



Michigan Statewide Commercial and Industrial Lighting Hours-of- Use Study

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DRAFT
REPORT



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EXECUTIVE SUMMARY

This executive summary presents results for the Consumers Energy and DTE Energy Commercial & Industrial (C&I) Lighting Hours of Use Metering Study. This study was designed to collect, analyze, and report data of a representative sample of metered C&I lighting to inform the estimates of electric energy and demand impacts of Energy Opportunities (EO) program lighting measures. The main focus of this work was to determine lighting hours-of-use (HOU), which is an important “assumed” value in lighting energy and demand savings estimates. Current electric energy and demand savings calculations for the Michigan Energy Measures Database (MEMD) related to lighting measures assume 3,680 annual HOU and a peak coincidence factor of 0.90 for most non-high bay lighting measures based on secondary research conducted for the State of Wisconsin (4,160 HOU and 0.95 CF for high bay lighting).¹

Key Findings

The research team calculated the updated value for hours of use and the preliminary value for coincidence factor by combining metered observations with the lighting controls study results. These metered observations were weighted by metered space and facility type and then adjusting for all facility types collected in the incidence study. These overall values, as well as the existing MEMD values, are presented in **Error! Reference source not found.**²

Table E- 1. Hours of Use and Coincidence Factor Values

Variable	Current MEMD Value (a)	Calibrated Value (b)	Ratio (b)/(a)
Hours of Use	3,680	2,744	0.755
Coincidence Factor	0.90	0.505	0.561

^a Current MEMD Value is based on the non-high bay estimates.

Methodology

The research team determined preliminary lighting hours-of-use (HOU) and coincidence factors (CF) using metered lighting data from Wave 1 of this metering study and from the 2013 Lighting Controls Study. The team installed lighting loggers to measure lighting use over a metering period averaging 42 days. Based on the lighting use during the metered period, the team estimated weekday and weekend usage and modeled annual hours based on those usage estimates and observed holidays or other facility closures. The research team also modeled preliminary CF estimates based on lighting use for the hours between 3PM and 5PM.

¹ PA Consulting and KEMA. 2010. *Focus on Energy Evaluation: Business Programs: Deemed Savings Manual V1.0*. March 22, 2010

² Facilities with significantly different operating hours than those described in this report may be more appropriately served through a custom energy savings approach to account for their greater variation in HOU and CF.

The research team aggregated the logger level estimates to the space-type level (such as, “restrooms”) for each facility based on the installed wattages in each space. Then, the research team aggregated the facility estimates to an overall estimate for a facility type based on the installed lighting wattage in each facility. Finally, the research team aggregated the facility-type estimates to the overall estimate based on the distribution of facility types in Michigan.

1. INTRODUCTION

This report presents results for the Commercial Lighting Hours-of-Use Study conducted by EMI Consulting for Consumers Energy and DTE Energy in 2013 and 2014. The report begins by providing some background information, then describes study methodology, and presents the study results.

1.1 Background and Study Objectives

The overarching objective of this study was to collect, analyze, summarize, and report data to calibrate the hours-of-use (HOU) and peak coincidence factors (CFs) for commercial & industrial (C&I) lighting to inform potential adjustments to the Michigan Energy Measures Database (MEMD). This study is important to the success of the Energy Optimization (EO) Plan as C&I lighting measures contribute approximately 75% to the expected electric energy savings of Consumers Energy and DTE Energy programs each year. The study provides the MPSC and EO Program administrators with accurate, up-to-date data for use in determining energy savings, which in turn, will provide more accurate energy savings estimates.

The MEMD was developed by Morgan Marketing Partners (MMP) as the basis for the initial energy efficiency potential estimates in the EO Plan. Michigan's EO Program administrators now use the MEMD for the development and update of their EO program plans as well as for the calculations of the gross energy and demand savings achieved in each program year for included measures. Among other things, the MEMD specifies the per-unit energy (kWh, MCF) and demand (kW) impact estimates of each measure in the database. The per-unit impacts of MEMD measures are stipulated, or "deemed" until there is consensus among parties that a revision to the MEMD is warranted.³

The purpose of this study is to collect reliable data on C&I lighting HOU and CFs for the State of Michigan to validate and/or calibrate the MEMD to more accurately reflect local operating conditions and provide a more granular approach for estimating HOU at C&I facilities where possible (i.e., provide several HOU estimates for use at varying facility or space types). This study focuses on C&I HOU and CFs, as these are the two values used in energy saving and demand calculations that are currently assumed. Current electric energy and demand savings calculations for the MEMD related to lighting measures assume 3,680 annual HOU and a peak coincidence factor of 0.90 for most non-high bay lighting measures based on secondary research conducted for the State of Wisconsin (4,160 HOU and 0.95 CF for high bay lighting).⁴ The Wisconsin report relied exclusively on secondary data, none of the included studies represented any Midwestern states or were completed after 2006.⁵

³ "Parties" refers to the collective membership of either the Program Design and Implementation Collaborative or the Evaluation Collaborative, under the auspices of the Michigan Public Service Commission.

⁴ PA Consulting and KEMA. 2010. *Focus on Energy Evaluation: Business Programs: Deemed Savings Manual V1.0*. March 22, 2010

⁵ The Wisconsin report synthesized results from six previous studies. Four of these were conducted in California; one in Massachusetts and Maryland; one was a national DOE study.

