000	-	6.6	40,500		42%
	EEM-3	Reduce operating hours for various units	-	83,400	700	11.0	77,200	600	93%
	EEM-5	Reduce AHU SA-1 operating hours	-	15,000	500	0.0	15,000	500	100%
1384	EEM-1	Optimize supply air temperature (SAT) reset	26.1	27,700	-	26.1	27,700	-	100%
	EEM-2	Optimize economizer on AHU-2	-	19,100	-	0.0	16,200	(1,100)	85%
	EEM-3	Optimize HVAC schedules	-	49,700	(5,100)	0.0	48,400	(14,300)	97%
	EEM-4	Increase Variable Air Volume (VAV)	6.4	10,200	760	6.4	10,200	760	100%
	EEM-5	Install economizers on AHU-1, 4-6	141.0	238,600	26,790	131.5	228,400	22,790	96%
	EEM-6	Implement Chilled Water Supply Temperature (CHWST) reset	-	75,300	-		75,300		100%
1507 (EEM1) 1537 (EEM2&3)	EEM-1	Install Evaporative Cooling Medium on Air-Cooled Chillers	141.0	379,800	-	141.0	379,800	-	100%
	EEM-2	Install Electronically Commutated (EC) Motors on Computer Room Air Handler and Underfloor Plug Fans	21.0	182,100	-	15.8	138,800		76%
	EEM-3	Install 3 CHW Cooled Variable Speed CRAHs	1.7	14,800	-	1.7	14,800	-	100%
Program Total			**422**	**2,222,800**	**30,320**	**412**	**1,969,000**	**21,280**	**89%**

3.4 Project-Level EM&V Results

This section provides a description of the EM&V results for each project that participated in the CIEEP (Enovity) program in FY 2015.

3.4.1 Project 1067-03.1

The facility is a medical center campus that provides treatment and extended care for its patients. The facility consists of more than twenty buildings. All work for this project was done in Building 100 which was built in 1994 and is the medical center's hospital and clinics building. The building is a 495,000 square foot 4-story structure with a basement. The implemented energy savings measures included:

- EEM-1: Condenser Water Plant Upgrade: including 3 new cooling towers, 3 new motors and condenser water pump to reduce overall condenser plant performance
- EEM-2: Optimize Chiller Staging for Existing Chillers: two 1,500 ton and one 500 ton units were optimized to take advantage of chillers' peak performance efficiencies

The implementer performed savings calculations for these measures in custom Excel spreadsheets. TRC used EMS trend data and motor nameplate information to confirm the calculation inputs.

TRC confirmed that the number of measures and operating hours for EEM-1 and EEM-2 matched the values claimed, and made no adjustments to those parameters.

The ex ante savings calculations for EEM-2 used existing conditions for the baseline. Because EEM-2 was an optimization project, TRC agreed that the use of existing conditions was appropriate. However, EEM-1 involved new equipment installation including cooling towers, fans, pumps, and motors. The ex ante savings calculation used existing conditions for the baseline. Because this was a large equipment replacement that would have triggered Title 24, the equivalent of Title 24-2008 code efficiencies should have been applied as baseline. TRC referenced minimum motor efficiencies from Title 24 at the time of the original installation in 1994 to revise the existing conditions baseline in the ex ante calculation, and then applied the code-compliant efficiencies for the time of the new installation (Title 24-2008). The reduced incremental difference in motor efficiencies between existing and installed (assumed by the implementer) compared with code and installed (assumed by TRC) resulted in a reduction in electricity savings of 29.7% for EEM-1. TRC calculated the total site project kWh realization rate as 86.2%.

3.4.2 Project 1270-01.2A

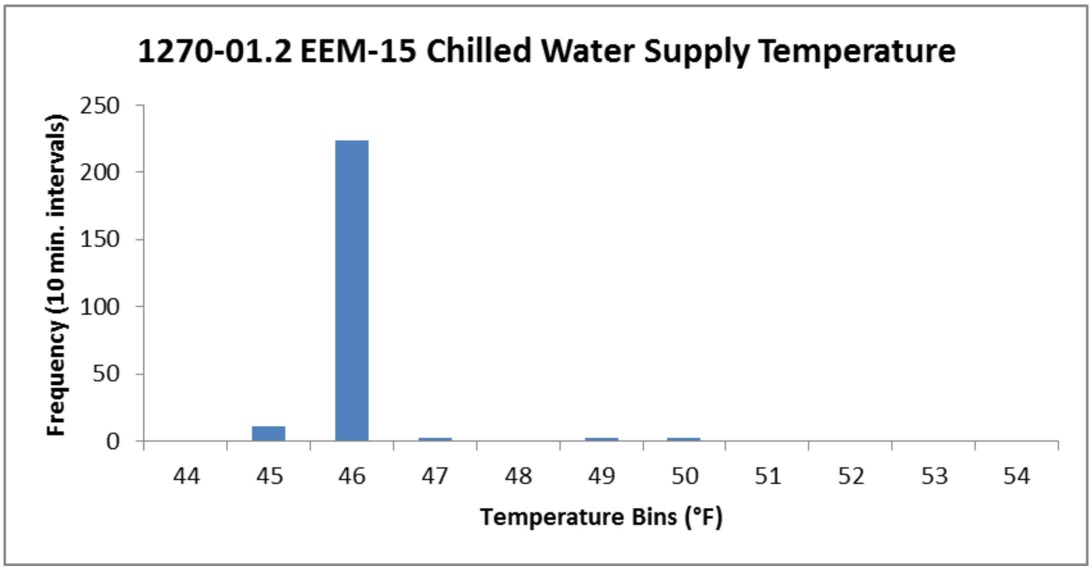
The project site is a rectangular shaped building comprised of high-bay manufacturing areas along with supporting laboratories and offices, receiving and storage areas, and testing facilities. The total facility size is approximately 162,000 square feet. The implemented energy savings measure for this project was:

- EEM-15: Installation of Variable Speed Chiller with Efficiency Greater that Title 24-2008 Code Minimum

The implementer performed savings calculations for this measure in custom Excel spreadsheets. TRC used EMS trend data and chiller nameplate information to confirm the calculation inputs, including equipment size and efficiency. The savings for this project come from the incremental chiller efficiency difference between Title 24-2008 code minimum and the higher performing installed chiller. TRC made no adjustments to the baseline assumption, because the implementer assumed Title 24-2008 as the baseline.

During the data analysis and calculation review, TRC discovered a difference in the chilled water supply temperature in the ex ante calculation (i.e., the proposed case of the inspection calculation): 48°F, versus what TRC found based on trend data: 45.5°F. Figure 7 shows results of TRC's analysis of the trend data, supporting our assumption of 45.5°F for the ex post calculation. Note that, although TRC had access only to trend data from winter months, chilled water supply temperature for systems is typically *lower* for hotter outdoor air temperatures. Thus, the chilled water supply temperature during non-winter months is probably less than or equal to the 45.5°F found here.

Figure 7. Histogram of Chilled Water Supply Temperature (CIEEP Project 1270-01.2)



A decreased chilled water supply temperature increases chiller energy consumption due to the increased workload on the compressor. This adjustment to the calculation resulted in a reduction in electricity savings of 30.6%, for a project kWh realization rate of 69.4%.

3.4.3 Project 1301-02.1A

The building is a single-story research facility consisting of laboratories, a vivarium, and office spaces. The total square footage of this building is approximately 30,000 square feet. The implemented energy savings measures included:

- EEM-1: Chiller Plant Upgrade – Installed new 160 ton variable speed chiller and optimize chilled water flow for reduced energy use at part-load conditions
- EEM-2: Retrofit Air Handler Supply Fans with Variable Frequency Drives (VFDs) on AHU-1 (40 hp), AHU-2 (20 hp), AHU-3 (25 hp), and AHU-4 (25 hp) Motors

The implementer performed savings calculations for these measures in custom Excel spreadsheets. TRC used EMS trend data and chiller and motor nameplate information to confirm the calculation inputs.

TRC confirmed that the number of measures, efficiency of those measures, and operating hours for EEM-1 and EEM-2 matched the values claimed, and made no adjustments to those parameters. In addition, TRC made no adjustments to the baseline assumptions for either EEM-1 or EEM-2. For baseline assumptions, the ex ante savings calculations for EEM-2 assumed existing conditions. Because EEM-2 was an optimization project, TRC agreed that the use of existing conditions was appropriate. EEM-1 involved both the installation of a new variable speed chiller and chiller plant optimization. The baseline ex ante savings calculations used existing conditions. The chiller replacement would have triggered Title

24, but the existing (constant speed) chiller met Title 24-2008 efficiencies. Therefore, TRC confirmed that the existing conditions were appropriate for the ex post savings for EEM-1.

The EEM-1 ex ante calculation included a correlation that reduced chiller water (CHW) flow-based on decreasing outside air temperature (OA), to a minimum CHW flowrate of 350 gallons per minute (gpm). The trend data revealed that the chilled water pump speed does not drop below 50 Hz or 83% of full speed (50 Hz/60 Hz = 83%). The baseline maximum is 450 gpm, so TRC revised the CHW minimum flow to 374 gpm (450 gpm x 83% = 374 gpm). This adjustment to the calculations reduced the ex post electricity savings by 8.9% due to increased pump energy.

For EEM-2, TRC found an error in the Air Handling Unit (AHU)-1 heating energy use for the proposed case in the ex ante calculation. The formula mistakenly summed the use for AHUs 2 through 4 instead of summing the natural gas use for AHU-1 only, resulting in an annual natural gas savings of 6,670 therms. This error improperly inflated the proposed case use, which in turn decreased the natural gas savings. TRC revised the formula, resulting in an adjusted annual natural gas savings of 12,030 therms. There was no change in savings from ex ante to ex post from an operational standpoint.

The overall project kWh realization rate is 95.2%, and the natural gas realization rate is 180%.

3.4.4 Project 1304-04.1

This 8-story office tower was built in 1965, and includes open and private offices, conference rooms, corridors, restrooms, a datacenter, an assembly hall, and a cafeteria. The implemented energy savings measures included:

- EEM-1: Optimize Airside Economizer Operation for AHU S-T4 to reduce mechanical cooling energy
- EEM-3 Reduce Operating Hours for AHUs S-T1, S-T2, S-T3, X-T1, and S-A4 to reduce fan, cooling, and heating energy use. The HVAC system serving the tower and the mezzanine had an operating schedule from 4 AM to 10 PM, Monday to Friday. Trend logs showed no load at 4:00 a.m., so the project included reducing the operating schedule through the Building Automation System to start at 6:00 a.m.
- EEM-5 Reduce Operating Hour for AHU S-A1 to reduce fan, cooling, and heating energy use

The implementer used eQUEST (v 3.64) to simulate baseline and proposed energy use for the facility using parametric runs for the efficiency measures. This project did not include any equipment installations. TRC used recent EMS trend data provided by the site to verify temperature, setpoint, and scheduling inputs to the energy model. As all of these energy savings measures were optimization strategies, the ex ante existing case baseline used by the implementer was deemed appropriate by TRC and used for the ex post savings calculations.

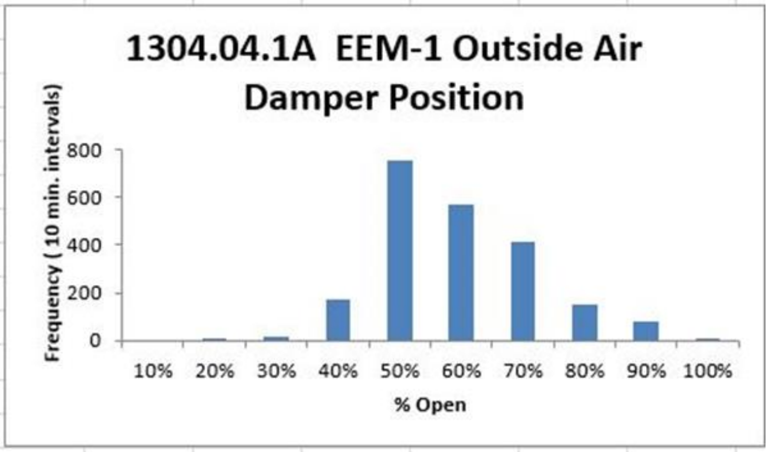
Overall, trend data showed the model to be consistent for EEM-5 scheduling, inconsistent with EEM-3 scheduling, and inconsistent with proper airside economizer operation for EEM-1. Consequently, TRC made no adjustments to EEM-5 savings calculations, but adjusted the calculations for EEM-1 and EEM-3 as described below.

For EEM-1, trend data for proper economizer operation *should* show the outside air (OA) percentage modulating between minimum OA and 100% OA based on a temperature or enthalpy strategy. However, actual trend data showed a modulating OA percentage that did not appear to be correlated with OA temperature. In addition, economizer operation never reached 100% OA. While it was beyond the scope of this evaluation to identify the reasons for this improper operation, it could be because the economizer was not sequenced correctly, because the temperature sensor is not working correctly, or other reasons. TRC recommends that CPAU staff work with facility staff to review sequences and settings in order to maximize savings.

Because there was no correlation of OA percentage with weather conditions, TRC modified the model to a weighted average, static value of 60% OA, to simulate the current operating condition.[1] Figure 8 shows the analysis which TRC used to develop a weighted average of 60% OA.

Figure 8. Frequency of Outside Air Damper Position for Economizer (CIEEP Project 1304.4 EEM-1)

OA % Open Bin	Frequency
10%	0
20%	3
30%	18
40%	175
50%	753
60%	568
70%	412
80%	148
90%	80
100%	3
Ttl Occurences	2160
Weighted Avg.	59%



This reduced ex post from ex ante electricity savings by 57.8%, due to increased mechanical cooling and chiller energy consumption.

Based on trend data for EEM-3, TRC identified that the runtime in the implementer's model was longer than current conditions. Consequently, TRC changed the model schedule from 4 am-10 pm M-F to 5 am-9 pm M-F. This affected fan motor, heating, and cooling energy. This increased the electricity savings by 7.8% due to the decrease in fan runtime, but decreased the natural gas savings (which were low: 700 therms) by 14.3%, because there was less runtime to save heating energy than in the ex ante model.

The project realization rate for all measures is 68.3% for energy (kWh) and 91.7% for natural gas.

3.4.5 Project 1384-01.3

This is a multi-functional facility that includes offices and research and development (R&D) areas in three buildings. The implemented energy savings measures included the following, which affected five air handling units (AHU-1, 3, 4, 5 and 6) and two air conditioning units (AC-2, 3, and 5):

- EEM-1: Optimize Supply Air Temperature (SAT) Reset for AHU-1 and AHU-3 to increase supply air temperature (SAT) depending on Outdoor Air (OA) temperature
- EEM-2: Optimize Airside Economizer Operation for AC-2 to reduce mechanical cooling energy

[1] The OA dampers were modulating but not operating properly per the trend data. The only way to simulate this in eQUEST is to assume one fixed position for the dampers. TRC calculated a weighted average for the damper position based on operating conditions, and input this value into eQUEST.

- EEM-3: Optimize Operating Schedules for AC-2, AC-3, AHU-1, AHU-3, AHU-5, and AHU-6 to reduce fan, cooling, and heating energy use
- EEM-4: Increase Zone Temperature Deadband to 5°F to save heating and cooling energy use
- EEM-5: Install Economizers on AHU-1, AHU-3, AHU-4, AHU-5, AHU-6, and AC-5 to reduce mechanical cooling energy
- EEM-6: Implement Chiller Water (CHW) Temperature Reset to increase CHW supply temperature from 42°F to a range of 44-45°F based on OA temperature to reduce chiller energy consumption

The implementer performed savings calculations for these measures in custom Excel spreadsheets. TRC used EMS trend data to confirm the calculation inputs.

