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| To: | Illinois Technical Advisory Committee (TAC) |
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| From: | Ryan Powanda, Qi Jin, Vergil Weatherford, Sagar Deo; Navigant |
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| Date: | June 28, 2018 |
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| Re: | Illinois Commercial Lighting Load Shape Development Using EmPOWER Maryland Lighting Logger Data |

# Introduction

This memorandum details Navigant’s approach in summarizing commercial lighting logger data collected during five separate metering studies for EmPOWER, Maryland, during the years 2010, 2011, 2012, 2013, and 2016. These data are summarized to derive 8760 lighting load shapes for the Illinois Technical Reference Manual (TRM). Navigant is recommending that the IL Technical Advisory Committee (IL TAC) adopt these lighting load shapes in the IL TRM in the interim while additional primary research is conducted in Illinois during forthcoming commercial lighting metering studies. Navigant submits the building-level and commercial sector-level load shapes as a separate Microsoft Excel file to the IL TAC.[[1]](#footnote-1)

Navigant’s commercial lighting metering study conducted in Maryland in 2016 was a long-term metering study intended to log both summer and winter periods and to determine whether commercial lighting consumption varies from month to month and throughout the year. These results provided statistically robust estimates of peak demand impacts during both summer and winter PJM interconnection performance periods. Navigant submitted the hours of use (HOU) and coincidence factor (CF) results from this study to the Mid-Atlantic TRM[[2]](#footnote-2), and also provides detailed documentation of study design and methods in a recent International Energy Program Evaluation Conference (IEPEC) conference paper detailing the EmPOWER 2017 Winter Metering study.[[3]](#footnote-3)

Table 1 shows the number of sites and loggers used from the EmPOWER lighting metering study to derive 8760 load shapes for the IL TRM. These sample sizes are summarized by six primary building types, and an ‘Other’ building type which comprise less frequent building types.

Table 1: Lighting Metering Sample Size Summary[[4]](#footnote-4)

| Building Type | Number of Logged Sites | Total Number of Lighting Loggers Included in Analysis |
| --- | --- | --- |
| Education | 91 | 244 |
| Grocery | 23 | 76 |
| Health | 23 | 87 |
| Office | 51 | 168 |
| Retail | 57 | 156 |
| Warehouse/Industrial | 71 | 251 |
| Other | 201 | 485 |
| Total | 517 | 1,467 |

*Source: Navigant EmPOWER Maryland Lighting Metering Study*

# Data Analysis Methodology

Navigant used a different analysis methodology to derive 8760 lighting load shapes for the IL than was used in the EmPOWER 2017 Winter Metering study to derive annual HOU and CF results. The EmPOWER study established a relationship between summer and winter peaks based on a regression model fit using the 2016 actual logged period (winter/summer) and applied to the historic (summer-only) data to refine the estimate of winter peak CF. In the current analysis of this data for the IL TRM to derive hourly load shapes, Navigant employs a simplified approach using a binned extrapolation method to extrapolate from logged periods to the full year.

In the binned extrapolation method, Navigant calculated average on-time fractions for each logger using the following binning variables - hour of day, weekday and weekend/holiday day types. Navigant then used these binned averages to extrapolate to hours of the analysis period for which on-time fractions were not logged. For the 2016 EmPOWER Winter Metering study, the average logged period was approximately 9 months during the winter, spring, and summer months. For the data collected during the 2010-2013 studies, the average logged period was approximately 1 month during the summer.

Using the logger data from the 517 sampled sites as a starting point, Navigant extrapolated and summarized the data to generate both building-level and space-level load shapes. In the EmPOWER study, Navigant summarized HOU and CF estimates at the space-level where possible by combining logger results from unique space type to form larger groups which, when combined, yielded statistically significant parameter estimates.[[5]](#footnote-5) Table 2 shows the space type results summarized in the EmPOWER study.