Data collection for Wave 1 of this metering study consisted of two main parts: (1) an on-site field inspection report of sampled C&I facilities, and (2) metering of lighting to determine HOU and inform CFs. In addition, an incidence study, completed during recruitment for participating facilities, collected information on the distribution of facility types across the C&I customer population.

The analysis of the data will produce estimates of the following for commercial lighting in Michigan:

- Lighting HOU
- Peak coincidence factors
- Type, number and wattage of lighting equipment
- Heating and cooling equipment specifications and usage

2. METHODOLOGY

This section briefly describes the research methods used to conduct this study, including research design, sample design, recruitment and field protocols, QA/QC, and analysis methods.

2.1 Research Design

For this study the research team used data collected from facilities to estimate hours of use at a facility and space-type level. Data was collected during two waves of metering. The first wave, from January to April 2014, gathered preliminary hours-of-use data but did not include any peak period measurements. The second wave, from April to August 2014, will include measurements from the peak demand period and will be used to refine hours-of-use and coincidence factors on a facility and space type level. In addition, the research team also used data collected during metering for the lighting controls study for this study.

The research team recruited participants for on-site metering from randomly selected Consumers Energy and DTE Energy customer samples to collect lighting hours-of-use, facility operating hours, type and wattage of fixtures, and peak coincidence factors for different facility types. The data collected is summarized in Table 2-1.

Table 2-1. Data Collected

Data Type	Data Collection Method ^a
Lighting Hours-of-Use	Metering
Peak Coincidence Factors	Metering
Facility Operating Hours	Field Technician Report
Inventory of Space Types	Field Technician Report
Type, Number, and Nominal Wattage of Lighting Equipment	Field Technician Report
Heating and Cooling Equipment Specifications and Usage	Field Technician Report
Facility Distribution	Incidence Study
a. Timing notes: The Incidence Study was conducted in conjunction with recruitment for the metering study. The Field Technician Report is based on data collected during the on-site visits. The metering data are from meters installed during the on-site visits.	

2.2 Sample Design

The team developed the sample frame for this study from comprehensive C&I customer population files provided by Consumers Energy and DTE Energy.

Overall, 180 C&I facilities were randomly selected from the sample frame and recruited to participate in the two waves of lighting metering for this study. With these 180 facilities, the sample includes 3,248 inventoried spaces and 1,360 metered observations of spaces.⁶

Table 2-2. Participating Facilities by Facility Type and Utility

Facility Type	CE		DTE		Total	
	Count	%	Count	%	Count	%
Apartments	8	8%	1	1%	9	5%
Assembly	7	7%	3	4%	10	6%
Industry	10	9%	2	3%	12	7%
Lodging	1	1%	0	0%	1	1%
Medical	5	5%	4	5%	9	5%
Office	19	18%	12	16%	31	17%
Other	10	9%	7	9%	17	9%
Restaurant	6	6%	3	4%	9	5%
Retail	29	27%	39	53%	68	38%
School (K-12)	5	5%	1	1%	6	3%
Warehouse	6	6%	2	3%	8	4%
Total	106	100%	74	100%	180	100%

While these facilities are intended to be representative, participants must self-select into the study through recruitment. Therefore, there is a possibility of sample bias. The most likely places for sample bias are:

- Industry:** The distribution of Michigan industrial facilities may not follow that of the participants. Out of 12 industrial facilities agreeing to participate in this study, all are light industry, and only one is a multiple shift facility. Without additional data from “heavy” industry sites, the research team is unable to determine the degree of this possible bias or correct for it. Recent program evaluations in Michigan have shown an average HOU for multiple shift industrial sites that is more than double what was observed in this study.⁷ Given this high degree of variation among industrial facilities, the evaluation team recommends that these facilities continue to complete projects based on custom incentives.
- Office:** The distribution of Michigan office facilities may not follow that of the participants. The 31 office facilities in the study had an average size of just over 4,000 square feet. This is substantially below the national average for office space. However, the research team’s

⁶ There were an average of 5.9 different space types per facility.

⁷ Conversation with Navigant Consulting regarding custom program evaluation results.

analysis of the available data on office space in Michigan indicates that our sample is likely representative of the population of offices in the state. This report describes this analysis in more detail in the Descriptive Statistics section.

2.3 Study Recruitment

The research team contacted customers by telephone to recruit them for this study. Customers were randomly contacted from the sample frames until the quota for each utility stratum in the sample design was filled and the research team attempted five contacts with each customer before the customer was dropped from the sample frame.

Recruiting for this hours-of-use study was broken up into two parts: winter and summer. The research team recruited 180 metering participants for the winter metering period. Most of these participants chose to remain in the study group for summer metering; two chose not to remain. The team recruited an additional two sites to install for summer metering.

The scripts for the recruitment telephone calls were developed and included in the study protocols manual (separate document). The scripts were designed to: (1) identify the most appropriate individual at the customer site, (2) determine eligibility for the study, (3) confirm contact information and facility address, (3) collect information on facility type, and (4) schedule an on-site visit for equipment inventory and logger installation.

The research team collected information on facility type from non-participants (customers who were contacted and declined to participate) in order to inform the Incidence Study on facility type. One significant unknown among the Michigan C&I population is the distribution of facility types; without facility type distributions, it is impossible to estimate actual precision of the study results. To gain better insight into the actual distribution of facility types throughout the Consumers Energy and DTE Energy service areas, the research team embedded this incidence study within the recruitment effort.