TRC reviewed that the number of measures, efficiency of those measures, and operating hours, and visually verified equipment on-site. EEMs 1, 4, and 6 matched the values claimed, so TRC made no adjustments to the calculations for those measures.

EEM-2 and EEM-5 are measures for airside economizer repair and installation, respectively. Trend data for proper economizer operation should show the outside air (OA) percentage modulating between minimum OA and 100% OA based on a temperature or enthalpy strategy. However, the trend data for various AHUs showed OA percentages that were not as high as they should have been based on some OA temperatures – i.e., the economizers were not taking full advantage of "free cooling", as explained further below.

EEM-2 called for resequencing the operation of the economizer on AC-2. The EMS showed that there was a low temperature economizer lockout of 50°F for this unit – i.e., the unit would not use the economizer for an OA temperature below 50°F. In addition, one would expect the OA percentage to be 100% between 50°F and the high temperature changeover point. The ex ante saving calculation used a 20% minimum OA input below 50°F and 100% OA input between 50°F and 65°F. The trend data showed the OA percentage to be a weighted average of 17% below 53°F, and 53% between 53°F and 60°F. When the OA is not at 100% during economizer mode, it is not taking full advantage of free cooling and needs supplemental mechanical cooling to meet the load, which in turn increases chiller energy use. TRC made these revisions to reflect actual economizer operation to the ex post calculations which resulted in a 15.2% decrease in electricity savings for EEM-2.

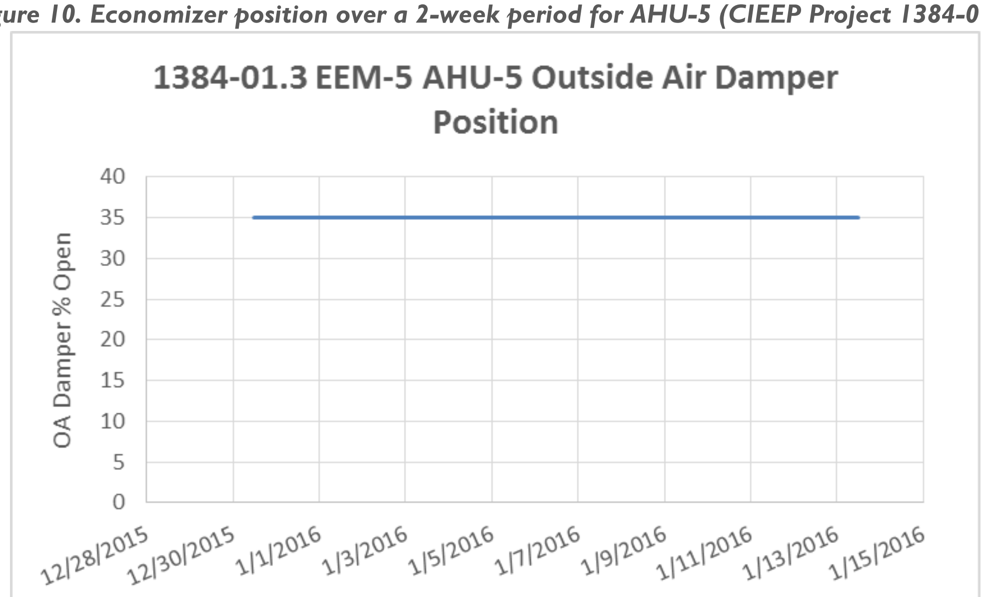
EEM-3 optimized scheduling for various AC and AHUs. TRC reviewed trend data and EMS screenshots for all of these units and found discrepancies between the present (actual) operating runtimes and the runtimes used in the ex ante calculations. Runtime affects fan motor, cooling, and heating energy. TRC updated the runtimes in the ex post calculations to reflect present conditions. Figure 9 shows the differences in ex ante and ex post runtimes. Note the substantial range in differences for the runtimes assumed in the ex ante calculations compared with the runtimes found by TRC: Most runtimes decreased in the ex post calculations, but another runtime increased by almost two-fold. (These revisions also affect EEM 5, "Install air-side economizers at AHU-1, 3, 4, 5 & 6", as decreasing runtime hours reduce economizer savings in cases where they are working.) TRC's adjustment to runtime reduced overall savings for EEM-3 by 2.6% for electricity and resulted in an additional *negative* 9,200 therms of natural gas savings. The large difference in gas usage is primarily due to the added overnight operating hours for AHU-5.

Figure 9. Air Handler Runtime Adjustments (CIEEP Project 1384-01.3 EEM-3)

Air Handler Runtime Hours		
Unit	**Ex Ante**	**Ex post**
AC-2	4,590	4,507
AC-3	3,654	2,638
AHU-1	3,654	2,973
AHU-3	3,654	2,428
AHU-5	4,959	8,760
AHU-6	8,760	8,760

EEM-5 involved installing economizers on the AHUs listed above. TRC reviewed the measure based on the runtime data associated with EEM-3 and also found operational issues with the economizers, as shown in Figure 14 below. A major adjustment to the savings was for AHU-5. The runtime hours increased significantly, from 4,959 hours in the ex ante calculation to 8,760 hours in the ex post calculation. This resulted in negative savings for EEM 3 AHU-5. However, due to the economizer being stuck continuously at 35%, these increased hours did not increase savings for EEM 5 AHU-5. Figure 10 shows the trend data indicating that the economizer was stuck at 35% open.

Figure 10. Economizer position over a 2-week period for AHU-5 (CIEEP Project 1384-01.3)



In addition, TRC found that AHU-3 was not operating as to be expected and to maximize savings. The outside air damper for the unit should have been at 100% for much of the study period, but trend data found that it was modulating instead. To account for this change in operation, TRC assumed a weighted average damper position of 50% to adjust the savings calculation. Figure 11 shows TRC's analysis supporting the 50% assumption.

Figure 11. Frequency of Outside Air Damper Position for Economizer (CIEEP Project 1384-01.3)

OA % Open Bin	Frequency
10%	265
20%	46
30%	84
40%	109
50%	114
60%	117
70%	113
80%	72
90%	52
100%	143
Ttl Occurrences	1115
Weighted Avg	50%

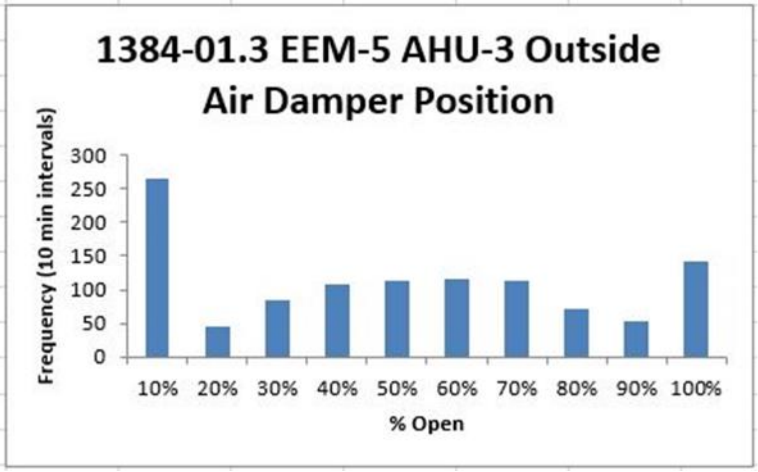


Figure 12 summarizes that economizer operating issues for EEM-5. The trend data indicate that the air side economizers are functional but not optimized.

Figure 12. Economizer Operating Issues for CIEEP Project 1384-01.3 EEM-5

Economizer OA Damper Issues	
Unit	**Conditions Found at Verification**
AHU-3	Opens to a maximum of 80%
AHU-5	Stuck at 35% open

TRC made the necessary revisions to the ex post calculations to reflect actual conditions, which resulted in decreased electricity savings of 4.3% and decreased natural gas savings of 40.3% for EEM-5. The reduction in natural gas savings was because of the economizer problems for AHU-3 and AHU-5. Because outdoor air was constantly being introduced for these AHUs, there were additional heating loads when heating was required. TRC recommends that CPAU staff work with facility staff to review the EMS sequences and settings in order to maximize savings.

The overall project realization rate for all measures at the site is 96.6% for kWh savings and 36.3% for natural gas.

3.4.6 Projects 1537-01.1 and 1537-01.2

This facility is a 45,319 square foot, 3-story building that serves as a data center. The majority of the building space is comprised of server and Uninterruptible Power Supply (UPS) rooms. The implemented energy savings measures included:

- EEM-1: Install Evaporative Cooling Medium to Pre-Cool Air for Condensers on 3 Air-Cooled Chillers to enhance chiller efficiency
- EEM-2: Install Electronically Commutated (EC) Motors and Underfloor Plug Fans on 21 Computer Room Air Handler (CRAH) Units replacing single speed motors and centrifugal fans for better performance
- EEM-3 Install 3 Water-Cooled Variable Speed Computer Room Air Handler (CRAH) Units replacing lower performing Computer Room Air Conditioner (CRAC) units

The implementer performed savings calculations for these measures in custom Excel spreadsheets. TRC requested trend data, but the site contact never provided it. However, TRC was able to confirm calculation inputs using EMS data, spot measurements, and chiller and motor nameplate information.

EEM-1 was an optimization project that correctly used the existing conditions for the baseline for the ex ante savings calculations. TRC reviewed the equipment efficiencies and data and found the project to be operating as proposed. TRC did not make any adjustments to the ex post calculations.

EEM-2 and EEM-3 involved equipment installations which would have triggered T24-2008 code as the baseline. After reviewing the pre- and post-installation data and calculations from the implementer and the T24 minimum efficiency requirements, TRC discovered that the original existing equipment was more efficient than code. Consequently, TRC used the existing equipment operating values as the applicable baselines for EEM-2 and EEM-3.

TRC analyzed the EMS data and ex ante calculations for EEM-3 and determined that the measure was operating as calculated, so made no revisions for the ex post calculations for EEM-3. TRC conducted a similar review for EEM-2 and discovered that the ex ante calculation was based on a power spot measurement of only one of 21 project units. TRC used motor nameplate data and fan speeds from EMS data for multiple units to calculate full load and average operating load kW for the CRAH units. TRC used this average and applied it to both the baseline and verified spot measurements from the ex ante calculations to better reflect the energy use for all of the units. This adjustment results in an ex post savings reduction of 23.8% for kWh and 24.8% for kW for the CRAH supply fan power and energy.

The overall project realization rate is 92.5% for kWh and 96.8% for kW.

4 COMMERCIAL ADVANTAGE PROGRAM (CAP)

4.1 Program Overview

The Commercial Advantage Program (CAP) provides CPAU commercial and industrial customers with incentives for energy saving appliances, lighting, and custom retrofits. Projects can apply for either deemed rebates or custom incentives. For the rebate track, program participants receive incentives for qualifying approved appliances or lighting, and program staff use a calculator based on the TRM to calculate ex ante savings. For custom retrofit measures, a professional licensed engineer calculates the energy savings measures and CPAU staff or a CPAU representative conducts pre- and post-installation inspection to validate the savings. All CAP projects are implemented by the customer or their contractor, and CPAU or a third party (Energy and Resource Solutions - ERS) conducts project measurement and verification.

In FY 2015, twelve projects participated in the program.

4.2 EM&V Approach

TRC verified savings for the CAP by identifying a sample of projects, conducting a desktop review for all sampled projects, and conducting on-site verifications for a subsample of projects.

4.2.1 Sampling

TRC used a stratified ratio estimation design to select the sample for the CAP. Using stratified ratio estimation reduced the total number of projects that need to be sampled to reach 90/10 confidence/precision compared to simple random sampling. TRC divided the sample into three strata to create an equivalent percentage of total savings in each stratum. This left only a few projects in each of the top two strata. By sampling all of the projects in the top two strata, TRC achieved 100% certainty within those groups. TRC sampled at 90/20 confidence/precision in the third tier (the small savings stratum) to meet the overall target of 90/10 for verification of total program savings.

The majority of FY 2015 projects were deemed lighting projects. However, as shown in Figure 13, project 1045 – a custom HVAC project – provided two-thirds of the total program ex ante energy savings.

Figure 13. CAP Projects Sampled for EM&V

Count	Project ID	Ex Ante Annual kWh Savings	Measure	Stratum	Selected for Sample	Selected for On-site	Confidence / Precision for Stratum
1	1045	750,184	Custom HVAC controls	1	Yes	Yes	100%
2	1033	93,999	Lighting	2	Yes	Yes	100%
3	1032	84,640	Lighting	3	Yes	Yes	90%/20%
4	1031	79,327	Lighting	3			
5	1036	59,555	Lighting	3	Yes	Yes	
6	1044	14,601	Lighting	3			
7	1028	12,797	Lighting	3	Yes		
8	1039	9,929	Lighting	3			
9	1034	9,612	HVAC	3	Yes		
10	1035	6,396	HVAC	3			
11	1029	3,999	Lighting	3	Yes		
12	1019	3,717	HVAC	3			
Total		**1,128,756**					

Overall, TRC achieved 90% confidence and 7% precision with the sample for CAP for first year energy savings.

4.2.2 On-site Verification

There was only one custom project reviewed – project 1045, a custom HVAC controls optimization project that contributed two-thirds of the ex ante kWh savings. For the on-site verification of this project, TRC reviewed trend data to compare operating conditions with the input parameters in the ex ante savings and interviewed the facility operator.

For the on-site verification of projects with deemed measures, TRC verified that:

- The number of installed measures claimed had been installed and remained in operation;
- The installed equipment including type, model, and energy use - e.g., wattage for lighting measures, met the specifications in program files;
- The room locations of the installed measures matched what was claimed, since location affects hours of use;
- The location of the installed measures in conditioned and unconditioned space matched program files, since this influences heating and cooling interactive effects calculations.

For projects with large numbers of measures installed in multiple rooms or areas, TRC verified a sample of measures. To select measures for verification, TRC identified the rooms or areas with measures showing the highest savings claims. TRC would also spot-check measures with low savings claims in nearby areas. If TRC found a discrepancy between installed vs. claimed, TRC would sample more heavily or verify a census of measures.

4.2.3 Desktop Review

For the desktop review, TRC reviewed the savings algorithms to:

- Compare hours of use (HOU) claimed versus HOU based on the building type and location (e.g., room type) of where the measures were installed. TRC used DEER deemed assumptions for HOU (not actual facility operating hours) for all CAP projects undergoing desktop review, because all of these projects' measures were deemed.
- Verify that the baseline efficiency assumption was appropriate, according to the guidelines set by the TRM, and as described in Figure 17 in Section 5.2.

Based on our on-site findings and desktop review, TRC adjusted input parameters for the savings calculation(s) for each project.

4.3 Overview of EM&V Results

Figure 14 provides results for each CAP project verified. As shown, for the custom HVAC project, TRC made adjustments to the operating conditions based on trend data, which increased energy savings. For the deemed projects, TRC increased the efficiency of measures installed for four projects, and reduced the number of measures installed for one project. As shown in Figure 14, the first year energy (kWh) savings realization rate for the projects sampled was 103%. After applying sampling weights, the overall program kWh realization rate was 102%.

