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Final Report

LED Impact Evaluation Report

Prepared for
California Public Utilities Commission

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Executive Summary

This report documents the activities undertaken by the Nonresidential Downstream Lighting Impact Evaluation of the 2010-2012 investor-owned utilities' (IOU) energy efficiency programs. The primary goal of this impact evaluation, discussed in this report, is to develop estimates of key savings parameters for indoor LED lamps and reflectors that can be used to inform future ex-ante net and gross kW and kWh energy savings values for these measures. An additional goal for this evaluation is to utilize these parameter level results in order to develop kW and kWh unit energy savings (UES) values, impact load shapes and net-to-gross ratios (NTGRs) for the LED lamp and reflector measures for a key set of building types. Additional non-impact information is examined as well in order to support future LED program planning.

For the 2010-12 portfolio of IOU programs, LED measures comprised approximately 1.24% of total statewide portfolio kWh savings and this share of savings had more than doubled through Q2 of 2013[1]. It is important to note that, since this evaluation is prospective looking, in that the primary objective is to support future ex-ante estimates of savings, rather than evaluate ex-post performance for a specific time period, the sample frame was extended from 2010-12 to include 2013 (Q1-2). As discussed in Section 2, indoor lamps and reflectors comprised 15% and 22%, respectively, of ex-ante gross kWh savings associated with LED measures throughout the two program periods. Furthermore, these measure savings were highly concentrated within the following building types:

- Office – Small
- Restaurant – Fast Food
- Restaurant – Sit Down
- Retail – Large
- Retail – Small

The primary research issues for this evaluation focus on developing estimates of key impact parameters for indoor LED lamp and reflector measures within these building types. These parameters, that include operating hours, baseline wattages, installed wattages, installation rates

[1] Excluding savings associated with Codes and Standards programs.

and net-to-gross ratios (NTGRs), can be used to inform future ex-ante net and gross kW and kWh energy savings values. More specific researchable issues are briefly listed below:

- Confirm installations (verification). This includes on-site verification of measure installations to confirm the installations reported by the IOUs.
- Estimate baseline and replacement equipment wattages, operating hours, and use shapes to support the estimate of energy savings values and 8760 impact load shapes.
- Estimate participant free-ridership.
- Utilize the above results and the primary data collected to support these efforts, to develop kW and kWh unit energy savings (UES) values, impact load shapes and net-to-gross ratios (NTGRs) for the LED lamp and reflector measures.

1.1 Key Findings

Overall, 249 site-measures were evaluated in order to develop installation rates, the impact parameters and the resulting UES values for LED lamps and reflectors within the 5 building types referenced above. Likewise, 562 site-measures were evaluated throughout the self-reported phone survey analysis in order to develop NTGRs for these measures and segments. Table 1-1 and Table 1-2 convey the installation rates, impact parameter estimates and the resulting ex-post UES values for each segment and measure. Results have been provided here across program periods. Table 1-3 provides the NTGRs for each segment and measure that were garnered from an analysis of the phone survey data. The evaluation results are presented within these tables and discussed throughout the report, but to summarize:

Installation Rates

As discussed in Section 4.2, installation rates were fairly similar between market segments when examined across program periods and were all within 10% of the statewide mean. For both LED lamps and reflectors, sit down restaurants had the lowest installation rates at 83% and 84%, respectively. Reasons for installation rates being less than 100% at the time of the on-site inspection varied between measures and segments across program periods, but in general, equipment failure and removal were the most common reasons.

UES Values

As discussed in Section 4.3 and 4.4, the per unit energy savings associated with each measure is a function of operating hours and the wattage difference between the baseline and installed equipment. Overall, operating hours varied significantly between segments for each measure when examined across program periods. Small offices and retail establishments had the lowest operating hours among all segments for both measures and restaurants (both fast food and sit down) had the highest operating hours for both technologies. Wattage ratios[2] for LED lamps ranged from 6.0 in small offices to 7.7 in fast food restaurants, while ratios for LED reflectors ranged from 4.7 in small offices to 5.6 in fast food restaurants.

As a result, ex-post UES values varied significantly. This variation is highly correlated to operating hours. Overall, when compared to the average ex-ante UES estimates for LED lamps, ex-post UES are generally lower for small offices and retail, very similar for sit down restaurants and about twice as high in fast food restaurants. For LED reflectors, ex-post UES values are greater than average ex-ante values for all segments.

Net-to-Gross Ratios

As discussed in Section 4.6, the objective of this analysis was to develop net-to-gross ratios for indoor LED lamps and reflectors by the five building type segments. The approach for estimating NTGRs was based on a self-report methodology utilizing 562 participant survey phone responses. This methodology was based on the large nonresidential free ridership approach developed by the NTGR Working Group and documented in Appendix C, Methodological Framework for Using the Self-Report Approach to Estimating Net-to-Gross Ratios for Nonresidential Customers[3]. The methodology estimated three separate measurements of free ridership from different inquiry routes and then averaged the values to derive the final free ridership estimate at the measure level.

The NTGRs don't vary significantly between segments for either LED measure. They range from .65 to .69 for LED lamps and .64 to .68 for LED reflectors (These ranges don't include large retail because of smaller sample sizes although the NTGR for each measure in this segment is roughly .50). These ex-post NTGR estimates are all well below ex-ante assumptions for all segments and measures.

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2 Wattage ratio = baseline lamp wattage / retrofit lamp wattage

3 This document can also be found at : http://www.energydataweb.com/cpucFiles/pdaDocs/910/Nonresidential%20NTGR%20Methods%202010-12%20101612.docx

Table 1-1: Installation rates and Unit Energy Savings (UES) values for LED Lamps by Program Period and Building Type

Program Period	Building Type	Installation Rate	Operating Hours	Coincident Peak	Wattage Ratio	Ex-Post UES kWh	Ex-Post UES kW
2010 – 2013 (Q1-Q2)	Office – Small	85%	1,707	34%	6.0	72	0.01
	Restaurant – Fast Food	85%	5,018	81%	7.7	279	0.05
	Restaurant – Sit Down	83%	3,404	62%	6.8	153	0.03
	Retail - Large	95%	4,328	91%	6.5	359	0.08
	Retail – Small	89%	2,026	47%	6.8	96	0.02
	All Building Types	**86%**	**3,086**	**58%**	**6.9**	**159**	**0.03**

Table 1-2: Installation rates and Unit Energy Savings (UES) values for LED Reflectors by Program Period and Building Type

Program Period	Building Type	Installation Rate	Operating Hours	Coincident Peak	Wattage Ratio	Ex-Post UES kWh	Ex-Post UES kW
2010 – 2013 (Q1-Q2)	Office – Small	87%	2,269	49%	4.7	125	0.03
	Restaurant – Fast Food	98%	4,189	63%	5.6	258	0.04
	Restaurant – Sit Down	84%	4,394	80%	5.5	236	0.04
	Retail - Large	93%	3,754	95%	4.5	230	0.06
	Retail – Small	91%	3,025	81%	5.4	155	0.04
	All Building Types	**91%**	**3,374**	**79%**	**5.0**	**190**	**0.04**

Table 1-3: NTGRs for LED Lamps and Reflectors by Program Period and Building Type

Program Period	Building Type	LED Lamps	LED Reflectors
		NTGR kWh	NTGR kWh
2010 – 2013 (Q1-Q2)	Office – Small	0.69	0.64
	Restaurant – Fast Food	0.66	0.65
	Restaurant – Sit Down	0.67	0.68
	Retail - Large	0.50	0.51
	Retail – Small	0.65	0.65
	All Building Types	**0.65**	**0.59**

1.2 Key Recommendations

This section presents recommendations related to the findings developed in this evaluation. Section 5 of the report explains each of these recommendations in more detail. These recommendations are directed at the verification analysis, the impact parameters that comprise the unit energy savings calculations and the net-to-gross ratios.

Installation Rates

- Continue to utilize on-site verification analyses to determine installation rates, especially within segments, like restaurants, where failure and removal rates were high. Verification also provides information regarding the activity areas LED measures are being installed within facilities. These types of data points will have a significant effect, not only installation rates, but on the unit energy savings values generated from LED measures as well.

Operating Hours

- Continue to monitor LED measures with lighting loggers as part of the on-site visit to develop a more robust catalog of impact load shapes by building type and space type.
- It is important to understand where LED measures are being installed over time since this will have a significant effect on impact load shapes and the results energy savings values generated from those measures.

Wattage Ratios

- Continue to utilize on-site visits to gather information on what baseline technologies LED measures are replacing. This evaluation found that LED technologies were generally replacing higher wattage incandescent lighting and halogens, but if LED lighting begins to replace CFL technologies the wattage assumptions associated with those measures may change over time.
- Continue to collect make and model information on LED retrofit equipment as a part of the on-site verification process. Future evaluations should gather this information in conjunction with the on-site survey in order to create a more robust catalog of LED technologies being installed within facilities.

Net-to-Gross Ratios

- Continue to update NTGR estimates to reflect changes in the market conditions. Program influence has played the most important role in deciding whether or not to replace existing equipment before the end of its useful life. However, other factors, like the perceived energy savings benefits, for economic and conservation reasons, played an important role as well.
- Continue to utilize an on-site survey instrument that further gauges why a participant ultimately retrofitted their existing equipment beyond what is captured in the NTG analysis.

2

Introduction and Overview of Study

This report documents the activities undertaken by the Nonresidential Downstream Lighting Impact Evaluation of the 2010-2012 investor-owned utilities' (IOU) energy efficiency programs. The primary goal of this impact evaluation, discussed in this report, is to develop estimates of key impact parameters for indoor LED lamps and reflectors that can be used to inform future ex-ante net and gross kW and kWh energy savings values for these measures. An additional goal for this evaluation is to utilize these parameter level results in order to develop kW and kWh unit energy savings (UES) values, impact load shapes and net-to-gross ratios (NTGRs) for the LED lamp and reflector measures for a key set of building types. Additional non-impact information is examined as well in order to support future LED program planning.

This report presents the findings and results from that evaluation, which includes a presentation of the goals and objectives of the evaluation, the researchable issues, information on the measure groups evaluated, data sources used, the approach for sampling, the verification analysis, the methods to determine energy and demand impacts, the resulting unit energy savings (UES) values and the NTG ratios.

2.1 Evaluation Research Objectives

The primary research issues for this evaluation focus on developing estimates of key impact parameters for indoor LED lamp and reflector measures. These parameters, that include operating hours, baseline wattages, installed wattages, installation rates and net-to-gross ratios (NTGRs), can be used to inform future ex-ante net and gross kW and kWh energy savings values. Specific researchable issues are briefly listed below.

- Confirm installations (verification). This will include on-site verification of measure installations to confirm the installations reported by the IOUs.
- Estimate baseline and replacement equipment wattages, operating hours, and use shapes to support the estimate of energy savings values and 8760 impact load shapes.
- Estimate participant free-ridership to support the development of net-to-gross ratios.
- Utilize the above results and the primary data collected to support these efforts, to develop kW and kWh unit energy savings (UES) values, impact load shapes and net-

to-gross ratios (NTGRs) for the LED lamp and reflector measures installed within the following building types:

- Office – Small
- Restaurant – Fast Food
- Restaurant – Sit Down
- Retail – Large
- Retail – Small

2.2 Overview of Measures and Building Types Evaluated

Over the course of Nonresidential Downstream Lighting Impact Evaluation, LED measures have contributed an increasing percentage of savings to the overall portfolio. Participation among all LED measures over 2010-12 was approximately 1.24% of total statewide portfolio kWh savings[1]. Furthermore, this percentage of savings had more than doubled throughout Q1-Q2 of 2013. Table 2-1 and Table 2-2 summarize the overall participation in LED measures and the corresponding percentage of total kWh savings for 2010-12 and 2013 (Q1-Q2), respectively.

Table 2-1: 2010 – 2012 LED Participation by Measure

Measure	kWh Savings	% kWh Savings	Unique sites	Unique Contacts
Lighting Indoor LED Exit Sign	11,996,223	10%	10,263	9,473
Lighting Indoor LED Fixture	16,543,645	14%	868	269
Lighting Indoor LED Lamp	18,960,637	16%	3,254	2,432
Lighting Indoor LED Other	11,598,933	10%	270	181
Lighting Indoor LED Reflector Lamp	24,510,175	21%	2,558	2,240
Lighting Indoor LED Signage	1,674,869	1%	9,399	9,364
Lighting Outdoor LED Fixture	9,205,766	8%	497	122
Lighting Outdoor LED Holiday	2,681	0%	2	2
Lighting Outdoor LED Other	5,124,206	4%	293	151
Lighting Outdoor LED Signage	1,968,000	2%	643	495
Lighting Outdoor LED Street Light	17,059,588	14%	756	267
Lighting Outdoor LED Traffic	135,357	0%	111	6
Total	**118,780,079**	**100%**	**28,914**	**25,002**

[1] This excludes savings associated with Codes and Standards Programs.

Table 2-2: 2013 (Q1-Q2) LED Participation by Measure

Measure	kWh Savings	% kWh Savings	Unique sites	Unique Contacts
Lighting Indoor LED Exit Sign	2,418	0%	40	8
Lighting Indoor LED Fixture	5,042,810	15%	104	56
Lighting Indoor LED Lamp	4,449,444	13%	2,835	2,769
Lighting Indoor LED Other	1,156,035	3%	19	7
Lighting Indoor LED Reflector Lamp	9,319,642	27%	2,569	2,485
Lighting Indoor LED Signage	82,572	0%	565	560
Lighting Outdoor LED Fixture	2,746,946	8%	106	59
Lighting Outdoor LED Other	942,958	3%	67	26
Lighting Outdoor LED Signage	163,030	0%	1	1
Lighting Outdoor LED Street Light	8,844,159	26%	463	134
Refrigeration Case LED Lighting	1,643,702	5%	480	317
Total	**34,393,717**	**100%**	**7,249**	**6,422**

Indoor LED lamps comprise 16% and 13% and indoor LED reflectors comprise 21% and 27% of the total ex-ante gross kWh savings for non-residential downstream LED measures in 2010-12 and 2013 (Q1-Q2), respectively. While LED fixtures make up a significant portion of the LED portfolio savings and were originally included in the research plan, they have been eliminated from this analysis given the small number of sites participating. This made it difficult to recruit enough sites to produce reliable results at the building type level.

Along with the two LED measures, five building types were chosen given that the distribution of savings was concentrated heavily within them. Table 2-3 and Table 2-4 summarize the overall participation in LED lamps and reflectors and corresponding percentage of total kWh savings from 2010 to 2013 (Q1-Q2) by building type. Small offices, restaurants and small retail establishments represent a significant percentage of portfolio savings. Large retail has low participation and significant savings, however, for many of the retail sites the large versus small designation was based on CIS usage information. There was the potential that some small retail could be reclassified as large retail (and vice versa) once sites were visited, so large retail were ultimately included in the sample design.