The on-site visits were typically scheduled into two- to four-hour time slots depending on facility size, and the recruiter made every possible effort to work with the customer to schedule a convenient time for the visit. In some circumstances, this required adapting time slots or scheduling a customer across multiple time slots. The recruiter also attempted to schedule on-site visits to maximize the number of sites visited by the field technicians each day.

2.4 Field Protocols

The initial on-site visit was comprised of a brief survey, a comprehensive facility lighting and space type inventory, and the installation of the logging equipment. The lighting inventory survey was used to determine the total number and types of lighting fixtures, usage categories, typical hours-of-use, and operating schedules for each space in the facility covered in the study. The customer was interviewed in order to determine any fixture details that could not be inspected.

The field technician used the lighting and space type inventory to determine which lighting could have loggers installed. Spaces were randomly selected from the eligible lighting to be logged.

For this study, the field technicians used Hobo UX-90-002 and U12-012 loggers. The UX90-002 logger is a light on/off state logger that registers a change in state based on observed ambient light levels and a user-adjustable sensitivity level. The U12-012 logger is a light intensity (footcandle) logger. The U12-012 logger records the measured light level (footcandles) at a user-defined interval. The field technicians installed Hobo U12-012 loggers in locations that are expected to have a greater variance in ambient light level conditions, such as rooms with large windows or multiple independent light sources. Additionally, U12-012 loggers typically were installed in locations with dual-level lighting or dimming capability.

2.5 QA/QC

The evaluation team reviewed the logger, facility, and space for any missing data. Data were reviewed for completeness, consistency, and reasonableness. Ultimately, data from 93 of the 1,360 participant loggers were dropped because of “bad” logger data.

2.6 Analysis Methods

Descriptive statistics are computed and presented to describe the sample of facilities included in the study. For all computed results, the research team has summarized the data at the space type (within facility types), facility type, as well as overall using appropriate weighting. Weighting methods to the facility-type level are described in Appendix A. Results are presented in terms of counts, percentages, means, and standard deviations.

The primary metrics analyzed are:

- Hours of Use
- Peak Coincidence Factor
- Lighting Equipment Inventory
- Heating and Cooling Equipment Specifications and Usage

Hours of Use

Average annual HOU were calculated from metered data. Data from individual loggers was averaged across week and weekend days for which the logger collected data so each logger/space is represented in an estimated annual HOU value. The team aggregated logger level estimates of annual HOU to the facility-type level. Average annual HOU are reported by facility type with a 90% confidence interval.

Peak Coincidence Factor

The peak coincidence period for this study is defined as 3PM to 6PM on non-holiday weekdays during the three consecutive hottest days in July in accordance with the utilities’ definition of peak. The peak coincidence factor is defined as the percentage of peak period that a light is on. For each logger, the peak coincident factor is computed as the average across all weekdays collected and adjusted based on reported facility closures.

It is important to emphasize that the first metering period for this study does not coincide with the utilities’ peak period – this first wave occurs in the winter and spring, while peak period is in the summer. As such, the research team provides *preliminary* estimates of peak coincidence for the

2015 MEMD Update. For these preliminary estimates, the research team uses the metered data to estimate peak coincidence. The approach for estimating peak coincidence involves two steps: (1) creation of weekday and weekend profiles based on the metered data and (2) calculating the coincidence factor (CF) based on the modeled *weekday* profile based on reported facility operation. These resulting modeled values were then converted to facility-type CF. Preliminary CF are reported by facility type with a 90% confidence interval.

The second metering period will occur during the summer peak period. Metering data from this period will coincide with the utilities' peak period. As such, the research team will provide an updated estimate of peak coincidence based on these data. The research team will develop profiles of lighting use by hour to identify the portion of C&I lighting that is in use during the summer peak period.

Lighting Equipment Inventory

The lighting equipment of Wave 1 participants was inventoried through a comprehensive survey of each facility's type, number and nominal wattage of installed lighting. Lighting equipment is tabulated and reported by space type.

Heating and Cooling Equipment Specifications and Usage

This study collected information on facility HVAC equipment of Wave 1 participants, to begin to provide some insights into this issue. HVAC equipment was not be metered as part of this study, only observed. To-date, comprehensive information on the potential interactions of lighting and HVAC has not been conducted in Michigan. The information collected through this study is summarized by facility type.

Incorporating Lighting Controls Study

Last year, this team conducted a metering study to determine the difference in lighting HOU and CF for controlled and non-controlled lighting.⁸ That metering study included HOU and CF estimates for 3,224 spaces in School, Office, and Industrial Warehouse spaces.

⁸ Commercial Lighting Controls Metering Study. Presentation dated June 18, 2013. Retrieved from: http://www.dleg.state.mi.us/mpsc/electric/workgroups/progdesign/lcs_ce_2013_06_16.pdf

3. DETAILED RESULTS

The following section provides the detailed results of the research team's analysis. This includes three categories of results:

1. Results from lighting loggers installed during Wave 1 combined with results from the Lighting Controls Study
2. Descriptive statistics for the sampled facilities and spaces in Wave 1, and
3. Data on heating and cooling system types were collected for the inventoried spaces during the on-site visits.

Descriptive statistics about the sampled facilities and spaces include the number of observations, the operating hours of the facilities, and the square footage of the facilities and spaces included in Wave 1 of the metering study. Hours-of-use and coincidence factor results from the Wave 1 loggers and Lighting Controls Study are presented by facility type.

