Opinion **Dynamics**

Illinois Statewide Residential LED Hours of Use Study Results

To: Ameren Illinois Company (AIC)
From: Opinion Dynamics Evaluation Team
Date: December 22, 2017
Re: Illinois Statewide Residential LED Hours of Use Study Results

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This memorandum provides the results of the Illinois Statewide Residential LED Hours of Use study. The key goal of the study was to develop statewide estimates of LED hours of use (HOU) and peak coincidence factors (CF), both summer and winter, to use in future estimation of energy and demand savings impacts for residential lighting measures. The results of this study will go into the Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0 (IL-TRM V7.0).

Study Background and Summary

The Illinois Statewide Residential LED Hours of Use study is a joint research effort between Commonwealth Edison (ComEd) and Ameren Illinois Companies (AIC). This study is a part of a broader in-home lighting and customer decision making study. As part of the study, Opinion Dynamics identified and recruited a representative sample of homes with LEDs and completed site visits during which technicians collected detailed lighting inventory and deployed lighting loggers on a set of randomly selected fixtures with LEDs. In total, we visited 152 homes and deployed 415 loggers. The deployed loggers recorded lighting usage for an extensive period of time from November 29, 2016 through September 1, 2017.

Logger data underwent rigorous cleaning to remove malfunctioning loggers and loggers with insufficient data. Overall, a total of 350 loggers were used in the analysis. To ensure the representativeness of the HOU of the entire year and not just the period during which lighting usage was logged, we annualized lighting usage by fitting sinusoid regression models. We conducted goodness of fit analysis following industry best practices and made determinations where to use modeled results and in which cases to default to the observed results.

We carefully reviewed sample composition across a range of demographic and household characteristics and applied weights to alight the sample with the population of ComEd's and AIC's customers. The section below contains detailed results. Appendix A of this memo details the methodology used to develop the results.

Study Results

Hours of Use

The overall statewide average daily HOU for LEDs is 2.68 hours. Relative precision around the overall HOU estimate is 7% at 90% confidence. HOU by bulb type vary, with standard bulbs resulting in the highest HOU of 2.98, followed by specialty bulbs with an HOU estimate of 2.68. Reflectors have the lowest HOU of 1.71 hours.

Table 1. HOU Estimates by Bulb Type

Bulb Type	Number of Loggers	Number of Homes	HOU	Relative Precision
Standard	282	113	2.98	9%
Reflector	36	24	1.71	19%
Specialty	35	26	2.68	20%
Overall	**350**	**137**	**2.68**	**7%**

Table 2 provides HOU and CF estimates, and the associated relative precision, by utility. As can be seen in the table, AIC's daily average HOU is higher than ComEd's by about half an hour (3.13 vs. 2.58). The difference in the HOU could be explained by lower HOU in multifamily (MF) properties for ComEd than AIC[1], and a higher share of MF properties in ComEd territory as compared to AIC's (37% vs. 16%).

Table 2. HOU Estimates by Utility

Bulb Type	Number of Loggers	Number of Homes	HOU	Relative Precision
ComEd	200	70	2.58	10%
AIC	150	67	3.13	11%
Overall	**350**	**137**	**2.68**	**7%**

HOU and CFs vary by room type, with kitchens, living rooms, and dining rooms having the highest HOU, while bedrooms, basements, bathrooms, and other room types having the lowest HOU. Table 3 provides HOU and CF estimates by room, relative precision associated with each room-level HOU estimates, LED saturation in each room, as well as the share of all LEDs in each room type. Note the large relative precision values around the room-level estimates, which is indicative of a higher level of uncertainty.

Table 3. HOU Estimates by Room

Room Type	Number of Loggers	Number of Homes	HOU	Relative Precision	% of Sockets with LEDs in Each Room	% of All LEDs Across Rooms
Kitchen	48	43	4.24	14%	39%	18%
Living room	91	67	3.93	12%	35%	17%
Dining room	16	15	3.06	25%	22%	5%
Bedroom	61	43	2.37	23%	22%	13%
Basement	27	20	1.66	25%	22%	12%
Bathroom	51	40	1.10	14%	25%	18%
Other	56	43	2.66	22%	15%	17%
Overall	**350**	**137**	**2.68**	**7%**	**24%**	**100%**

Analysis of HOU values by key customer segments shows slightly higher HOU for single-family homes, owner-occupied homes, as well as homes occupied by customers with higher incomes and higher levels of education.

