The Keystone of Energy Efficiency: New Approaches to Data Analysis Methods in a Mid-Atlantic State

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ABSTRACT

The National Renewable Energy Laboratory asserts that "assumptions about baseline conditions form the basis for calculation of savings and should be defined for technology-based, energy efficiency programs" (Jayaweera & Haeri 2013). Many Energy Efficiency and Conservation programs use a Technical Reference Manual (TRM) to specify baseline assumptions, guiding the calculation and reporting of energy and demand savings. Since the inception of Pennsylvania's Act 129 statewide Energy Efficiency and Conservation programs in 2009 the savings assumptions for commercial lighting measures, such as hours of use (HOU) and coincidence factors (CF), have largely relied on secondary research based on studies conducted in neighboring jurisdictions. In September 2013, the Pennsylvania Statewide Evaluation Team embarked on one of North America's largest Commercial Light Metering studies in order to update measure assumptions used in the calculation of savings. Using primary data collection and proprietary data-collection software, coupled with detailed load shape analyses, Nexant developed Pennsylvania-specific load shapes, operating hours, coincidence factors, and HVAC interactive factors for the 10 most prevalent building types. This use of primary research provides a substantial improvement over the previous use of values adopted from secondary research by taking into account relevant considerations such as building stock and geographic location. This paper discusses the intricacies of the study that were designed to reduce several biases that have plagued previous studies of a similar nature.

Introduction

In many Energy Efficiency and Conservation programs, a Technical Reference Manual (TRM) is used to guide the calculation and reporting of energy and demand savings. Since the inception of these programs, a relatively small number of active programs have been able to conduct baseline studies for their customers. It has become typical for TRMs to borrow and reference one another with little regard for age of data or regional considerations. Table 1 shows how TRMs in the northeast have relied on one another throughout the years. Notice that some TRMs cite information up to six years old, and others use data observed 3,000 miles away in a dissimilar service territory.

Table 1. TRM Sources for HOU and CF Assumptions

TRM	Sources
Delaware, 2012	EmPOWER Maryland Commercial Lighting Program Evaluations (2010)
Efficiency Maine, 2014	NEEP C&I Lighting Load Shape Project FINAL Report (2011)
Efficiency Vermont, 2011	NEEP C&I Lighting Load Shape Project FINAL Report (2011)
Efficiency Vermont, 2013	NEEP C&I Lighting Load Shape Project FINAL Report (2011)

TRM	Sources
Mass Save, 2012	NEEP C&I Lighting Load Shape Project FINAL Report (2011)
Mid-Atlantic, 2011	EmPOWER Maryland Commercial Lighting Program Evaluations (2010)
Mid-Atlantic, 2013	NEEP C&I Lighting Load Shape Project FINAL Report (2011) EmPOWER Maryland Commercial Lighting Program Evaluations (2010)
National Grid (MA), 2011	NEEP C&I Lighting Load Shape Project FINAL Report (2011) National Grid's 2007 Design 2000plus Lighting Subprogram (2009)
National Grid (RI), 2013	NEEP C&I Lighting Load Shape Project FINAL Report (2011) National Grid's 2007 Design 2000plus Lighting Subprogram (2009)
National Grid (RI), 2014	NEEP C&I Lighting Load Shape Project FINAL Report (2011)
New York, 2010	Uses flat CF value of 1 for interior lighting applications HOU from 2008 California DEER Update Study
New York, 2014	Uses flat CF value of 1 for interior lighting applications HOU from 2008 California DEER Update Study
Pennsylvania, 2013	Mid-Atlantic TRM (2011)
Pennsylvania, 2015	Mid-Atlantic TRM (2011)

