Illinois Statewide LED HOU Study – Load Shape Development

To: Navigant Consulting

From: Opinion Dynamics Evaluation Team

Date: May 18, 2018

Re: Illinois Statewide LED HOU Study – Load Shape Development

This memorandum summarizes the study design, fieldwork, data cleaning, and analytic methodology that Opinion Dynamics used to support the load shape development process in the state of Illinois.

The goals of the analysis were to develop the following outputs:

* Estimates of average coincidence factors (CFs) for each hour of the day, broken down by weekdays and weekends, for each month of the year
* Estimates of average light bulb counts in a home and distribution of bulbs across key characteristics, such as technology, bulb type, and bulb shape

These outputs will serve as key inputs into the load shape development process.

To develop the desired outputs, Opinion Dynamics relied on the results from the Illinois Statewide Residential Lighting Inventory and LED Hours of Use (HOU) study. The study was a joint research effort between Commonwealth Edison (ComEd) and Ameren Illinois Companies (AIC). As part of the study, Opinion Dynamics identified and recruited a representative sample of homes and completed site visits during which technicians collected detailed lighting inventory and deployed lighting loggers on a set of randomly selected fixtures with LEDs.

Below is a summary of the study design and modeling efforts that we undertook. Along with this memo, we provide a spreadsheet with the results of the analysis in the desired format.

# Study Design and Fieldwork

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.[[1]](#footnote-1) All customers were eligible for the in-home lighting inventory, but only customers with LEDs installed in their homes were eligible for the HOU study. We installed light loggers on LEDs in the homes of 74 AIC and 78 ComEd customers. In total, we installed 415 light loggers across 152 AIC and ComEd homes.

Figure . Sample Design for the Statewide Lighting Logger Study

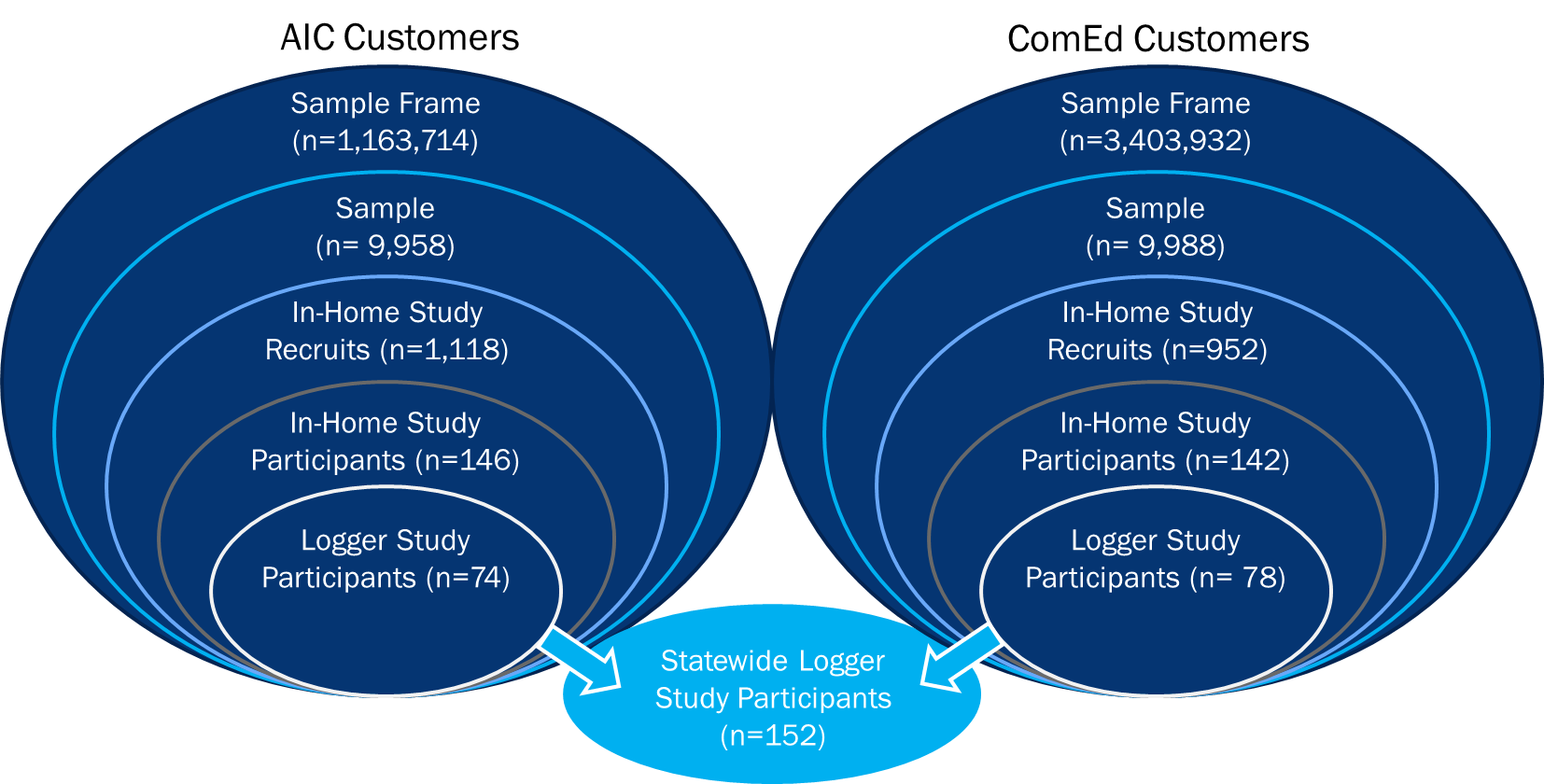


Table 1 provides the timeline for the study. As can be seen in the table, light loggers remained in place for an extensive period of time, capturing usage during the winter and summer peak periods as well as during a shoulder season (spring).