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[1] Average daily HOU in MF properties in is 2.25 in ComEd's service territory and 5.04 in AIC's service territory. These results, however, are based on small sample sizes (20 and 10 sites and 51 and 26 loggers, respectively).

HOU are also higher in homes occupied by customers under 55 years of age. None of these differences, however, are statistically significant.

Table 4. HOU Estimates by Key Customer Characteristics

Room Type	Number of Loggers	Number of Homes	HOU	Relative Precision
Home type				
Single-family	273	107	2.74	8%
Multi-family	77	30	2.50	15%
Home Ownership				
Own	293	116	2.75	8%
Rent	57	21	2.18	25%
Income				
<$50,000	123	49	2.66	14%
$50,000–$100,000	115	43	2.05	14%
$100,000+	99	40	3.54	12%
Education				
Less than college degree	162	66	2.57	10%
College degree+	188	71	2.75	11%
Age				
Under 55 years old	198	71	2.72	10%
55 years or older	146	65	2.55	11%

To place the HOU estimates derived through this study in perspective, we compared the results from this study to the HOU values recommended for use for LEDs in the IL-TRM Version 5.0 (V5.0). The TRM-recommended HOU values are based on a lighting logger study of CFLs conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. As can be seen in Table 5, the HOU are considerably higher for standard LEDs, somewhat higher for specialty LEDs, and considerably lower for reflector LEDs.

Table 5. Comparison of HOU Estimates to IL-TRM V5.0

Bulb Type	Average Daily HOU	
	This Study	IL-TRM V5.0
Standard	2.98	2.07[a]
Reflector	1.71	2.36[b]
Specialty	2.68	2.32[c]

[a] HOU is for residential and in-unit multifamily

[b] HOU for interior reflectors

[c] HOU for specialty generic light bulbs

We also compared the results of this study with other HOU studies conducted across the country. As can be seen in Table 6 below, the HOU estimates from this study are within the range of the other studies' estimates.

Table 6. Comparison of HOU Estimates across Studies

Study Name	Study Timing	n	HOU Result	Notes
New England HOU Study	2013	848	3.0	Efficient bulbs
Pennsylvania Statewide Residential Light Metering Study	2014	206	3.0	Efficient bulbs
DEP 2012 CFL HOU Study	2012	100	2.92	CFLs only
Southern Utility Residential Lighting Logger Study	2016	107	2.88	LEDs only
Illinois Residential Lighting Logger Study	**2017**	**101**	**2.68**	**LEDs only**
Midwestern Residential Lighting Logger Study	2017	101	2.66	LEDs only
Indiana Statewide CFL HOU Study	2012-2013	67	2.47	CFLs
EmPOWER Maryland HOU Metering Study	2014	111	2.46	Efficient bulbs
ComEd PY5/PY6 Lighting Logger Study	2014	85	2.32	Standard CFLs

Coincidence Factors

Table 7 summarizes summer and winter peak CF estimates, and associated relative precision, overall as well as by bulb type. As can be seen in the table, the overall summer peak CF is 0.122 and the overall winter peak CF is 0.127. Summer and winter peak CFs are higher for standard and specialty LEDs than for reflector LEDs.

Table 7. Summer and Winter Peak CF Estimates by Bulb Type

Bulb Type	# of Loggers	# of Homes	Result	Relative Precision
Summer Peak CF				
Standard	282	113	0.128	13%
Reflector	36	24	0.108	29%
Specialty	35	26	0.112	26%
Overall	350	137	0.122	11%
Winter Peak CF				
Standard	282	113	0.144	10%
Reflector	36	24	0.060	21%
Specialty	35	26	0.150	19%
Overall	350	137	0.127	8%

Summer peak CFs are virtually the same between ComEd and AIC (0.120 vs. 0.128), while winter peak CFs are lower for ComEd (0.123 vs. 0.148). Table 8 summarizes winter and summer peak CFs by utility.