Table 2-3: 2010 – 2013 (Q1-Q2) Participation for LED Lamps by Building Type

Building Type	kWh Savings	% kWh Savings	Unique Sites	Unique Contacts
Hotel	1,452,769	6%	33	24
Office - Small	1,394,207	6%	1,135	1,101
Other	1,026,122	4%	1,060	1,051
Restaurant - Unknown	3,872,515	17%	877	347
Restaurant - Fast Food	714,777	3%	299	293
Restaurant - Sit Down	991,745	4%	328	306
Retail - Large	9,867,985	42%	172	38
Retail - Small	2,249,902	10%	1,160	1,065
Miscellaneous	1,840,060	8%	1,025	976
Total	**23,410,081**	**100%**	**6,089**	**5,201**

Table 2-4: 2010 – 2013 (Q1-Q2) Participation for LED Reflectors by Building Type

Building Type	kWh Savings	% kWh Savings	Unique Sites	Unique Contacts
Hotel	1,529,692	5%	48	39
Office - Small	2,292,076	7%	872	819
Other	1,724,626	5%	782	778
Restaurant - Unknown	813,183	2%	293	290
Restaurant - Fast Food	1,038,209	3%	374	357
Restaurant - Sit Down	1,514,234	4%	322	291
Retail - Large	15,233,268	45%	182	72
Retail - Small	6,048,721	18%	1,324	1,229
Miscellaneous	3,635,809	11%	930	850
Total	**33,829,817**	**100%**	**5,127**	**4,725**

2.3 Overview of Impact Evaluation Approach

As stated earlier, along with the development of key impact parameters, a secondary objective is to develop kW and kWh unit energy savings (UES) values, impact load shapes and net-to-gross ratios (NTGRs) for the LED lamp and reflector measures. Originally, the ex-post analysis was going to be restricted to 2010-12 program participants, but because there was limited participation in LED measures in that period, the sample frame utilized to meet these evaluation objectives was expanded to include customers that participated through Q2 of 2013. Because this evaluation is prospective looking, in that the primary objective is to support future ex-ante estimates of savings, rather than evaluating ex-post performance for a specific time period, it is not necessary to limit the evaluation sample frame to only 2010-12 participants.

Certain non-impact information was also gathered throughout the on-site verification process. Information regarding where LED measures were being installed within facilities as well as reasons for why equipment was not installed and operable at the time of the on-site visit, provide additional qualitative information that can be used to help inform future program planning.

A NTG analysis was also performed using a self-report analysis based on participant phone survey data. This analysis resulted in a number of NTGRs that could be used to understand the level of free ridership within the LED market. Not only was a NTGR analysis performed on the phone survey sample, but sites that ultimately agreed to an on-site survey were asked additional questions regarding why they had installed LED equipment and the level of influence that certain factors played in their decision to retrofit their existing lighting equipment with LED measures.

Section 4 discusses, in detail, the approaches that were used to develop parameter estimates, ex-post UES energy savings values, the NTGR's and the non-impact information.

The verification analysis and development of UES values were based on on-site data collection, which is discussed in more detail in Section 3. The on-site visits collected data that supported a number of parameters that were used in the following algorithm to estimate ex-post gross savings. This algorithm is based on developing hourly impacts to create an impact load profile. From this profile, impacts could be aggregated to develop an annual ex-post gross kWh savings value, or averaged over a set of specific hours to develop an ex-post gross kW savings value. The general algorithm applied to estimate energy savings for a specific hour is:

$$\text{Impact\_Hour\_i} = \begin{bmatrix} (\text{Baseline\_Wattage} \times \text{Percent\_On\_Pre\_Hour\_i}) \\ -(\text{Post\_Wattage} \times \text{Percent\_On\_Post\_Hour\_i}) \end{bmatrix}$$

Where,

Baseline_Wattage = the wattage associated with the measures that were replaced.

Post_Wattage = the wattage associated with the measures that were installed.

Percent_On_Pre = the percentage of time the baseline equipment is on during a specific hour i, which is obtained from adjusted self-reported operating hours gathered on site. These estimates are associated with LED measures that were installed in conjunction with an occupancy sensor.

Percent_On_Post = the percentage of time the installed equipment is on during a specific hour i, which is obtained from either logger data usage or adjusted self-reported operating hours gathered on site. Often times the Percent_On_Pre and Percent_On_Post are assumed to be equal, except in the case where an occupancy sensor was installed in conjunction with an LED measure.

The remainder of this report will discuss the following:

- Section 3 discusses the data sources that were utilized to estimate each of the individual parameters that comprise the impact load shapes, the sample design and resulting data used in the evaluation.
- Section 4 presents the final study results as well as the overall impact evaluation approach in more detail, including the methods used for estimating each individual impact parameter, including the installation rate, the various wattage values, the pre- and post operating hours and the NTGRs.
- Section 5 presents conclusions and recommendations that may provide support to future program planning.

There are also a number of appendices that discuss the data sources and inform the methodologies for this report in more detail. These appendices are similar and, in many cases, identical to the ones presented in nonresidential downstream lighting impact evaluation report. All references to those appendices are as follows:

- Appendix A presents the participant telephone survey instrument.
- Appendix B presents the on-site survey instrument.
- Appendix C presents the responses to the phone survey questions.
- Appendix D presents the net-to-gross analysis framework developed by the NTGR Working Group.
- Appendix E presents the lighting logger field installation procedures.
- Appendix F presents the logger data validation process.
- Appendix I presents the method used to adjust the self-reported operating schedules.

3

Data Sources, Sample Design, and Data Collection

3.1 Data Sources

A number of data sources were utilized to support the development of each impact parameter in order to develop gross ex-post kW and kWh UES values, installation rates and NTGRs for LED lamps and reflectors in this study. They are discussed in more detail below.

3.1.1 On-Site Data Collection

On-site visits collected data to support a number of parameters used in the impact algorithm. Verification data was collected to support installation rates, storage rates and LED measure specific wattages. Self-report data was also gathered on the wattage of pre-existing equipment when actual equipment replaced was not on site to help support the estimate of pre-retrofit wattages. Likewise, self-report data was gathered on lighting equipment usage schedules to aid in the development of pre- and post-retrofit load shapes. The use of the verification data to develop installation rates is discussed in Section 4.2, the development of operating schedules using self-report data is discussed in Section 4.3 and the development of wattage values is discussed in Section 4.4.

3.1.2 Time of Use Lighting Loggers

As part of the on-site visit, a sample of installed lighting equipment was monitored to gather time-of-use data to support the development of operating hours. Lighting loggers using optical sensors were used for this study. The development of lighting usage load shapes using logger data is discussed in detail in Section 4.3.1.

3.1.3 Participant Phone Survey

A phone survey was conducted to recruit customers for the on-site visit, as well as collect data useful for the net-to-gross (NTG) analysis and various other components of the evaluation. The NTG analysis is discussed in detail in Section 4.6.

3.1.4 2006-08 and 2010-12 Logger Data

Logger data from the 2006-08 CPUC Small Commercial Contract Group evaluation and the 2010-12 Nonresidential Downstream Lighting Impact Evaluation were utilized to adjust customer self-reported operating schedules for LED measures. The use of this data to adjust the self-reported operating schedules is discussed in detail in Section 4.3.

3.2 Data Collection

3.2.1 Sample Design

On-Site Sample Design

As mentioned above, the on-site visits collected data to support a number of the impact parameters including the installation rates, pre- and post-wattages and pre- and post-operating hours. The on-site sample was designed to develop statistically significant results at the LED technology-building type segment level. The Research Plan for this evaluation discusses the sample design in greater detail, but the resulting design focuses on developing estimates of key impact parameters that can be used to develop future ex-ante net and gross kW and kWh energy savings values for LED lamps and reflectors. Sample sizes were developed with the objective of being able to estimate a given parameter that has a COV of 0.5 with a relative precision of 20% measured at the 90% confidence level (90/20 relative precision).

The sample design was developed early on in the evaluation cycle when only 2010-2012 participation data was available. Therefore, there was some uncertainty in the levels of participation that would occur during the first quarter of 2013, or in the contribution to energy and demand savings from specific segments. The sample design was revisited after the first quarter of 2013 tracking data became available. This involved adding new segments, Fast Food and Sit Down restaurants and removing measures, like LED fixtures, where there were a small number of sites participating, which made it difficult to recruit enough sites to produce reliable results at the building type level.

Section 3.2.2 below discusses the data collection content for the on-sites, but to summarize, the on-sites attempted to collect verification data, pre- and post-wattage data, and pre and post self-report operating schedules. Lighting loggers were also installed in a majority of the sites. The 2006-08 Small Commercial evaluation developed a set of adjustment factors that can be used to adjust self-reported usage schedules to more accurately reflect actual usage, and develop use shapes. Therefore, this evaluation relied on those adjustment factors to develop pre- and post-retrofit use shapes in the event that an occupancy sensor was installed in conjunction with an LED measure or if the on-site surveyor was unable to log a specific measure[1].

[1] The savings associated with the LED measure derive from the adjusted pre-retrofit schedule and the occupancy sensor is credited with the reduced usage from the installed LED.

3.2.2 Achieved Primary Data Collection

<u>On-Site Survey Data Collection Summary</u>

Table 3-1 through Table 3-4 below summarize the resulting on-site data collection activity conducted for this evaluation. Table 3-1 summarizes the number of sites visited for the evaluation. However, some sites that were visited resulted in the auditor not being able to perform the on-site audit. Reasons for this include uncooperative site contacts, non-responsive contacts, and business privacy and security. Therefore, Table 3-2 summarizes the number of sites that were considered “lost” as data was not collected for the evaluation. Table 3-3 summarizes the number of sites for which data was collected that supported the development of installation rates, wattage estimates, and operating schedules. Totals are shown for both unique sites and the total number of site-HIM combinations that were visited. As mentioned above, not all sites included the installation of lighting loggers. Table 3-4 summarizes the number of sites for which lighting loggers were installed for the use of developing operating profiles. Roughly 90% of all LED measures that were evaluated on site were monitored. Sample sizes are shown by HIM, program period and building type. Although the overall results of this evaluation combined data collected from the 2010-12 and 2013 set of sampled participants, results in this section and throughout the rest of the report are shown separately for each program period, as well as combined across periods.

Table 3-1: Number of On-site Visits by HIM, Program Period and Building Type

Program Period	Building Type	LED Lamp	LED Reflector	Total Sites	Unique Sites
2010 – 2012	Office – Small	25	16	41	32
	Restaurant – Fast Food	7	12	19	16
	Restaurant – Sit Down	15	15	30	23
	Retail - Large	1	3	4	4
	Retail – Small	22	13	35	26
	All Building Types	**70**	**59**	**129**	**101**
2013 (Q1-Q2)	Office – Small	14	13	27	24
	Restaurant – Fast Food	17	17	34	24
	Restaurant – Sit Down	15	15	30	19
	Retail - Large	1	3	4	3
	Retail – Small	18	18	36	28
	All Building Types	**65**	**66**	**131**	**98**
2010 – 2013 (Q1-Q2)	Office – Small	39	29	68	56
	Restaurant – Fast Food	24	29	53	40
	Restaurant – Sit Down	30	30	60	42
	Retail - Large	2	6	8	7
	Retail – Small	40	31	71	54
	All Building Types	**135**	**125**	**260**	**199**

Table 3-2: Number of Lost Site Visits by HIM, Program Period and Building Type

Program Period	Building Type	LED Lamp	LED Reflector	Total Sites	Unique Sites
2010 – 2012	Office – Small			-	
	Restaurant – Fast Food	1	-	1	1
	Restaurant – Sit Down	1	-	1	1
	Retail - Large	1	1	2	2
	Retail – Small			-	
	All Building Types	**3**	**1**	**4**	**4**
2013 (Q1-Q2)	Office – Small	2	2	4	4
	Restaurant – Fast Food	-	1	1	1
	Restaurant – Sit Down	-	1	1	1
	Retail - Large			-	
	Retail – Small	1	1	2	2
	All Building Types	**3**	**5**	**8**	**8**
2010 – 2013 (Q1-Q2)	Office – Small	2	2	4	4
	Restaurant – Fast Food	1	1	2	2
	Restaurant – Sit Down	1	1	2	2
	Retail - Large	1	1	2	2
	Retail – Small	1	1	2	2
	All Building Types	**6**	**6**	**12**	**12**

Table 3-3: Number of On-sites Used in the Evaluation by HIM, Program Period and Building Type

Program Period	Building Type	LED Lamp	LED Reflector	Total Sites	Unique Sites
2010 – 2012	Office – Small	25	16	41	32
	Restaurant – Fast Food	6	12	18	15
	Restaurant – Sit Down	14	15	29	22
	Retail - Large	1	2	3	3
	Retail – Small	22	13	35	25
	All Building Types	**68**	**58**	**126**	**97**
2013 (Q1-Q2)	Office – Small	12	11	23	20
	Restaurant – Fast Food	17	16	33	23
	Restaurant – Sit Down	15	14	29	18
	Retail - Large	1	3	4	3
	Retail – Small	17	17	34	26
	All Building Types	**62**	**61**	**123**	**90**
2010 – 2013 (Q1-Q2)	Office – Small	37	27	64	52
	Restaurant – Fast Food	23	28	51	38
	Restaurant – Sit Down	29	29	58	40
	Retail - Large	2	5	7	6
	Retail – Small	39	30	69	51
	All Building Types	**130**	**119**	**249**	**187**

Table 3-4: Number of On-sites with Lighting Loggers Installed by HIM, Program Period and Building Type

Program Period	Building Type	LED Lamp	LED Reflector	Total Sites	Unique Sites
2010 – 2012	Office – Small	19	13	32	24
	Restaurant – Fast Food	5	11	16	13
	Restaurant – Sit Down	13	15	28	21
	Retail - Large	2	3	5	5
	Retail – Small	21	12	33	23
	All Building Types	**60**	**54**	**114**	**86**
2013 (Q1-Q2)	Office – Small	11	9	20	17
	Restaurant – Fast Food	16	12	28	19
	Restaurant – Sit Down	13	13	26	17
	Retail - Large	1	3	4	3
	Retail – Small	17	16	33	25
	All Building Types	**58**	**53**	**111**	**81**
2010 – 2013 (Q1-Q2)	Office – Small	30	22	52	41
	Restaurant – Fast Food	21	23	44	32
	Restaurant – Sit Down	26	28	54	38
	Retail - Large	3	6	9	8
	Retail – Small	38	28	66	48
	All Building Types	**118**	**107**	**225**	**167**

Overall, 249 site-level HIMs (Table 3-3 totals) were evaluated across all HIM-program period-building type segments. Retail – Large were under-represented given the low participation level and the difficulty in recruitment for the on-site verification.