3.1 Logger Results

This section documents the research team's analysis of the lighting logger data collection. The section first presents hours-of-use and preliminary coincidence factors by facility type and then by space type within facility type. All results in this section are weighted by wattage of metered space type and facility type.

Facility Lighting Hours of Use

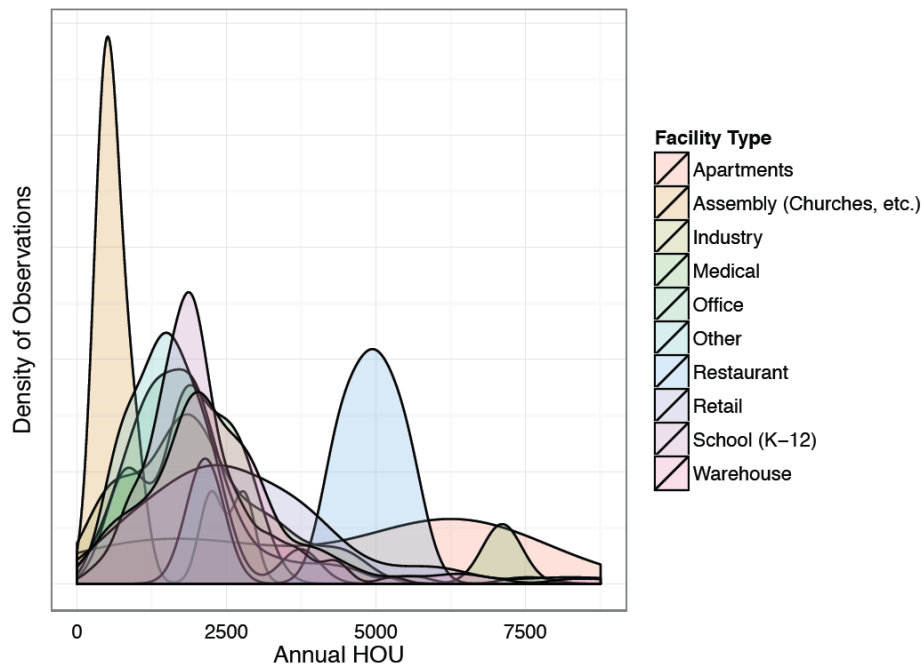
The research team summarized lighting hours-of-use (HOU) by facility type. The research team adjusted metered observations within each participating site to account for space type within a facility, using wattages of both metered and unmetered spaces. Table 3-1 shows the annual HOU and the lower and upper bounds of the 90% confidence interval. Lighting hours of use were aggregated to the total based on the distribution of facility types in the incidence study. The weighted mean HOU for these C&I facilities based only on the lighting study (Wave 1) is 2775.8 hours per year, while the weighted mean from the lighting controls study is 2167.7 hours per year. Combined, these studies provide an estimate of 2743.7 hours per year, with 4,491 observed spaces.

Table 3-1. Hours-of-Use by Facility Type

Facility Type	HOU	Std. Dev.	Loggers (n)	Relative Precision
Apartments	5,184	2325	55	10%
Assembly (Churches, etc.)	1,686	1171	99	12%
Industry	2,575	1205	86	8%
Lodging	1,515	NA	6	NA
Medical	3,222	2276	87	13%
Office	1,974	1113	1123	3%
Other	1,414	690	124	7%
Restaurant	4,046	1444	65	7%
Retail	2,830	1383	461	4%
School (K-12)	2,239	779	1276	2%
Warehouse	3,587	1980	1198	3%
Weighted Total	2,744	991.00	4,580	1%

These hours are distributed as shown in Figure 3-1. The figure shows the relative density of the distribution, much like a histogram except for relative rather than absolute proportions. Most of the facility hours of use are distributed normally; Apartments and Industry show a bimodal distribution.

Figure 3-1. Relative Distribution of Observed HOU by Facility Type



Facility Operating Hours

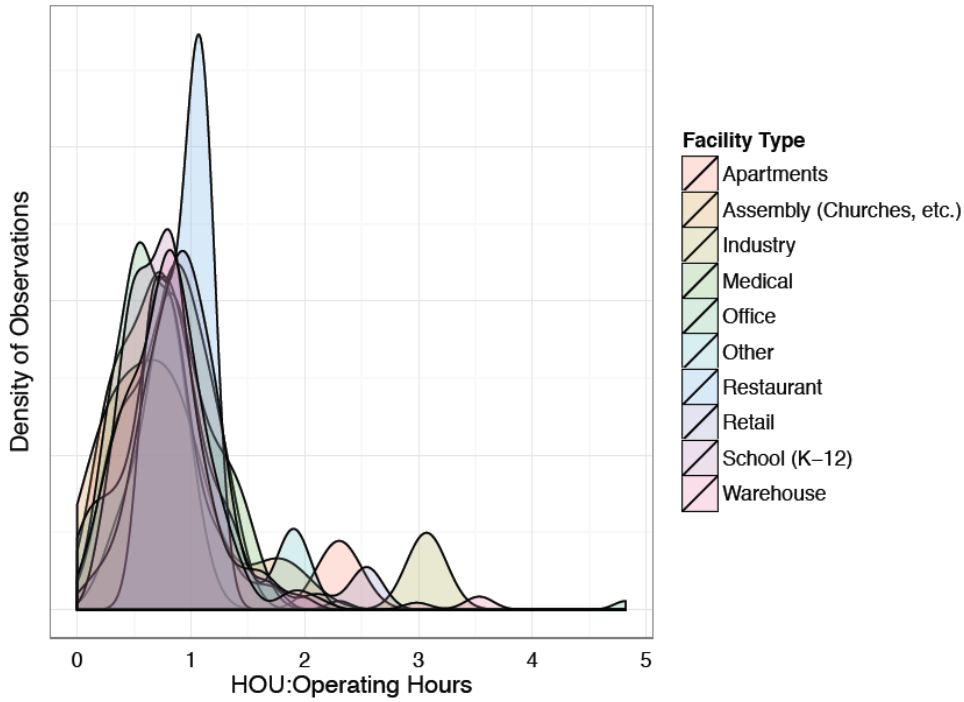
In addition, the team asked site contacts to describe the operating hours for the facilities. These operating hours were then compared to the observed lighting hours to develop a lighting-to-operating-hour ratio, as shown in Table 3-2. The evaluation team completed this analysis to better understand how the operating characteristics of a facility impact the lighting hours-of-use.