Table 8. Summer and Winter Peak CF Estimates by Utility

Bulb Type	# of Loggers	# of Homes	Result	Relative Precision
Summer Peak CF				
ComEd	200	70	0.120	14%
AIC	150	67	0.128	15%
Overall	350	137	0.122	11%
Winter Peak CF				
ComEd	200	70	0.123	11%
AIC	150	67	0.148	11%
Overall	350	137	0.127	8%

Table 9 compared summer peak CFs to the values recommended in IL-TRM V5.0. As can be seen in the table, this study resulted in higher CF values across all product types. IL-TRM V5.0 does not provide winter peak CFs, therefore we are unable to draw comparisons.

Table 9. Comparison of Summer Peak CF Estimates to IL-TRM V5.0

Bulb Type	Summer Peak CF	
	This Study	IL-TRM V5.0
Standard	0.13	0.07[a]
Reflector	0.11	0.09[b]
Specialty	0.12	0.08[c]

[a] CF for interior single family or unknown location or multifamily in unit
[b] CF for interior reflectors
[c] CF for specialty generic light bulbs

Appendix A. Detailed Methodology

Sample Design and Fielding

We recruited customers to participate in the study by mailing them a letter explaining the study and encouraging them to use the included web link to complete a short recruitment survey. Customers without internet access could call our survey center and complete the survey with an interviewer. We used the recruitment survey to identify, pre-qualify, and recruit customers into the different components of the study. All customers were eligible for the in-home lighting inventory and customer lighting preference study, but only customers with LEDs installed in their homes were eligible for the HOU study. Customers who participated in the HOU study had light loggers installed on their LEDs, which remained in place for approximately 8 months. Table 10 displays the dates of key study tasks.

Table 10. Study Timeline

Study Task	Dates
Recruitment Survey Fielded	November 2016 – January 2017
In-Home Lighting Inventories and Light Loggers Installed	December 2016 – February 2017
Consumer Preference Survey Fielded	April 2017 – May 2017
Light Loggers Removed	August 2017 – September 2017

Figure 1 illustrates the sample design and sizes for the statewide lighting logger study. As part of study recruitment, we drew simple random samples of 10,000 customers from the AIC and ComEd residential electric customer databases. After cleaning the sample, we mailed invitations to just under 10,000 customers from each utility. Slightly over 1,100 AIC and 950 ComEd customers completed the recruitment survey *and* agreed to participate in the study. From this group, we scheduled and completed in-home lighting inventories with 146 AIC and 142 ComEd customers.[2] We installed light loggers on LEDs in the homes of 74 AIC and 78 ComEd customers that had LEDs installed. In total, we installed 415 light loggers across 152 AIC and ComEd homes.

To encourage study participation, we provided incentives for the different phases of the project. Customers who participated in the in-home study and had lighting audit conducted received a $75 Visa gift card. Customers who participated in the lighting logger study received an additional $75 gift card when the loggers were removed.

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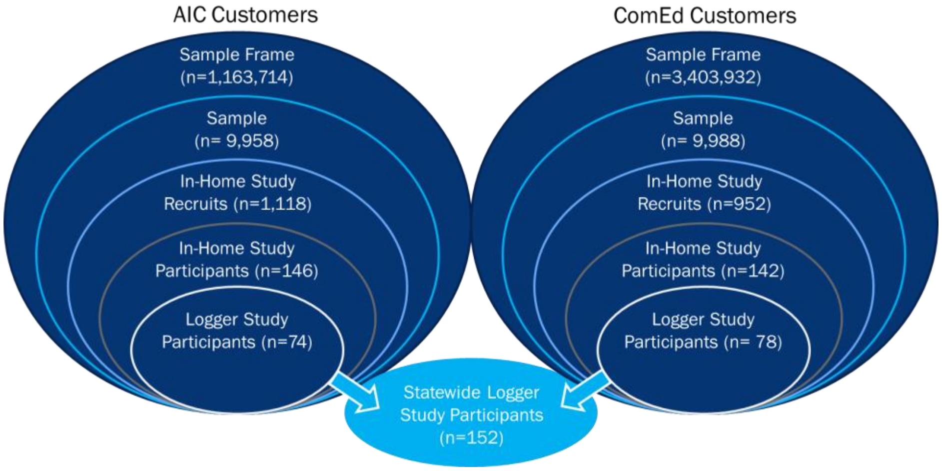
[2] We over-recruited participants because customers can change their minds when we call to schedule the in-home visit. It also may not be logistically possible to schedule visits with customers during the time the field team is in their area. Though we had intended to recruit more customers than we would include in the study, we had a higher response rate to the recruitment survey than we expected and ended up with a much greater number of recruits. We compared the observable characteristics of those that received an in-home audit to those that were recruited but ultimately did not participate in the study. We found no statistically significant differences between these two groups across a number of observable characteristics, including household type, house size, the total number of rooms, the total number of household members, the proportion of retirees, education levels, and household income.