Table : EmPOWER Building - Space Type Parameters Summarized

| Building Type | Space Types |
| --- | --- |
| Education | Classroom/Lecture, Corridor/Hallways, Office (Executive/Private), Office (Open Plan), Other, Office (General) | |
| Grocery | Retail Sales/Showroom, Other, Storage (Conditioned & Walk-In Refrigerator/Freezer) | |
| Health | Other, Corridor/Hallways | |
| Office | Corridor/Hallways, Lobby (Main Entry and Assembly), Office (General), Other | |
| Retail | Retail Sales/Showroom, Office (General), Other, Restrooms, Lobby (Main Entry and Assembly), Parking Garage | |
| Warehouse/  Industrial | Comm/Ind Work (General Low Bay), Auto Repair Workshop, Other, Storage (Conditioned & Walk-In Refrigerator/Freezer), Comm/Ind Work (General High Bay), Office (General), Restrooms | |
| Other | Mechanical/Electrical Room, Office (General), Restrooms, Storage (Conditioned & Walk-In Refrigerator/Freezer), Corridor/Hallways, Auto Repair Workshop, Retail Sales/Showroom, Kitchen/Break room & Food Prep, Other, Locker and Dressing Room, Parking Garage, Classroom/Lecture, Outside/Outdoor Area | |

*Source: Navigant EmPOWER Maryland Lighting Metering Study*

For the IL TRM load shapes analysis, Navigant also weighted the building-level load shape results to derive commercial sector-level indoor and outdoor lighting load shapes using weights calculated from ComEd C&I Standard and Small Business program tracking data. Navigant submits the building-level and sector-level load shapes as a separate Microsoft Excel file to the IL TAC and does not provide the space-level load shapes at this time. The methodology sections below details Navigant’s scheme to weight lighting logger parameters from the space-type to both building and sector-level results.

## Logger Weighting

For each parameter of interest (hours of use, summer and winter period coincidence factors), Navigant calculated weighted averages for each logged:

* Building type
* Space type
* Building type-space type combination

Each rolled-up building type, space type, and building type-space type factor starts with an individual logger in the space type of a building for a specific project. Navigant extrapolates this data to space type, building type-space type, and building type parameters by weighting at each level. Navigant calculates weighted averages so that the final values are representative of the overall EmPOWER program participant population rather than just the sampled circuits.

***Combining Loggers in the Same Area***

Starting with the individual space type within a particular building, Navigant had to account for the fact that some areas had more than one lighting logger installed for redundancy or because the space represented a large portion of the overall site-level lighting savings. In these instances, Navigant took a simple average of the parameters calculated for each logger.

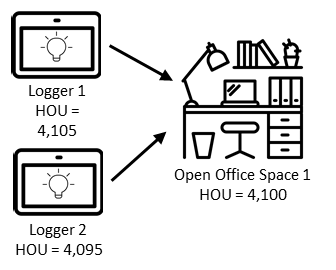


Figure 1: Combining Loggers within the Same Area

***Combining Logged Areas to a Single Building Type / Space Type Combination***

Once Navigant had a parameter value for each logged area in a site, the analysis team then took all the areas within a building type for a particular space type (e.g., open offices, hallways, conference rooms, etc.) and created a single parameter for that space type within that particular building type (see example in Figure 2). The parameters were averaged to compute a single parameter per space type per site.

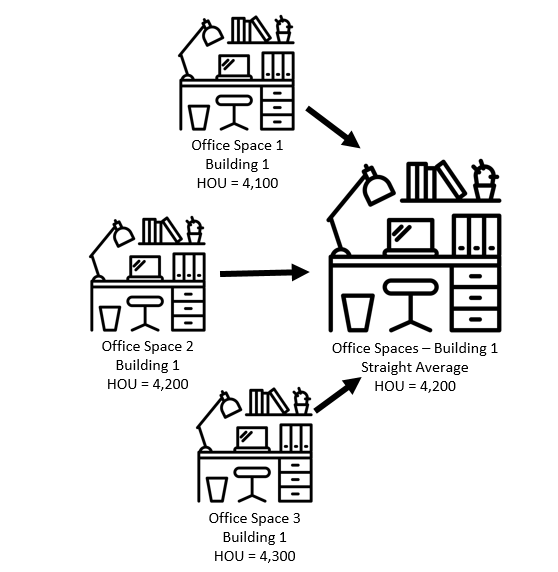


Figure 2: Combining Logged Areas to a Single Space Type per Site

***Combining Space Types across Sampled Sites to Derive Single Building Type / Space Type Parameters***

Navigant used the ‘connected watts’ metric to weight the results from various logged space types across sampled building sites to derive overall space-type parameters for each building type, as shown in Figure 3. Navigant summarized connected watts through analysis of EmPOWER program tracking data and onsite verification of fixture quantity and rated wattage.