For the sample of sites where lighting loggers were installed, the auditors attempted to log every activity area where the measures of interest were installed. Activity areas are defined as areas at the premise that have different operating schedules. However, site contacts restricted access to some areas at a few of the sites that were visited. Within each activity area, the lamps and fixtures that were logged were selected at random. Time-of-use lighting loggers were installed at the premise for up to 15 weeks to gather data with an average of 9 weeks. Installation of logging equipment was also not always possible due to a variety of other reasons. Engineers were limited in their efforts to install monitoring equipment at sites where there was no place on a fixture to install a logger, the contact did not like the aesthetic of the logger or where there was too much ambient light to be able to logger efficiently. For sites where monitoring was not feasible, data was still collected to support the verification analysis and self-report data was obtained from the operating schedules to aid in the development of operating hours. It is important to note, however, that engineers were very successful in installing logger equipment at the vast majority of sites and these loggers provided useful data with which load shape profiles could be created.

Table 3-5 summarizes the number of lighting loggers installed for the use of developing operating profiles. Lighting logger counts are shown by HIM, program period and building type. In total, 380 loggers were installed on LED measures.

Table 3-5: Number of Lighting Loggers Installed by HIM, Program Period and Building Type

Program Period	Building Type	LED Lamp	LED Reflector	Loggers
2010 – 2012	Office – Small	35	17	52
	Restaurant – Fast Food	6	14	20
	Restaurant – Sit Down	22	21	43
	Retail - Large	2	8	10
	Retail – Small	29	16	45
	All Building Types	**94**	**76**	**170**
2013 (Q1-Q2)	Office – Small	13	15	28
	Restaurant – Fast Food	29	13	42
	Restaurant – Sit Down	33	28	61
	Retail - Large	3	14	17
	Retail – Small	31	31	62
	All Building Types	**109**	**101**	**210**
2010 – 2013 (Q1-Q2)	Office – Small	48	32	80
	Restaurant – Fast Food	35	27	62
	Restaurant – Sit Down	55	49	104
	Retail - Large	5	22	27
	Retail – Small	60	47	107
	All Building Types	**203**	**177**	**380**

3.2.3 On-Site Data Collection Content

Generally, the data collected at each site included both visual observations and measurements. At each site, the field auditors observed the following:

- ***Site Information.*** This data included basic information about the business and the building itself. The field auditors recorded business type, total floor area, conditioned floor area, floor area by space use type, business hours, and also verified the cooling system type and heating fuel type reported by the phone survey. The conditioning state (unconditioned, heated, cooled, etc.) of each space use area was also noted.
- ***Customer Reported Equipment Operating Schedule.*** In addition to business hours, the field auditors asked the customers about equipment operation schedules for each specific lighting circuit with rebated fixtures. These schedules were recorded as the percent "on" time in each hour of every week day. Seasonal schedule variations were also recorded. Customers that installed occupancy sensors were also asked about their operating schedules prior to the retrofit to support the development of pre-retrofit load shapes.
- ***Lighting Lamp Data.*** Detailed information was collected for every rebated lamp. The primary collection method was visual verification, however the field auditors also asked for any documentation on site for the rebated lighting. It also included contextual data not directly affecting fixture power such as lighting application, mounting type, reflector, floor-to-fixture height, and control type. To gather baseline lamp information the auditor used four approaches for each measure on site. In each case the auditor tried to gather the same information as described above. The first was to locate lamps that were not retrofitted but in the same area or type of area and matched the baseline lamp description. The second approach was to look for spare baseline lamps in storage and maintenance areas. The third was to review any documentation regarding the previously installed lamps. The fourth approach was to gather the contacts' or maintenance staffs' best recollection of the baseline lamp information. If baseline information was not found for a measure the fields were left blank on the form to allow backfilling from high level analysis.
- ***Lighting Inventory.*** The final component of the field observations was the lighting inventory. This task required the field auditors to identify the rebated/targeted equipment that corresponded to each lighting schedule gathered, or in the case of when loggers were installed, the inventory corresponding to the installed lighting loggers. As many loggers were used as needed to represent the different activity areas and schedules. The information contained in the lighting inventory provided the "load" portion of determining the 8,760 load shape for the circuit. When combined with all of the other lighting circuits at the site, the load could be aggregated at both the site and space-type level.

- ***Time-of-Use Data Logging.*** This critical measurement involved leaving data loggers in place over some period to capture the typical usage of each defined lighting circuit. The field auditors attempted to install at least one data logger on every circuit feeding fixtures affected by the retrofit; often, a "backup" logger was also installed in case the primary logger failed. The information provided by the logger data provides the "shape" portion of determining the 8,760 load shape for this circuit. When combined with all of the other lighting circuits at the site, the shape can be aggregated at both the site and space-type level. Detailed information about the loggers and installation procedures are contained in Appendix E.

3.2.4 Logger Data Validation

Logger data quality control was accomplished by using the *viewLoggers* interface, an interactive program/tool developed by Itron that brings together contextual survey information and logger data information in a single interface, which enables review and quality control disposition. Features of the interface include:

- ***Contextual Survey Data.*** These data include business type, activity area (space use) type, scanned survey form, and photos also available.
- ***Logger Data.*** This data is displayed in several formats: original raw transition data, two graphical displays a week at a time and over the entire installation period.
- ***Repair of Data with Issues.*** viewLoggers also includes code for correcting data, such as loggers that span a daylight savings time (DST) event and logger data with time-drift issues.
- ***Data Review Dispositions and Comments.*** These categories include general operation (always off, random, consistent, always on), etc.

Note that the data for every logger was manually reviewed and dispositions indicated by an analyst. Further discussion of this process can be found in Appendix F, Lighting Logger Data Validation Process.

There were a total of 264 loggers used in the analysis for this study. The loggers were installed over the period between October 2013 and March 2014. The loggers were installed at each site for an extended period in most cases. More than 95% of the loggers recorded lighting usage for 6 weeks or more, with a maximum of 15 weeks for a several sites. On average, loggers had 9 weeks of data.

While the surveyors were on site removing the loggers, they also recorded extraction comments about the condition of the loggers and other extraction information needed for the quality control and analysis of the logger data. The data were downloaded from the loggers as soon as possible and the extraction information was entered into the survey database. Logger and computer date-times were recorded on the extraction form to help with correcting loggers with time-drift and DST issues.

With these data available, viewLoggers was used as the primary tool for the quality control process. As more and more loggers were processed, viewLoggers was modified to handle new issues and the interface improved, and more analysts were used to review the logger data. At the height of the data collection effort, a team of 2 to 3 analysts were reviewing and dispositioning logger data using viewLoggers.

Data Issues

As part of the validation process, the loggers were evaluated for known issues that could compromise the results. These included the following checks:

- Reviewing the data to see if a minimum number of weeks of data was recorded.
- Looking for large gaps in the data which might indicate that the logger was temporarily moved or that the battery failed or the logger fell from its position in the fixture.
- Scrutinizing the loggers for "flickering" and "sensitivity" issues.
- Evaluating the time/date stamps in the raw data files for time drift and inadvertent logger reset.
- Reviewing logger "pairs" (primary loggers with a back-up) to determine if the loggers were truly back-ups to each other. If the loggers were observed as not being on the same circuit then they were split in the database and the quantities of bulbs were distributed to each logger based on the information available on the form.

As the quality control process progressed a list of items became obvious to look for in the data. This section describes some of these items and gives a brief explanation of what this implies to the usability of the data. Further discussion of these issues can be found in Appendix F where the process of using viewLoggers is described.

- ***"False DST".*** A small number of loggers were synchronized before the change in Daylight Saving Time but installation after DST went into effect. This meant that all times recorded by the logger were an hour behind actual clock time for the entire installation period. This error was corrected, for the loggers identified as having this problem, automatically in viewLoggers.
- ***Time Drift.*** Some loggers experienced internal clock time drift issues, some minutes but others hours or days. This was observed during the Pilot Test period of the study the procedures were adjusted to catch logger data with this issue. As mentioned in Appendix F, viewLoggers was designed to catch this issue and make adjustments.

- ***Logger Reset.*** A feature of both of the Dent loggers used for this study is that when the reset button is held down for at least five seconds, the logger is completely cleared of data and internal clock set to 1/1/2001. During the first phase of the effort, this was not well known and some surveyors were heavy-handed with the reset button[2]. In addition, if a logger was cleared and then installed without ever being synchronized to the current time, the recorded data would be completely out of synch with real time. Fortunately in both cases, it was easy to use the actually installation date to correct this data.

The combination of the quality control process and issues with missing/lost loggers resulted in 264 of the 380 loggers being retained for analysis. The two most prevalent issues accounting for the loss of logger data were:

- ***Failed/Faulty Loggers with Insufficient Data.*** Loggers that did not collect sufficient data may have been the result of faulty batteries, loggers falling off and/or not being replaced correctly, and/or other mechanical issues. Loggers were expected to record a minimum of three weeks of data with a target of at least eight weeks. If the logger recorded significantly fewer days than this, the entire logger data was discarded. Insufficient data or no data having been recorded by the logger was the most significant reason why a logger was removed from the analysis.
- ***Lost, Missing, Stolen Loggers.*** The problem of theft was primary issue in this category, although it was by no means a serious issue, however, these loggers were never recovered.

Unusable Logger Data

As a result of the validation process, logger data was given the disposition of either good or unusable. The loggers that were unusable were marked as such due to the data issues previously described plus the additional issues described in this section. The dispositions described here are the ones available in viewLoggers (see Appendix F).

As stated above, the main reason that a logger was given a bad disposition was due to the fact that it provided insufficient data or no data at all. One reason for this could be the fact that LED lamps and reflectors typically provide directional light and loggers may not have captured that light sufficiently. Table 3-6 presents summary of other reasons for exclusion and the number of loggers with each disposition. It should be noted that a single logger may be tagged with one or more of the dispositions listed below. The counts in the table represent all the conditions marked on a single logger and hence cannot be added-up to get a total count of loggers failed. Also note

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2 This resulted in Dent creating a “firmware” change that removes the CLEAR feature from the logger.

that, backup loggers were identified and, if shown to represent exactly the same usage as their primary counterpart, were also not included in the analysis to prevent double counting the number of bulbs in the study.

Table 3-6: Reasons for Excluding Loggers from Analysis

Reason for Removal	Number of Loggers Marked with the Issue
Flickering	6
Sensitivity	12
Logger fell	1

The viewLogger dispositions are described in detail below:

- **Flickering.** This issue is identified as multiple transitions per second and/or minute for an extended period of time. Flickering can be caused from other light sources such as ambient daylighting. Flickering can also be caused by the sensitivity being set too close to the transition threshold. A failing bulb could also show up as flickering, however, if that could be determined it would not be a reason for disqualification of the logger data.
- **Sensitivity Issues.** Logger sensitivity settings are a manual process done by trial and error at the site. Loggers where the sensitivity is incorrectly set can produce different symptoms (i.e., Flickering, Always On, Always off). When conditions do not indicate the true state of the light being logged, then this flag is set and the logger is marked as bad. Extraction comments and the raw data can be very useful in troubleshooting this type of problem.
- **Logger Fell.** Issues with the magnets and other fastening devices cause problems with the loggers not staying where placed. As theses issue were discovered steps were taken to minimize the problem, but some loggers had to be disqualified before the issue was resolved.
- **Battery (Logger) Failed.** Battery failure was one of many reasons why a logger was disqualified. This is the only reason made available to the evaluator because it is the only one that can produce some results for validation. Heat damage was the other major failure observed with the loggers. The reason this is not an option for the validation process is that the data from a heat damaged logger is not downloadable.
- **Time Drift.** The issue of time drift is an interesting one. It seems the internal clocks in loggers with this problem do not cycle at the same rate as a normal clock. Many of the loggers like this were fixed with code, but some were so far off that it was felt that the fix would not be reliable. A few were marked as bad for this reason. This condition was auto corrected by the software when specific conditions were observed in the data. The evaluator could override this correction if deemed necessary, but in no instance was this done. If the correction did not work correctly the logger data was marked as unusable.

- **Other.** Some of the issues marked as other included:
  - Logger not recording data for periods of time not related to lamp or fixture failure.
  - Date of installation not consistent with other loggers at the site.
  - Data could not be downloaded from the logger.
  - Loggers were moved by people at the site
- **Lamp Failed.** This categorization is generally not used because the failure of a lamp does not constitute bad logger data. It constitutes the lack of use of a rebated lamp. This is generally what is being analyzed.
- **For Reset.** This condition was auto corrected by the viewLoggers when specific conditions were observed in the data. If viewLoggers detected that there was a problem with the logger being reset to factory defaults then this flag would be set. While it was possible for the analyst to override this correction, it was never set. If the correction was ineffective then the data was marked as unusable. It should be noted that this is not a condition for disqualification in and of itself. Unless the correction routine itself was ineffective, other issues must be specified to disqualify a logger needing the reset correction.

As a part of the logger validation process, roughly 18% of the loggers that had sufficient data were marked as unusable. With the resources that were made available to the analysts, this process ran smoothly and efficiently. As the process progressed, lessons learned were applied to loggers previously processed, which ensured that the same criteria were applied to all loggers available for the analysis.

3.2.5 Logger Data Used in Analysis

Table 3-7 presents the number of sites and number of loggers that were used in the analysis for each HIM by Program Period and Building Type. A total of 264 loggers were used in the analysis.

Table 3-7: Loggers Installed and Used in Analysis by HIM, Program Period and Building Type

Program Period	Building Type	LED Lamp	Sites	LED Reflector	Sites
2010 – 2012	Office – Small	23	16	9	8
	Restaurant – Fast Food	4	3	8	8
	Restaurant – Sit Down	15	10	6	4
	Retail - Large	2	1	2	2
	Retail – Small	17	10	12	8
	All Building Types	61	40	37	30
2013 (Q1-Q2)	Office – Small	11	8	12	7
	Restaurant – Fast Food	24	13	11	8
	Restaurant – Sit Down	27	12	17	8
	Retail - Large	3	1	13	3
	Retail – Small	22	15	26	13
	All Building Types	87	49	79	39
2010 – 2013 (Q1-Q2)	Office – Small	34	24	21	15
	Restaurant – Fast Food	28	16	19	16
	Restaurant – Sit Down	42	22	23	12
	Retail - Large	5	2	15	5
	Retail – Small	39	25	38	21
	All Building Types	148	89	116	69

3.2.6 On-Site Data Used to Support Pre- and Post-Retrofit Wattage Estimates

As part of the lighting inventory, detailed information was collected for every rebated lamp found on site. To develop pre-retrofit wattage values, a combination of approaches was utilized. If any of the equipment that was replaced was still on site, then similar information was gathered such that a lookup could be performed. If there was equipment still in place that had not been retrofitted that was reported to be the same as that replaced, then similar information was gathered on that equipment, and used to estimate pre-retrofit wattage. If no existing equipment was found on site, then customer self-report information was used to estimate wattages.