Figure 1. Sample Design for the Statewide Lighting Logger Study



Logger Deployment and Retrieval

During each home visit, the auditor recorded the quantity and type of lighting installed in the interior and exterior of each home. For each light socket, the auditor recorded the socket type (e.g., screw, pin, etc.), light switch control type (e.g., on/off, dimmer, etc.), bulb technology (e.g., CFL, LED), shape (e.g., A-lamp, reflector, globe, etc.), fixture type (e.g., table lamp, recessed ceiling fixture, etc.), and room type (e.g., bedroom, kitchen, etc.). The auditor also recorded information about all lighting found in storage but not in use. We collected information on all bulbs installed inside and outside of ComEd homes.

During the audits, technicians installed loggers on interior and exterior switches that control sockets with LEDs. For logger deployment purposes, during the site visits, technicians classified rooms into nine following distinct room types[3]:

- Kitchen
- Living room
- Bedroom
- Bathroom
- Dining room
- Basement
- Closet
- Outdoor
- Other

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[3] Note that the list of room types for lighting inventory is more detailed and includes 16 unique room types.

As part of the audit, technicians collected the information on the total number of switches, switch controls, total number of light sockets controlled by each switch, lighting technology (CFL, LED, incandescent, halogen, empty socket), and bulb shape (twist, reflector, globe) in each socket. Technicians entered this information in electronic tables. Upon completion of the audits, the tablet produced a list of eligible switches that controlled at least one LED for logging. We deployed up to ten loggers per home, with at least one in each of the distinct room types described above. For homes with fewer than nine rooms, we deployed more than one logger per room (but no more than three loggers per room) to increase the overall precision as well as to act as a backup logger(s). If a room had more than one eligible switch, we randomly selected the light switch to log. For each logger, we recorded the switch it was placed on and the count of light bulbs, by technology, it controlled. We also recorded a detailed description of the logger placement to aid in subsequent retrieval visits (e.g., light above master bathroom mirror).

In order to accurately capture lighting usage, we placed lighting loggers as close to the light source as possible, without compromising the aesthetics of the lighting. We recorded any instances when lighting loggers cannot be placed on the desired fixture and detail reasons (accessibility, homeowner objections). We embedded processes for selecting alternative light fixtures for logger placement.

As part of the logger deployment process, we calibrated each logger's sensitivity setting to make sure it only captures lighting from the dedicated fixture and does not accidentally capture ambient sources of lighting, such as daylight.

Upon completion of the study, we removed the loggers using standard procedures for logger testing prior to removal. We also conducted a closing interview with the homeowner about any changes in lighting usage over the course of the logging period.

Logger Data Preparation and Cleaning

We deployed a total of 415 loggers across 152 homes. We were unable to retrieve a total of 43 loggers. One logger was mistakenly placed on a switch with no LEDs. Four additional loggers were missing deployment detail. We dropped all of those loggers from the analysis.

To prepare the logger data for analysis, we performed a series of data-cleaning steps to ensure that only loggers with proper and reasonable data are included in our analysis. Those steps included:

- **Identification and removal of corrupted/failed loggers:** Initial review of the logger files identified loggers that were corrupted or failed to log the data properly. Corrupted/failed loggers consisted of those that: (1) did not contain any logs falling within the valid logging time frame (indicative of issues with logger clock calibration); (2) did not collect any data (indicative of the loggers not working properly); (3) contained logged data in stark contrast to self-reported socket usage (namely, loggers with no "on" time or very sporadically low "on" periods, while the homeowner reported the fixtures being always on or on most of the time). We identified six loggers that were corrupted/failed and therefore needed to be removed from further analysis.