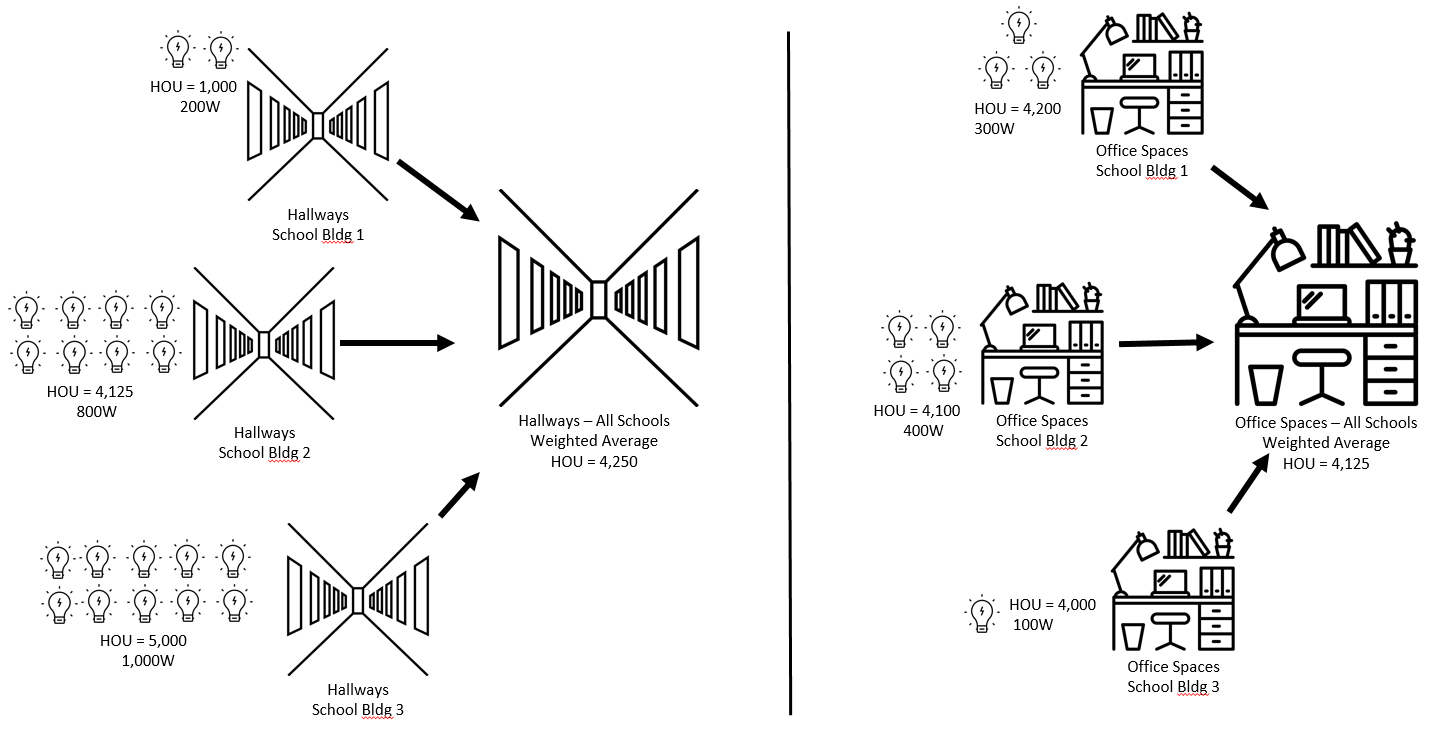


Figure 3 - *Combining Space-Types across Sites to Single Building Type-Space Type Factors*

***Weighting Building Type / Space Type Parameters to Derive Building-Level Parameters***

Navigant derived the building level weighted parameters using the building type-space type distribution from EmPOWER lighting program participation over multiple program years.