Table 3-8 and Table 3-9 present the number of sites visited and the number of lamps or fixtures where either pre- or post-retrofit wattage information was gathered. Results are presented for each HIM by Program Period and Building Type. It is important to note that for 2010-12 LED lamps installed in fast food restaurants, the pre-retrofit wattage observations exceed those for the post-retrofit period. As will be discussed in Section 4.4, it was the case that sometimes LED equipment was either removed or had failed prior to the on-site inspection. In this case, all lamps had been removed from the premise, however, the baseline equipment was known.

Table 3-8: Number of Wattage Observations Performed by Program Period and Building Type for LED Lamps

Program Period	Building Type	Sites	Pre-Retrofit Wattage Observations	Post-Retrofit Wattage Observations
2010 – 2012	Office – Small	25	57	57
	Restaurant – Fast Food	6	7	6
	Restaurant – Sit Down	14	23	28
	Retail - Large	1	2	2
	Retail – Small	22	26	31
	All Building Types	68	115	124
2013 (Q1-Q2)	Office – Small	12	13	16
	Restaurant – Fast Food	17	32	32
	Restaurant – Sit Down	15	32	43
	Retail - Large	1	3	3
	Retail – Small	17	32	33
	All Building Types	62	112	127
2010 – 2013 (Q1-Q2)	Office – Small	37	70	73
	Restaurant – Fast Food	23	39	38
	Restaurant – Sit Down	29	55	71
	Retail - Large	2	5	5
	Retail – Small	39	58	64
	All Building Types	130	227	251

Table 3-9: Number of Wattage Observations Performed by Program Period and Building Type for LED Reflectors

Program Period	Building Type	Sites	Pre-Retrofit Wattage Observations	Post-Retrofit Wattage Observations
2010 – 2012	Office – Small	16	22	21
	Restaurant – Fast Food	12	13	17
	Restaurant – Sit Down	15	36	37
	Retail - Large	2	10	10
	Retail – Small	13	14	21
	All Building Types	58	95	106
2013 (Q1-Q2)	Office – Small	11	20	21
	Restaurant – Fast Food	16	27	30
	Restaurant – Sit Down	14	22	32
	Retail - Large	3	15	15
	Retail – Small	17	38	43
	All Building Types	61	122	141
2010 – 2013 (Q1-Q2)	Office – Small	27	42	42
	Restaurant – Fast Food	28	40	47
	Restaurant – Sit Down	29	58	69
	Retail - Large	5	25	25
	Retail – Small	30	52	64
	All Building Types	119	217	247

Table 3-10 presents the number of lamps or fixtures where either pre- and post-retrofit wattage information was gathered for each HIM. 8 - 11 watt lamps replacing 41 – 60 watt incandescent lamps were the predominant retrofit for LED lamps. The range in retrofit for LED Reflectors was more evenly distributed.

Table 3-10: Pre and Post Retrofit Wattage Ranges for LED Lamp and Reflectors for both Program Periods

Pre and Post Retrofit	LED Lamp	LED Reflector
	Retrofit Observations	Retrofit Observations
4-7W LED replacing <26W	1	3
4-7W LED replacing 26-40W	1	16
4-7W LED replacing 41-60W	6	39
4-7W LED replacing 61-90W	3	
4-7W LED replacing >90W		1
8-11W LED replacing <26W	4	
8-11W LED replacing 26-40W	29	7
8-11W LED replacing 41-60W	123	12
8-11W LED replacing 61-90W	41	16
8-11W LED replacing >90W	5	3
12-17W LED replacing 41-60W		15
12-17W LED replacing 61-90W	5	47
12-17W LED replacing >90W	4	36
>17W LED replacing 41-60W	1	
>17W LED replacing 61-90W		4
>17W LED replacing >90W		15

3.2.7 2006-08 and 2010-12 Logger Data Used in Analysis

As mentioned, the 2006-08 logger data are being used along with the 2010-12 logger data to develop factors that can be used to adjust the self-reported operating hour schedules. That analysis was performed on CFL measures and the resulting adjustments have been utilized in the LED analysis to provide operating hours for measures that were not monitored or in the event that a logger provided insufficient information. The adjustments are made at the market segment and activity area level. Table 3-11 presents the number of sites and number of loggers that were used in this analysis for CFLs by market segment and activity area. Shown are the number of sites and loggers used from the 2006-08 study, the 2010-12 study, and totals. Only market segment-activity area combinations for which at least 8 sites were monitored are used in the analysis to ensure reliability in the adjustment factors. These adjustments were utilized only for building types and space types that corresponded to where LED lighting was being installed. It was thought that, since LED lamps and reflectors were often replacing incandescent and halogen lighting, that could very well be replaced with CFLs and have similar (or identical) operating schedules, that these adjustments could be applied to LED lighting as well. This approach was tested and the results are presented in Section 4.3.

Table 3-11: 2006-08 and 2010-12 Logger Data Used for Adjustment Factors by Market Segment and Activity Area for CFLs

Market Segment Activity Area	2006-08 SmCom		WO029		Total	
	Sites	Loggers	Sites	Loggers	Sites	Loggers
Office - Small						
Hallway/Lobby	34	54	4	5	38	59
Kitchen/Breakroom	10	10	1	1	11	11
Office	26	41	5	10	31	51
Other Misc	12	18	1	1	13	19
Restrooms	62	79	8	9	70	88
Storage	18	21	1	1	19	22
Total Office - Small	**103**	**223**	**16**	**27**	**119**	**250**
Restaurant						
Dining	64	129	8	16	72	145
Hallway/Lobby	36	48	1	1	37	49
Kitchen/Breakroom	26	29	1	1	27	30
Office	14	16	-	-	14	16
Other Misc	8	12	1	3	9	15
Restrooms	51	76	2	2	53	78
Storage	42	66	1	1	43	67
Total Restaurant	**107**	**376**	**11**	**24**	**118**	**400**
Retail – Large						
Other Misc	9	20	4	4	13	24
Restrooms	9	13	1	3	10	16
Retail Sales	15	34	3	8	18	42
Total Retail – Large	**27**	**67**	**7**	**15**	**34**	**82**
Retail – Small						
Comm/Ind Work	12	20	3	7	15	27
Hallway/Lobby	17	24	5	5	22	29
Office	23	28	2	2	25	30
Other Misc	14	16	3	4	17	20
Restrooms	92	117	17	22	109	139
Retail Sales	49	81	11	17	60	98
Storage	25	31	4	4	29	35
Total Retail – Small	**158**	**317**	**32**	**61**	**190**	**378**
Total	**395**	**983**	**66**	**127**	**461**	**1,110**

3.2.8 Operating Schedule Data Used in Analysis

Two sources of data were discussed above that provide data to support the development of 8,760 operating schedules for pre- and post-retrofit lighting usage: lighting logger data and adjusted self-report data. Table 3-12presents the number of sites and the unique number of operating schedules that were developed from these two data sources and available for use in the development of operating hours for LED lamp and reflector measures. Site and schedule counts are provided for each HIM by program period and building type. It is important to note that even though these sample sizes rely on a combination of loggers and adjusted self-report data, some of these combined sample sizes may be less than the lighting logger counts provided above. This is because multiple loggers are sometimes installed within a given schedule group. Those loggers are aggregated, as discussed below in the operating analysis section, to create a single load shape for that unique schedule group. Therefore, the sample sizes presented below can be less than the logger sample sizes listed above due to aggregation.

While Table 3-12 provides the number of unique schedules by analysis building type and program period, it is also important to note where exactly these LED measures are being installed. Table 3-13 presents the LED lamp and reflector installations by specific activity areas. The overall distribution of lamp and reflector installations by activity area doesn't change significantly between the periods except in a few cases. For the on-site sample, LED lamps installed in dining areas represent roughly 7% of all lamp installations for 2010-12 and 21% in 2013 (Q1-2). This is more than likely a product of having sampled more Restaurant Fast – Food in the 2013 period (15 sites relative to 4 in the 2010-12 period). LED lamps were being installed in restrooms much more often than any other activity area, representing 39% and 36% of the unique schedules analyzed, respectively. Likewise, of the 94 unique restrooms that were included in the post-retrofit analysis, 43 of those also had occupancy sensors installed in conjunction with the LED measure. For LED reflectors, dining areas contribute 24% and 22% of unique schedules for each period, respectively.

It is important to note that the site counts below in Table 3-12 for both LED lamps and reflectors is less than those reported in Table 3-1. As will be discussed in further detail in Section 4.1 this is a product of a number of sites (9 LED lamp and 5 LED_REF sites) where all the equipment had either been removed or had failed prior to the on-site inspection. While these sites do contribute to the verification analysis, they have zero weight in the UES calculation.

Table 3-12: Combined Operating Schedules Used for Post-Retrofit Analysis by HIM, Program Period and Building Type

Program Period	Building Type	LED Lamps		LED Reflectors	
		Sites	**Unique Schedules**	**Sites**	**Unique Schedules**
2010 – 2012	Office – Small	25	47	14	17
	Restaurant – Fast Food	4	5	12	16
	Restaurant – Sit Down	13	26	14	27
	Retail - Large	1	1	2	3
	Retail – Small	19	26	13	15
	All Building Types	62	105	55	78
2013 (Q1-Q2)	Office – Small	11	15	9	17
	Restaurant – Fast Food	15	25	16	21
	Restaurant – Sit Down	15	30	13	19
	Retail - Large	1	3	3	8
	Retail – Small	17	29	17	24
	All Building Types	59	102	58	89
2010 – 2013 (Q1-Q2)	Office – Small	36	62	23	34
	Restaurant – Fast Food	19	30	28	37
	Restaurant – Sit Down	28	56	27	46
	Retail - Large	2	4	5	11
	Retail – Small	36	55	30	39
	All Building Types	121	207	113	167

Table 3-13: LED Lamp and Reflector Installations by Unique Activity Area

Program Period	Activity Areas	LED Lamps		LED Reflectors	
		Unique Schedules	Distribution of Schedules	Unique Schedules	Distribution of Schedules
2010 – 2012	Dining	7	7%	19	24%
	Hallway/Lobby	15	14%	13	17%
	Kitchen/Break room	5	5%	5	6%
	Office	7	7%	6	8%
	Other Misc	6	6%	10	13%
	Outdoor	4	4%	3	4%
	Restrooms	41	39%	6	8%
	Retail Sales	5	5%	14	18%
	Storage	15	14%	2	3%
	Total	**105**	**100%**	**78**	**100%**
2013 (Q1-Q2)	Dining	21	21%	20	22%
	Hallway/Lobby	6	6%	5	6%
	Kitchen/Break room	2	2%	6	7%
	Office	7	7%	11	12%
	Other Misc	9	9%	12	13%
	Outdoor	2	2%	9	10%
	Restrooms	37	36%	10	11%
	Retail Sales	4	4%	14	16%
	Storage	14	14%	2	2%
	Total	**102**	**100%**	**89**	**100%**

4

Methodology and Results

This section provides an overview of the methods used to estimate the key impact parameters, the ex-post Unit Energy Savings (UES) values, the NTGRs and the results from those analyses.

4.1 Overview of Approach

The primary objective of this evaluation is to develop estimates of key impact parameters for indoor LED lamp and reflector measures. These parameters, that include operating hours, baseline wattages, installed wattages, installation rates and net-to-gross ratios (NTGRs), can be used to inform future ex-ante net and gross kW and kWh energy savings values.

A secondary objective is to utilize these parameter level results in order to develop kW and kWh unit energy savings (UES) values, impact load shapes and net-to-gross ratios (NTGRs) for the LED lamp and reflector measures for a key set of building types.

Additionally, this section contains non-impact information that can be used to inform future LED program planning. Section 4.2 not only contains the verification analysis, but it also provides information regarding rebated LED equipment that was not installed and operable at the time of the on-site visit and reasons why that was the case (failed equipment, replaced, etc) and Section 4.7 provides reasons for why individuals were installing LED equipment within their facilities in the first place.

As discussed in more detail below, the impact parameter estimates will be developed at the statewide level for two indoor LED high impact measures (HIMs) – LED lamps and LED reflectors – for the following building types:

- Office – Small
- Restaurant – Fast Food
- Restaurant – Sit Down
- Retail – Large
- Retail – Small

Because there was limited participation in LED measures in 2010-12, the sample frame utilized to meet these evaluation objectives was expanded to include customers that participated in the first quarter of 2013. Because this evaluation is prospective looking, in that the primary objective is to support future ex-ante estimates of savings, rather than evaluating ex-post performance for a specific time period, it is not necessary to limit the evaluation sample frame to only 2010-12 participants.

This section discusses, in detail, the inputs that were used to develop these parameter estimates. They also inform the general approach that was used to develop the unit energy savings (UES) values. The algorithm that was applied to estimate unit energy savings for a specific hour is:

$$\text{Impact\_Hour\_i} = \begin{bmatrix} (\text{Baseline\_Wattage} \times \text{Percent\_On\_Pre\_Hour\_i}) \\ -(\text{Post\_Wattage} \times \text{Percent\_On\_Post\_Hour\_i}) \end{bmatrix}$$

Where:

> Baseline_Wattage = the wattage associated with the measures that were replaced.
>
> Post_Wattage = the wattage associated with the measures that were installed.
>
> Percent_On_Pre = the percentage of time the baseline equipment is on during a specific hour i, which is obtained from adjusted self-reported operating hours gathered on site. These estimates are associated with LED measures that were installed in conjunction with an occupancy sensor.
>
> Percent_On_Post = the percentage of time the installed equipment is on during a specific hour i, which is obtained from either logger data usage or adjusted self-reported operating hours gathered on site. Often times the Percent_On_Pre and Percent_On_Post are assumed to be equal, except in the case where an occupancy sensor was installed in conjunction with an LED measure.

The remainder of this section will discuss the following:

- The approach for estimating each individual impact parameter, including the installation rate, the various wattage values and the pre and post operating hours.
- The approach for estimating the Net-to-Gross ratios.
- The resulting UES values and NTG ratios.
- An evaluation of non-impact information garnered from the on-site visit.

4.2 Installation Rate Analysis

The installation rate is defined as the percentage of equipment found to be installed and operable. The installation rate is estimated for each site based on data gathered during the on-site visit. As part of these on-site visits, an objective of the auditor was to attempt to identify all equipment installed along with a disposition of that equipment.