As is evident from the table, the Statewide Evaluator[1] for Pennsylvania's Act 129 statewide Energy Efficiency and Conservation programs has been no exception. Since the introduction of the Act in 2009 the savings assumptions for Pennsylvania's commercial lighting measures, such as HOU values and coincidence with the system peak have been taken from secondary research based on studies in other jurisdictions with several daisy-chained (and sometimes circular) references. To rectify this, in September 2013, Nexant embarked on one of North America's largest Commercial Light Metering studies on behalf of the Pennsylvania Public Utilities Commission in order to update measure assumptions used in the calculation of savings. Using proprietary data-collection software coupled with extensive load shape analyses, the Statewide Evaluation Team developed Pennsylvania-specific load shapes, operating hours, coincidence factors, and HVAC interactive factors for the 10 most prevalent building types in the state. The study provides a substantial improvement over the previous use of values adopted from secondary research by taking into account relevant considerations such as building stock and geographic location.

In recent history, two similar studies have been conducted: New England State Program Working Group's 2007 Coincidence Factor Study and NEEP's 2011 C&I Lighting Load Shape Project. Both studies reported four main sources of bias:

- The accuracy and calibration of tools,
- Measurement error,
- Sensor placement bias, and
- Sample selection bias (largely irrelevant in commercial sectors)

[1] The Statewide Evaluation Team is comprised of Nexant Inc. and GDS Associates, who provide audit activities for programs offered by Duquesne Light Company, Metropolitan Edison Company, Pennsylvania Electric Company, Pennsylvania Power Company, West Pennsylvania Power Company, PPL Electric Utilities Corporation, and PECO Energy Company.

Nexant's carefully planned study design incorporated unique solutions to mitigate these sources of bias while providing the most in-depth and specific study performed in recent history.

Study Methodology

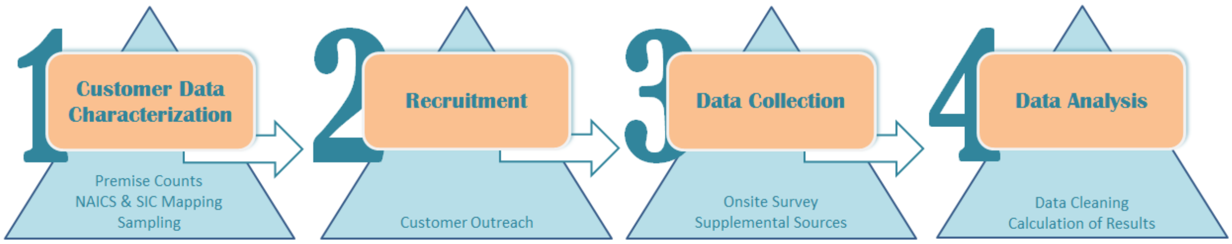

Figure 1. Overview of tasks involved in the Commercial Light Metering Study

The study was completed in four steps (as pictured in Figure 1), the unique treatment of the final two being the focus of this paper.

In the absence of large-scale light metering studies, many Energy Efficiency programs use evaluation, measurement, and verification results from previous participants to define at key assumptions. The National Renewable Energy Laboratory comments that "while 'as found' (existing) conditions usually represent an appropriate basis for establishing baselines for early replacement actions, either common practice or the requirements of applicable efficiency codes and standards are usually appropriate for the other categories of efficiency actions" (Jayaweera & Haeri 2013). The purpose of Nexant's study was to create baseline assumptions that represent common practice of all customers that may participate in future programs. As such, it was Nexant's belief that using data from only those who had participated in the past allows for bias in baseline assumptions as those participating in programs are more likely to be energy conscious customers with more advanced baselines than what is considered common practice for the region. Nexant's Commercial Light Metering Study allowed participation from any electric customer of the seven participating electric distribution companies with a non-residential account.

Data Collection

Primary data were collected for this study from August-2013 through September-2014. Data accrual was completed in three steps: record customer interview and lighting equipment inventory, install light loggers, and after a minimum of 45 days, remove light loggers. Data collection was completed electronically by trained engineers using iPads equipped with Nexant's iEnergy® Onsite[2] application. Each participating site received an initial site visit in which the engineer conducted a brief survey with the customer gathering basic site details such as hours of operation, holidays observed, and heating and cooling details. The engineer then surveyed the premises recording a detailed lighting and controls inventory into the Onsite application. The application allowed for the input of multiple space types; fixtures were then delineated into the corresponding space types to create unique line items for each space type and fixture combination.