***Combining Building-Level Load Shapes to Determine Commercial Sector-Level Parameters***

Lastly, Navigant combined building-level parameters across the various building types to determine the overall 8760 load shapes for commercial sector lighting. The overall 8760 load shape was calculated using a weighted average based on the distribution of participation (project count) across all building types for the prior two years of the ComEd Small Business and Business Standard programs. The ComEd tracking data contained 37 unique building types. Navigant mapped these 37 building types to one of the seven building types listed below to complete the weighting. Table 3 shows the weighting factors used to weight the building-level results to the sector-level.

Table 3: Building – Sector-Level Weighting Factors Using ComEd Tracking Data

| Building Type | Weighting Factors |
| --- | --- |
| Education | 0.75% |
| Grocery | 2.59% |
| Health | 1.19% |
| Office | 17.62% |
| Other | 17.76% |
| Retail | 42.94% |
| Warehouse/Industrial | 17.16% |

*Source: Navigant’s Analysis of ComEd Standard and Small Business Tracking Data; Weighted by Project Count*

## Uncertainty Analysis

Understanding the uncertainty around the hourly load shapes and hours-of-use parameters is key to being able to correctly interpret the results. Navigant considered only sampling error in the calculation of uncertainty.

Other sources of error not considered include:

* Within-site sampling error
* Instrumentation error of loggers, although Navigant performed thorough data cleaning and logger validation
* Logged-period-to-8760 extrapolation error

Navigant used the following equations to calculate the relative precision at the 90% confidence level for all the hourly 8760 coincidence factors (CF):

Where,

RP90 = Relative precision of the roll-up at 90% confidence

t90 = T-Statistic for 90% confidence level

SE = Standard Error of the roll-up

CF = Mean Coincidence factor for the roll-up

CFSD­ = Standard Deviation of the CF roll-up

n\_site = Number of sites being rolled-up

# Analysis Limitations and Considerations for Future Research

Navigant summarized load shapes for six main building types and an ‘Other’ building type that includes the remainder of logged data across less frequent building types. Navigant also summarized commercial sector-level load shapes for indoor and outdoor lighting.

Navigant recommends further research in Illinois to collect long-term lighting metering data (at least nine months including both summer and winter peak periods and a Fall or Spring shoulder season) for a large sample of building types. This research can be conducted with C&I lighting program participants alongside the standard evaluations conducted for Illinois utilities. The results from this analysis can provide robust estimates of HOU, CF, and load shapes at the building-level. Space-level analysis may reduce or eliminate the need for annual site specific metering studies for lighting program participants, as was done in Maryland for EmPOWER utilities. Future research can also include study design considerations for lighting controls.

1. “IL Commercial Lighting Load Shapes\_2018-06-28.xlsx” [↑](#footnote-ref-1)
2. http://www.neep.org/sites/default/files/resources/Mid\_Atlantic\_TRM\_V7\_FINAL.pdf [↑](#footnote-ref-2)
3. Hermansen K., Weatherford V., Elszasz J., Spencer J., and Robinson S (2017). Shedding Light on Winter Lighting. 2017 International Energy Program Evaluation Conference, Baltimore, MD. http://www.iepec.org/2017-proceedings/65243-iepec-1.3717521/t001-1.3718144/f001-1.3718145/a014-1.3718150/an053-1.3718151.html [↑](#footnote-ref-3)
4. The sample sizes used in this IL TRM load shape analysis are greater than the sample size used in the EmPOWER lighting metering study to derive HOU and CF. In the EmPOWER study, Navigant employed a Bayesian statistical analysis method to estimate within-site error calculation and improve confidence and precision of the resulting parameter estimates. This technique required a minimum of 3 loggers within each building type/space type combination for inclusion in the analysis. Navigant did not employ the Bayesian analysis technique for the IL load shapes analysis and can therefore use the additional sites and loggers in this analysis. [↑](#footnote-ref-4)
5. Maximum of 35% relative precision across both winter and summer CF parameters at the 90% confidence level. [↑](#footnote-ref-5)