The key measure count that is identified on site is the number of measures that are currently installed and in working condition (operable). The installation rate is calculated directly from this measurement:

$$\text{Installation Rate} = \frac{\text{Quantity of measures installed and operable from on-site visit}}{\text{Quantity of measures reported installed in tracking system}}$$

In addition to identifying the amount of equipment that was installed and operable, the auditor also identified the amount of equipment that was:

- Failed and in place – The number of measures that are currently installed, but were not in working condition (failed).
- Failed and replaced – The number of measures that had been installed, but then had failed and were replaced with a different technology.
- Removed and not replaced - The number of measures that had been installed, but had been removed (either due to failure or other reasons), but were not replaced, such that the lamp socket is empty.
- In storage – The number of measures that were found in storage and have not yet been installed.

Although the installation rate is defined as the percent found to be in place and operable, an analysis was also conducted to determine the percent of rebated measures that were actually received by a participant (received rate). This would include those in place and operable, burned out or replaced or placed in storage.

Table 4-1 and Table 4-2 present the installation rates (defined as installed and operable), received rates (percent of rebated measures determined to have actually been received by the participants), storage rates and failure/removal rates for each HIM by program period and building type. Also shown are the sample sizes and resulting relative precision measured at the 90% confidence interval.

Table 4-1: Disposition of Lighting Verification by Program Period and Building Type for LED Lamps

Program Period	Building Type	Sites	Received Rate	Failure Rate	Storage Rate	Removal Rate	Installation Rate	Relative Precision
2010 – 2012	Office – Small	25	89%	0%	0%	7%	82%	11%
	Restaurant – Fast Food	6	98%	0%	0%	44%	54%	81%
	Restaurant – Sit Down	14	93%	11%	0%	10%	72%	23%
	Retail - Large	1	94%	0%	0%	0%	94%	-
	Retail – Small	22	95%	3%	0%	2%	90%	11%
	All Building Types	**68**	**93%**	**3%**	**0%**	**11%**	**79%**	**8%**
2013 (Q1-Q2)	Office – Small	12	100%	4%	0%	4%	93%	12%
	Restaurant – Fast Food	17	94%	2%	0%	0%	92%	10%
	Restaurant – Sit Down	15	95%	0%	0%	6%	89%	9%
	Retail - Large	1	100%	0%	0%	0%	100%	-
	Retail – Small	17	98%	9%	0%	1%	88%	10%
	All Building Types	**62**	**97%**	**3%**	**0%**	**3%**	**91%**	**5%**
2010 – 2013 (Q1-Q2)	Office – Small	37	92%	1%	0%	6%	85%	8%
	Restaurant – Fast Food	23	95%	2%	0%	8%	85%	13%
	Restaurant – Sit Down	29	95%	4%	0%	8%	83%	10%
	Retail - Large	2	95%	0%	0%	0%	95%	15%
	Retail – Small	39	97%	7%	0%	1%	89%	7%
	All Building Types	**130**	**94%**	**3%**	**0%**	**6%**	**86%**	**4%**

Table 4-2: Disposition of Lighting Verification by Program Period and Building Type for LED Reflectors

Program Period	Building Type	Sites	Received Rate	Failure Rate	Storage Rate	Removal Rate	Installation Rate	Relative Precision
2010 – 2012	Office – Small	16	94%	2%	0%	0%	92%	13%
	Restaurant – Fast Food	12	98%	0%	0%	0%	98%	4%
	Restaurant – Sit Down	15	98%	2%	0%	13%	83%	16%
	Retail - Large	2	67%	0%	0%	0%	67%	246%
	Retail – Small	13	71%	0%	0%	0%	71%	47%
	All Building Types	**58**	**77%**	**1%**	**0%**	**1%**	**75%**	**12%**
2013 (Q1-Q2)	Office – Small	11	97%	18%	0%	0%	80%	23%
	Restaurant – Fast Food	16	98%	0%	0%	0%	98%	5%
	Restaurant – Sit Down	14	97%	0%	0%	12%	85%	16%
	Retail - Large	3	100%	0%	0%	0%	100%	0%
	Retail – Small	17	98%	1%	0%	0%	98%	3%
	All Building Types	**61**	**98%**	**4%**	**0%**	**1%**	**93%**	**4%**
2010 – 2013 (Q1-Q2)	Office – Small	27	95%	8%	0%	0%	87%	11%
	Restaurant – Fast Food	28	98%	0%	0%	0%	98%	4%
	Restaurant – Sit Down	29	97%	1%	0%	12%	84%	11%
	Retail - Large	5	93%	0%	0%	0%	93%	18%
	Retail – Small	30	92%	1%	0%	0%	91%	11%
	All Building Types	**119**	**94%**	**2%**	**0%**	**1%**	**91%**	**4%**

Installation rates vary significantly from one building type to another as well as across program periods for both LED technologies. For LED lamps, the removal rate for both restaurant types and small offices is significantly greater. While the small sample size for Restaurant – Fast Food contributes to a very high removal rate in 2010-12 (1 site removed all of the lamps and represented almost half of that segment's weight) the reason for that removal is fairly consistent with other segments. By and large, lamps were removed because the lighting they provided was not aesthetically pleasing, too strong or too directional. The same is true for LED reflector measures. Failure rates also contributed significantly to lower installation rates, especially for the restaurant and retail – small segments. On average, site contacts that had self-reported LED failures claimed that the lamps or reflectors burned out within 6 to 8 months of installation. This could explain, at least for sit down restaurants, why the failure rate is 11% for the 2010-12 period and 0% in the 2013 period.

While relative precisions vary significantly across building types for each technology, they are all within the 90/15 range or better when combined across program periods for all but a couple of segments.

4.3 Operating Hour Analysis

One of the primary inputs into the gross savings calculations are the 8760 load shapes, or percent on, for lighting equipment. There were multiple methodologies employed to develop these percent on load shapes, which are discussed in this section. More specifically, this section will discuss the development of the following:

- Post-Retrofit 8760 load shapes based on logger data
- Self-Report Adjustment Factors using 2006-08 and 2010-12 logger and self-report data
- Post-Retrofit 8760 load shapes based on self-report data and the self-report adjustment factors
- Post-Retrofit 8760 load shapes based on combining the logger based profiles with the adjusted self-report profiles
- Pre-Retrofit 8760 load shapes based on self-report data and the self-report adjustment factors

Development of 8760 Post-Retrofit Percent-On Load Shapes using Logger Data

The objective of this analysis was to develop 8760 hourly load shapes of the percentage of the hour that the lights are on (percent on) for the post-retrofit equipment. The goal is to develop load shapes for each site and each specific measure monitored at the activity area (or space type) level.

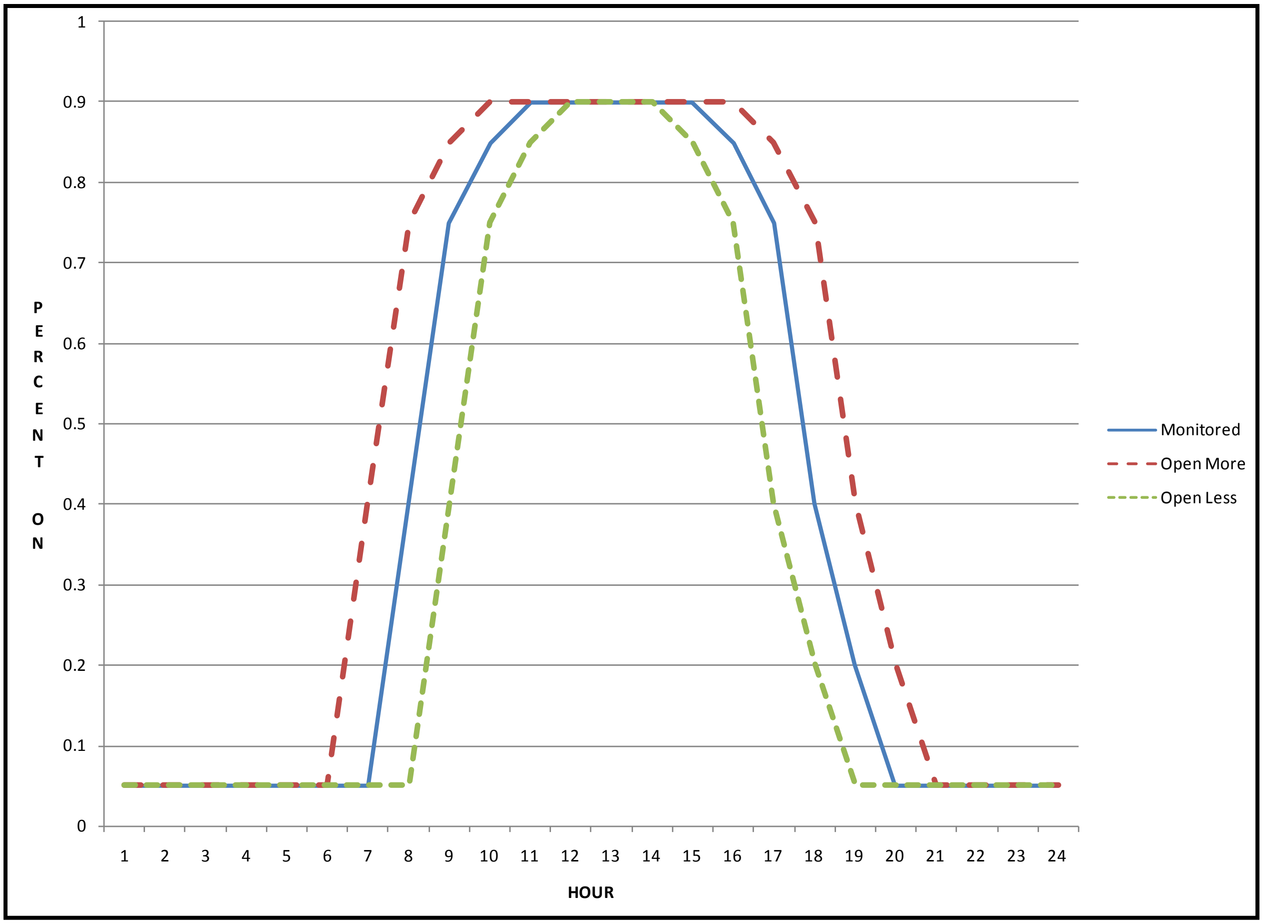
Because loggers were not installed for a full year (approximately 9 weeks on average), the logger data needed to be extrapolated out to a full year of 8760 hours. The 2006-08 Small Commercial lighting logger study investigated the effects of changes in daylighting over the course of the year, and normal changes in business hours that some businesses experience over the course of the year. The study indicated that there was no discernable difference in usage over time that would be related to the effects of changes in daylighting. Therefore, our 8760 extrapolation did not directly take into consideration the effects of changes in daylight levels over the year.

Customers did provide their current business hours, and reported if these hours changed over the course of the year. If a customer reported a change in business hours for a portion of the year, the 8760 profile was adjusted accordingly. Using the monitored data, eight average daily profiles were developed for each day of the week, and separately for holidays, for each logger. For each profile, the midpoint of the open period and the midpoint for the closed period were determined. If a business reported being open more hours during another unmonitored time during the year, the profiles were shifted by expanding the profile around the open midpoint, and collapsing the profile around the closed midpoint. The opposite was true if the business reported being closed more hours, so that the profiles were shifted by expanding the profile around the closed midpoint, and collapsing the profile around the open midpoint. The shifting around the midpoints was chosen for two reasons. First, the load shapes tend to be most consistent for the hours around these two points (generally the peak and the trough of the load shape). Second, if a customer reported a shift in the business hours (same number of open hours, but at a different time) this approach would have the effect of simply just shifting the entire profile. Less than 2% of customers reported having seasonal schedules. Only 3 sites had their 8760 profiles adjusted to account for seasonal business hour changes. [1]

Figure 4-1 provides an example of a business that was open from 9 a.m. to 5 p.m. during the monitored period, and how the load shape would change if the business hours changed from 10 a.m. to 4 p.m., or 8 a.m. to 6 p.m. Essentially the midpoint at 1 p.m. is being stretched out, or the hours around 1 p.m. are being collapsed; and the converse is true around the closed midpoint at 1 a.m.

[1] It is also important to note that this was the same methodology used for the 2006-08 Small Commercial Contract Group Direct Impact Evaluation

Figure 4-1: Example of Load Shape Shift due to Business Hour Changes



The final step after extrapolating each individual logger to an 8760 load profile, is to aggregate each logger up to a site-activity area level by measure. This aggregation only occurs when there is more than one logger at a site in a similar space type. To aggregate the loggers, a weight is associated with each logger that is equal to the number of fixtures/lamps to which the logger corresponds. The result is an 8760 post-retrofit percent-on load shapes, developed at the site, measure, activity area level.

<u>Development of 8760 Post-Retrofit Percent-On Load Shapes using Adjusted Self-Report Schedules</u>

As mentioned previously, lighting loggers were installed in the vast majority of, but not all of the sites. As part of the 2006-08 Small Commercial evaluation, a set of adjustment factors were developed that can be used to adjust self-reported usage schedules to more accurately reflect actual usage, and develop use shapes. The methodology for developing and applying these self-report adjustment factors is described in the IEPEC conference paper "Is the Customer Always Right? A Cost-Effective Method for Estimating Lighting Usage in Commercial Buildings", provided in Appendix I.

This evaluation utilized this same approach, but incorporated both the 2006-08 and any relevant 2010-12 logger collected for this study, to develop adjustment factors to apply to self-reported post-retrofit use shapes for sites that did not have loggers installed. For measures that we were unable to log or when logger data was compromised, we collected detailed self-report schedules that could be adjusted using the approach documented in Appendix I.

As mentioned, the adjustment factors utilized data collected for both this 2010-12 study as well as the 2006-08 Small Commercial study. This analysis included over 1,110 loggers monitoring CFL's in more than 450 facilities that represented building types used in this analysis. As part of the on-site survey for both studies, participants were asked to estimate their lighting usage by activity area within their building and to provide their business lighting hours. For those customers that were monitored, it was possible to compare the participants' actual lighting usage to both their self-reported lighting usage and their business operating hours. Comparisons were made at the HIM, building type and activity area level. Furthermore, rather than simply comparing annual operating hours, comparisons were made for four different use periods (relative to self-reported business hours): Opening Shoulder, Open, Closed Shoulder, or Closed. The Open period was defined as all hours of the day for which the business was open. The Opening and Closing shoulders were defined as the two hours before opening and after closing, respectively. The Closed period was defined as all hours for which the business was closed, and not in one of the two shoulder periods. For the open period, a ratio of actual logger to self-report usage could be estimated by HIM, building type, activity area, and usage period. Then these ratios, or adjustment factors, could then be applied to a self-report schedule by building type, activity area, for the open period. However, for the closed and shoulder periods, rather than develop and apply adjustment factors, average usages values were estimated from the logger sample and these usage values were used directly for those time periods. The reason why adjustment factors were not developed and applied to these periods is because the self-reported usage during these periods was often claimed to be zero. A zero value cannot be adjusted by a multiplicative factor, therefore a constant factor was used. Again, this constant factor was the actual average usage found in the logger sample for those time periods, and was applied by HIM, building type and activity area.