Nexant's iEnergy® Onsite application included a random fixture selection algorithm which, once activated by the engineer, selected fixtures for logging based on each unique line item's percentage of contributed load to that of the entire facility. This tool was added to reduce sensor placement bias, which occurs when the fixtures selected for logging do not accurately represent the operating schedule for the overall lighting system. The random equipment selection algorithm is explored in further detail in the flowchart in Figure 2.

[2] More details on Nexant's iEnergy® Onsite can be found at http://www.nexant.com/products/nexant-ienergy/ienergy-onsite

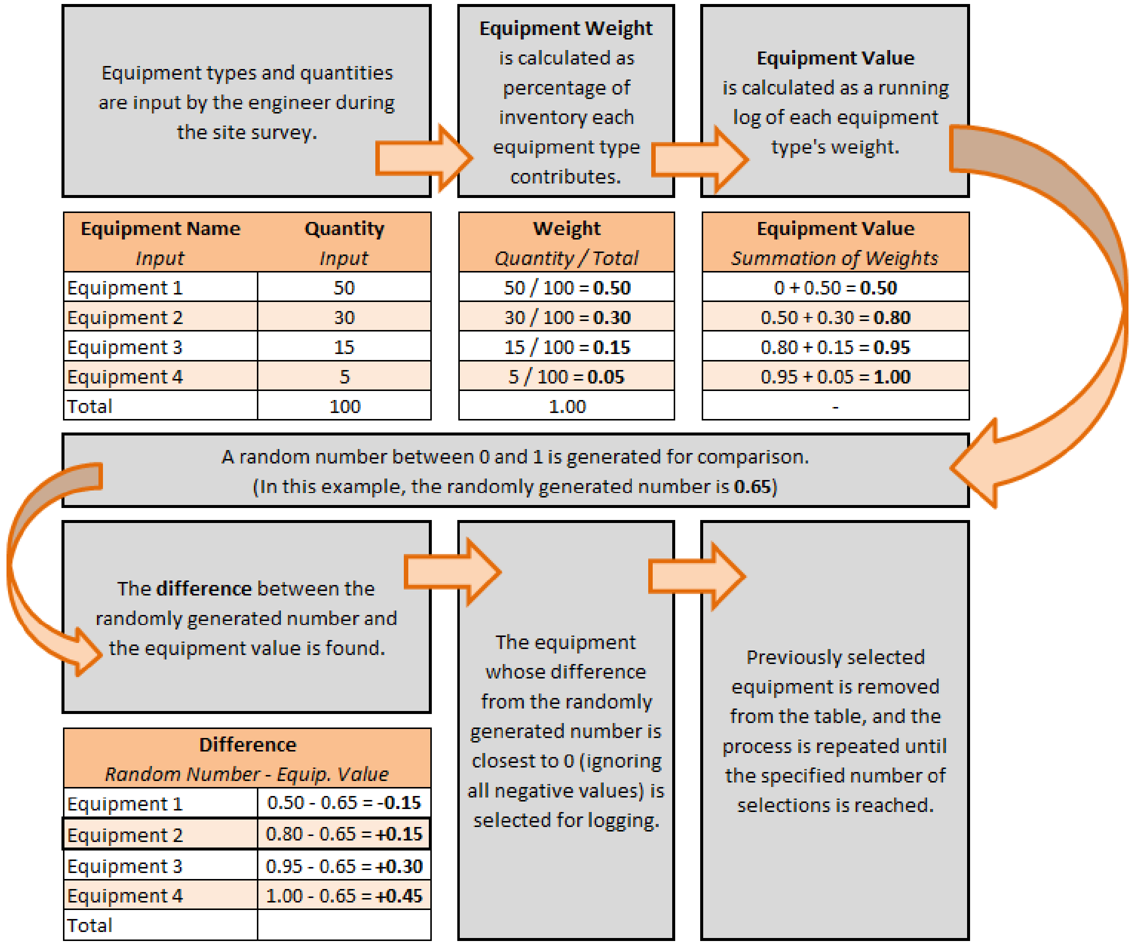

Figure 2. Random equipment selection process

Once fixtures for logging had been identified, the engineer installed one of three logger types depending of the unique characteristics of the space and fixture:

- HOBO® U9-002 light on/off
- HOBO® U12-012 light intensity logger
- HOBO® U9-006 occupancy meter/light logger

Having a choice of three different logger types in the field helped to reduce the biases associated with the accuracy and calibration of tools. The HOBO® U12-012 is designed to take lumens/ft^2 readings at a predetermined interval, five minutes in the case of the Nexant study. Collection of data in this manner required an engineer to visually inspect each logger file in order to determine a lighting power density threshold above which the light would be considered to be "on". These light intensity loggers proved useful in situations where ambient lighting was unavoidable, such as in high-bay applications or linear fluorescent fixtures that were not fully enclosed.

The vast majority of the equipment logged was logged using the HOBO® U9-002 light on/off logger, which records a fixture's on/off status as dictated by calibration performed by the engineer at the time of installation. The calibration is adjustable from 10 to 100 lumens/m^2 and is most suitable for installation inside linear fluorescent fixtures, which made up the bulk of the logged fixtures. In the event that only on/off loggers were available in situations where ambient lighting was unavoidable, fiber optic light-pipes were used to focus the logger's sensor directly at the light source.

The HOBO® U9-006 loggers operate in the same manner as the U9-002, but provide additional detail on movement of objects within the space. A small amount of these loggers were installed on fixtures without occupancy sensors to gain insight into how much savings potential exists in these situations. The logger types selected as well as the logger's serial number were also input into the Onsite application for future indexing of logger information.

All data collected though the iEnergy® Onsite application was transmitted to Nexant's cloud-based DSM Central system for real time access and processing. This synchronization enabled the delivery of instant results in the form of a comprehensive Microsoft Excel database. Once completed, the database provided a full report of the following for each site within the study:

- Customer name,
- Electric utility,
- Site address,
- Date and time of site visit,
- Building type and age,
- General HVAC information,
- Detailed operating schedule,
- Willingness to pay details,
- Space type of fixture,
- Space type square footage,
- Space type estimated hours of use,
- Space type air conditioning,
- Quantity of fixtures per space type,
- Fixture type and corresponding details*,
- Logger type installed, and
- Logger serial number.

Corresponding fixture details were a function of the fixture type selected. Linear fluorescent fixtures required inputs for lamp type (i.e. T5, T8, or T12), length, lamp quantity, ballast type, and application (high- or low-bay); while all other lamps required inputs for bulb wattage, application (high bay or low bay), and base-type. As linear fluorescent fixtures did not have an input for fixture wattage, fixture wattages were assigned to each linear fluorescent fixture in the database using Appendix C of the 2014 PA TRM, which contains a table specifying standard wattages for over 900 common fixture types. Fixture wattages were needed for each line item in the database in order to calculate load contribution and create load shapes for each site within the study.

Data Analysis

Following the collection of primary data, Nexant calculated HOU, peak CFs, and HVAC interactive effects using SAS software in conjunction with Microsoft Excel. Data were evaluated within a statewide context, as well as the context of each building type.

Data Cleaning

Each of the three logger types installed records and presents the data collected differently. For the purposes of this study, all of the data obtained were converted into one common format specifying hourly intervals and the associated percentage of time the logged light was on within each hour.

As the installation and removal of light meters spanned several months, loggers were sometimes launched, or activated, in Daylight Savings Time (EDT), but read out in Eastern Standard Time (EST). The loggers are programmed to record data in GMT -5, and are not equipped to change the timestamp mid-logging in the event that the time switches from EDT to EST or vice versa. Once all data was compiled, all loggers were adjusted to Eastern Prevailing Time using SAS, meaning that the timestamp was adjusted for all entries occurring after the switch.