- **Logger date "trimming":** This step was necessary to ensure that extraneous observations (i.e., logs) associated with logger placement, testing, and calibration were not a part of the analysis. Logger data were "trimmed" to remove all logs recorded "on" before the logger installation date, as well as on or after the logger retrieval day. To determine and validate deployment and retrieval dates, we used data recorded by the field staff as part of the deployment and retrieval process. For each logger, we trimmed the start date to be the first full day of logging and the end date to be the last full day of logging. For loggers received in the mail and therefore missing a clear indicator of the logging end period,[4] we carefully reviewed each individual logger's log patterns to determine an appropriate end date. Comparing the selected end date to the ship date of the package validated this assumption. We did not drop any loggers as a result of this step.

- **Identification of loggers with short logging periods**: Once "trimmed," we calculated logging periods for each logger. Some loggers may have failed or been removed by the residents during the early part of the logging period and therefore only contained logging data for a small fraction of the period. To increase the reliability of the HOU estimates, loggers logging for less than one month were excluded from the analysis. We identified five loggers with a short logging period that needed to be removed from the analysis.

- **Analysis of unexpected/suspicious usage patterns:** To ensure proper operation of the loggers throughout the logging period, we performed an extensive analysis of logger usage patterns and flagged loggers with unusual or unexpected patterns for further review and validation. We explored a variety of patterns, including long "on" periods, long "off" periods and usage gaps, no "on" periods, and high variance in usage and usage changes over time. We did not drop any loggers as a result of this step.

- **Analysis of logger flickering:** We thoroughly explored logger flickering and its impact on the HOU estimates. Logger flickering is caused by an external stimulus, such as sunlight or moisture interference. Flickering commonly manifests itself in short "flicks" or "on" and "off" periods. Flickering is generally difficult to identify and correct for because it is hard to determine whether the short-interval "on/off" periods are false positives or false negatives. We explored the impact logger flickering could have on average daily HOU by calculating, for each logger, the total number of logs that each logger recorded and normalizing the total number of logs to the days that the logger was in the field, thus arriving at an average number of logs per day. A high count of logs per day is usually indicative of loggers flickering. We then estimated the impact that potential logger flickering could have on the HOU estimates by summing for each logger every 1–10 second "on/off" period[5] and dividing them by the total number of days that the logger was deployed. The resulting number presents an upper bound of the impact that flickering has on the HOU estimates. The results of the analysis revealed that the impacts of the flickering issue on the estimation of the average daily HOU are negligible. As such, we did not make any adjustments to the logger data.

During the logger data cleaning process, we paid special attention to the loggers placed on exterior fixtures. Logging exterior lighting usage is particularly challenging for the following reasons:

- **Difficulty of logger placement:** the nature of the lighting fixtures and their positioning makes it more challenging to place the loggers, thus leading to exclusion of certain fixtures and the resulting biases in the HOU.

- **Exposure to daylight:** by the virtue of being outside, loggers placed on exterior fixtures have more exposure to daylight and may mistake daylight for the light being on, thus leading to higher than actual

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[4] Those loggers were removed and mailed to us by residents; thus, the retrieval process did not follow standard retrieval procedures.

[5] 1–10 second "on" and "off" periods were determined as the most common "flicker" periods. This is a very conservative range because the 10-second "on/off" pattern is a very conceivable usage pattern for people to exhibit.

HOU. Even the most careful logger calibration and placement often does not mitigate the erroneous logging of daylight.

- **Exposure to the elements:** loggers placed outside are exposed to temperature fluctuations (subzero temperatures in the winter and hot days in the summer) and inclement weather conditions (rain, snow, wind, etc.) and are therefore prone to premature failure and data corruption.

As part of this study, we placed a total of six loggers on exterior fixtures. We conducted a careful analysis of those loggers' log patterns. Our analysis pointed to possible daylight exposure and presence of corrupted data. As the result of the analysis, we decided to exclude exterior loggers from the estimation of the HOU and CFs.