Although the CAP program did not report ex ante therm savings, two CAP projects were interior lighting projects that would have negative therm savings due to interactive effects. TRC calculated therm savings for both of these projects – one of which was included in the sample shown in Figure 14, and the other of which was not sampled. For these two projects, TRC identified the therm/kWh value based on the building type from the TRM, and multiplied this by the ex post kWh value. TRC also reviewed the HVAC measures installed through the program (both in the sampled and non-sampled projects) to identify any possible positive therm savings, but did not identify any equipment that generated natural gas savings. For example, CAP projects 1034, 1035, and 1045 were for HVAC measures, but these had electric heat.

Section 4.4 provides more detail for each project.

Figure 14. CAP Project EM&V Results – First Year Gross Savings

						Ex Ante 1st Year		Ex Post 1st Year			
Project ID	**Measure Overview**	**No. of measures installed**	**Measure Efficiency**	**HOU**	**Baseline Energy Use**	**Demand Savings (kW)**	**Energy Savings (kWh)**	**Demand Savings (kW)**	**Energy Savings (kWh)**	**Realization Rate (% kWh)**	**Natural Gas (Therms)**
1045	Custom optimization of HVAC controls	✓	Confirmed, but calculation corrected	✓	✓	-	750,184	-	813,530	108%	-
1033	Replacement of exterior T5, CFL and MH fixtures and lamps with LEDs; Installation of occupancy sensors	✓	Proposed fixture wattage adjusted to specification sheet wattage	✓	✓	7.2	93,999	7.0	53,705	57%	-
1032	Replacement of exterior fluorescent T8, CFL and incandescent MR-16 with LEDs; Installation of occupancy sensors	✓	Proposed fixture wattage adjusted to specification sheet wattage	✓	✓	5.4	84,640	5.0	41,925	50%	-
1036	Replacement of incandescent MR-16 lamps with MR-16 LED lamps; Installation of occupancy sensors	Removed occupancy sensors, reduced number of lamps installed	✓	✓	✓	13.6	59,555	11.7	49,690	83%	(194)
1028*	Replacement of exterior MH to LED	✓	Proposed fixture wattage increased to specification sheet wattage	✓	✓	-	12,797	-	18,508	145%	-
1034*	Replacement of 36 HVAC units with efficient models	✓	✓	Not Applic	Adjusted to Replace on burn-out	0.0	9,612	4.4	8,460	88%	
1029*	Replacement of exterior MH to LED	✓	Proposed fixture wattage increased to specification sheet wattage	✓	✓	-	3,999	-	5,784	145%	-
Total for Projects Sampled						**26.2**	**1,005,892**	**28.2**	**991,601**	**103%**	**(194)**

✓ = Confirmed

*Verified through desk review only. Number and efficiency of measures installed were compared to invoices. Location of measures for HOU and interactive effect was verified via work

4.4 Project-Level EM&V Results

4.4.1 Project 1045

Project 1045 was implemented at a 310,000 square foot, five building office campus. The buildings have multiple tenants and are all used as office space. The buildings are independently conditioned with single-fan dual-duct (SFDD) variable air volume (VAV) systems. The cold-deck (CD) duct is cooled by a direct-expansion (DX) system while the hot-deck (HD) duct is heated by electric resistance coils. Through the CAP Custom Rebate option, the owner contracted retrofit upgrades to the existing HVAC systems on the buildings. The energy savings measures included:

- EEM-1: CD/HD Supply Air Temperature (CDSAT and HDSAT) Reset for Buildings 2-5 based on Outside Air Temperature (OAT).
- EEM-2: CD/HD Supply Air Temperature (SAT) Reset for Building 1 based on Outdoor Air Temperature (OAT) and Return Air Temperature (RAT).
- EEM-3: Supply Fan Static Pressure Optimization for Building 1.

The implementer performed savings calculations for these measures in custom Excel spreadsheets. The calculation model predicts supply air temperature for both heating and cooling based on outside air temperature. The implementer had supported the Ex-Ante savings with a comparison of pre- and post-implementation trend data gathered from October through December 2014, which included a range of OATs.[1]

Using the Ex-Ante data, TRC reviewed the regression line of the CDSAT and HDSAT vs. OAT to confirm the optimization. TRC's analysis of the ex ante calculation for EEM-1 and EEM-2 determined that savings were based on CDSAT and HDSAT vs. OAT curves (Baseline and Proposed) which included the cooling and heating lockout regions[2]. This was an error in the Ex-Ante calculation: During the cooling lockout region (at or below 52°F), the model should indicate no mechanical cooling, since all cooling is supplied by outside air in this temperature range. The same is true for heating at or above 70°F.

For the ex post case, TRC created new curves that excluded the lockout regions. TRC's revised curve fit is based on the actual pre-installation (baseline) and post installation trend data. In the revision, TRC applied limits to the CDSAT and HDSAT to transition the supply air from mechanical cooling or electrical resistance heating to mixed air when the OAT is within the cooling or heating lockout region. TRC's revision corrects the calculation to remove the (non-existent) heating and cooling energy use from inside the lockout regions. The resulting adjustment increased savings for EEM-1 and EEM-2. TRC accepted the EEM-3 savings with no adjustments.

Figure 15 shows example trend lines for the cold deck and hot deck supply temperatures based on OAT.

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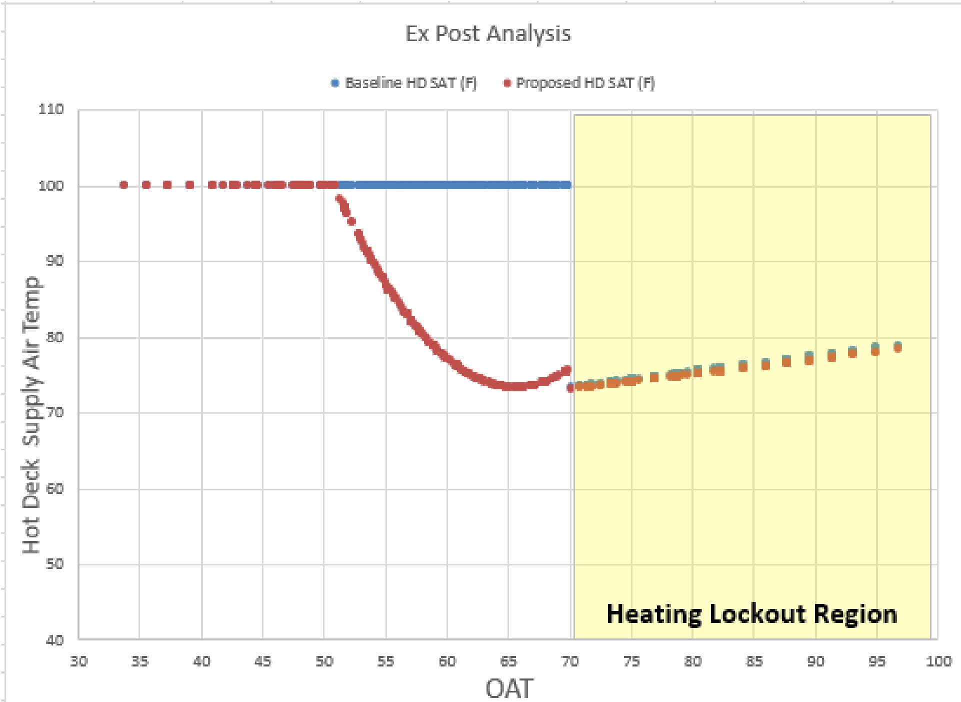
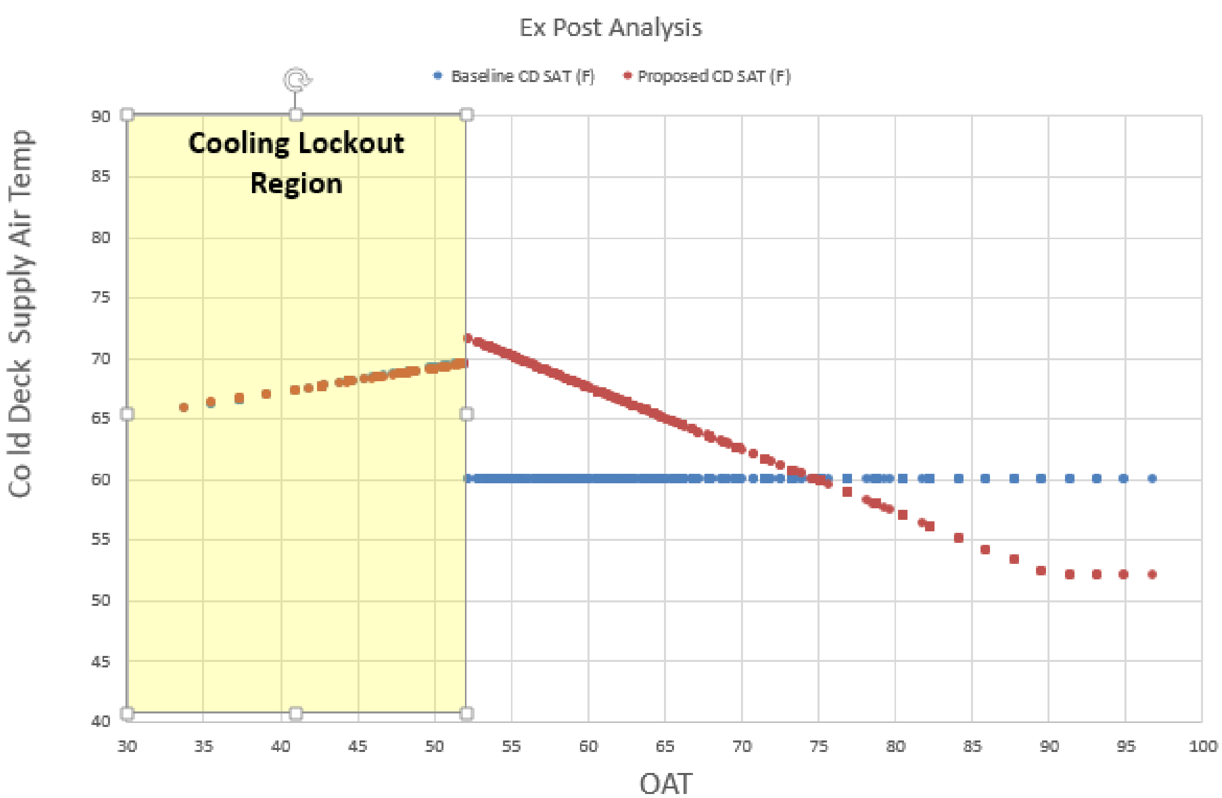
[1] TRC obtained additional EMS trend data from the site contact in January 2016 to compare actual operating conditions to the proposed operation. TRC analyzed the data and noted that the data included only a very limited range of outside air temperature, and was not sufficient to extrapolate the post operations. This data was not used in the analysis.

[2] For hot deck (heating): The lockout is 70°F; meaning when OSA is at or above 70°F, no heating can take place. For cold deck (cooling): The lockout is 52°F; meaning when OSA is at or below 52°F, no cooling can take place.

Figure 15. Ex Post Cold Deck and Hot Deck: Example Trend Lines (CAP project 1045 EEM-1)





4.4.2 Project 1033

Project 1033 was implemented in a parking garage for a medical clinic. The owner contracted the replacement of high output linear fluorescent T5 fixtures, T8 fixtures, CFLs and MH fixtures with LEDs. The LED replacements for the T5 and T8 fixtures also included the addition of occupancy sensors. The project claimed the existing condition for all measures, all of which were code compliant.

TRC verified project savings through an on-site verification of a sample of measures, a review of the savings algorithm, and a review of the site plans. For all sampled areas, the number and type of measures installed on the site plans matched what TRC inspected.

Based on our on-site verification and desk review, TRC:

- TRC confirmed that the number of measures installed, the room locations of the measures for HOU, and their location in conditioned or unconditioned space for interactive effects, matched what was claimed. TRC also confirmed that the baseline assumptions were correct.
- Adjusted the efficiency of the installed fixture wattage. TRC found that the measure installed was slightly less efficient than the measure claimed. TRC adjusted the efficiency of the installed LED linear replacement fixtures to reflect the correct wattage.

4.4.3 Project 1032

Project 1032 was implemented at the same medical complex as project 1033, but in a different underground garage. Through the program, the owner contracted the replacement of fluorescent T8, CFL and incandescent MR-16 with LEDs. The LED replacements for the T8 fixtures also included the addition of occupancy sensors. The project claimed the existing condition for all measures, all of which were code compliant.

TRC verified project savings through an on-site verification of a sample of measures, and a review of the savings algorithm. TRC verified project savings through an on-site verification of a sample of measures, a review of the savings algorithm, and a review of the site plans. For all sampled areas, the number and type of measures installed on the site plans matched what TRC inspected.

Based on our on-site verification and desk review, TRC:

- Confirmed that the number of measures installed, the room locations of the measures for HOU, and their location in conditioned or unconditioned space for interactive effects, matched what was claimed. TRC also confirmed that the baseline assumptions were correct.
- Adjusted the efficiency of the installed fixture wattage. TRC found that the measure installed was slightly less efficient than the measure claimed. TRC adjusted the efficiency of the installed LED linear replacement fixtures to reflect the correct wattage.

4.4.4 Project 1036

Project 1036 is a retail store. Through the program, the owner contracted the replacement of incandescent MR-16 lamps with MR-16 LED lamps. The project also claimed the installation of occupancy sensors for the LED lighting. The project used a code compliant fixture as the baseline.

TRC verified project savings through an on-site verification of the installed measures, and a review of the savings algorithm. TRC checked counts of the installed fixtures and occupancy controls and noted discrepancies in the installed lamps counts – TRC found a total of 280 lamps installed instead of 327 lamps. TRC also did not find occupancy sensors installed on the LED lighting. Furthermore, based on interviews with site personnel, the area where the occupancy sensors were claimed to have been installed is always occupied by sales associates during hours of operation.

Based on our on-site verification and desk review, TRC:

- Confirmed the efficiency of the LEDs installed and hours of use based on room location.
- Reduced the total number of LEDs installed and removed savings from all occupancy sensors.

During the on-site inspection, TRC noted that a significant fraction of the newly installed LEDs (12 lamps, or 4% of total) were burned out. TRC did not make adjustments to the savings claims, but we provide recommendations based on this and related findings in Section 9.

4.4.5 CAP Results for Projects Verified through Desktop Review

In addition to the four projects for which TRC conducted on-site verification, TRC conducted a desktop review of three projects by reviewing project documentation, including invoices and specification sheets. This section describes the results.

Project 1028

Project 1028 was implemented at a middle school. The project focused on the replacement of exterior metal halide lamps to LEDs. TRC verified the number of measures installed, and the location of measures as outdoor lighting based on project documentation. TRC also confirmed the use of existing conditions as the baseline. However, TRC reduced the installed fixture wattage based on the specification sheet in the project documentation.

Project 1034

Project 1034 was implemented at a motel. The project replaced thirty-six packaged terminal air conditioning (PTAC) HVAC units with more efficient PTAC models. TRC verified the number of measures installed and the efficiencies of the systems using specification sheets in the project file.