The next step was to remove spurious observations that may have been recorded during installation and removal of the logger. Depending on when the engineer activated the logger and how long the installation took, it was not uncommon for the logger to record information during transport and installation that was not representative of the actual site operation. All data recorded during the entire day of installation and removal as recorded in the scheduling database were discarded.

The collected logger data was compared to the customer supplied "estimated hours of use" field noted in the iEnergy Onsite® database for the space that was logged. Special consideration was given to logger data showing more than a 25% difference from the customer reported hours of use. Similarly, logger data files showing either 0% or 100% operation throughout the entire logging period were analyzed on a case by case basis to determine whether or not they should be discarded.

In previous coincidence factor studies, it was noted that seasonality was not taken into consideration. While this does not present a problem in most commercial facilities, it most certainly is cause for concern in the education sector. To accommodate this in the Nexant study, for all cases where a customer reported their facility operated seasonally, the engineer requested detailed operation schedules from the customer including dates of seasonality, and operating hours associated with each date range. Logger data from sites marked in the database as having seasonal operation were then individually analyzed to make sure the annualization of the logger data appropriately reflected the site's operation. This was done by applying ratios to seasonal date ranges based on the percentage of operation during the date range in question with respect to the logged date range. Table 2 provides an example of an education facility that was logged from November 13, 2013, through March 12, 2014, with noted decreased hours during the period of June 6, 2015, through August 20, 2015. The adjustment factor is based on the hours of operation the customer provided for the seasonal time frame as compared to the logged data. In the example shown, the customer noted that the facility operates 7:00 a.m. to 6:00 p.m. on weekdays and 8:00 a.m. to 12:30 p.m. on Saturdays in the summer, which was found to be 24% less and 5% more than the logger data, respectively.

Table 2. Sample seasonality adjustment table

Project ID	PECO_xxxx
Install Date	**11/13/2013**
Removal Date	**3/12/2014**
Season 1 Start Date	1/1/2015
Season 1 End Date	6/5/2015
Season 1 Weekday Action	Logger
Season 1 Saturday Action	Logger
Season 1 Sunday Action	Logger
Season 2 Start Date	**6/6/2015**
Season 2 End Date	**8/20/2015**
Season 2 Weekday Action	**-24%**
Season 2 Saturday Action	**+5%**
Season 2 Sunday Action	**=**
Season 3 Start Date	8/21/2015
Season 3 End Date	12/31/2015
Season 3 Weekday Action	Logger
Season 3 Saturday Action	Logger
Season 3 Sunday Action	Logger

A small portion of the fixtures logged were found to have lighting controls installed. Previous studies acknowledged this by creating two separate load shapes: one for lighting where controls were present, and one for lighting utilizing manual controls. Pennsylvania's 2014 TRM presents HOU and CF values under the assumption that the lights in question are not utilizing any lighting control strategies. The TRM then assigns a standard savings factor of 24% to any fixture attached to an occupancy sensor. As the results of this study would serve as the new HOU and CF values for the 2016 TRM, it was important that the new values were consistent with lighting controlled manually; otherwise, a savings factor applied to HOU and CF values including the effects of lighting controls would ultimately overstate the savings achieved. In order to avoid this, if a logger, for example, recorded the operating hours of a lighting fixture attached to an occupancy sensor to be 3,000 hours, our analysis used an input of 3,947 hours according to Equation 1 below.

Equation 1. Sample adjustment for lighting controls

$$Adjusted\ HOU = \frac{Logged\ HOU}{1 - SVG} = \frac{3{,}000}{1 - 24\%} = \mathbf{3{,}947\ Hours}$$

Hours of Use (HOU) Calculations

Lighting equipment installed was broken down into two types: screw-based CFLs and LEDs, and other general service lighting. The HOU and CF findings were analyzed discretely for these two equipment types as large discrepancies were found in the operation of the two. This is a new method that has not previously been explored, and is substantiated by large differences in key variables between the two types of up to 62% in the case of HOU values and 85% in the case of CF values.