Table 3-2. Lighting to Operating Hours Ratio by Facility Type with 90% Confidence

Facility Type	Ratio of Lighting Hours-of-Use to Operating Hours	Std. Dev.	Loggers (n)	Relative Precision
Apartments	0.84	0.19	55	5%
Assembly	0.96	0.49	99	9%
Industry	0.96	0.30	86	6%
Lodging	1.43	NA	6	NA
Medical	0.55	0.45	87	14%
Office	0.79	0.42	1123	3%
Other	0.85	0.29	124	5%
Restaurant	0.85	0.51	65	12%
Retail	1.19	1.26	461	8%
School	0.72	0.36	1276	2%
Warehouse	0.78	0.47	1198	3%
Weighted Total	0.95	0.23	4,580	1%

These ratios are distributed as shown in Figure 3-2. The figure shows the density of the distribution, much like a histogram except for relative rather than absolute proportions. Most of the observations show lighting operating less than the facility operating hours. However, there are a few outliers, notably “other” facilities, apartments, retail locations, and industrial facilities.

Figure 3-2. Distribution of Lighting to Operating Hours Ratio by Facility Type



Preliminary Facility Coincidence Factors

The coincidence factors used in this report are defined as the percentage of time that a light is on during the peak period of weekdays between 3PM to 6PM and intended to be used to calculate peak demand savings. Note that this first wave of data does not include the actual summer peak period, but presents the preliminary modeled coincidence factors using the data collected to date. These values will be updated when complete Wave 2 data are available that includes the summer peak. The weighted mean CF for these C&I facilities based only on the lighting study (Wave 1) is 0.51, while it is 0.35 based only on the lighting controls study. Combined, these studies provide an estimate of 0.51, with 4,491 observed spaces.

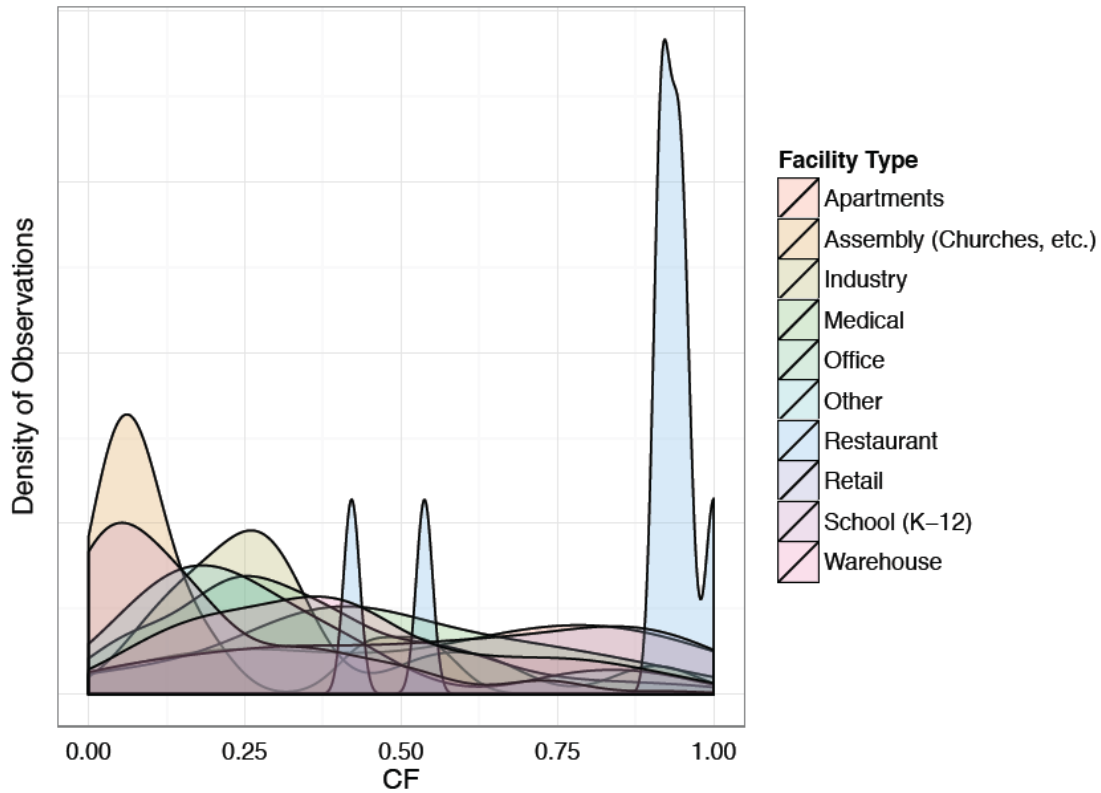
Preliminary coincidence factors are presented by facility type in Table 3-3.