In the end, we used 350 of the 415 deployed loggers for analysis (84%). This is a typical logger attrition rate for a study of this duration. Table 11 provides a summary of logger attrition.

Table 11. Logger Attrition Summary

Cut or Drop Decision	Loggers Affected		Sites Affected	
	#	%	#	%
Total deployed	415	100%	152	100%
Unusable loggers	**65**	**16%**	**31**	**20%**
Unable to retrieve	43	10%	17	11%
Missing deployment data	4	1%	3	2%
Corrupted/failed loggers	6	1%	4	3%
Short logging period	5	1%	4	3%
Logged Incandescent	1	<1%	1	1%
Exterior Loggers	6	1%	6	4%
Total used in analysis	**350**	**84%**	**137**	**90%**

Hours of Use Annualization Process

It is well-known that the number of daylight hours affect hours of lighting use. Lighting logger studies that do not log usage during the entire year must annualize their results so they apply to the entire year and not simply the logged period. While this study did not cover the whole year, loggers were in place for most of the year, capturing data on usage during the spring, summer, and part of the fall. A fielding period of this length is likely to result in observed HOU estimates that are similar to annual values for a large share of loggers. Using observed estimates is preferable for those loggers given the modeling uncertainty that the annualization process might introduce. By reviewing the annualization modeling results, we can determine the loggers for which it is appropriate to use observed values and the loggers for which it is better to use the modeled values.

We annualized the lighting usage data using an individual ordinary least squares (OLS) regression model. The model specification is provided in the equation below.

Equation 1. Hours of Use Model Specification

$$Hd = \alpha + \beta \sin(\theta d) + \varepsilon d$$

Where:

Hd = HOU on day d, starting with d=1 on January 1.

α = The intercept representing HOU when sin(θd)=0. Since average sin(θd) for the year is equal to zero by design, evaluating the model at the average declination angle leaves only the constant to estimate HOU; therefore, the intercept term is equal to average annualized HOU for each bulb.

β = Sine coefficient, or the difference between the HOU on the solstice and days with the average annual declination angle.

$Sin(\theta d)$ = Sine of the solar declination angle or day d converted to follow the change in the HOU and adjusted to fit the −1 to +1 interval with an average of zero for the year (for ease of analysis). The solar declination angle represents the latitude at which the sun is directly overhead at midday. We used the following formula to calculate the sine of the solar declination angle for each day of the year:

$$\sin(-\pi * 2 * (284+d)/365)$$

εd = Residual error

We fit sinusoid regression models separately for weekends and weekdays for each individual logger and then combined the results in proportion to the percent of weekends versus weekdays in a year. We analyzed each regression model for goodness of fit to determine if the individual bulb was sufficiently daylight-sensitive to justify regression-based annualization and to determine if the sinusoid model could provide a reliable estimate (i.e., the sinusoid model accurately represented trends in lighting use over time). Specifically, we looked at:

- **Significance of the sine coefficient t-statistic.** Loggers with a t-statistic lower than 1.282 or higher than −1.282 were flagged as "poor fit" (meaning that the solar declination angle is not significantly different from 0 at a 90% confidence level).
- **Magnitude of the sine coefficient**. Models that resulted in extremely high sine coefficients (absolute magnitude of five or more) were flagged as "poor fit."[6]
- **The value of the intercept.** Models with the negative intercept were flagged as "poor fit."
- **The direction of the coefficient.** Models with a negative regression coefficient (indicating positive relationship with daylight hours) were flagged as "poor fit." This accounts for the regression model predicting increased HOU as the daylight hours increase.

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[6] In many of those cases, use changed dramatically during different periods of the study and it was not possible to determine typical use. For example, lights may have stayed continuously on for a portion of the study and then were used intermittently.

If any of the parameters described above were true, we replaced the modeled HOU with non-annualized observed daily average HOU. As part of this exercise, we replaced most of the modeled results (71%) with observed HOU estimates. This is not unusual given the duration of the metering effort.

Coincidence Factor Estimation

CFs represent the fraction of time during the peak period that the light is on. We used the following definitions of peak periods in the CF calculations:

- **Summer peak period:** non-holiday weekday, between June 1 and August 31, between the hours of 1pm and 5pm Central Time
- **Winter peak period:** non-holiday weekday, between January 1 and February 28, between the hours of 6am and 8am, and 5pm and 7pm Central Time

Loggers were in the field for most of the summer and winter seasons, thus covering both summer and winter peak periods and minimizing the need for annualization.