The data collected over the logging duration were tabulated per hour per week to create an average 192-hour operation schedule reference table (as pictured below in Table 3) for each logger retrieved. The 192 hours correspond to 24 hours of each of eight distinct day types (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and holiday). Annual hourly load shapes were created for each logger by mapping each hour of each day in the 2015 calendar to the 192-hour reference table. This method of analysis assumed that the average Monday throughout the logged period is representative of all Mondays throughout the year (and likewise for each Tuesday, Wednesday, etc.) unless seasonal operation was otherwise noted in the iEnergy® Onsite database.

Table 3. Sample 192-hour reference table

	Hour Ending Value										
Day Type:	...	10	11	12	13	14	15	16	17	18	19	...
(1) Sunday	...	76%	86%	86%	86%	86%	86%	85%	40%	4%	< 1%	...
(2) Monday	...	55%	72%	85%	100%	100%	100%	94%	56%	9%	< 1%	...
(3) Tuesday	...	83%	92%	100%	100%	100%	100%	90%	78%	30%	14%	...
(4) Wednesday	...	84%	84%	99%	100%	100%	100%	100%	73%	9%	< 1%	...
(5) Thursday	...	94%	100%	100%	100%	100%	100%	91%	64%	21%	14%	...
(6) Friday	...	100%	100%	100%	100%	96%	82%	76%	58%	4%	< 1%	...
(7) Saturday	...	77%	86%	86%	86%	86%	86%	86%	76%	6%	< 1%	...
(8) Holiday	...	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	...

1. Table abridged due to size.

2. Percentages shown represent the percentage of each hour lights were found on.

Operating characteristics from logged holiday data were applied only to any day noted as an observed holiday in each site's assessment. This is unique to the Nexant study as previous studies typically used the standard PJM holiday list as opposed to readily available site-specific information. In the assessment, the engineer was able to specify if the site was closed or if it observed only reduced operation for each specific holiday. For sites metered during a holiday, the collected data were applied to any day marked as a holiday. For facilities that were not metered during a holiday, holiday hours were taken from the assessment information provided by the customer to the engineer onsite and recorded in the tablet.

The annualized HOU obtained by mapping the 192-hour reference table to the 2015 calendar from various spaces within a facility were weighted by the relative contribution to the lighting load of the facility. As discussed previously, each fixture type recorded in the lighting inventory was either assigned a wattage in the data collection tool by the engineer, or was linked to the Wattage Table in Pennsylvania's 2014 TRM in the case of linear fluorescents. The lamp types and fixture counts collected during the site visit in conjunction with their assigned wattages were used to determine the total lighting load as well as the connected load per specific space type for each assessment submitted. The percentage of connected load each space type contributed to the total connected load was calculated per site and averaged to create space type weighting factors to be applied to all loggers collected from a building of the matching building type. Table 4 below shows the weighting factor results of a sample 20 restaurant sites evaluated.

Table 4. Calculation of restaurant space type weighting

Assessment ID:	100048	100130	...	100144	100145	100343	100371	Avg.
Total Connected Load (W):	**2,175**	**9,044**	...	**18,540**	**3,682**	**3,600**	**1,211**	-
Dining Area	47%	88%	...	49%	42%	62%	21%	47%
Kitchen/Food Preparation	0%	6%	...	20%	33%	6%	32%	24%
Restrooms	6%	6%	...	13%	3%	2%	48%	9%
Storage	5%	0%	...	2%	17%	29%	0%	7%
Other	36%	0%	...	0%	0%	0%	0%	4%
Sales Floor	0%	0%	...	0%	0%	0%	0%	4%
Interior Office	6%	0%	...	2%	0%	0%	0%	3%
Hallways	0%	0%	...	10%	3%	0%	0%	1%
Exterior Office	0%	0%	...	0%	0%	0%	0%	< 1%
Lounge/Break Room	0%	0%	...	0%	0%	0%	0%	< 1%
Lobby/Reception	0%	0%	...	2%	0%	0%	0%	< 1%
Mechanical Room	0%	0%	...	0%	2%	0%	0%	< 1%
Meeting/Conference Area	0%	0%	...	2%	0%	0%	0%	< 1%
Shipping and Receiving	0%	0%	...	0%	0%	0%	0%	< 1%

1. Table abridged due to size.
2. The "Avg." column represents the straight average across each row and is not weighted by size of the facility.
3. Shaded rows represent space types which were not logged.