Table 3-3. Preliminary Coincidence Factors by Facility Type

Facility Type	CF	Std. Dev.	Loggers (n)	Relative Precision
Apartments	0.71	0.27	55	8%
Assembly (Churches, etc.)	0.28	0.22	99	13%
Industry	0.45	0.29	86	11%
Lodging	0.17	NA	6	NA
Medical	0.59	0.26	87	8%
Office	0.35	0.20	1123	3%
Other	0.27	0.18	124	10%
Restaurant	0.78	0.25	65	6%
Retail	0.61	0.29	461	4%
School (K-12)	0.19	0.17	1276	4%
Warehouse	0.52	0.30	1198	3%
Weighted Total	0.51	0.18	4,580	1%

These coincidence factor values are distributed as shown in Figure 3-3 and are much more widely distributed than the estimates for HOU. The Wave 2 metering data will likely improve the precision of these estimates.

Figure 3-3. Distribution of Observed CF by Facility Type



Space Hours of Use

The research team summarized hours-of-use (HOU) by space type within facility types, as shown in Table 3-4. Some spaces are particularly low-use spaces, such as classroom spaces in “Other” facilities and gym spaces in Assembly facilities. For clarity, individual estimates are highlighted to indicate their value in relation to other values within the same facility type. That is, high HOU estimates within a facility are shaded green while low estimates are shaded red.

Table 3-4 Hours-of-Use by Space Type by Facility Type

Space Type	Facility Type										
	Apartments	Assembly	Industry	Lodging	Medical	Office	Other	Restaurant	Retail	School (K-12)	Warehouse
Assembly	4,890	1,064	NA	NA	NA	NA	899	NA	NA	NA	NA
Break Room	NA	884	1,257	NA	1,200	1,829	1,682	NA	1,802	1,303	2,918
Cafeteria	NA	375	NA	NA	NA	NA	NA	NA	NA	2,356	1,775
Classroom	NA	596	NA	NA	NA	NA	172	NA	4,842	1,429	NA
Conference	4,035	488	1,671	NA	675	971	261	NA	1,018	1,221	1,277
Dining	1,448	NA	NA	NA	NA	NA	1,758	4,452	NA	NA	NA
Equipment	NA	707	780	NA	975	2,064	1,610	1,324	2,034	NA	NA
Gym	563	101	NA	NA	NA	NA	1,406	NA	6,566	2,545	NA
Hallway	8,528	1,424	2,995	NA	3,778	1,914	2,098	4,896	2,262	3,598	2,483
Kitchen	2,329	1,308	1,936	NA	3,818	2,037	308	5,081	1,737	1,626	1,925
Library/CPU	NA	1,782	NA	NA	NA	NA	NA	NA	NA	1,767	NA
Office (Closed)	1,929	678	1,620	NA	1,291	1,671	1,575	4,683	2,449	1,444	1,994
Office (Open)	3,020	2,734	2,334	8,760	2,455	2,378	2,223	NA	3,417	2,338	2,758
Other	4,366	2,213	1,215	NA	2,523	2,550	1,853	NA	3,263	2,111	2,202
Production	NA	NA	2,959	NA	NA	1,972	NA	NA	2,897	NA	3,351
Restroom	38	873	431	267	685	1,212	1,679	3,212	587	1,515	1,140
Retail	NA	3,184	2,632	NA	2,716	3,558	NA	NA	2,825	NA	NA
Storage	1,904	401	927	17	984	992	1,325	3,077	1,801	1,420	1,516
Warehouse	NA	NA	2,195	NA	NA	1,661	1,945	NA	2,550	NA	2,295

Preliminary Space Coincidence Factors

The research team summarized coincidence factors by space type within facility types, as shown in Table 3-5. The coincidence factors used in this report are defined as the percentage of time that a light is on during the peak period of weekdays between 3PM to 6PM and intended to be used to calculate peak demand savings. Note that this first wave of data does not include the actual summer peak period, but presents the preliminary modeled coincidence factors using the data collected to date. These values will be updated when complete Wave 2 data are available that includes the summer peak. For clarity, individual estimates are highlighted to indicate their value in relation to other values within the same facility type. That is, high estimates within a facility are shaded green while low estimates are shaded red.