However, TRC adjusted the annual savings per unit from 267 kWh per unit to 235 kWh per unit. To develop the per savings assumption, TRC used the value for a replace-on-burnout (ROB) PTAC system installed in a motel, from the Northern California Power Agency (NCPA) Energy Efficiency (EE) Reporting Tool. This tool provides different savings assumptions for early retirement vs. ROB PTAC units, and different values for motels vs. hotels.

- TRC assumed ROB because the program did not have documentation supporting a claim of early retirement. TRC also telephoned facility staff, but they could not provide an estimate of the age of the equipment replaced. While TRC's best guess was that at least the majority of the equipment was operating when it was removed, TRC needed some evidence that the removed equipment had not reached its EUL to claim early retirement.
- TRC assumed a motel based on the telephone interview with facility staff. The staff reported that the facility more closely meets the definition of a motel (e.g., entrance from the exterior) than a hotel (e.g., entrance from a lobby, and includes amenities such as conference rooms).

Based on this adjustment to the savings per unit, TRC reduced the energy (kWh) savings for this project.

Project 1029

Project 1029 was implemented at a primary school. The project focused on the replacement of exterior metal halide lamps to LEDs. TRC verified the number of measures installed, and the location of measures as outdoor lighting based on project documentation. TRC also confirmed the use of existing conditions as the baseline. However, TRC reduced the installed fixture wattage based on the specification sheet in the project documentation.

5 RightLights Plus Program

5.1 Program Overview

The RightLights Plus Program provides small and medium businesses with incentives for lighting, vending, HVAC, and controls upgrades, as well as technical assistance. Program participants receive an energy audit, through which energy upgrades are identified. A program trade ally – i.e., a participating contractor – installs the recommended upgrades and receives the program rebates. The participant pays the contractor for the remainder of the project not covered by the program. Commercial electricity customers are eligible, as well as multi-family buildings for installations in common areas. RightLights Plus is implemented by a third party, Ecology Action, which uses a lighting calculator to estimate ex ante project savings. In FY 2015, 23 projects participated in the program.

5.2 EM&V Approach

TRC verified savings for the RightLights Plus program by identifying a sample of projects, conducting a desktop review for all sampled projects, and conducting on-site verifications for a subsample of projects.

5.2.1 Sampling

TRC used a stratified ratio estimation design to select the sample for RightLights Plus. Using stratified ratio estimation reduced the total number of projects that need to be sampled to reach 90/10 confidence/precision compared to simple random sampling. TRC divided the sample into three strata to create an equivalent percentage of total savings in each stratum. This left only a few projects in each of the top two strata. By sampling all of the projects in the top two strata, TRC achieved 100% certainty within those groups. TRC sampled at 90/20 confidence/precision in the third tier (the small savings stratum) to meet the overall target of 90/10 for verification of total program savings.

Figure 16 shows the kWh stratum for each project, whether TRC selected the project for sampling, whether TRC selected the project for on-site verification, and the confidence and precision that TRC achieved for each stratum.

Figure 16. RightLights Plus Projects Sampled for EM&V

Count	Project Number	Ex Ante Annual kWh Savings	Stratum	Selected for Desktop Review	Selected for On-Site	Confidence / Precision for each Stratum
1	4n1kC	356,527	1	Yes	Yes	100%
2	4lTl4	288,340	2	Yes	Yes	
3	5mkqD	236,191	2	Yes	Yes	100%
4	5nv2z	111,617	2	Yes	Yes	
5	4x7pY	67,728	3	Yes	Yes	90%/20%
6		56,383	3			
7		52,966	3			
8	6dFDg	49,104	3	Yes	Yes	
9		44,485	3			
10	5n2nd	38,692	3	Yes	No	
11		34,957	3			

Count	Project Number	Ex Ante Annual kWh Savings	Stratum	Selected for Desktop Review	Selected for On-Site	Confidence / Precision for each Stratum
12		20,574	3			
13		20,435	3			
14	4xAky	16,109	3	Yes	No	
15		14,822	3			
16		12,340	3			
17	5mlVJ	12,197	3	Yes	No	
18		11,599	3			
19		9,995	3			
20	4yhFd	8,085	3	Yes	No	
21		7,535	3			
22		6,685	3			
23		1,458	3			

Overall, TRC achieved 90% confidence and 3% precision with the projects sampled for first year energy savings.

5.2.2 Desktop Review

For the desktop review, TRC reviewed the savings algorithms to:

- Compare hours of use (HOU) claimed versus HOU based on the building type and location (e.g., room type) of where the measures were installed. TRC used DEER deemed assumptions for HOU (not actual facility operating hours), since RightLights Plus are deemed measures.
- Verify that the baseline efficiency assumption was appropriate, according to the guidelines set by the TRM and technical analysis conducted by TRC, as described in the section, Baseline Adjustments.

5.2.3 Baseline Adjustments

TRC reviewed baseline assumptions for all projects sampled. Figure 17 summarizes the baseline condition assumed by the program implementer for the ex ante savings calculations, compared with the baseline condition assumed by TRC for the ex post savings calculations.

Figure 17 lists the measure replacements in descending order of their ex ante savings contribution to the RightLights Plus program. For example, incandescent A-lamp replacements represented the highest energy savings for the program in FY 2015. Note that EISA refers to the federal Energy Independence and Security Act, implemented one year prior in California under Assembly Bill 1109, and IRL refers to a federal regulation governing Incandescent Reflector Lamps.

Figure 17. Summary of Baseline Assumptions for Lighting Replacements

Measure	Early retirement or replace on burnout (ROB)	Ex Ante Baseline	Ex Post (Adjusted) Baseline
Incandescent A-lamp to LED	Early retirement and ROB	Incandescent (e.g., 60W)	EISA-compliant (e.g., 43W halogen)
Reflector (R) and Parabolic Aluminized Reflector (PAR) lamps to LED	Early retirement and ROB	Incandescent PAR and R (e.g., 75W 1225 lumen PAR30)	IRL-compliant (e.g., 65W PAR30)
MR-16 to LED	Early retirement and ROB	MR-16	MR-16
Metal Halide (MH) to LED	Early retirement	Probe start MH	Probe start MH
T12 to High Performance T8 (HPT8)	Early retirement	T12	Dual baseline: T12 (baseline 1), 1st gen T8 (baseline 2)
T8 to HPT8	Early retirement and ROB	1^{st} generation T8	1^{st} generation T8
High Pressure Sodium (HPS) to CFL or LED	Early retirement and ROB	HPS	HPS
T12 to HPT8	ROB	1^{st} generation T8	1^{st} generation T8

TRC provides a description of the rationale for our baseline assumptions in the remainder of this section.

5.2.3.1 Incandescent, Reflector, and PAR Lamp Baselines

For projects with incandescent A-lamp, Reflector (R), and Parabolic Aluminized Reflector (PAR) lamps, the ex ante savings claims generally assumed existing conditions for both early retirement and replace-on-burn out (ROB) measures. For incandescent lamps, manufacturing regulations have been in effect in California since January 2011-January 2013 (with the regulation implementation date depending on the lumen range[1]) that have phased out traditional incandescent lamps in the 40-100W range. Based on guidance provided in TRM Chapter 16[2], TRC adjusted the existing baseline lamp wattages to meet code-compliant wattages. For example, TRC adjusted the wattage for an existing 100 W incandescent A-lamp to 72 W. Similarly, federal regulations[3] on the manufacturing of R and PAR lamps took effect in July 2012

[1] The U.S. DOE provides an overview of lamp phase-out schedules for EISA and AB 1109 by lumen bin on their Lighting Facts website: http://www.lightingfacts.com/Library/Content/EISA

[2] CMUA TRM Section 16.1.1 Baseline Examples: “Federal regulations baseline adjustment – Lighting fixtures with T12 lamps will be retrofitted with high performance T8 lamps and new ballasts. Recent federal regulations have ceased the manufacturing of standard T12 lamps, such as the ones in the fixtures to be retrofitted. If the existing stock of T12 replacement lamps has been depleted, then T12 lamps are not a viable option. Therefore, the baseline energy use is based on a fixture lamp that meets federal regulations. The lamp choices would be either first-generation T8 lamps or code-compliant T12 lamps.”

[3] U.S. DOE: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps; Final Rule: www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr34080.pdf

that raised the efficacy requirements (lumens per watts) of these products. TRC adjusted the baseline wattage of R and PAR lamps so that the wattage met the federal efficiency requirement for the existing (replaced) lumens per watt. For example, the baseline wattage for an existing incandescent 75 W (1225 Lumen) PAR30 lamp would be adjusted to 65 W based on the existing lamp wattage and lumen output.

TRC did not adjust baseline wattages for MR-16 lamps (i.e., TRC assumed MR-16 lamps for the existing condition, consistent with the ex ante savings claims) because these are still compliant with federal and state regulations. Similarly, TRC assumed existing conditions (did not adjust the baseline assumptions) for lamps outside of the wattage range of state and federal regulations – such as incandescent lamps < 40W or >100W which are exempt from EISA, or 30R or 65R lamps which are exempt from the IRL.

TRC used a single baseline, rather than a dual baseline, for early retirement of these measures because most of these lamps would have burned out within the year: Incandescent lamps have short measure lives – approximately 2000 hours based on DEER.[1] The replaced lamps were in room areas with annual hours of use that were typically in the range of 2000-4000 hours. Thus, the remaining useful life of these lamps would generally have been less than one year.

5.2.3.2 Linear Fluorescent Lamp Baselines

Traditional linear fluorescent T12s have also been phased out under federal legislation (General Service Fluorescent Lamps Standards – GSFL). The ex ante savings assumption was based on existing conditions – i.e., assumed T12 for the baseline. For the ex post savings for early retirement measures, TRC used a dual baseline, with the existing condition (T12) as the first baseline, and a GSFL-compliant lamp – a first generation T8 – as the second baseline. Following the precedent set by DEER, TRC assumed that the first baseline applied to the first one-third of the measure life, and the second baseline applied to the last two-thirds of the measure life. Consequently, TRC's baseline assumption did not affect the first-year savings calculations compared with ex ante savings calculations for the first year.

For replace-on-burn out (ROB) T12s, TRC assumed a federally compliant lamps – i.e., a first generation T8 – for the entire measure life.

For replacements of T8 lamps and fixtures, TRC did not make changes to the baseline, since these lamps and fixtures met federal regulations.

5.2.3.3 Metal Halide and High Pressure Sodium Baselines

For metal halide (MH) and high pressure sodium (HPS) lamps replacements, the ex ante savings were based on existing conditions. TRC also assumed existing conditions, since the lamps that were replaced are still compliant with regulations and available in the market. Note that there is a federal regulation requiring probe-start MH *luminaires* – i.e., lamps and ballasts. However, the replacements done through the program were lamp change-outs, not luminaire replacements, so this regulation would not have applied.

5.2.4 On-site Verification

For the on-site verification, TRC verified that:

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[1] http://www.deeresources.com/files/DEER2013codeUpdate/download/EUL-RUL_CalculatingDEERValuesForLighting_2014-02-05.pdf

- The number of installed measures claimed had been installed and remained in operation;
- The installed equipment, including type, model, and energy use - e.g., wattage for lighting measures, met the specifications in program files;
- The room locations of the installed measures matched what was claimed, since location affects hours of use;
- The location of the installed measures in conditioned and unconditioned space matched program files, since this influences heating and cooling interactive effects calculations.

For projects with large numbers of measures installed in multiple rooms or areas, TRC verified a sample of measures. To select measures for verification, TRC would identify the rooms or areas with measures showing the highest savings claims. TRC would also spot-check measures with low savings claims in nearby areas. If TRC found a discrepancy between installed vs. claimed, TRC would sample more heavily or verify a census of measures.

Based on our on-site findings and desktop review, TRC adjusted input parameters for the savings calculation(s) for each project, as described below.

5.3 Overview of Program EM&V Results

Figure 18 provides results for each verified RightLights Plus project. As shown, for all projects sampled, TRC's EM&V results confirmed that the number of measures, efficiency of measures, and location of measures (for HOU and interactive effects calculations) matched the values claimed. The one adjustment that TRC made for kWh savings was to the baseline energy assumed for some measures. The resulting first year kW realization rate was 85% (based on a weighted average of the projects sampled). Based on the sampling weights, the program first year kWh realization rate was 88%.

Figure 18 also shows that TRC calculated a much lower demand savings (145 kW) than the program claimed (243 kW) for the sampled projects. The low demand savings realization rate for this program (52%, once sampling weights were applied) was because:

1. The ex ante demand savings included savings from exterior lights. Following protocols set by DEER 2014, TRC assumed no demand savings for exterior lighting. (Note that TRC *did* assume demand savings for lighting in parking garages, because those lights often operate during daylight hours.)
2. The baseline adjustments described above for energy (kWh) savings also reduced demand (kW) savings.

Detailed project-level results are presented after Figure 18.

Figure 18. RightLights Plus EM&V Results by Project- First Year Gross Savings

						Ex Ante 1st Year Savings		Ex Post 1st Year Savings			
Project ID	**Measure Overview**	**No. of measures installed**	**Measure Efficiency**	**HOU**	**Baseline Energy Use**	**Demand Savings (kW)**	**Energy Savings (kWh)**	**Demand Savings (kW)**	**Energy Savings (kWh)**	**Realization Rate (% kWh)**	**Natural Gas (Therms)**
4n1kC, 5nv2z	Replacement of interior and exterior incandescent A, PAR and MR-16 lamps with LEDs	✓	✓	✓	A-lamp and PAR lamp baseline adjusted from existing conditions to EISA and IRL compliant	90.7	468,145	58.9	375,963	80%	(4,108)
4lTl4	Replacement of interior incandescent PAR and MR-16 lamps with LEDs	✓	✓	✓	PAR lamp baseline adjusted from existing conditions to IRL compliant	51.5	288,340	37.1	207,742	72%	(1,039)
5mkqD	Replacement of interior incandescent MR-16 and PAR lamps with LEDs and the retrofit or replacement of exterior metal-halide fixtures with LEDs	✓	✓	✓	PAR lamp baseline adjusted from existing conditions to IRL compliant	57.8	236,191	25.1	235,420	99.7%	(562)
4x7pY	Retrofit or replacement of exterior metal-halide fixtures with LEDs	✓	✓	✓	✓	16.5	67,728	-	67,728	100%	-

						Ex Ante 1st Year Savings		Ex Post 1st Year Savings			
Project ID	**Measure Overview**	**No. of measures installed**	**Measure Efficiency**	**HOU**	**Baseline Energy Use**	**Demand Savings (kW)**	**Energy Savings (kWh)**	**Demand Savings (kW)**	**Energy Savings (kWh)**	**Realization Rate (% kWh)**	**Natural Gas (Therms)**
6dFDg	Replacement of interior T12 and 1st generation T8 fluorescent fixtures with high performance T8 fluorescent fixtures; and the replacement of MR-16 lamps with LEDs	✓	✓	✓	T12 baseline adjusted from existing conditions to dual baseline	8.5	49,104	8.5	49,104	100%	(258)
5n2nd*	Replacement of T12 fixtures with T8, incandescent lamps with CFLs, and incandescent PAR lamps with LEDs	✓	✓	✓	T12 baseline adjusted from existing conditions to dual baseline; PAR lamp baseline adjusted from existing conditions to IRL-compliant	10.1	38,692	9.2	35,459	91.6%	(3)
4xAky*	Replacement of the existing incandescent A and MR-16 lamps with LEDs	✓	✓	✓	Incandescent A-lamp baseline adjusted from existing conditions to EISA-compliant	3.4	16,109	2.7	15,222	94%	(59)
5mlVJ*	Replacement of T12 fixtures with T8 fixtures	✓	✓	✓	T12 baseline adjusted from existing conditions to dual baseline	3.2	12,197	3.2	12,197	100%	(1)
4yhFd*	Replacement of MH fixtures with LED fixtures	✓	✓	✓	Confirmed	2.0	8,085	-	8,085	100%	-
Total for Projects Sampled						**243**	**1,184,590**	**145**	**1,006,919**	**85%**	**(6,030)**

✓ = Confirmed

*Project verified through desk review only. Number and efficiency of measures installed were compared to invoices. Location of measures for HOU and interactive effect was confirmed via work orders.