Because the study design called for five loggers per site, most assessments contained more space types than were logged. The random selection algorithm in the iEnergy® Onsite application was configured to favor spaces with higher contributions to connected load. For example, Assessment 100144 in Table 4 included lighting equipment from 8 space types, but only 5 were logged.

Of the 20 sites included in the example above, no loggers were installed in the space types shaded in blue which are labeled as sales floor, interior office, exterior office, lounge/break room, lobby/reception, mechanical room, meeting/conference area, or shipping and receiving. In aggregate these 8 space types accounted for only 7% of the load observed across all 20 sites. The weighting of the logged spaces was then redistributed across only those space types with accompanying logger data. Table 5 below shows how the final HOU were calculated from the logger data collected and the redistributed weighted space types.

Table 5. Calculation of restaurant HOU

Space Type	Weight		Annualized HOU		Weight*HOU
Dining Area	0.49	x	2,304	=	1,129
Kitchen/Food Preparation	0.25	x	3,058	=	765
Restrooms	0.09	x	4,353	=	392
Storage	0.10	x	713	=	71
Other	0.05	x	6,596	=	330
Hallways	0.01	x	2,452	=	25
Total	**1.00**				**2,711**

Note that each sampled site within a given building type was weighted equally. Data collected from a logger installed in the hallways of a 500,000 square foot hospital was given equal weight as data from a 5,000 square foot dentist's office.

Coincidence Factor (CF) Calculations

The Pennsylvania 2014 TRM defines the peak CF as the fraction of the connected load that occurs during the peak demand window (from 2 p.m. to 6 p.m. for all non-holiday weekdays in the months of June through August). From the 192-hour reference table created for each logger, the average percentage displayed on non-holiday weekdays from hours ending 15 to 18 in June, July, and August was calculated as the CF for that logger. Table 6 illustrates the CF calculation for a logger installed in an interior office within a miscellaneous building.

Table 6. Calculation of coincidence factor

	Hour Ending Value											
Day Type:	...	10	11	12	13	14	15	16	17	18	19	...
(1) Sunday	...	76%	86%	86%	86%	86%	86%	85%	40%	4%	< 1%	...
(2) Monday	...	55%	72%	85%	100%	100%	100%	94%	56%	9%	< 1%	...
(3) Tuesday	...	83%	92%	100%	100%	100%	100%	90%	78%	30%	14%	...
(4) Wednesday	...	84%	84%	99%	100%	100%	100%	100%	73%	9%	< 1%	...
(5) Thursday	...	94%	100%	100%	100%	100%	100%	91%	64%	21%	14%	...
(6) Friday	...	100%	100%	100%	100%	96%	82%	76%	58%	4%	< 1%	...
(7) Saturday	...	77%	86%	86%	86%	86%	86%	86%	76%	6%	< 1%	...
(8) Holiday	...	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	...

1. Table abridged due to size.

2. Percentages shown represent the percentage of each hour lights were found on.

In this example, the average percentage of time the light spent on within the shaded cells is 67%, making the CF for this logger is 0.67. The aggregated CF per building type to be presented in the study results was ultimately calculated by applying the same space type weighting as was defined in the HOU calculations. The calculation of the CF in this fashion assumed that the operation observed from 2 p.m. to 6 p.m. during the weeks of logging consistently represents the operation observed from 2 p.m. to 6 p.m. in June through August, unless seasonal operation was otherwise noted in the assessment.