Table 3-5 Preliminary Coincidence Factors, by Space Type

Space Type	Facility Type										
	Apartments	Assembly	Industry	Lodging	Medical	Office	Other	Restaurant	Retail	School (K-12)	Warehouse
Assembly	0.62	0.14	NA	NA	NA	NA	0.18	NA	NA	NA	NA
Break Room	NA	0.21	0.20	NA	0.24	0.38	0.25	NA	0.39	0.06	0.49
Cafeteria	NA	0.07	NA	NA	NA	NA	NA	NA	NA	0.22	0.21
Classroom	NA	0.05	NA	NA	NA	NA	0.12	NA	0.81	0.12	NA
Conference	0.66	0.06	0.32	NA	0.06	0.19	0.04	NA	0.25	0.12	0.25
Dining	0.17	NA	NA	NA	NA	NA	0.33	0.88	NA	NA	NA
Equipment	NA	0.06	0.09	NA	0.26	0.36	0.33	0.09	0.37	NA	NA
Gym	0.18	0.00	NA	NA	NA	NA	0.88	NA	0.89	0.21	NA
Hallway	0.98	0.27	0.58	NA	0.75	0.33	0.44	0.93	0.51	0.35	0.41
Kitchen	0.37	0.21	0.44	NA	0.86	0.32	0.03	0.99	0.42	0.12	0.35
Library/CPU	NA	0.20	NA	NA	NA	NA	NA	NA	NA	0.12	NA
Office (Closed)	0.48	0.11	0.25	NA	0.31	0.29	0.27	0.92	0.51	0.13	0.35
Office (Open)	0.68	0.54	0.37	1.00	0.54	0.44	0.45	NA	0.60	0.20	0.46
Other	0.56	0.44	0.31	NA	0.48	0.44	0.16	NA	0.67	0.28	0.41
Production	NA	NA	0.42	NA	NA	0.42	NA	NA	0.70	NA	0.48
Restroom	0.01	0.16	0.06	0.03	0.15	0.21	0.29	0.60	0.11	0.12	0.21
Retail	NA	0.35	0.36	NA	0.42	0.70	NA	NA	0.66	NA	NA
Storage	0.49	0.06	0.10	0.00	0.15	0.13	0.26	0.51	0.40	0.12	0.24
Warehouse	NA	NA	0.27	NA	NA	0.30	0.23	NA	0.52	NA	0.38

Lighting Equipment Inventory

The research team inventoried the lighting equipment in each space, by lighting type, wattage, and controls. The inventories included metered and non-metered lighting – all lighting in the facilities. The research found that the majority of inventoried lighting across space types was found to be fluorescent or incandescent, as shown in Table 3-6.

Table 3-6. Lighting Equipment Distribution for Each Space Type in Wave 1

Space Type	CFL	Fluorescent	HID	Incandescent	Induction	LED	Other	Total
Assembly	19.7%	39.3%	--	40.5%	--	0.4%	--	100%
Break Room	1.6%	93.6%	--	4.8%	--	--	--	100%
Cafeteria	8.5%	83.7%	6.8%	1.1%	--	--	--	100%
Classroom	0.4%	99.6%	--	0.1%	--	--	--	100%
Conference	1.4%	84.9%	--	13.7%	--	--	--	100%
Dining	4.2%	50.9%	--	33.1%	--	6.1%	5.6%	100%
Equipment	1.0%	73.4%	8.5%	17.2%	--	0.0%	0.0%	100%
Gym	0.2%	20.6%	79.2%	--	--	--	--	100%
Hallway	9.2%	84.3%	0.5%	4.9%	0.0%	0.4%	0.6%	100%
Kitchen	1.9%	96.6%	1.2%	--	--	0.3%	--	100%
Library/CPU	6.3%	92.8%	--	0.9%	--	--	--	100%
Office (Closed)	2.0%	95.2%	--	2.8%	--	--	--	100%
Office (Open)	3.0%	92.8%	0.8%	3.3%	--	0.0%	--	100%
Other	2.5%	52.6%	31.4%	2.9%	--	9.8%	0.8%	100%
Production	--	66.9%	33.1%	--	--	--	--	100%
Restroom	8.2%	72.0%	--	19.6%	--	0.1%	--	100%
Retail	2.3%	75.7%	--	10.0%	--	0.3%	11.6%	100%
Storage	1.8%	73.7%	17.4%	7.0%	--	0.1%	--	100%
Warehouse	0.5%	72.2%	26.9%	0.1%	--	--	0.4%	100%

Most of the lighting inventoried by the research team did not have lighting controls. Warehouse spaces and restrooms were most likely to have occupancy controls, as shown in Table 3-7. Note that these are identified in the field, and thus, the estimated values for HOU and CF include the effect of lighting controls.

Table 3-7. Portion of Lighting Wattage with Lighting Controls by Space Type in Wave 1

Space Type	No Control	Occupancy Sensor
Assembly	97.9%	2.1%
Break Room	97.0%	3.0%
Cafeteria	98.2%	1.8%
Classroom	98.9%	1.1%
Conference	99.7%	0.3%
Dining	100.0%	--
Equipment	99.3%	0.7%
Gym	100.0%	--
Hallway	98.6%	1.4%
Kitchen	95.1%	4.8%
Library/CPU	100.0%	--
Office (Closed)	98.3%	1.7%
Office (Open)	97.7%	2.3%
Other	99.9%	0.1%
Production	98.8%	1.1%
Restroom	88.9%	11.1%
Retail	100.0%	--
Storage	98.7%	1.3%
Warehouse	64.9%	35.1%

3.2 Descriptive Statistics

This section provides descriptive statistics for participant facility types, incidence study facility types, the number of loggers per facility type, the space types metered, and facility square footage for Wave 1. These data are provided in order to assess the representativeness of the study sample.

Participant Facility Types

The research team recruited participants for on-site metering from randomly selected Consumers Energy and DTE Energy customer samples to collect lighting hours-of-use, facility operating hours, type and wattage of fixtures, and peak coincidence factors for different facility types⁹. Table 3-8 shows the facility types of the first wave of metering study participants.