5.4 Project-Level EM&V Results

5.4.1 Project 4n1kC and 5nv2z

Projects 4n1kC and 5nv2z were implemented at the same apartment building and assisted living facility. Through the program, the owner conducted a self-install replacement of interior and exterior incandescent A, PAR and MR-16 lamps with LEDs. The project claimed early retirement for most measures, and replace on burn-out for the remaining measures.

TRC verified project savings through an on-site verification of a sample of measures, and a review of the savings algorithm.

Based on our on-site verification and desk review, TRC:

- Confirmed the number of measures installed, efficiency of measures installed, hours of use, and the interactive effects. TRC confirmed that the number, type, and energy use of the installed measures, the room locations of the measures, and their location in conditioned or unconditioned space, matched what was claimed. TRC also confirmed the baseline energy use for MR-16 lamps.
- Adjusted the baseline energy use for A-lamp and PAR lamps. The ex ante baseline wattages used the existing lamp wattages, which consisted mostly of incandescent A, PAR and MR-16 lamps. TRC adjusted the existing baseline lamp wattages for the incandescent A and PAR lamps to meet wattages compliant with state and federal regulations. TRC also removed demand (kW) savings for exterior lighting measures. This adjustment reduced the energy and demand savings for the project compared with ex ante savings claims.

5.4.2 Project 4lTl4

Project 4lTl4 was implemented at a retail department store. Through the program, the owner conducted a self-install replacement of interior incandescent PAR and MR-16 lamps with LEDs. The project claimed early retirement for most measures, and replace on burn-out for the remaining measures.

TRC verified project savings through an on-site verification of a sample of measures, and reviewed the savings algorithm. There were some areas of the store that were inaccessible due to a remodel. Consequently, TRC checked that all of the accessible areas had the installed measures. For the measures installed in inaccessible areas, TRC reviewed work orders to confirm that the number and efficacy of the measures claimed, and held interviews with the facility manager, who reported that these measures were installed in the areas as claimed.

Based on our on-site verification and desk review, TRC:

- TRC confirmed that the number, type, and energy use of the installed measures, the room locations of the measures, as well as its location in conditioned or unconditioned space, matched what was claimed. TRC also confirmed the baseline energy use for MR-16 lamps.
- Adjusted the baseline energy use for PAR lamps. The ex ante baseline wattages used the existing lamp wattages which consisted mostly of incandescent PAR and MR-16 lamps. TRC adjusted the existing baseline lamp wattages for the PAR lamps to meet federal code-compliant wattages.

5.4.3 Projects 5mkqD

Project 5mkqD was implemented at a large office building complex. Through the program, the owner contracted the replacement of interior MR-16 lamps and a small number of incandescent PAR and with LEDs, and the retrofit or replacement[1] of exterior metal-halide fixtures with LEDs. The project claimed early retirement for the majority of measures, and replace on burn-out for one of the measures.

TRC verified project savings through an on-site verification of a sample of measures, and a review of the savings algorithm. Based on our on-site verification and desk review, TRC:

- Confirmed that the number, type, and energy use of the installed measures, the room locations of the measures, as well as its location in conditioned or unconditioned space, matched what was claimed. TRC also confirmed the baseline energy use for MR-16s and metal halides.
- Adjusted the baseline energy use for PAR lamps. The ex-ante baseline wattages used the existing lamp wattages which consisted mostly of interior incandescent PAR and MR-16 lamps and exterior metal-halide. TRC adjusted the existing baseline lamp wattages for the PAR lamps to meet federal code-compliant wattages. TRC also removed demand (kW) savings for exterior lighting. These adjustments reduced energy and demand savings.

TRC noted during the on-site inspections that a few of the LEDs replacing MR-16s in recessed cans had burned out.

5.4.4 Project 4x7pY

Project 4x7pY was implemented at a large office complex. Through the program, the owner contracted the retrofit or replacement of exterior metal-halide fixtures with LEDs. The project claimed early retirement for most measures, and replace on burn-out for the remaining measures.

TRC verified project savings through an on-site verification of all installed measures and a review of the savings algorithm. Based on our on-site verification and desk review, TRC:

- Confirmed the number of measures installed, efficiency of measures installed, hours of use, interactive effects, and baseline energy use. TRC confirmed that the number, type, and energy use of the installed measures, the room locations of the measures, as well as its location in conditioned or unconditioned space, matched what was claimed. The ex-ante baseline wattages were not adjusted as they were found to meet federal code-compliant wattages.

  TRC made no adjustments to the savings claims for this project.

5.4.5 Project 6dFDg

Project 6dFDg was implemented at a hospital. Through the program, the owner contracted the replacement of interior T12 and 1st generation T8 fluorescent fixtures with high performance T8 fluorescent fixtures; and the replacement of MR-16 lamps with LEDs. The project claimed early retirement for all measures.

[1] For projects with fixture "retrofits", the program installed a new LED driver board (including ballast), but retained the existing fixture housing. For fixture replacements, the program replaced the entire fixture – housing, lamp, and ballast.

TRC verified project savings through an on-site verification of a sample of measures, and a review of the savings algorithm. Based on our on-site verification and desk review, TRC:

- Confirmed that the number, type, and energy use of the installed measures, the room locations of the measures, as well as its location in conditioned or unconditioned space, matched what was claimed. TRC also confirmed the baseline energy use for the T8 fixtures.
- Adjusted the baseline energy use for T12 fixtures. The ex-ante baseline wattages used the existing lamp wattages, which consisted mostly of T12 fixtures and MR-16 lamps. TRC adjusted the existing baseline lamp wattages for the T12 fixtures according to a dual baseline, where the first baseline was the existing condition and the second baseline was a 1st generation T8 fixture.

5.4.6 RightLights Plus Results for Projects Verified through Desktop Review

In addition to the five projects for which TRC conducted on-site verification, TRC conducted a desktop review of four projects. This section describes the results.

Project 5n2nd

Project 5n2nd was implemented at a large office complex. The project primarily replaced T12 fixtures with T8s, but also replaced a small number of incandescent lamps with CFLs and incandescent PAR lamps with LEDs. The project claimed early retirement for all of the measures. The ex-ante baseline wattages used the existing lamp wattages, which consisted mostly of fluorescent T12 fixtures and PAR lamps. TRC adjusted the existing baseline lamp wattages for the T12 fixtures to a dual baseline – with existing conditions assumed for the first baseline (up to year 5) and a 1st generation T8 lamp assumed for the second baseline (years 6-15). TRC also adjusted the baseline for PAR lamps to meet IRL-compliant wattages.

Project 4xAky

Project 4xAky was implemented at a retail store. The project replaced the existing incandescent A and MR-16 lamps with LEDs. The project claimed early retirement for most of the measures, and ROB for one of the measures. The ex-ante baseline wattages were adjusted for the incandescent A-lamp to meet EISA-compliant wattages.

Project 5mlVJ

Project 5mlVJ was implemented at a large office complex. The project replaced T12 fixtures with T8 fixtures. The project claimed early retirement for all of the measures. The ex-ante baseline wattages were adjusted for the incandescent A-lamp to meet federal code-compliant wattages. The ex-ante baseline wattages were adjusted for the T12 fixtures to a dual baseline, as described for project 5mkqXD.

Project 4yhFd

Project 4yhFd was implemented at a primary school. The project replaced exterior MH fixtures with LED fixtures. The project claimed early retirement for all of the measures. No adjustments were made to the ex-ante savings for this project.

6 BUSINESS NEW CONSTRUCTION

6.1 Program Overview

The Business New Construction program provides incentives and technical assistance for new construction nonresidential projects that exceed the required energy efficiency standards. The program sets a minimum of 20% above Title 24 for incentives. The program also provides tiered incentives for buildings modeled with energy savings higher than 20%.

In FY 2015, one project participated in the Business New Construction program.

6.2 EM&V Results

Because this program had only one participant in FY 2015, this section provides TRC's approach to conducting EM&V for this one project. (TRC does not provide a program-level EM&V approach description, as we do for other programs.)

The new building is a three-story standalone retail store. The building has a total of 123,706 square feet of floor area and consists of mainly retail spaces, with supporting storage areas, offices, restrooms, and electrical and mechanical rooms. The implemented energy savings measures included:

- EEM-1: Cool Roof for reduced cooling load
- EEM-2: High Performance Windows & Glazing for reduced heating a cooling load
- EEM-3: Variable Frequency Drives on AHU Supply Fans for twelve 15 hp motors
- EEM-5: High Efficiency Interior Lighting
- EEM-6: Demand Control Ventilation based on carbon dioxide (CO2) levels to reduce fan speed to save energy during low occupancy
- EEM-7: Instantaneous Hot Water Heaters to reduce standby losses for natural gas energy savings

For the ex ante savings calculation, the implementer developed an energy simulation with eQUEST software to simulate the Title 24-2008 code compliant baseline and proposed cases. The simulation determined if the project qualified for an incentive, and the level of that incentive. The ex ante simulation showed that the compliance margin for this project was 20.1%. The simulation also calculated the energy savings derived from specific measures that were modeled as better than code minimum.

TRC conducted a site visit, reviewed EMS schedules and trend data, and made the necessary changes in the eQUEST simulation to reflect current operating conditions.

Prior to the site visit, TRC reviewed the project investigation and verification reports, eQUEST energy simulation model, and as-built plan set to become familiar with project scope, modeling methodology, and savings for each of the implemented measures.

During the on-site field visit, TRC:

- Conducted a brief staff interview to determine any major operational or occupancy changes since measure implementation

- Visually verified lighting and equipment installation quantity, make, and model. For example, TRC visually verified the installation of the cool roof, glazing, supply fan VFDs, CO2 sensors, and the instantaneous hot water heaters. For the lighting, TRC reviewed lighting as-builts and schedule and sampled large sections of each floor to confirm fixture and lamp counts and types.
- Reviewed Energy Management System (EMS) schedules and settings
- Obtained EMS trend data, screenshots, and equipment performance, specification product submittals, and as-built plan sets

As this project was new commercial building construction, it was required to meet Title 24 building code standards. At the time the building permits were issued, Title 24-2008 was in effect. Therefore, TRC determined that the T24-2008 standard was the applicable baseline for this project. The ex ante savings calculation (including the existing eQUEST model) was developed based on a T24-2008 baseline.

After the site visit, TRC reviewed EMS trend data and submittals for installed product performance and compared these with the ex ante energy model inputs. TRC determined that the measures were all installed and operating as proposed. TRC made no adjusts to the ex post savings, and the realization rate for the project is 100%. Figure 19 shows the EM&V results for this program.

Figure 19. Business New Construction Program Results – First Year Gross Savings

Project Number	Description	Ex Ante 1st Year Savings			Ex Post 1st Year Savings			Realization Rate (% kWh)
		kW	kWh	Therms	kW	kWh	Therms	
746	Cool Roof, High performance windows and glazing, variable frequency drives on supply fans, LEDs, demand control ventilation, instantaneous hot water heaters	0	473,100	0	0	473,100	0	100%

7 Appliance Recycling

7.1 Program Overview

The Appliance Recycling program offers rebates to consumers for the pick-up of their old, inefficient (yet operable) refrigerator(s) or freezer(s). Recycled appliances can be primary or secondary units, and the customer can choose to replace the recycled unit, or remove it without replacement. The old appliances are sent to a recycling center and permanently removed from further use. A third party contractor, JACO Environmental, operated the program in FY 2015.

Based on the program database, there were eighty-four refrigerators and twelve freezers recycled in the Appliance Recycling program in FY 2015.

7.2 EM&V Approach

The program used the CPAU TRM values to assume deemed ex ante energy savings: 616 kWh and 0.124 kW per refrigerator and 643 kWh and 0.129 kW per freezer. The TRM cites DEER 2011 energy savings for these values.

To develop ex post savings, TRC and its team member Klos Energy Consulting conducted billing analysis using data from all program participants that had sufficient, clean data. The TRC team cleaned the billing data and conducted regression analysis to identify a change in kWh usage. The TRC team developed multiple regression models, including one that separated replaced units from removed units, separated primary units from secondary units, and one that that combined refrigerators with freezers, before selecting the model shown in Equation 1. The TRC team selected the final model shown in Equation 1 because it created reasonable, statistically-significant estimates of savings for refrigerators. Section 10.2 in the Appendix presents each of the alternative models, along with the reasons they were not selected as the final model.

7.3 Results

7.3.1 Refrigerators: Energy and Demand Savings

Equation 1 shows the regression model that the TRC team developed to estimate energy savings due to recycling of refrigerators. As described in the Freezers section, TRC did not have enough data points to reliably develop an energy savings estimate for recycling of freezers, so TRC used the TRM assumptions to estimate freezer savings.

$$MEC_{cm} = a_c + b_1 CDD_m + b_2 HDD_m + b_3 Post_{cm} + \varepsilon_{cm} \quad \text{(Equation 1)}$$

Where:

MEC_{cm} = *Monthly Energy Consumption for Customer c during Month m*

a_c, $b_{1\text{-}3}$ = *Coefficients calculated through curve fitting*

CDD_m = *Cooling Degree Days during Month m*

HDD_m = *Heating Degree Days during Month m*

$Post_{cm}$ = *A binary variable equal to 1 if Month m is after refrigerator pickup date for Customer c, and equal to 0 if Month m is before or equal to refrigerator pickup date*

ε_{cm} = *Error term for Customer c during Month m*

The coefficients on the weather terms (Cooling Degree Days and Heating Degree Days) account for the customer's usage responses to weather, leaving a weather-normalized estimate of base usage for each month. Coefficient b_3 represents the average change in monthly base usage after the appliance has been picked up. If this coefficient is negative, it represents monthly savings from the program on a per participant basis.

Note that this is a fixed effects methodology, which is possible because time-series data is available for many different customers. The term a_c represents the unique characteristics of each individual customer's base energy usage. The fixed effects methodology can identify the effect of these unique characteristics without explicitly modeling the components. This means that the energy usage effects of customer characteristics that are fixed (i.e., do not vary over time), such as square footage of conditioned space, presence of air-conditioning, lifestyle preferences, etc., are included in the model without the need to identify their specific causes.

The TRC team's regression model results are shown in Figure 20. Based on the regression model results, the TRC team estimated energy savings to be 36.9 kWh per month, which totals 443 kWh per year per recycled refrigerator. As shown in Figure 20, the statistical significance of this modeling result was very strong: prob (t) = 0.0003.