Summer Peak Coincidence Factor Estimation

Of the 350 loggers used in the analysis, only 12 logged lighting usage for less than a month of the summer peak period, while the remaining 338 logged two months or more (two-thirds or more). For the 12 loggers that logged lighting usage for less than a month of the summer peak period, we annualized usage during the peak hours of the day using the same regression model specification as for the HOU and performed a similar goodness of fit assessment. The models for all 12 loggers were a poor fit. For those loggers, we estimated lighting usage during peak hours based on the observed lighting usage for the entire logged period as opposed to just the summer period. We calculated the summer peak CF by summing, for each logger, the time the light was on during the summer peak hours and dividing the result by the number of hours within the peak period.

Winter Peak Coincidence Factor Estimation

Of the 350 loggers used in the analysis, only six logged lighting usage for less than a month of the winter peak period. The remaining 344 logged more than a month, of which half logged lighting usage for the entire duration of the winter peak period. For the six loggers that logged lighting usage for less than a month of the winter peak period, we annualized usage during the peak hours of the day using the same regression model specification as for the HOU and performed a similar goodness of fit assessment. We used modeled results for one of the six loggers. The modeled results for the remaining five loggers were a poor fit. For those loggers, we estimated lighting usage during peak hours based on the observed lighting usage for the entire logged period as opposed to just the winter period.

Data Weighting

We aggregated individual logger data in stages. First, we aggregated individual loggers to room-level HOU and CF estimates in order to adequately account for the fact that some loggers logged a LED that was on a switch that controlled more than one LED. Therefore, the logged LED represents all LEDs on the same switch. We then further weighted room-level HOU and CF estimates by the share of LEDs in each room type.

Lighting metering studies are involved and require time and effort on behalf of the customer. Certain customer types may be less likely to participate in such a study (e.g., those with higher incomes or those employed full-time). If the customers that are under- or overrepresented in our sample have different lighting usage patterns, the study results, namely HOU and CFs, will suffer from non-response error and will not be representative of the broader population.

As part of our analysis, Opinion Dynamics explored the presence of non-response bias in the site visit sample by comparing the study's site visit participants to the broader population on a range of observable characteristics associated with the lighting usage.

Customers eligible for the study are customers with LEDs. We do not have data on the demographics and household characteristics of AIC and ComEd customers with LEDs. Because this study included site visits with a broader sample, we were able to assess the potential for non-response bias through a two-stage approach:

- **Compare in-home study participants to the population of AIC and ComEd customers.** We compared the composition of the in-home study participants to the population of AIC and ComEd customers. We used the U.S. Census Bureau's 2010–2015 American Community Survey (ACS) data to obtain information on each utility's customer base. The sample of home study participants had more homeowners, single-family residents, and slightly more customers with higher income levels.

- **Compare logger study participants to eligible customers that filled out the recruitment survey.** We compared the demographic and household characteristics of the households that participated in the logger study with those of all customers eligible for the study, as determined through the recruitment survey. This comparison allowed us to assess whether customers who agreed to participate in the logger study were different from those who qualified but chose not to participate. We found that our site visit sample was well aligned across key demographic and household characteristics.

Based on this analysis, we developed and applied survey weights based on homeownership to align the sample with the population. We applied the weights to the in-home study participant sample. We did not weight the data by home type or income because home type and income are highly correlated with homeownership, and weighting the data by the latter aligns the sample by the former. In addition to applying home ownership weights, we weighted the data by utility to account for the oversampling of AIC customers. We weighted the results in proportion to the share of each utility's customers in the population. Table 12 summarizes the weights that we applied.

Table 12. Weighting Summary for Statewide LED HOU Study

Utility	Home Ownership Status	Population	% Population	Site Visits	% Site Visits	Weight
ComEd	Own	2,221,313	49%	108	38%	1.30
	Rent	1,182,619	26%	34	12%	2.19
Ameren	Own	822,209	18%	107	37%	0.48
	Rent	341,505	7%	39	14%	0.55