By applying the adjustment factors to the open time period, and the usage values to the closed and shoulder time periods, an 8,760 load shapes could be developed at the measure and activity area level.

To validate this process, we took the sample of 2010-12 and 2013 (Q1-Q2) LED lamp and reflector participants that were monitored in this study and created an adjusted self-report estimate of annual operating hours based on the 2006-08 and 2010-12 factors discussed above. For this sample of monitored participants, we then compared their actual logger results to their adjusted self-report results as well as their unadjusted self-reports. Table 4-3 presents a comparison of operating hours developed from the logger data and the adjusted/non-adjusted self-report method. The adjusted self-report operating hours compare very well to the actual monitored hours. These differences range from .12% to 4.3%. It is important to note that, unadjusted self-reports are all lower than both the monitored hours and adjusted hours. These differences range from 6% to 20% relative to the monitored sample. Overall, the differences between the adjusted self-report results and the monitored data are not statistically significant.

Table 4-3: Comparison of Logged Data, Adjusted/Unadjusted Self-Report Operating Hours by Program Period for LED Lamps and Reflectors

Program Period		Logged		Adjusted Self Report		Unadjusted Self Report	
HIM		HOU	SE	HOU	SE	HOU	SE
2010 – 2012	LED Lamp	3,956	298	3,960	233	3,259	211
	LED Reflector	3,212	273	3,331	178	2,571	177
2013 (Q1-Q2)	LED Lamp	3,843	286	3,779	199	3,595	241
	LED Reflector	3,601	114	3,760	60	3,391	87
2010 – 2013 (Q1-Q2)	LED Lamp	3,881	213	3,841	152	3,481	174
	LED Reflector	3,537	106	3,690	63	3,256	82

Final 8760 Post-Retrofit Percent-On Load Shapes

As mentioned, both the logger data and adjusted self-report schedules were capable of developing 8760 post-retrofit percent-on load shapes at the site, measure, activity area level. For the purpose of presenting results for this report, these site-measure-activity area level load shapes were aggregated to the building type level. To perform this aggregation, each site-space type profile is weighted to represent the number of lamps/fixtures being represented in the population. Table 4-4 and Table 4-5 provide the average annual operating hours (which combine the monitored measures where available and the adjusted self-reports otherwise) and coincident peak factors for the on-site sample by HIM, Program Period and Building Type.

Table 4-4: Post-Retrofit Annual Hours of Operation and Coincident Factors by Program Period and Building Type for LED Lamps

Program Period	Building Type	Sites	Operating Hours	Relative Precision	Coincidence Factor	Relative Precision
2010 – 2012	Office – Small	25	1,746	20%	33%	21%
	Restaurant – Fast Food	4	4,488	28%	85%	36%
	Restaurant – Sit Down	13	3,770	16%	69%	19%
	Retail - Large	1	4,767		99%	
	Retail – Small	19	2,144	39%	40%	28%
	All Building Types	**62**	**3,178**	**11%**	**62%**	**11%**
2013 (Q1-Q2)	Office – Small	11	1,593	30%	37%	34%
	Restaurant – Fast Food	15	5,102	14%	80%	14%
	Restaurant – Sit Down	15	3,248	23%	59%	17%
	Retail - Large	1	1,201		31%	
	Retail – Small	17	1,924	20%	53%	24%
	All Building Types	**59**	**2,964**	**13%**	**56%**	**11%**
2010 – 2013 (Q1-Q2)	Office – Small	36	1,707	16%	34%	17%
	Restaurant – Fast Food	19	5,018	12%	81%	12%
	Restaurant – Sit Down	28	3,404	14%	62%	12%
	Retail - Large	2	4,328	128%	91%	123%
	Retail – Small	36	2,026	21%	47%	18%
	All Building Types	**121**	**3,086**	**8%**	**58%**	**8%**

Table 4-5: Post-Retrofit Annual Hours of Operation and Coincident Factors by Program Period and Building Type for LED Reflectors

Program Period	Building Type	Sites	Operating Hours	Relative Precision	Coincidence Factor	Relative Precision
2010 – 2012	Office – Small	14	2,245	22%	51%	22%
	Restaurant – Fast Food	12	3,768	26%	72%	24%
	Restaurant – Sit Down	14	4,310	9%	83%	9%
	Retail - Large	2	4,212	116%	81%	79%
	Retail – Small	13	2,631	21%	69%	21%
	All Building Types	**55**	**3,356**	**9%**	**72%**	**8%**
2013 (Q1-Q2)	Office – Small	9	2,306	37%	45%	35%
	Restaurant – Fast Food	16	4,305	25%	61%	28%
	Restaurant – Sit Down	13	4,466	16%	76%	11%
	Retail - Large	3	3,683	13%	98%	10%
	Retail – Small	17	3,163	11%	86%	9%
	All Building Types	**58**	**3,395**	**9%**	**77%**	**7%**
2010 – 2013 (Q1-Q2)	Office – Small	23	2,269	19%	49%	18%
	Restaurant – Fast Food	28	4,189	18%	63%	19%
	Restaurant – Sit Down	27	4,394	9%	80%	7%
	Retail - Large	5	3,754	12%	95%	8%
	Retail – Small	30	3,025	9%	81%	8%
	All Building Types	**113**	**3,374**	**6%**	**79%**	**5%**

Operating hours and coincidence factors also vary among building types. Both restaurant types generally have longer operating hours than any other segment, for both LED lamps and reflectors. It is important to note that lower than expected operating hours for the 2013 Retail – Large LED lamp segment is the result of those measures being installed in three activity areas (restrooms, storage, other miscellaneous) within the large retail facility. Twenty of the twenty-seven rebated lamps were installed in storage areas that averaged 350 hours per year (the self-report was 530 hours).

Differences in operating hours across both program periods could be a function of the random nature of the sampling process as well as the activity areas where the LED technologies are being installed.

While relative precisions vary significantly across building types for each technology, they are all within the 90/20 range or better when combined across program periods (for sample sizes greater than 2).

4.4 Pre- and Post- Retrofit Wattages

Another key set of parameters are the pre and post wattages. Various approaches and data sources were utilized to develop these wattage values, which are discussed in this section. More specifically, this section will discuss the development of the following:

- Post-Retrofit Wattages – based on verified data on site
- Pre-Retrofit Wattages – based on self-report data and other information gathered on site

Post-Retrofit Wattages

Post-retrofit wattages were based on lamp information gathered by the on-site auditor. In limited cases (7% of measures) it was not possible to gather wattage information, because all the measures had been either removed or had failed prior to the on-site inspection. Likewise, for 4 measures, post-retrofit wattages were assigned based on the measure name.

Table 4-6 and Table 4-7 present the average post-retrofit wattages found for each LED measure by program period and building type. As mentioned above, in some cases (7% of measures) no LED equipment was found on site, so the post-retrofit wattage observations do not sum to the number of sites that were surveyed. For LED lamp measures, this resulted in 8 sites not providing post-wattage information. For LED reflectors, the number of wattage observations is greater than the number of sites because multiple reflector measures were installed at some sites.

Table 4-6: Post Wattage Estimates by Program Period and Building Type for LED Lamps

Program Period	Building Type	Post Retrofit Wattage	Wattage Observations	Relative Precision
2010 – 2012	Office – Small	9	25	10%
	Restaurant – Fast Food	11	4	16%
	Restaurant – Sit Down	8	14	3%
	Retail - Large	15	1	
	Retail – Small	8	19	2%
	All Building Types	**13**	**63**	**5%**
2013 (Q1-Q2)	Office – Small	8	11	2%
	Restaurant – Fast Food	8	15	7%
	Restaurant – Sit Down	8	15	3%
	Retail - Large	15	1	
	Retail – Small	8	17	5%
	All Building Types	**8**	**59**	**3%**
2010 – 2013 (Q1-Q2)	Office – Small	9	36	7%
	Restaurant – Fast Food	8	19	8%
	Restaurant – Sit Down	8	29	2%
	Retail - Large	15	2	0%
	Retail – Small	8	36	3%
	All Building Types	**9**	**122**	**4%**

Table 4-7: Post-Wattage Estimates by Program Period and Building Type for LED Reflectors

Program Period	Building Type	Post Retrofit Wattage	Wattage Observations	Relative Precision
2010 – 2012	Office – Small	14	14	13%
	Restaurant – Fast Food	11	13	19%
	Restaurant – Sit Down	9	21	18%
	Retail - Large	18	2	250%
	Retail – Small	10	17	17%
	All Building Types	**14**	**67**	**9%**
2013 (Q1-Q2)	Office – Small	16	12	10%
	Restaurant – Fast Food	14	24	13%
	Restaurant – Sit Down	16	15	15%
	Retail - Large	18	4	6%
	Retail – Small	12	28	9%
	All Building Types	**17**	**83**	**2%**
2010 – 2013 (Q1-Q2)	Office – Small	15	26	8%
	Restaurant – Fast Food	13	37	11%
	Restaurant – Sit Down	12	36	14%
	Retail - Large	18	6	15%
	Retail – Small	12	45	8%
	All Building Types	**14**	**150**	**4%**

Pre-Retrofit Wattages

Pre-retrofit wattages were developed using a variety of sources including participant application information, visual inspection on site and self-report information from the participant gathered on site.

In each case the surveyor tried to gather the same information as described above for the post-retrofit wattages. The first was to locate fixtures that were not retrofitted but in the same area or type of area and match the baseline fixture description. The second approach was to look for spare baseline lamps in storage and maintenance areas. The third was to review any documentation regarding the previously installed lamps and fixtures. The fourth approach was to gather the contacts' or maintenance staffs' best recollection of the baseline fixture-lamp information.

If pre-retrofit wattage information was not available, average wattage values were used. An average wattage value was used for 17% of LED measures. There are two ways in which unknown wattages were populated. In the first case, the configuration of the replaced equipment is known, but not the wattage. In this case, average wattages can be applied by the pre-configuration using the same approach as described above for post-retrofit wattages.

However, in other cases, the configuration of the replaced equipment is not known. In these instances, all that is known is the measure that was installed. For these cases, average pre-wattages were developed that corresponded to the installed measures, and these average pre-wattages could then be applied to a participant by their installed measure configuration.

Table 4-8 through Table 4-11 present the average pre-retrofit for each LED measure as well as a comparison of average pre and post wattages by program period and building type.

Table 4-8: Pre-Wattage Estimates by Program Period and Building Type for LED Lamps

Program Period	Building Type	Pre Retrofit Wattage	Wattage Observations	Relative Precision
2010 – 2012	Office – Small	53	25	9%
	Restaurant – Fast Food	95	5	18%
	Restaurant – Sit Down	52	15	13%
	Retail - Large	100	1	
	Retail – Small	63	19	5%
	All Building Types	**70**	**65**	**7%**
2013 (Q1-Q2)	Office – Small	47	12	10%
	Restaurant – Fast Food	61	16	7%
	Restaurant – Sit Down	53	15	10%
	Retail - Large	65	1	
	Retail – Small	50	17	10%
	All Building Types	**55**	**61**	**5%**
2010 – 2013 (Q1-Q2)	Office – Small	51	37	7%
	Restaurant – Fast Food	64	21	9%
	Restaurant – Sit Down	53	30	7%
	Retail - Large	98	2	52%
	Retail – Small	56	36	6%
	All Building Types	**61**	**126**	**5%**

Table 4-9: Pre-Wattage Estimates by Program Period and Building Type for LED Reflectors

Program Period	Building Type	Pre Retrofit Wattage	Wattage Observations	Relative Precision
2010 – 2012	Office – Small	65	15	9%
	Restaurant – Fast Food	57	13	14%
	Restaurant – Sit Down	53	22	10%
	Retail - Large	77	2	204%
	Retail – Small	56	17	10%
	All Building Types	**65**	**69**	**7%**
2013 (Q1-Q2)	Office – Small	81	13	13%
	Restaurant – Fast Food	81	24	12%
	Restaurant – Sit Down	82	15	12%
	Retail - Large	79	4	22%
	Retail – Small	65	28	9%
	All Building Types	**74**	**84**	**5%**
2010 – 2013 (Q1-Q2)	Office – Small	70	28	8%
	Restaurant – Fast Food	75	37	10%
	Restaurant – Sit Down	66	37	10%
	Retail - Large	79	6	17%
	Retail – Small	63	45	7%
	All Building Types	**71**	**153**	**4%**

Table 4-10: Combined Pre and Post Retrofit Wattage Estimates by Program Period and Building Type for LED Lamps

Program Period	Building Type	LED Lamp		
		Pre Retrofit Wattage	Post Retrofit Wattage	Wattage Ratio
2010 – 2012	Office – Small	53	9	6.0
	Restaurant – Fast Food	95	11	8.3
	Restaurant – Sit Down	52	8	6.9
	Retail - Large	100	15	6.7
	Retail – Small	63	8	7.8
	All Building Types	**70**	**13**	**5.5**
2013 (Q1-Q2)	Office – Small	47	8	5.9
	Restaurant – Fast Food	61	8	7.6
	Restaurant – Sit Down	53	8	6.8
	Retail - Large	65	15	4.3
	Retail – Small	50	8	6.0
	All Building Types	**55**	**8**	**6.8**
2010 – 2013 (Q1-Q2)	Office – Small	51	9	6.0
	Restaurant – Fast Food	64	8	7.7
	Restaurant – Sit Down	53	8	6.8
	Retail - Large	98	15	6.5
	Retail – Small	56	8	6.8
	All Building Types	**61**	**9**	**6.9**

Table 4-11: Combined Pre and Post Retrofit Wattage Estimates by Program Period and Building Type for LED Reflectors

Program Period	Building Type	LED Reflectors		
		Pre Retrofit Wattage	Post Retrofit Wattage	Wattage Ratio
2010 – 2012	Office – Small	65	14	4.5
	Restaurant – Fast Food	57	11	5.3
	Restaurant – Sit Down	53	9	5.9
	Retail - Large	77	18	4.4
	Retail – Small	56	10	5.4
	All Building Types	**65**	**14**	**4.7**
2013 (Q1-Q2)	Office – Small	81	16	5.0
	Restaurant – Fast Food	81	14	5.7
	Restaurant – Sit Down	82	16	5.2
	Retail - Large	79	18	4.5
	Retail – Small	65	12	5.5
	All Building Types	**74**	**17**	**4.3**
2010 – 2013 (Q1-Q2)	Office – Small	70	15	4.7
	Restaurant – Fast Food	75	13	5.6
	Restaurant – Sit Down	66	12	5.5
	Retail - Large	79	18	4.5
	Retail – Small	63	12	5.4
	All Building Types	**71**	**14**	**5.0**

Again, despite variations given differences in sample size, the post-retrofit LED wattages are fairly consistent among building types, but the baseline equipment being replaced has much more variability. The average post wattage for LED lamps is roughly 8W (excluded the retail – large segment) and 15W for the reflector segment. Generally speaking, LED reflectors are replacing higher wattage base equipment than LED lamps.