Figure 20. Refrigerator Regression Model Results

Coefficient	Estimate	Std Err	T Value	Prob t
a_c (Intercept)	1.38E-14	4.20949	0	1
b_1 (for CDD term)	0.47133	0.12658	3.72	0.0002
b_2 (for HDD term)	0.70315	0.043	16.35	<.0001
b_3(for Post term)	-36.9432	10.16804	-3.63	0.0003

The estimated savings of 443 kWh per year per customer for refrigerators in the FY 2015 Appliance Recycling program is lower than the deemed value of 616 kWh for recycled refrigerators in the California Technical Resource Manual (TRM). While it was beyond the scope of this evaluation to investigate the reason for this discrepancy, the TRC Team identified several possible reasons why the observed savings from this program are lower than the TRM value:

- CPAU customers may have had more refrigerators replaced, rather than removed without replacement, compared to DEER assumptions
- CPAU customers may have had newer or more efficient refrigerators recycled than what DEER assumes
- CPAU customers may have had refrigerators that were different sizes or had different features, or CPAU customers had different refrigerator usage patterns than DEER assumptions

To estimate coincident peak savings, the annual savings were divided by the number of hours that refrigerators are normally in use during a year, which is 8760 hours (i.e., all hours of the year). However, this assumes that the load curve is flat and refrigerators run at the same level during all hours of use.

Previous metering studies have shown that this is not true.[1] There is extra usage when the surrounding temperatures are warmer in summer, particularly if the refrigerator is not in a cooled environment. There is also extra usage during the daytime when there are more refrigerator door openings compared to the nighttime. To account for these two differences, a Temperature Adjustment Factor of 1.23 and a Load Shape Adjustment Factor of 1.15 are factored into the original flat load curve estimate.[2]

$$KW\ Savings = \frac{Annual\ KWH\ Savings}{8760\ hours} * Temp\ Adj\ Factor * Load\ Shape\ Adj\ Factor$$

$$KW\ Savings = \frac{443\ KWH}{8760\ H} * 1.23 * 1.15 = 0.072\ kW$$

Based on this methodology, estimated coincident peak demand savings are 0.072 kW per refrigerator.

7.3.2 Freezers: Energy and Demand Savings

There were twelve freezer pick-ups during FY 2015, but only four of these cases had sufficient, clean data for analysis. Two of the four were freezers that were not replaced, and they showed a very high savings of 1,049 kWh per year that were statistically significant at the 95% confidence level. However, savings estimates were not significant for the two units that had been replaced.

Given the very small number of freezers contributing to this savings estimate (two), sample bias was a high concern. It is unlikely that these two freezers are representative of the whole population of twelve. Consequently, the TRC team concluded that the billing analysis did not create valid savings estimates for freezers. Instead, the TRM savings values were retained: 643 kWh and 0.129 kW per recycled freezer.

7.3.3 Natural Gas Savings

Building modeling indicates that the recycling of refrigerators and freezers results in an increase in heating energy use due to interactive effects: These appliances release waste heat, so when these units are removed or replaced with more efficient units, they generate less waste heat. Building models therefore show that homes must therefore operate their heating equipment more to make-up for this loss in heat. Consequently, the TRC team estimated the interactive effect (negative therm savings) that would result from the additional natural gas use needed for heating after units were recycled.

To develop the natural gas savings per unit, the TRC team used values from DEER 2014. While DEER provides an estimate of therms/ unit savings for recycled refrigerators and freezers, DEER assumes a different kWh/ unit savings for refrigerators than what the TRC team developed using regression analysis, and a different kWh/unit for freezers than what the TRM assumes. Because the therms/ unit savings is proportional to energy (kWh) savings, the TRC team adjusted the therms/ units savings in DEER so that it was proportional to the energy savings we assumed.

Using DEER 2014, The TRC team identified the average kWh/unit and therm/unit savings for recycled refrigerators and freezers for Climate Zone 4 (where Palo Alto is located), averaged across all residential

[1] Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004, pp. 47-48.

[2] This methodology and the factor values come from the Mid-Atlantic Technical Reference Manual Version 2.0, published by the NEEP Regional Evaluation, Measurement & Verification Forum, page 34.

building types. The TRC team divided the therm/unit savings by the kWh/unit values[1] from DEER, to develop a therm/kWh ratio. The TRC team then multiplied the therm/kWh ratio by the kWh/unit value we estimated for CPAU, to estimate a therm/unit value that was adjusted for CPAU kWh savings. Finally, the TRC team multiplied the therm/unit CPAU value by the total number of recycled units to estimate total therm savings. The equations below show the results.

For Refrigerators:

Therm/kWh = Therm/unit (from DEER) / kWh/unit (from DEER) =

-16.4 Therm/unit / 688 kWh/unit = -.024 Therm/kWh

Therms/unit for CPAU = Therm/kWh x kWh/unit (as calculated by TRC team) =

-.024 Therm/kWh x 443 kWh/unit = -10.6 Therm/unit

Total Therm Savings for CPAU = Therm/unit x Units Recycled =

-10.6 Therm/units x 84 Units = - 888 Therms

For Freezers:

Therm/kWh = Therm/unit (from DEER) / kWh/unit (from DEER) =

-16.1 Therm/unit / 718 kWh/unit = -.022 Therm/kWh

Therms/unit for CPAU = Therm/kWh x kWh/unit (from TRM, and assumed by TRC team) =

-.022 Therm/kWh x 643 kWh/unit = -14.4 Therm/unit

Total Therm Savings for CPAU = Therm/unit x Units Recycled =

-14.4 Therm/units x 12 Units = - 173 Therms

Combining results for refrigerators and freezers, the TRC Team calculated -1,061 Therms savings from the Appliance Recycling Program.

Figure 21 provides the final gross annual program savings results.

[1] The kWh/unit values the TRC identified from DEER 2014 does not match the kW/unit values from the TRM. This may be because the TRM used DEER for 2011 values (since DEER 2014 was not yet published). In addition, the TRC team used climate zone 4 values, while the TRM was written for all CA municipal utilities, so presumably uses values that represent statewide averages.

Figure 21. Appliance Recycling Program: Gross Annual Savings

Description of Measures	No. of Measures	Ex Ante Annual Savings			Ex Post Annual Savings				
		Per Unit Savings Assumptions	kW	kWh	Per Unit Savings Assumptions	kW	kWh	Therms	Realization Rate (% kWh)
Refrigerators	84	0.124 kW, 616 kWh	10.4	51,744	0.072 kW, 443 kWh, -10.6 Therms	6.0	37,239	(888)	72%
Freezers	12	0.129 kW, 643 kWh	1.5	7,716	0.129 kW, 643 kWh, -14.4 Therms	1.5	7,716	(173)	100%
Program Total	**96**		**12.0**	**59,460**		**7.6**	**44,955**	**(1,061)**	**76%**

8 CALCULATION OF NET AND LIFECYCLE SAVINGS

8.1 Net Savings

To calculate net savings, TRC multiplied the gross savings for each measure by the NTGR. TRC obtained the NTGR values for each measure from the Northern California Power Agency (NCPA) Energy Efficiency (EE) Reporting Tool based on the E3 calculator, which took NTGR values from DEER 2014.

Figure 22 provides program level net first year savings results. TRC used the same NTGR values as the program assumed for the ex ante savings. TRC's adjustments to net savings resulted from adjustment to gross savings.

The gross and net natural gas savings values in Figure 22 include interactive effects. The net natural gas savings values assume a NTGR of 80% for all programs except the Appliance Recycling program, which has a NTGR of 70%.

Figure 22. Net 1st Year Savings

	Ex Post Gross Savings			Ex Post Net Savings			
Program	**Demand (kW)**	**Energy (kWh)**	**Natural Gas (Therms)**	**NTGR**	**Demand (kW)**	**Energy (kWh)**	**Natural Gas (Therms)**
CIEEP (Enovity)*	412	1,969,000	21,280	80%	330	1,575,200	17,024
Home Energy Report	0	1,604,272	0	100%	0	1,604,272	
RightLights Plus*	157	1,306,405	(7,823)	80%	126	1,045,124	(6,259)
(CAP)*	33	1,156,252	(251)	80%	26	925,002	(201)
Business New Constr.*	0	473,100	0	85%	0	402,135	0
Res. Smart Energy	0	92,831		80%	0	74,265	
REAP Low Inc	0	69,409		80%	0	55,527	
Appliance Recycling*	7.6	44,955	(742)	70%	5	31,468	(520)
Hospitality	60	44,209		85%	51	37,578	
Res New Constr.	0	18,589		80%	0	14,871	
SCVWD	0	91		80%	0	73	
Program Total	**670**	**6,779,113**	**12,463**	**N/A**	**538**	**5,765,515**	**10,045**

TRC also presents net natural gas savings under two different sets of assumptions, shown in Figure 23. This figure shows net natural gas savings with and without interactive effects, and under two different NTGRs, as described below.

- **With and without interactive effects:** For the RightLights Plus, CAP, and Appliance Recycling program, because these programs included interior lighting or appliances, building models predict that these measures would result in negative natural gas savings due to interactive effects. (Interactive effects refer to the increase in heating use, because efficient interior lighting and appliances release less waste heat.)
    - CPAU has historically not accounted for interactive effects, because they are the only California Publicly Owned Utility that provides natural gas, and because of the lack of supporting field data supporting interactive effects values. To align with this reporting precedent, TRC provides ex post savings values *without* interactive effects.
    - TRC also provides ex post natural gas savings *with* interactive effects, following the protocol set by the CPUC reporting procedures. To calculate the ex post therm savings from interactive effects, TRC identified the therm/kWh value based on the building type from the TRM for lighting measures or based on the appliance recycled from DEER 2014 for appliances. TRC then multiplied this therm/kWh by the ex post kWh value to calculate ex post natural gas savings.
- **Under a natural gas NTGR of 100%, and under the program-specific NTGR assumed for electricity savings**. CPAU has historically assumed a 100% NTGR for natural gas savings. The rationale is that natural gas equipment is typically capital intensive, and natural gas is relatively inexpensive. Both of these should decrease the likelihood that the participant would have installed the same equipment in the absence of the program, making free ridership very low or nonexistent. However, for FY 2015, the equipment that produced natural gas savings also produced electricity savings. All measures that generated natural gas savings were in the CIEEP program. The two measures that generated substantial natural gas savings were for retrofitting air handling unit supply fans with variable frequency drivers, and installing economizers on air handling units. Both measures reduced cooling (electricity) and heating (natural gas) use. It is unknown whether the customer was motivated by electricity savings, heating savings, or a combination of both. Consequently:
    - TRC provides net natural gas savings using a 100% NTGR, which would reflect a participant decision motivated primarily by natural gas savings.
    - TRC provides net natural gas savings using a 80% NTGR for all programs (except Appliance Recycling, for which the NTGR is 70%), which would reflect a participant decision motivated primarily by electricity savings.

Figure 23. Gross and Net Annual Natural Gas Savings

	Ex Ante		Ex Post		
CPAU Program	**Gross Savings (Therms)**	**Net Savings (Therms)**	**Gross Savings (Therms)**	**Net Savings: 100% NTG (Therms)**	**Net savings: 80% NTG (Therms)**
CIEEP (Enovity)	30,320	24,256	21,280	21,280	17,024
Right Lights Plus	0	0	(7,860)	(7,860)	(6,259)
CAP	0	0	(251)	(251)	(201)
Business New Construction	0	0	0	0	0
Appliance Recycling	0	-	(742)	(742)	(520)
Total without interactive Effects	**30,320**	**24,256**	**21,280**	**21,280**	**17,024**
Total with Interactive Effects	**N.A.**	**N.A.**	**12,427**	**12,427**	**10,045**

8.2 Lifecycle Savings

This section describes the methodology used to calculate ex post lifecycle savings. We begin by describing our EUL assumptions, and then describe how we calculated measure-level, project-level, and program level lifecycle savings.

8.2.1 Effective Useful Life (EUL) Assumptions

For all measures, TRC used the TRM assumptions for identifying the effective useful life (EUL) where possible. If the TRM did not provide a measure-specific EUL, TRC used DEER 2014 values.

For some lighting measures, the TRM provided a range for the EUL. In particular, the TRM provides the EUL for LED lamps and fixtures as, "Range of 5–15 years (rated fixture or lamp life divided by annual operating hours for each building type)."[1] For these measures, TRC used the rated life from DEER 2014 and divided it by the assumed operating hours for the particular space type. For example, DEER 2014 assumes a rated life of 20,000 hours for an LED lamp and 50,000 hours for an LED fixture[2]. For an LED installed in a space for which DEER 2014 assumes 4,350 hours per year, TRC divided 20,000 hours by 4,350 to estimate a measure life of 4.6 years.

8.2.2 Measure-Level Lifecycle Savings

For measures with a single baseline, TRC calculated lifecycle savings by multiplying first year savings by the EUL for each measure. Since almost all measures had a single baseline, TRC used this approach for the vast majority of measures.

In the case of dual baseline measures – which applied only to the early retirement of T12 fixtures and lamps – TRC calculated the lifecycle savings as described above: i.e., multiplying one-third of the EUL by

[1] TRM section 6.4, "LED Lighting", p. 6-6.

[2] California Public Utilities Commission (CPUC), 2014. "EUL-RUL Calculating DEER Values for Lighting 2014-02-05".

the first year savings and two-thirds of the EUL by an annual savings number estimated compared to a code-compliant baseline.

8.2.3 Project-Level Lifecycle Savings

For projects with a single measure, TRC calculated project lifecycle savings according to the description in Section 8.2.2 for measure-level lifecycle savings. (In other words, for single-measure projects, project-level savings equaled measure-level savings.) Note that all T12 early retirement projects were single-measure projects.

For projects with multiple measures, TRC calculated a project measure life based on a weighted average, where the EUL of each measure was weighted by the first year savings of that measure.

$$\text{Project measure life} = \sum_{\text{measures in project}} [\text{measure ex post kWh x measure EUL}] \,/\, \sum_{\text{measure in project}} [\text{measure ex post kWh}]$$

TRC then multiplied the project measure life by the first year savings to estimate project lifecycle savings.

8.2.4 Program-Level Lifecycle Savings

For programs where TRC verified a census of projects, TRC first calculated the lifecycle savings for each project, as described in Section 8.2.3. TRC then summed the lifecycle savings across all projects for the program total lifecycle savings.

For programs where TRC conducted sampling, TRC first calculated the lifecycle savings for each project sampled, as described in Section 8.2.3. To apply sampling weights, TRC needed ex ante lifecycle savings for each sampled project. CPAU staff provided program-level, but not project-level ex ante lifecycle savings. Consequently, TRC developed an “assumed ex ante lifecycle savings” for each project as follows:

- For RightLights Plus, all projects were for the installation of LEDs and T8 lamps and fixtures, which have an EUL of 15 years (unadjusted for operating hours, as CPAU staff reported was done for the ex ante savings). TRC multiplied ex ante first year savings by 15 years to develop an assumption of ex ante lifecycle savings. As a check, TRC conducted this “assumed ex ante lifecycle” calculation for all RightLights plus projects (not just those sampled), and the sum matched the value reported by CPAU for ex ante program lifecycle savings: 1,478,824 kWh.
- For CAP, projects included a mix of measures, including lamp and fixture replacements, occupancy sensors, HVAC optimization, and HVAC equipment replacements. TRC took first year kWh savings per measure from a program workbook provided by CPAU, and multiplied each measure kWh by the EUL of the measure based on the NCPA Energy Efficiency (EE) Reporting Tool, to calculate measure-level lifecycle savings. For projects with multiple measures, TRC then summed the lifecycle savings across all measures for project lifecycle savings. Similar as for RightLights Plus, TRC conducted this “assumed ex ante lifecycle” calculation for all CAP projects (not just those sampled), and the sum matched the value reported by CPAU for ex ante program lifecycle savings: 9,217,183 kWh.