Table . Study Timeline

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

# Data Cleaning and Weighting

We carefully cleaned the onsite lighting inventory data. As part of the cleaning process, we analyzed the data for gaps, performed outlier analysis and analysis of unrealistic data combinations (e.g., spiral LEDs) and resolved any inconsistencies found.

Of the 415 deployed loggers, we were able to retrieve 398 loggers. The data from the retrieved loggers underwent rigorous cleaning to remove malfunctioning loggers and loggers with insufficient data. 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.

During the logger data cleaning process, we paid special attention to the loggers placed on exterior fixtures. Logging exterior lighting usage is particularly challenging due to difficulty of logger placement, exposure to daylight, and exposure to the elements. 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 analysis.

Due to their involved nature of light logger studies, certain customer types may be less likely to participate (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. We 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. 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. 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 2 summarizes the weights that we applied.

Table . 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 |

# Logger Data Modeling

As part of the original scope of the IL Statewide Lighting HOU Study, we deployed loggers from January through August. This left a gap to fill when developing coincidence factors (CF) for each hour of the day, weekdays vs. weekends, and each month. We used a linear fixed effects model to generate CF predictions during the periods that we did not log, based on the data we collected during the study period. We used actual observed CF during hours that have sufficient data and only used modeled CF during hours where we don’t have sufficient data.

It is well-known that the number of daylight hours affects HOU. We address this by including the solar declination angle in the model. In addition, in an effort to differentiate lighting usage month-to-month and weekend vs. weekday, we added these terms into the model. Finally, as part of the model, we included weights account for the survey design and sampling biases at the household and room level. We included weights by bulbs associated with loggers, bulbs across room types where loggers were deployed, utility, and homeownership, to account for the survey design and sampling biases at the household and room level.

We tested several different methodologies and a variety of model specifications before we selected the model below to predict CF during the unmeasured period. We assessed the model by checking that it correctly predicted CF for the periods where we do have sufficient data. The final model is a fixed-effects multivariate model with the specification provided below.

Equation Model Specification

*where:*

= Average percent of lighting usage per hour

= 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 intervals 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:

= Flag for whether the date is a weekend. Weekday federal holidays are also considered weekends

= Hour dummies for each hour of the day

= Dummies for 3 seasons—summer (Jun-Aug), winter(Dec-Feb), and shoulder months

= Homeownership status—owner or renter

= Ameren or ComEd

= Room dummies for each room type—bedroom, bathroom, basement, dining room, kitchen, living room, other

= Average bulb-specific constant

= Coefficient for the incremental difference between the CF on the solstice and days with the average annual declination angle

= Coefficient for the incremental change in CF associated with the day being on a weekend

= Set of coefficients for the incremental change in CF in associated different hours of the day for each hour

= Set of coefficients for the incremental change in CF associated with different seasons for each hour of the day

= Set of coefficients for the incremental change in CF associated with each utility for each hour of the day

= Set of coefficients for the incremental change in CF associated with homeownership status for each hour of the day

= Set of coefficients for the incremental change in CF associated with room type for each hour of the day

= Set of coefficients for the incremental change in CF associated with being on a weekend for each hour of the day

= Error term

Using a mix of modeled and observed results, we developed average estimates of coincidence factors for each hour of the day for weekends and weekdays and for each month of the year.

Analysis Limitations and Considerations for Future Research

The key limitations of the analysis include:

* Uncertainty due to changing market conditions – the metering study reflects LED lighting usage given the LED socket saturation at the time of the study. Increasing socket saturation with LEDs may lead to different patterns of LED usage and as a result coincidence factors and load shapes.
* Modeling uncertainty – modeling coincidence factors at the requested level of detail (e.g., hourly for every month of the year by weekday vs. weekends) results in greater variation of the results within each reporting unit and therefore higher error surrounding each individual estimate.
* Measurement error – while Opinion Dynamics did all possible due diligence to identify and correct for possible lighting interference, it is possible that the logger data may contain some daylight contamination. The magnitude and the impact of remaining possible daylight interference in the data is unknown. Accurately correcting for it is next to impossible given the logging equipment used and available information on lighting usage in homes.

Understanding differences in load shapes by bulb type (e.g., standard vs. specialty LEDs) and customer type (e.g., single-family vs. multi-family residents) can be beneficial in informing how different LEDs are used among different customer cohorts. Our study was unable to support such analysis due to limited sample sizes for key subgroups of interest.

1. 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. [↑](#footnote-ref-1)