Overall, relative precisions are within the 90/10 range or better for LED lamps and within the 90/20 range or better for LED reflectors when combined across program periods (for sample sizes greater than 2).

4.5 Unit Energy Savings (UES) Values

As mentioned earlier, a secondary objective was to perform an ex-post analysis for 2010-2012 program participants in order to develop kW and kWh unit energy savings (UES) values, impact load shapes and net-to-gross ratios (NTGRs) for the LED lamp and reflector measures throughout that program period. Again, because this evaluation is prospective looking, in that the primary objective is to support future ex-ante estimates of savings, rather than evaluating ex post performance for a specific time period, the UES values have been developed for each program period as well across program periods.

The UES values are a function of the wattage difference between the pre-retrofit and post-retrofit equipment multiplied by the operating hours for kWh and the coincident peak factor for kW. Table 4-12 and Table 4-13 present those results at the program period and building type level for LED lamps and reflectors, respectively. Table 4-14 and Table 4-15 summarize both the average ex-ante UES values as well as the ex-post UES estimates. The interactive effects have been removed for both kW and kWh average ex-ante UES values.

In general, greater operating hours contribute to high UES values for several segments. This is certainly the case for the restaurant segments for both LED measures. Typically, LED measures were being installed in dining areas within these building types.

Since the delta wattages and operating hours, which consist of 249 individual site-measures, vary significantly from one HIM and building type to the next as well as (to a lesser extent) across program periods, the ex-post UES differs from the average ex-ante UES considerably. In general, ex-post UES values are less than ex-ante assumptions for LED lamps installed in Office – Small and Retail – Small. This is more than likely a condition of lower operating hours within these segments, relative to ex-ante assumptions. LED lamps in Restaurant – Sit Down compare very well, while Restaurant – Fast Food has much higher unit energy savings from the ex-post evaluation period relative to the ex-ante assumptions. Again, higher operating hours contribute significantly to differences between the ex-ante and ex-post values. LED reflectors installed in small offices and retail compare very well for the 2010-12 period, but deviate much more so in the 2013 (Q1-2) period. All other ex-post values are greater than average ex-ante assumptions.

Table 4-12: Unit Energy Savings (UES) values for LED Lamps by Program Period and Building Type

Program Period	Building Type	Sites	Operating Hours	Coincident Peak	Delta Wattage	Ex-Post UES kWh	Ex-Post UES kW
2010 – 2012	Office – Small	25	1,746	33%	44	76.84	0.01
	Restaurant – Fast Food	4	4,488	85%	84	373.73	0.07
	Restaurant – Sit Down	13	3,770	69%	44	168.30	0.03
	Retail - Large	1	4,767	99%	85	405.20	0.08
	Retail – Small	19	2,144	40%	55	118.50	0.02
	All Building Types	**62**	**3,178**	**62%**	**58**	**182.92**	**0.04**
2013 (Q1-Q2)	Office – Small	11	1,593	37%	39	62.61	0.01
	Restaurant – Fast Food	15	5,102	80%	53	271.41	0.04
	Restaurant – Sit Down	15	3,248	59%	45	146.56	0.03
	Retail - Large	1	1,201	31%	50	60.06	0.02
	Retail – Small	17	1,924	53%	42	80.39	0.02
	All Building Types	**59**	**2,964**	**56%**	**47**	**139.19**	**0.03**
2010 – 2013 (Q1-Q2)	Office – Small	36	1,707	34%	42	72.92	0.01
	Restaurant – Fast Food	19	5,018	81%	56	279.35	0.05
	Restaurant – Sit Down	28	3,404	62%	45	153.07	0.03
	Retail - Large	2	4,328	91%	83	359.25	0.08
	Retail – Small	36	2,026	47%	46	96.14	0.02
	All Building Types	**121**	**3,086**	**58%**	**52**	**159.93**	**0.03**

Table 4-13: Unit Energy Savings (UES) values for LED Reflectors by Program Period and Building Type

Program Period	Building Type	Sites	Operating Hours	Coincident Peak	Delta Wattage	Ex-Post UES kWh	Ex-Post UES kW
2010 – 2012	Office – Small	14	2,245	51%	51	112.71	0.03
	Restaurant – Fast Food	12	3,768	72%	46	175.69	0.03
	Restaurant – Sit Down	14	4,310	83%	44	188.53	0.04
	Retail - Large	2	4,212	81%	59	250.70	0.05
	Retail – Small	13	2,631	69%	46	119.36	0.03
	All Building Types	**55**	**3,356**	**72%**	**51**	**172.37**	**0.04**
2013 (Q1-Q2)	Office – Small	9	2,306	45%	65	149.54	0.03
	Restaurant – Fast Food	16	4,305	61%	67	287.51	0.04
	Restaurant – Sit Down	13	4,466	76%	66	295.63	0.05
	Retail - Large	3	3,683	98%	61	227.97	0.06
	Retail – Small	17	3,163	86%	53	168.60	0.05
	All Building Types	**58**	**3,395**	**77%**	**57**	**193.34**	**0.04**
2010 – 2013 (Q1-Q2)	Office – Small	23	2,269	49%	55	125.58	0.03
	Restaurant – Fast Food	28	4,189	63%	62	258.06	0.04
	Restaurant – Sit Down	27	4,394	80%	54	236.09	0.04
	Retail - Large	5	3,754	95%	61	230.99	0.06
	Retail – Small	30	3,025	81%	51	155.12	0.04
	All Building Types	**113**	**3,374**	**79%**	**57**	**190.90**	**0.04**

Table 4-14: Ex-Ante and Ex-Post UES Comparison for LED Lamps by Program Period and Building Type

Program Period	Building Type	kWh UES		kW UES	
		Ex-Ante	**Ex-Post**	**Ex-Ante**	**Ex-Post**
2010 – 2012	Office – Small	106.84	76.84	0.02	0.01
	Restaurant – Fast Food	224.41	373.73	0.04	0.07
	Restaurant – Sit Down	146.70	168.30	0.03	0.03
	Retail - Large	180.93	405.20	0.03	0.08
	Retail – Small	131.14	118.50	0.02	0.02
	All Building Types	**152.73**	**182.92**	**0.03**	**0.04**
2013 (Q1-Q2)	Office – Small	95.66	62.61	0.02	0.01
	Restaurant – Fast Food	111.33	271.41	0.02	0.04
	Restaurant – Sit Down	147.20	146.56	0.02	0.03
	Retail - Large	181.94	60.06	0.03	0.02
	Retail – Small	96.71	80.39	0.02	0.02
	All Building Types	**113.77**	**139.19**	**0.02**	**0.03**
2010 – 2013 (Q1-Q2)	Office – Small	104.08	72.92	0.02	0.01
	Restaurant – Fast Food	130.48	279.35	0.02	0.05
	Restaurant – Sit Down	147.03	153.07	0.02	0.03
	Retail - Large	181.12	359.25	0.03	0.08
	Retail – Small	110.63	96.14	0.02	0.02
	All Building Types	**126.15**	**159.93**	**0.02**	**0.03**

Table 4-15: Ex-Ante and Ex-Post UES Comparison for LED Reflectors by Program Period and Building Type

Program Period	Building Type	kWh UES		kW UES	
		Ex-Ante	Ex-Post	Ex-Ante	Ex-Post
2010 – 2012	Office – Small	123.51	112.71	0.03	0.03
	Restaurant – Fast Food	135.86	175.69	0.02	0.03
	Restaurant – Sit Down	125.95	188.53	0.02	0.04
	Retail - Large	196.39	250.70	0.03	0.05
	Retail – Small	127.37	119.36	0.02	0.03
	All Building Types	**166.33**	**172.37**	**0.03**	**0.04**
2013 (Q1-Q2)	Office – Small	95.51	149.54	0.02	0.03
	Restaurant – Fast Food	109.71	287.51	0.02	0.04
	Restaurant – Sit Down	132.31	295.63	0.02	0.05
	Retail - Large	221.73	227.97	0.04	0.06
	Retail – Small	77.84	168.60	0.01	0.05
	All Building Types	**114.25**	**193.34**	**0.02**	**0.04**
2010 – 2013 (Q1-Q2)	Office – Small	112.68	125.58	0.02	0.03
	Restaurant – Fast Food	116.95	258.06	0.02	0.04
	Restaurant – Sit Down	128.82	236.09	0.02	0.04
	Retail - Large	216.54	230.99	0.03	0.06
	Retail – Small	89.97	155.12	0.02	0.04
	All Building Types	**143.11**	**190.90**	**0.02**	**0.04**

4.6 Net-to-Gross Analysis

The approach for estimating net-to-gross ratios (NTGRs) was based on the large non-residential free ridership approach developed by the Net-to-Gross Ratio (NTGR) Working Group and documented in Appendix C, Methodological Framework for Using the Self-Report Approach to Estimating Net-to-Gross Ratios for Non-residential Customers. The NTGR is calculated as the average of three program attribution indices (PAI) known as PAI-1, PAI-2, and PAI-3. Each of these scores represents the highest response or the average of several responses given to one or more questions about the decision to install a program measure. The participant phone survey was the basis for the inputs to each score.

- **Program attribution index 1 (PAI–1)** is a score that reflects the influence of the most important of various program-related elements in the customer's decision to select a given program measure. The PAI-1 score is calculated as the highest program influence factor divided by the sum of the highest program influence factor and the highest non-program influence factor. Some example non-program factors are: previous experience with the measure, recommendation from an engineer, standard practice, corporate policy, compliance with rules or regulations, organizational maintenance or equipment replacement policies and "other – specify." Payback is treated as a program influence factor if the rebate/incentives played a major role in meeting payback criteria, but is treated as a non-program influence factor if it did not play a major role in meeting payback criteria.
- **Program attribution index 2 (PAI–2)** is a score that captures the perceived importance of program factors (including rebate/incentives, recommendation, and training) relative to non-program factors in the decision to implement the specific measure that was eventually adopted or installed. This score is determined by asking respondents to assign importance values to the program and most important non-program influences so that the two total 10. The program influence score is adjusted (i.e., divided by 2) if respondents had made the decision to install the measure before learning about the program. The final score is divided by 10 to be put into decimal form, thus making it consistent with PAI-1.
- **Program attribution index 3 (PAI–3)** is a score that captures the likelihood of various actions the customer might have taken at the given time and in the future if the program had not been available (the counterfactual). This score is calculated as 10 minus the likelihood that the respondent would have installed the same measure in the absence of the program. The final score is divided by 10 to put into decimal form, thus making it consistent with PAI-1 and PAI-2.

The NTGR is estimated as an average of these three scores. If one of the scores is not available (generally due to respondents giving a "don't know" or "refusal" response), then the NTGR is estimated as the average of the two available scores. If two or more scores were missing, results are discarded from the calculation.

Table 4-16 and Table 4-17 present NTGRs for each LED measure by Building Type and Program Period, and include the sample size and corresponding relative precision for results weighted by ex-post kWh and kW, respectively. LED lamps in Office – Small has the highest NTGR which goes from 73% in the 2010-12 period to 64% in 2013 (Q1-2). Sit-down restaurants in the 2013 (Q1-2) period also have a NTGR greater than 70% for both LED technologies. Despite the smaller sample sizes, Retail – Large facilities have the lowest NTGR.

Overall, there is not a tremendous amount of variation across building types and inconsistent variations across program periods for either measure. The achieved relative precision are all within the 90/5 level when examined across program cycles for both measures (with the exception of Retail – Large).

Table 4-18 and Table 4-19 present a comparison of the ex-ante and ex-post NTGRs. Overall, the ex-post results are much lower than ex-ante assumptions for all segments.

Table 4-16: LED Lamp NTGRs by Building Type and Program Period

Program Period	Building Type	n	NTGR kWh	Relative Precision	NTGR kW	Relative Precision
2010 – 2012	Office – Small	48	0.73	4%	0.74	4%
	Restaurant – Fast Food	12	0.61	18%	0.61	18%
	Restaurant – Sit Down	15	0.64	3%	0.64	3%
	Retail - Large	2	0.37	24%	0.37	23%
	Retail – Small	50	0.65	4%	0.65	5%
	All Building Types	**127**	**0.64**	**4%**	**0.63**	**4%**
2013 (Q1-Q2)	Office – Small	58	0.64	5%	0.64	4%
	Restaurant – Fast Food	26	0.64	5%	0.64	5%
	Restaurant – Sit Down	19	0.72	6%	0.72	6%
	Retail - Large	1	0.58		0.58	
	Retail – Small	46	0.65	5%	0.65	5%
	All Building Types	**150**	**0.66**	**2%**	**0.66**	**3%**
2010 – 2013 (Q1-Q2)	Office – Small	106	0.69	3%	0.69	3%
	Restaurant – Fast Food	38	0.66	4%	0.66	5%
	Restaurant – Sit Down	34	0.67	4%	0.67	4%
	Retail - Large	3	0.50	25%	0.51	24%
	Retail – Small	96	0.65	3%	0.65	3%
	All Building Types	**277**	**0.65**	**2%**	**0.65**	**2%**

Table 4-17: LED Reflector NTGRs by Building Type and Program Period

Program Period	Building Type	n	NTGR kWh	Relative Precision	NTGR kW	Relative Precision
2010 – 2012	Office – Small	45	0.65	5%	0.65	5%
	Restaurant – Fast Food	18	0.69	9%	0.69	9%
	Restaurant – Sit Down	17	0.64	9%	0.64	9%
	Retail - Large	6	0.49	28%	0.48	29%
	Retail – Small	61	0.66	4%	0.65	4%
	All Building Types	**147**	**0.56**	**4%**	**0.55**	**4%**
2013 (Q1-Q2)	Office – Small	48	0.63	7%	0.63	7%
	Restaurant – Fast Food	25	0.64	6%	0.64	6%
	Restaurant – Sit Down	17	0.72	5%	0.72	5%
	Retail - Large	7	0.59	3%	0.59	3%
	Retail – Small	41	0.64	5%	0.64	5%
	All Building Types	**138**	**0.64**	**3%**	**0.64**	**3%**
2010 – 2013 (Q1-Q2)	Office – Small	93	0.64	4%	0.64	4%
	Restaurant – Fast Food	43	0.65	5%	0.65	5%
	Restaurant – Sit Down	34	0.68	5%	0.68	5%
	Retail - Large	13	0.51	13%	0.52	13%
	Retail – Small	102	0.65	3%	0.65	3%
	All Building Types	**285**	**0.59**	**2%**	**0.59**	**2%**