For both RightLights Plus and CAP, TRC then applied sampling weights to the lifecycle savings of each sampled project to develop program-level ex post lifecycle savings.

8.2.5 Summary of Lifecycle Savings and Adjustments

Figure 24 provides the program-average EUL, and each program's lifecycle savings results. As shown, TRC calculated a much lower lifecycle savings than the ex ante calculations showed for RightLights Plus and (to a lesser extent) CAP.

Figure 24. Gross and Net Lifecycle Energy Savings

	Ex Ante Lifecycle		Input Values for Ex Post Lifecycle		Ex Post Lifecycle		
CPAU Program	**Gross Savings (kWh)**	**Net Savings (kWh)**	**Ex Post 1st Year Gross Savings (kWh)**	**Average Measure Life (Yr)**	**Gross Savings (kWh)**	**Net Savings (kWh)**	**Gross Realization Rate (%)**
CIEEP (Enovity)*	30,825,400	24,660,320	1,969,000	12.1	23,899,000	19,119,200	78%
Home Energy Report	1,604,272	1,604,272	1,604,272	N.E.	1,604,272	1,604,272	100%
RightLights Plus*	22,182,361	17,745,889	1,306,405	7.0[1]	8,576,613	6,861,290	39%
CAP*	9,217,183	7,373,746	1,156,252	5.5[2]	6,169,482	4,935,585	67%
Business New Construction*	5,677,200	4,825,620	473,100	12.7	6,008,370	5,107,115	106%
Res. Smart Energy	1,054,909	843,927	92,831	N.E.	1,054,909	843,927	100%
REAP Low Income	805,610	644,488	69,409	N.E.	805,610	644,488	100%
Appliance Recycling*	297,300	237,840	44,955	4.8	217,058	151,940	73%
Hospitality	530,508	450,932	44,209	N.E.	530,508	450,932	100%
Res. New Construction	223,068	178,454	18,589	N.E.	223,068	178,454	100%
SCVWD	1,001	801	91	N.E.	1,001	801	100%
Total	**72,418,812**	**58,566,290**	**6,779,113**		**49,089,891**	**39,898,005**	**68%**

Furthermore, TRC's lifecycle kWh savings realization rates were lower than first year kWh savings realization rates for these programs. The reasons for the adjustments for lifecycle savings were the following, in descending order of significance:

1. **Adjustments to lighting measure EUL based on operating hours.** For the ex ante lifecycle savings estimate for lighting measures, the RightLights Plus and CAP program (or program implementer) assumed the EUL without adjusting for the operating hours of the measure,

[1] Based on projects sampled. Average measure life for program multiplied by first-year savings (kWh) does not equal lifecycle savings (kWh) because of sampling weights, and because of dual baseline measures.

[2] Based on projects sampled. Average measure life for program multiplied by first-year savings (kWh) does not equal lifecycle savings (kWh) because of sampling weights.

although the TRM calls for adjusting lighting measure EULs by operating hours. For example, for LED lamps, the programs generally assumed 15 years, regardless of where the lamps were installed. For the ex post lifecycle savings estimate, TRC adjusted the EUL based on the operating hours, according to DEER assumptions for building type and space type. For example, for an LED installed in an area for which DEER assumes 4,350 hours per year, TRC estimated a measure life of 4.6 years, as described in Section 8.2.1.

TRC's adjustment to lighting EUL based on operating hours aligns with the TRM guidance cited in section 8.2.1. In addition, the adjustment to lighting EUL based on operating hours follows the precedent set by the CPUC lighting impact evaluations for Investor Owned Utility (IOU) programs. For example, the most recent impact evaluation for the 2014 IOU Nonresidential Deemed Lighting program calculates a "service life" based on the EUL divided by the operating hours[1]. The average service life in that CPUC impact evaluation for LEDs was found to be 8.7 years[2], similar to the 7.0 years that TRC calculated for the RightLights Plus program (which primarily incentivized LEDs).

Note that the majority of the lifecycle savings reductions for RightLights Plus and CAP were because of this adjustment.

2. **Adjustments to first year savings.** All of TRC's adjustments to first year kWh savings also affected lifecycle kWh savings. In particular for the RightLights Plus program, TRC adjusted baseline conditions for some lamp types (e.g., replacement of incandescent lamps) to meet current federal or state regulations, rather than existing conditions. These first year savings adjustments compounded the adjustments specific to lifecycle savings.
3. **Accounting for dual baseline.** The RightLights Plus program included several T12 early replacement projects, for which the ex ante program calculations assumed existing conditions for the entire EUL. For the ex post lifecycle calculations, TRC assumed a dual baseline for T12 early replacement projects, under which savings for the first one-third of the EUL was calculated assuming existing conditions, and the last two-thirds of the EUL was calculated assuming code-compliant conditions. This did not affect first year savings, but reduced lifecycle savings. Because T12 replacements comprised a small fraction of program savings, this was a relatively small fraction of the lifecycle savings adjustments for the RightLights Plus program.

[1] Itron, 2016. "2014 Nonresidential Downstream Deemed ESPI Lighting Impact Evaluation Report." Draft report, dated February 23, 2016. Section 4.4.4.

[2] Based on the Itron 2016 report: from dividing lifecycle savings in Table 5-2 by first year savings in Table 5-1.

9 PROGRAM RECOMMENDATIONS

In general, the CPAU FY 2015 programs were successful in providing energy, demand, and natural gas savings to CPAU customers. TRC's evaluated savings were generally similar to the ex ante savings for each program. In other words, while TRC's project-level savings estimates were sometimes very different (much lower, and in other cases much higher) than the ex ante project-level estimates, the programs generally had realization rates close to 100% for first year energy savings, and had relatively high realization rates for demand, natural gas savings, and lifecycle energy savings.

However, TRC identified opportunities for improvement during the evaluation. While it was beyond our scope to provide a comprehensive set of recommendations (such as those developed through a process evaluation), TRC provides the following recommendations based on the EM&V results. We begin with overarching recommendations that apply to all (or many) of the programs evaluated, and then present program-specific recommendations.

9.1 Overarching Recommendations

For all third party programs, the implementer should provide the EUL of each measure, its operating hours, the resulting service life (for measures such as lighting where operating hours affect the EUL), and resulting lifecycle savings. This will allow CPAU staff to check that proper assumptions are applied for lifecycle savings, such as adjustments to EUL based on operating hours for lighting measures, or the use of dual baselines for measures where this is appropriate. These practices should increase the lifecycle realization rate in future evaluations.

Programs should also report lifecycle savings at the project (not just program) level, so that the evaluator can more accurately extrapolate EM&V results to a program level, if the evaluator uses sampling. For this evaluation, TRC was able to recreate project-level ex ante lifecycle savings where we conducted sampling (RightLights Plus and CAP)[1]. However, this process would have been more difficult (and possibly led to inaccurate ex ante lifecycle savings estimates) if there had been a greater mix of measures in these programs.

CPAU staff should also discuss baseline assumption policies for different project types. Once these are finalized, CPAU staff should discuss these baseline assumptions with program implementers. In this evaluation, TRC identified what we believe to be the most appropriate baseline assumption for a variety of programs and project types. CPAU could use the baselines assumed in this evaluation as a guide for its discussions. Overall, TRC's adjustment to the baseline (compared to the program's) were:

- Assume code conditions for measures governed by federal or state regulations, rather than existing condition. This includes lamp replacements for removed lamps with short EULs that no longer meet federal or state regulations (for RightLights Plus and CAP), as well as ROB equipment replacements that would trigger Title 24 installed through CIEEP (Enovity) or the CAP customer track.

[1] TRC believes that our "assumed ex ante lifecycle" savings for RightLights Plus and CAP projects were correct, because our sum of project savings for those programs equaled the program ex ante savings reported by CPAU.

- Assume dual baseline for some measures, including for T12 early replacements in lighting programs (particularly RightLights Plus), and for early retirement of equipment (e.g., for CIEEP and custom projects in CAP).

9.2 CIEEP (Enovity)

There were multiple CIEEP projects where the operating conditions at the time of TRC's verification did not match ex ante assumptions. For example,

- One site had two economizers installed through the program that were not operating correctly. One was stuck at 35% open, while the other did not open beyond 80%.
- At another site, the economizer operation was not correlated with outdoor air temperature. This could be due to improper sequencing, a temperature sensor not operating correctly, or another issue.
- The chilled water supply temperature was different at one site from the ex ante calculations.

In order to maintain persistence for energy savings from projects, the program should consider requiring commissioning or acceptance testing to verify that the equipment is at least installed and operating initially as designed/planned. CPAU could also consider requiring that the site provide follow-up trend data six to twelve months after project completion. CPAU technical staff or a trained 3rd party should review the trend data to ensure that the installed measures are operating as expected, and notify the customer and (if appropriate) the contractor that installed the equipment if it is not operating properly. In addition, CPAU program staff should work with FY 2015 participants to address the operational issues identified in this evaluation.

There were two projects where the implementer assumed existing conditions for the baseline, but the installation of the equipment triggered code (Title 24), so code should have been used as the baseline condition. (In one of these cases, existing equipment met Title 24, so TRC did not make adjustments to the savings calculation.) CPAU program staff should clarify baseline assumption protocols with the program implementer and discuss which assumption should be used with which project types. TRC describes our baseline assumptions for CIEEP projects in Section 3.2, which CPAU could use as guidance for baseline assumption protocols. As part of this discussion, CPAU staff should discuss the conditions for which the implementer can assume early retirement, documentation needed to claim early retirement, and the calculation for dual baseline. There was one CIEEP (Enovity) project that TRC determined to be an early retirement of equipment, for which the dual baseline would be the most appropriate (i.e., existing condition for the remaining useful life, and code-compliant for the remainder of the EUL). However, the existing condition met code (Title 24-2008), so TRC did not need to adjust the savings value.

9.3 CAP

For CAP, for five of the seven projects evaluated, TRC found differences in the number or efficiency of the measures installed compared to project savings claims. Some of TRC's adjustments increased savings, while others decreased savings. To increase the accuracy of ex ante savings assumptions, CPAU should consider conducting a more rigorous final project verification procedure. TRC's scope did not include a review of program procedures, but CPAU staff could review (or have a third party review) current program quality assurance procedures to identify if there are opportunities for improvement.

In addition, for several projects, the ex ante savings estimates in the program database and the inspection report did not match. In other words, the final ex ante kWh savings value in the 3rd party inspection report was not the number entered in the program database for ex ante kWh savings. For example, for CAP 1045 (the largest savings project), the final inspection report showed 654,965 kWh, but the program database showed savings of 750,184 kWh. It is likely that the savings estimate in the inspection report (not the database) more accurately reflected energy savings at the time of project installation. CPAU program staff should update program values based on the most recent inspection report.

CPAU staff should also ensure that an appropriate type of high efficacy lighting product is installed through CAP, as well as RightLights Plus. TRC identified two projects – one through RightLights Plus and one through CAP – where several LEDs installed through the program had already burned out. In both cases, the failed LEDs were installed in recessed cans. For the CAP project, 4% of the LEDs had failed within a few months of installation. CPAU program staff should consult lighting experts or use lighting installation guidelines – such as those provided by the U.S. Department of Energy[1], and work more closely with partnering contractors and customers (for participant self-installation projects) to ensure that lighting measures installed are appropriate for each application – including lamp-socket compatibility.

9.4 RightLights Plus

For the RightLights Plus program, TRC's primary adjustments to energy (kWh) savings were to the baseline assumptions. TRC recommends that CPAU staff develop baseline assumption policies that reflect the most recent federal and state requirements for lighting measures. The baseline assumptions that TRC used for this evaluation, presented in Section 5.2.3, could be used as a basis for these lighting baseline assumption policies. CPAU staff should then discuss these baseline policies with the program implementer.

TRC also made adjustments to demand (kW) savings, because the program had originally claimed demand savings for exterior lighting, such as those installed in parking lots. CPAU should work with the program implementer to ensure that ex ante demand savings do not include savings for exterior lighting except where appropriate (such as in parking garages).

In addition, as described in Section 9.3 for CAP, there was one RightLights Plus project where a few LEDs installed through the program had burned out. CPAU should follow the recommendations described in Section 9.3 to ensure that an appropriate type of high efficacy lighting product is installed, to reduce the incidence of early equipment failure.

9.5 Business New Construction

For the Business New Construction program, TRC found a 100% energy (kWh) savings realization rate, so we do not provide any recommendations regarding project M&V procedures. However, TRC noted that the website for the program currently states that "Customers must be 10% more efficient than required by Title 24 to receive a rebate."[2] Because Palo Alto has a Green Building Ordinance, CPAU staff reported that the minimum requirement for participation in the Business New Construction program is 20%

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[1] An example guidance document is provided here: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_mr16-lamps.pdf

[2] From the CPAU program website, accessed March 3, 2016: http://www.cityofpaloalto.org/gov/depts/utl/business/rebates/construction.asp

above Title 24. CPAU should update its program website to reflect this participation requirement, and any other key requirements for the program.

9.6 Appliance Recycling

The Appliance Recycling program had the lowest first year energy (kWh) savings realization rate of all programs evaluated. This is because TRC's billing analysis found that savings per recycled refrigerator were lower than the deemed savings assumptions from the TRM (which are based on DEER 2011). TRC's analysis was specific to CPAU territory and is based on recent billing data. In contrast, the DEER savings assumption apply to the entire state of California, are older[1], and many of the assumptions used to develop the DEER assumptions (e.g., number of refrigerators replaced vs. removed but not replaced) are not described in DEER documentation. The refrigerator recycling characteristics may change in future years for CPAU customers; for example, replaced equipment may be a different age (most likely newer), or more units may be replaced rather than removed, than the refrigerators evaluated here. However, TRC's regression analysis had a very high level of statistical significance, and TRC believes that our refrigerator savings analysis is more likely to reflect savings for CPAU customers than the values in the TRM. Consequently, CPAU should consider reducing the deemed savings assumption for the Appliance Recycling program based on the outcome of this evaluation.

[1] DEER 2011 supporting documentation does not state the year or the geographic region for the data supporting the refrigerator or freezer recycling assumptions.

10 APPENDICES

This section includes the following appendices:

- The rationale for why CPAU and TRC selected CIEEP (Enovity), RightLights Plus, CAP, Business New Construction, and Appliance Recycling for FY 2015 evaluation instead of other CPAU programs.
- Additional analysis that TRC and its team member Klos Energy Consulting conducted for the Appliance Recycling program, including a description of the various regression models tested, and how the TRC team identified the final model used.

10.1 Rationale for Selecting Programs for FY 2015 Evaluation

Figure 25 presents each program in the CPAU FY 2015 portfolio, its ex ante energy (kWh) savings, the most recent evaluation (prior to 2015), the result of the draft EM&V prioritization based on the July 20, 2015 annual planning meeting, whether or not the program was ultimately selected for FY 2015 evaluation, and the final rationale for this decision.