Interactive Factor (IF) Calculations

A reduction in lighting load affects the cooling and heating requirements of a building. Energy efficient lighting technologies typically emit less heat than their less efficient counterparts; this creates cooling benefits in the summer as less heat has to be removed from the space, and heating penalties in the winter as more heat needs to be added. To account for these impacts in areas with electric cooling and/or electric heating, energy and demand savings from lighting retrofits are adjusted by the HVAC Energy Interactive Factor (IF_{energy}) and the HVAC Demand Interactive Factor (IF_{demand}), respectively. IF_{energy} is the summation of cooling benefits and heating penalties attributed to electric heating and cooling equipment divided by the total lighting savings. IF_{demand} is the ratio of the peak kW reduction for summer cooling to the demand savings from a lighting project, where the peak kW reduction is the average hourly kW reduction during PJM summer coincident peak hours.

A supplemental Excel-based tool was developed in order to calculate the two interactive factors based on the data collected from the metering study. Creation of the tool started by calculating the sensible heat gain of all observed lighting retrofit combinations in PECO's tracking data for the most recent available four quarters according the ASHRAE 90.1 equation for sensible heat gain. Using savings values from the same tracking data, energy savings and demand reduction profiles were created proportionately to the annual lighting load shapes observed in the metering study for each building type. Building occupancy was determined based on the probability that lights would be active. A building type was assumed to be "occupied" whenever the probability of the lights being on was greater than 40%.

Building type-specific cooling load shapes were created from eQuest modeling runs used to develop equivalent full load hours (EFLHs) for cooling systems, while building type-specific heating and cooling set point trends were taken from Pennsylvania's Phase II baseline study. Data was compared to the average statewide temperatures in order to understand HVAC operation schedules.

Electric cooling benefits and electric heating penalties were calculated for each building type as a function of lighting load shape (dictated by the building type), installed and removed lighting specifications, heating and cooling efficiencies, heating and cooling setpoints, heating fuel type, and dry bulb temperature. Interactive factors were then calculated for all building types from the heating and cooling benefits. The resulting interactive factors showed the influence from the percentage of electrically heated space, which ranged from a low 0.1% for warehouse to a high of 61.1% for restaurants. A lower percentage of electrically heated space resulted in a smaller heating penalty and a higher IF_{energy} while a higher percentage of electrically heated space resulted in a larger heating penalty and a lower IF_{energy}.

Conclusions

Table 7. HOU and CF Results of Commercial Light Metering Study Compared to Pre-existing Values

	2016		2014		△	
Building Type	**HOU**	**CF**	**HOU**	**CF**	**HOU**	**CF**
Education	2,371	45%	2,190	56%	8%	-20%
Grocery	6,471	93%	4,660	87%	39%	7%
Health	2,943	52%	4,185	72%	-30%	-27%
Institutional/Public Service	1,419	23%	3,155	62%	-55%	-63%
Lodging	3,579	45%	4,399	50%	-19%	-9%
Miscellaneous	2,830	58%	4,056	62%	-30%	-6%
Office	2,294	48%	2,567	61%	-11%	-21%
Restaurant	4,747	77%	3,613	65%	31%	18%
Retail	2,915	66%	2,829	73%	3%	-10%
Warehouse	2,545	48%	2,868	58%	-11%	-17%

Since the inception of Pennsylvania's Energy Efficiency market in 2009, the savings assumptions for lighting measures have been borrowed from other jurisdictions without concern for regional differences in climate and typical operating schedules. The impetus for updated assumptions is validated with differences of up to 63% and 55% in CF and HOU values observed respectively. This study enabled the team to develop, across the seven largest electric distributing companies in the Commonwealth of Pennsylvania, contemporary Pennsylvania-specific information regarding key parameters that influence energy and demand savings calculations. The unique methodologies and precise tools used allowed Nexant to create much more accurate results than previous studies of a similar nature by taking advanced precautions to eliminate biases noted in Nexant's predecessors. The software system used for sampling, data recording, and data processing increased the efficiency of the study while improving the credibility of the results.

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