Table 4-18: Comparison of Ex-Ante and Ex-Post NTGRs by Building Type and Program Period for LED Lamps

Program Period	Building Type	NTGR kWh		NTGR kW	
		Ex-Post	Ex-Ante	Ex-Post	Ex-Ante
2010 – 2012	Office – Small	0.73	0.85	0.74	0.85
	Restaurant – Fast Food	0.61	0.82	0.61	0.82
	Restaurant – Sit Down	0.64	0.85	0.64	0.85
	Retail - Large	0.37	0.79	0.37	0.79
	Retail – Small	0.65	0.85	0.65	0.85
	All Building Types	**0.64**	**0.85**	**0.63**	**0.85**
2013 (Q1-Q2)	Office – Small	0.64	0.85	0.64	0.85
	Restaurant – Fast Food	0.64	0.85	0.64	0.85
	Restaurant – Sit Down	0.72	0.85	0.72	0.85
	Retail - Large	0.58	0.77	0.58	0.77
	Retail – Small	0.65	0.85	0.65	0.85
	All Building Types	**0.66**	**0.85**	**0.66**	**0.85**
2010 – 2013 (Q1-Q2)	Office – Small	0.69	0.85	0.69	0.85
	Restaurant – Fast Food	0.66	0.84	0.66	0.84
	Restaurant – Sit Down	0.67	0.85	0.67	0.85
	Retail - Large	0.50	0.78	0.51	0.78
	Retail – Small	0.65	0.85	0.65	0.85
	All Building Types	**0.65**	**0.85**	**0.65**	**0.85**

Table 4-19: Comparison of Ex-Ante and Ex-Post NTGRs by Building Type and Program Period for LED Reflectors

Program Period	Building Type	NTGR kWh		NTGR kW	
		Ex-Post	Ex-Ante	Ex-Post	Ex-Ante
2010 – 2012	Office – Small	0.65	0.85	0.65	0.85
	Restaurant – Fast Food	0.69	0.84	0.69	0.84
	Restaurant – Sit Down	0.64	0.84	0.64	0.84
	Retail - Large	0.49	0.82	0.48	0.82
	Retail – Small	0.66	0.85	0.65	0.85
	All Building Types	**0.56**	**0.84**	**0.55**	**0.84**
2013 (Q1-Q2)	Office – Small	0.63	0.85	0.63	0.85
	Restaurant – Fast Food	0.64	0.85	0.64	0.85
	Restaurant – Sit Down	0.72	0.80	0.72	0.81
	Retail - Large	0.59	0.78	0.59	0.78
	Retail – Small	0.64	0.84	0.64	0.84
	All Building Types	**0.64**	**0.83**	**0.64**	**0.83**
2010 – 2013 (Q1-Q2)	Office – Small	0.64	0.85	0.64	0.85
	Restaurant – Fast Food	0.65	0.85	0.65	0.85
	Restaurant – Sit Down	0.68	0.82	0.68	0.82
	Retail - Large	0.51	0.79	0.52	0.79
	Retail – Small	0.65	0.85	0.65	0.85
	All Building Types	**0.59**	**0.82**	**0.59**	**0.83**

4.7 Non-Impact Analysis

The on-site survey process not only facilitated verification analyses and the development of impact parameter estimates for LED lamps and reflectors, it also served as a way of understanding why individuals were installing LED equipment in the first place. As part of the on-site survey process, the auditors asked the site contact to rate (on a scale of 1 – 10) the influence that certain factors had on their decision to retrofit their existing lighting with LED equipment. These results, which are presented in Table 4-20, provide additional qualitative information regarding LED lighting installations throughout 2010-12 and 2013 (Q1-2) program period.

Overall, burned out equipment was not a significant factor in the participants' decision to retrofit their existing lighting although, on average, fast food restaurants had a higher level of influence from this category. The presumed energy efficiency and longer lamp life of LED lighting as well as less maintenance and the influence of conservation were all very important decision making points for each of the building types within the on-site sample. Overall, the availability of an incentive was the most influential factor that went into a participant's decision to retrofit.

Table 4-20: Level of Influence for LED Retrofit by Building Type (Scale of 1 – 10)

Retrofit Due To:	Office – Small	Restaurant – Fast Food	Restaurant – Sit Down	Retail - Large	Retail - Small
Equipment Burned Out	0.8	3.1	1.5	0.0	1.6
Inadequate Light Levels	0.7	3.6	1.3	0.7	2.0
Remodel	0.7	3.1	1.0	0.0	1.2
Safety of Occupants	3.1	5.5	2.6	7.3	3.2
Productivity of Occupants	3.7	5.6	2.4	7.3	3.1
Lower Energy Consumption	9.5	10.0	8.3	10.0	9.1
Longer Lamp Life	9.5	9.2	8.3	10.0	8.8
Less Maintenance	9.6	9.2	8.4	10.0	8.7
Energy Conservation (going green)	9.2	8.9	8.1	10.0	8.1
Incentive	9.9	9.5	10.0	10.0	10.0

Alternatively, site contacts were asked to state what the single-most important factor was in determining whether or not to retrofit their existing equipment with LED lighting. The results, which are presented Table 4-21 and Table 4-22, provide a discrete understanding of the decision makers' rationale for retrofitting their existing equipment. For both LED technologies, across all building types, the availability of a utility rebate was the primary reason for lighting retrofit for the majority of participants. However, the input from a contractor played an important role in deciding whether or not to install LEDs, as well as the perceived efficiency and energy savings associated with the installation. Roughly a quarter of the Restaurant Fast Food LED Lamp sample self-reported that contractor influence played the most significant role in determining whether or not to install LEDs and, for LED reflectors (across all segments), contractor influence played an even more significant role. Self-reported energy efficiency and energy savings claims also had an influence for many of the segments as well.

It is important to note that the percentage of sites that self-reported that a utility rebate was the primary reason for the retrofit does not match the corresponding NTGR's for each of the segments. There are a number of reasons why that may be the case. For one, these estimates represent the on-site sample only whereas the NTG values include phone survey respondents. Similarly, the NTG ratio is a product of a number of attribution questions whereas the site contacts were asked to provide the single most important influence. Despite these differences, this analysis provides evidence that there are number of reasons why LED measures were being installed throughout 2010 to 2013 (Q1-2). This is especially true for restaurants and small retail establishments.

Table 4-21: Reasons for LED Lamp Retrofit by Building Type for On-Site Sample

Retrofit Due To	Office - Small	Restaurant - Fast Food	Restaurant - Sit Down	Retail - Large	Retail - Small
Appearance					
Contractor	5%	13%	24%		15%
Efficiency		4%	17%		
Energy Savings		4%	3%		
Rebate	95%	70%	55%	100%	74%
Unknown		9%			10%
n	**37**	**23**	**29**	**2**	**39**

Table 4-22: Reasons for LED Reflector Retrofit by Building Type for On-Site Sample

Retrofit Due To	Office - Small	Restaurant - Fast Food	Restaurant - Sit Down	Retail - Large	Retail - Small
Appearance		4%		20%	3%
Contractor	11%	29%	21%	20%	23%
Efficiency		7%	10%		
Energy Savings		7%	10%		
Rebate	78%	54%	52%	60%	70%
Unknown	11%		7%		3%
n	**27**	**28**	**29**	**5**	**30**

5

Conclusions and Recommendations

This section presents conclusions and recommendations from the LED lamp and reflector impact evaluation for the 2010 – 2013 Q2 program period. This section discusses, not only the parameters that were evaluated throughout the program periods, but the specific measures and market segments, where applicable.

5.1 Conclusions

Below, the resulting installation rates, operating hours, pre- and post-wattage values, unit energy savings values and net-to-gross ratios (NTGR) are compared across market segments for indoor LED lamp and reflector measures. The purpose of these comparisons is to help inform future ex-ante net and gross kW and kWh energy savings values and highlight market segments that are generating greater savings which can be targeted for future studies. Again, the market segments that were analyzed as part of this evaluation are:

- Office – Small
- Restaurant – Fast Food
- Restaurant – Sit Down
- Retail – Large
- Retail – Small

Installation Rates

As discussed in Section 4.2, installation rates were fairly similar between market segments when examined across program periods and were all within 10% of the statewide mean. For both LED lamps and reflectors, sit down restaurants had the lowest installation rates at 83% and 84%, respectively. This was mainly a function of high removal rates (8% and 12%) within this segment and 4% failure rate for LED lamps across the program periods. For all other segments, failure and removal rates were also the primary reasons that installation rates were less than 100% at the time of the on-site inspection. The main reasons for measures having been removed, which were garnered from the on-site contact, was that the light the LED equipment provided was too directional, too bright or not aesthetically pleasing. On average, equipment that had failed had done so within 6 to 8 months of installation.

Operating Hours

As discussed in Section 4.3, operating hours varied significantly between segments for each technology when examined across program periods. Small offices had the lowest operating hours for LED lamps and reflectors at 1,707 and 2,269 hours, respectively. This was followed by small retail establishments at 2,026 and 3,025 hours. These building types typically have shorter business hours, relative to the other segments, and, generally, the LED measures (especially lamps) were being installed in lower usage areas within these segments across program periods. Restaurants (both sit down and fast food) tended to have much higher operating hours for both technologies. This is generally the case given that restaurants are often open longer periods of time throughout the day and LED lighting was being installed in high energy usage activity areas like dining areas.

Pre and Post Wattages

As discussed in Section 4.4, both LED lamps and reflectors tended to be replacing similar equipment (either incandescent lighting or halogens). The average pre-wattage for LED lamps was 61W and 71W for reflector measures. The post-retrofit wattages for LED lamps and reflectors, however, were 9W and 14W, respectively. Wattage ratios for LED lamps ranged from 6.0 in small offices to 7.7 in fast food restaurants, while wattage ratios for LED reflectors ranged from 4.7 in small offices to 5.6 in fast food restaurants.

Unit Energy Savings Values

As discussed in Section 4.5, UES values are highly correlated to operating hours. For LED lamps, both restaurant types exhibit the higher per unit energy savings, whereas small offices provide the lowest per unit savings (Note that large retail is not discussed given the small sample size). For LED reflectors, restaurants, again, exhibit the highest per unit energy savings. While the sample size was small, large retail also have the opportunity to realize significant per unit savings, given their higher operating hours and wattage ratios. Overall, when compared to the average ex-ante UES estimates for LED lamps, ex-post UES are generally lower for small offices and retail, very similar for sit down restaurants and over 100% greater in fast food restaurants. For LED reflectors, ex-post UES values are greater than average ex-ante values for all segments. Again, this is a function of generally higher operating hours, which are highly correlated to where, with businesses, these measures are being installed.

Net-to-Gross Ratios

As discussed in Section 4.6, Net-to-Gross ratios don't vary significantly between segments for either LED measure. They range from .65 to .69 for LED lamps and .64 to .68 for LED reflectors (Again, these ranges don't include large retail although the NTG for each measure in this segment is roughly .50). These ex-post estimates are all well below ex-ante assumptions for all segments and measures. While the ex-post NTG for LED lamps in small offices for 2010-12 is greater than that of the 2013(Q1-2) period (.73 relative to .64), that pattern is not generally consistent within other segments.

5.2 Recommendations for Future Evaluation Efforts

The following recommendations are provided to guide future evaluation efforts and market studies for LED measures.

Verification Analysis

Utilize on-sites. Given the varying levels of installation rates, on-site verification is an important method by which LED measure installation can be confirmed. In all cases, installation rates were less than 100% for all segments and measures. Likewise, on-sites provide more information beyond just installation rates. Specifically, they provide information on where the measures are being installed, if they are being put in storage and if they are failing or being removed. Given the increasing contribution of LED measures to claimed ex-ante kWh portfolio savings, these data are critical for future evaluation efforts.

Wattage Analysis

Collect make and model information on the retrofit equipment. One component of the on-site survey effort was to collect make and model information on the LED equipment. These data, when looked up using manufacturer cut sheets, provide more accurate post-retrofit wattage information than any other methodology. Future evaluations should gather this information in conjunction with the on-site survey in order to create a robust catalog of LED technologies being installed. This information also provides evidence regarding what specific technologies are failing and performing well in the market. Given the high failure and removal rates for some segments in this evaluation, this information is critical for future program planning.

Collect baseline wattage information. This evaluation found that the average baseline to retrofit wattage for LED lamps and reflectors was roughly 7 to 1 and 5 to 1, respectively. Given the significant potential energy savings associated with low wattage LED measures replacing higher wattage baseline equipment, it is important to collect as much information on what equipment was being replaced and the associated wattages. Likewise, the building type and space type associated with those wattages can vary significantly. Those data can have a significant effect on the per unit energy savings.

Lighting Logger Analysis

Continue to use lighting logger data collection to accurately estimate load shape profiles. While this analysis found a strong correlation between adjusted self-report operating schedules (using data based on logged CFL) and actual LED logger data, a more robust analysis of LED operating hours in future evaluation efforts is critical, given the fact that operating hours contribute significantly to unit energy savings (UES) values. These data will also help to inform estimates of operating hours by activity area. As discussed in Section 3.2.8, this evaluation found that restrooms represented the greatest distribution of LED lamp installations across program periods at 36%. Likewise, the share of dining area installations increased from a share of 7% in 2010-12 to 21% in 2013 (Q1-2). LED reflectors were generally being installed in dining areas (23% share) and retail sales areas (17% share). These activity areas often have very different operating schedules not only across activity areas, but within specific building types as well. Given the significant differences in operating schedules for these activity areas and building types, additional logger data can only provide more value added to future program planning and unit energy savings calculations.

Net-to-Gross Analysis

Continue to update NTGR estimates to reflect changes in the market condtions. Program influence continues to play the most critical role, but as discussed in Section 4.7, there are many other reasons why individuals are replacing existing equipment before the end of its useful life. Perceived energy savings benefits, for economic and conservation reasons, play an important role in decisions to retrofit existing equipment with LED technologies. Contractor influence had a significant effect on some individuals as well. A more thorough understanding of how this contractor influence is applied can be uniquely beneficial in developing future LED program design. Likewise, NTGRs may change over time given potential changes in market structure and early adoption. Moving forward, it will be important to capture such changes when examining free-ridership.