Figure 25. FY 2015 EM&V Program Selection

Program	Ex Ante Energy (kWh)	Most Recent Evaluation	Draft EM&V Priority	Evaluated in FY 2015?	Rationale for Evaluating / Not Evaluating Program
CIEEP (a.k.a. Enovity)	2,222,800	FY 2013	High	Yes	Program with highest ex ante savings
Home Energy Report	1,604,272	FY 2011	Medium	No	No control group available for conducting billing analysis for evaluation
Right Lights	1,478,824	FY 2012	High	Yes	High savings and had not been evaluated for several years
Commercial Advantage Program (CAP)	1,128,756	FY 2013	High	Yes	High savings, particularly for one custom projects
Business New Construction	473,100	FY 2015	Low	Yes	High savings in one custom project
Smart Energy	92,831		Low	No	Low savings
REAP Low Income	69,409	FY 2013	Low	No	Low savings and recently evaluated
Appliance Recycling	59,460	before FY 2012	Medium	Yes	Had not been evaluated for several years, and concerns that deemed values were too high
Hospitality	44,209	FY 2013	Medium	No	Ex ante therm savings were high (not shown), but program had recently been evaluated
Residential New Construction	18,589		Low	No	Low Savings
Santa Clara Valley Water District (SCVWD)	91		Low	No	Low Savings

10.2 Appliance Recycling Billing Analysis Detail

This appendix provides more detail on the TRC team's billing analysis for the Appliance Recycling Program, including a description of the various regression models tested, and how the TRC team identified the final model used for the Appliance Recycling results.

10.2.1 Data Preparation

Two sets of data were provided to support the billing analysis: 1. Program participation data from the third party administrator, JACO, and 2. Monthly billing data for each participant in the program from CPAU.

The program participation data identified the type of equipment that was picked up, the date of the pick-up, characteristics of the appliance, and whether the participant was planning to replace the appliance with a new model or remove the appliance without replacement.

The monthly billing data covered November 2012 through October 2015. The program year was July 2014 through June 2015. Appliances were picked up at various times throughout the program year. This means there was at least a year and a half of pre-participation data for almost all participants, and at least four months of post data for most participants. This was a sufficient amount of data to support development of a pre vs. post billing analysis model, assuming that clean data was available for most of the participants during this period.

Figure 26 shows the disposition table that the TRC team developed during the data cleaning process to document how many participants had sufficient data for analysis. Figure 26 also shows how many participants had to be removed from the analysis, and the reasons why. Note that the TRC team developed its analysis at the participant-level, rather than unit-level, because we used whole house energy usage data. Consequently, participants that had recycled multiple units were removed from the analysis.

Figure 26. Disposition of Appliances for Recycling Program Analysis

	Refrigerators	Freezers	Total Projects (Units)	Customers (Accounts)
Total Participation for FY 2015	84	12	96	94
Less: Cust with no billing data (A)	3	1	4	4
New Total	81	11	92	90
Less: Cust with two units recycled (B)	3	1	4	2
New Total	78	10	88	88
Less: Cust with no post billing data (C)	9	2	11	11
New Total	69	8	77	77
Less: Cust with bad post data (D)	0	1	1	1
New Total (used for Model 3)	69	7	76	76
Less: Cust with no replacement data (E)[1]	8	3	11	11
New Total (used for Models 1 and 2)	**61**	**4**	**65**	**65**

[1] As described in the Section, Alternative Models, participants with no replacement data were only removed in Models 1 and 2. Because Model 3 (the model that was ultimately used) did not consider whether a participant removed or replaced a unit, data from these participants were included in Model 3.

The goal of the analysis was to develop savings estimates separately for refrigerators and freezers since the TRM savings are different. Each refrigerator and freezer counted as one project, or unit, within the program. Customers participating in the program can have more than one unit recycled, so the number of projects was slightly higher than the number of participating customers.

The TRC team removed projects from the billing analysis for the following reasons:

(A) Four customers were removed because there was no billing data available for them. The exact reason for this is unknown, but it could be because the customer did not stay at the same address throughout the analysis period of May 2012 through October 2015. Monthly billing data is only used for analysis if it is for the same participant at the same address. A new customer moving into a participating address would have a different level of energy usage due to lifestyle differences, and it would not be possible to estimate accurate program savings using their data.

(B) Two customers each had two units recycled. Since both units affect the customer's total energy use seen in the monthly billing data, any observable reduction in energy use would not be assignable to a particular unit. To keep the analysis clean, the four units picked up from these two customers were removed from analysis.

(C) Eleven customers did not have billing data available in the post period, i.e. – after their appliance was recycled. Without post data, it was not possible to estimate savings.

(D) Upon close inspection, it was found that one participant that had recycled a freezer had bad post data. For a few months after the pick-up, the customer's total monthly usage dropped to a very low value, indicating that the premise was no longer occupied. After a few months of low usage, the total usage dropped to zero. The reduction in usage was more than could be accounted for by removal of a single freezer. If the data had been left in the analysis, it would have created an unreasonably high estimate of savings from freezer removal, particularly because the total number of freezers was very small. Since this data was not really reflecting savings from freezer removal, it was removed. Note that, since the TRC team ultimately used the TRM assumptions for freezers, the disposition of this participant did not affect finals savings values. However, the removal of this participant (and the removal of other freezer-recycling participants, as the reasons described above) contributed to the low number of data points for freezers.

In the end, 69 refrigerators had good data for inclusion in the final model. This represents 82% of the eighty-four total refrigerators in the program during FY 2015. Since this is a large share of the total, and there are no known reasons why the units that were removed from the analysis sample would have different savings than the units that stayed in the sample, sample bias should not be a concern in the estimated savings for refrigerators in this program. There were also 7 freezers (58% of total units) with good data for analysis. But as described in the next section (Alternative Models), the TRC team believed this was not a large enough sample size to represent savings from all units in the program.

10.2.2 Alternative Models

The TRC team developed and tested several models with the data before reaching the best, final model. This section provides an overview of each model, the rationale for why TRC rejected alternative models, and how the TRC team ultimately developed the best, final model.

Model 1 looked at separate savings estimates for units that were reported as replaced and units that were reported as not replaced, and it also included interactive terms for CDD and HDD in the post period. The interactive terms would allow the model to capture potentially different weather effects during the post period. If they existed, they could create biased savings estimates if they were not accounted for.

The equation for Model 1 was:

$$MEC_{cm} = a_c + b_1 CDD_m + b_2 HDD_m + b_3 PostCDD_m + b_4 PostHDD_m + b_5 PostReplace_{cm} + b_6 PostNoReplace_{cm} + \varepsilon_{cm}$$

Where:

MEC_{cm} = Monthly Energy Consumption for Customer c during Month m

a_c, $b_{1\text{-}6}$ = Coefficients calculated through curve fitting

CDD_m = Cooling Degree Days during Month m

HDD_m = Heating Degree Days during Month m

$PostCDD_m$ = Cooling Degree Days during Month m if Month m is after pickup date, and 0 if Month m is before or equal to pick up date

$PostHDD_m$ = Same as $PostCDD_m$, but with Heating Degree Days

$PostReplace_{cm}$ = An interactive binary variable equal to 1 if Customer c replaced their unit and Month m is after their pickup date, and equal to 0 if otherwise

$PostNoReplace_{cm}$ = An interactive binary variable equal to 1 if Customer c did not replace their unit and Month m is after their pickup date, and equal to 0 if otherwise

ε_{cm} = Error term for Customer c during Month m

Figure 27 shows results for Model 1. Model 1 results showed that the coefficient on the post-period CDD term was not statistically significant so the post-period CDD term was removed from all future models.

Figure 27. Model 1 Results for Refrigerators and Freezers with Changing Weather Effects

Coefficients	**Estimate**	**Std Err**	**T Value**	**Prob t**
a_c (for Intercept)	1.53E-14	4.408	0	1
b_1 (for CDD)	0.580	0.186	3.12	0.002
b_2 (for HDD)	0.676	0.052	12.98	<.0001
b_3 (for Post CDD)	-0.010	0.300	-0.03	0.980
b_4 (for Post HDD)	0.278	0.145	1.91	0.056
b_5 (for Post Replace)	-60.3	36.2	-1.66	0.096
b_6 (for Post No Replace)	-69.3	36.9	-1.88	0.061

The coefficient for the post-period HDD term was borderline statistically significant – (prob [t] was 0.056). Consequently, the TRC team looked more closely at the difference in HDD between the pre and post evaluation periods. Figure 28 shows that during six of the winter months, the post period was much warmer than the pre period.

Figure 28. Average HDD in the Pre vs. Post Periods for Appliance Recycling Program

Month	Pre	Post	Diff %
Jan	426	397	-7%
Feb	322	208	-35%
Mar	203	164	-19%
Apr	137	175	27%
May	64	164	155%
Jun	17	27	
Jul	3	0	
Aug	5	0	
Sep	6	6	
Oct	93	13	-86%
Nov	238	206	-14%
Dec	445	303	-32%
TOTAL	1960	1662	

Imbalanced weather conditions in the two years can have some effect on the HDD coefficient in each year. Given this imbalance in conditions combined with the borderline statistical significance, the TRC team considered the HDD coefficient for the post period unreliable and also removed it from future iterations of the model. With the removal of the two post period weather variables, the TRC team's equation for Model 2 was:

$$MEC_{cm} = a_c + b_1 CDD_m + b_2 HDD_m + b_3 PostReplace_{cm} + b_4 PostNoReplace_{cm} + \varepsilon_{cm}$$

Where:

MEC_{cm} = Monthly Energy Consumption for Customer c during Month m

a_c, $b_{1\text{-}4}$ = Coefficients calculated through curve fitting

$PostReplace_{cm}$ = An interactive binary variable equal to 1 if Customer c replaced their unit and Month m is after their pickup date, and equal to 0 if otherwise

$PostNoReplace_{cm}$ = An interactive binary variable equal to 1 if Customer c did not replace their unit and Month m is after their pickup date, and equal to 0 if otherwise

And all other variables are as described for Model 1.

As shown in Figure 29, Model 2 results found that the estimate for the coefficients for Post Replace and Post No Replace were very similar: -31 kWh/month for Post Replace and -35 kWh/month for Post No Replace. Thus, the results of Model 2 showed that there was very little difference in the estimated savings for units reported as replacement vs. units that reported as no replacement.

Figure 29. Model 2 Results for Refrigerators and Freezers with Constant Weather Effects

Coefficients	Estimate	Std Err	T Value	Prob t
a_c (for Intercept)	1.39E-14	4.42	0	1
b_1 (for CDD)	0.397	0.134	2.98	0.003
b_2 (for HDD)	0.666	0.045	14.80	<.0001
b_3 (for Post Replace)	-31.1	14.4	-2.16	0.031
b_4 (for Post No Replace)	-35.3	15.9	-2.22	0.026

It should be noted that three primary refrigerators were labeled as "not replaced" in the data from the program implementer. The TRC team believed this was an improbable condition for a primary refrigerator, so assumed that all primary refrigerators were replaced, regardless of what the data stated. This may also indicate a lack of reliability in the "replace" vs. "not replaced" data provided by customers.

For verification of this finding, the TRC team also ran Model 2 separately for refrigerators and freezers, as shown in Figure 30 and Figure 31. The TRC team again found no significant difference in energy savings between replacement and no replacement units for refrigerators. However, the TRC team did find a difference between replacement and no replacement units for freezers. The savings estimate for freezers with replacement was not statistically significant, but savings were very large, 1,049 kWh per year, for freezers without replacement. While this high level of savings is statistically significant at the 95% level, it is based on only two cases. While the recycling of these two particular freezers yielded high savings, the TRC team believed it was unlikely that this average would be maintained over a larger population of freezers.

Figure 30. Model 2 Results for Refrigerators only

Coefficients	Estimate	Std Err	T Value	Prob t
a_c (for Intercept)	1.46E-14	4.62	0	1
b_1 (for CDD)	0.444	0.139	3.19	0.001
b_2 (for HDD)	0.702	0.047	14.9	<.0001
b_3 (for Post Replace)	-30.2	14.2	-2.12	0.034
b_4 (for Post No Replace)	-34.8	17.7	-1.97	0.049

Figure 31. Model 2 Results for Freezers Only

Coefficients	Estimate	Std Err	T Value	Prob t
a_c (for Intercept)	-3.34E-15	12.18	0	1
b_1 (for CDD)	-0.504	0.411	-1.23	0.222
b_2 (for HDD)	0.091	0.126	0.72	0.473
b_3 (for Post Replace)	36.1	60.9	0.59	0.553
b_4 (for Post No Replace)	-87.4	43.9	-1.99	0.048

After testing Models 1 and 2, the TRC team concluded that the most robust estimate of savings would come from a model that combined both replaced and not replaced refrigerators, because there was very little difference in the savings estimates for those two groups. Also, the TRC team removed freezers from the analysis, because there were only a few of them and the savings estimate for those few cases was very different.

These changes yielded Model 3, which used the following equation:

$$MEC_{cm} = a_c + b_1 CDD_m + b_2 HDD_m + b_3 Post_{cm} + \varepsilon_{cm}$$

Where:

MEC_{cm} = Monthly Energy Consumption for Customer c during Month m

a_c, $b_{1\text{-}3}$ = Coefficients calculated through curve fitting

CDD_m = Cooling Degree Days during Month m

HDD_m = Heating Degree Days during Month m

$Post_{cm}$ = A binary variable equal to 1 if Month m is after refrigerator pickup date for Customer c, and equal to 0 if Month m is before or equal to refrigerator pickup date

ε_{cm} = Error term for Customer c during Month m

By combining replaced and not replaced refrigerators into the same model in Model 3, the TRC team could include the eight refrigerators that were missing replacement data in the analysis. This increased the sample size for Model 3 from 61 to 69, which is 82% of the total 84 refrigerators recycled in FY2015.

Figure 32. Model 3 Results for Refrigerators Only

Coefficients	Estimate	Std Err	T Value	Prob t
a_c (for Intercept)	1.38E-14	4.20	0	1
b_1 (for CDD)	0.471	0.127	3.72	0.0002
b_2 (for HDD)	0.703	0.043	16.35	<.0001
b_3 (for Post)	-36.9	10.2	-3.63	0.0003

Thus, as shown in Figure 32, Model 3 estimated an average savings of 36.9 kWh per month for all refrigerators, or 443 kWh per year. This savings was highly statistically significant: Prob (t) = 0.0003.

The TRC team then conducted additional modeling (Model 4) to determine if savings differences could be detected for primary vs. secondary units. The TRC team expected that primary units received more use (i.e., more door openings) than secondary units, which would lead to greater savings for primary units. The results of Model 4 estimated *higher* savings for secondary units than for primary units, which is the opposite of what was expected. (Model 4 results not shown.) The TRC team believed that this result was probably due to the fact that many secondary units do not get replaced. To differentiate between these effects, the TRC team developed Model 5 to estimate separate savings for primary refrigerators, secondary refrigerators with replacement, and secondary refrigerators without replacement. However, there was not a large enough sample to achieve statistically significant savings estimates for each separate group. (Model 5 results not shown.) The TRC team's conclusion was that the sample size was only sufficient to support a reliable estimate of average savings for all refrigerators.

The TRC team's overall conclusion from the billing analysis was to use Model 3 for estimating refrigerator savings, because it provided the most reliable, and statistically significant savings estimates. Model 3 estimated 443 kWh/year and 0.072 kW. The TRC team's determination of demand savings is described in Section 7.3.

The TRC team did not consider any of the models valid for estimating freezer savings, because the sample sizes were small and sampling bias was a concern. Consequently, the TRC team used the TRM deemed savings estimates for freezer savings: 643 kWh and 0.124 kW per freezer.