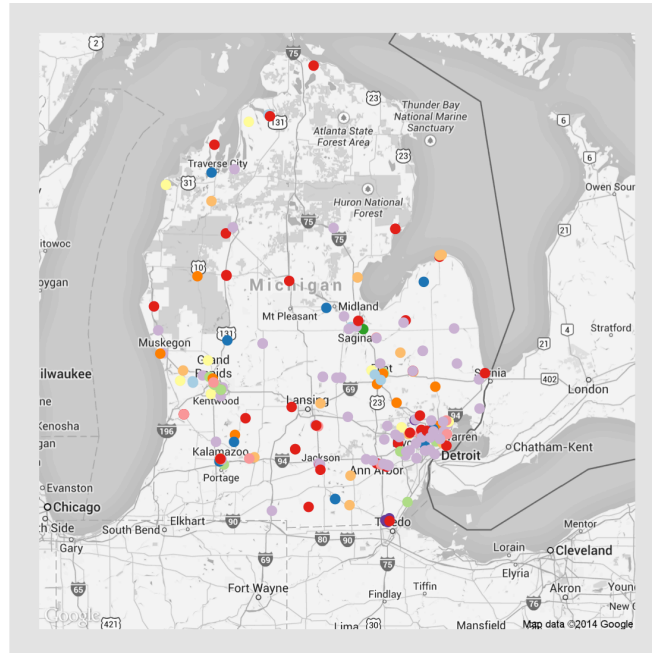
Table 3-8. Facility Types Included in Metering Study, Wave 1

Facility Type	Count	Percent
Apartments	9	5%
Assembly (Churches, etc.)	10	6%
Industry	12	7%
Lodging	1	1%
Medical	9	5%
Office	31	17%
Other	17	9%
Restaurant	9	5%
Retail	68	38%
School (K-12)	6	3%
Warehouse	8	4%
Total	180	100%

⁹ Our sample included general C&I rate customers only and as such, may not be applicable to the largest industrial customers. However, in general, these customers most often complete self-directed or custom projects.

As discussed above, the sample for this study was selected from Consumers Energy and DTE Energy customer records. As part of our recruiting effort, we recruited facilities located throughout the Lower Peninsula, as shown in Figure 3-4 below.

Figure 3-4 Locations of Facilities in the Metering Study, Wave 1



Incidence Study Facility Types

The study included a facility incidence study; the distributions from this study are shown in Table 3-9. This was a random sample of the population, and the results are expected to be representative of the distribution of facility types in Michigan. The portion of facilities is used to weight the overall averages for HOU and CF.

Table 3-9. Facility Types as Reported by All Facilities through Incidence Study

Facility Type	Count	Percent
Apartments	53	6%
Assembly (Churches, etc.)	61	7%
Industry	65	7%
Lodging	9	1%
Medical	47	5%
Office	211	24%
Other/None of the above	59	7%
Restaurant	47	5%
Retail	288	33%
School (College/University)	1	<1%
School (K-12)	20	2%
Warehouse	25	3%
Total	886	100%
Refused to Provide	115	--

Loggers by Facility Type

Lighting loggers were installed at 180 facilities for the first metering period of this study. Altogether the research team installed 1,360 loggers with an average of 7.6 loggers per facility (Table 3-10).

Table 3-10. Loggers by Facility Type in Wave 1

Facility Type	Loggers	Percent
Apartments	55	4%
Assembly (Churches, etc.)	99	7%
Industry	86	6%
Lodging	6	0%
Medical	87	6%
Office	266	20%
Other	127	9%
Restaurant	65	5%
Retail	461	34%
School (K-12)	60	4%
Warehouse	48	4%
Total	1,360	100%

The lighting controls study includes an additional 3,224 loggers installed at 377 facilities with an average of 8.6 loggers per facility as shown in **Table 3-11**.

Table 3-11. Loggers by Facility Type in Lighting Controls Data

Facility Type	Loggers	Percent
Office	857	27%
School (K-12)	1,216	38%
Warehouse	1,151	36%
Total	3,224	100%

Space Types

Table 3-12 shows the space types that were observed in the Wave 1 study. Across facilities types, the most commonly observed spaces were closed offices, restrooms, and storage. The space types accounting for the most lighting wattage are classrooms and other.

Table 3-12. Metered Space Types across All Facilities in Wave 1

Space Type	Number of Spaces	Percent of Spaces	Lighting Wattage	Percent of Lighting Wattage	Loggers	Percent of Loggers
Assembly	80	2.46%	55,807	2.95%	34	2.5%
Break Room	63	1.94%	21,073	1.11%	45	3.3%
Cafeteria	20	0.62%	29,668	1.57%	7	0.5%
Classroom	297	9.15%	344,169	18.17%	47	3.5%
Conference	95	2.93%	47,895	2.53%	43	3.2%
Dining	40	1.23%	13,652	0.72%	22	1.6%
Equipment	125	3.85%	56,620	2.99%	58	4.3%
Gym	21	0.65%	90,675	4.79%	10	0.7%
Hallway	342	10.54%	155,764	8.22%	112	8.2%
Kitchen	68	2.09%	24,276	1.28%	45	3.3%
Library/CPU	19	0.59%	26,877	1.42%	6	0.4%
Office (Closed)	488	15.03%	133,836	7.07%	210	15.4%
Office (Open)	208	6.41%	152,775	8.07%	128	9.4%
Other	288	8.87%	255,062	13.47%	125	9.2%
Production	58	1.79%	82,252	4.34%	35	2.6%
Restroom	435	13.40%	54,208	2.86%	175	12.9%
Retail	128	3.94%	72,166	3.81%	63	4.6%
Storage	385	11.86%	131,200	6.93%	142	10.4%
Warehouse	86	2.65%	145,830	7.70%	53	3.9%
Total	3246	100.0%	1,893,805	100%	1,360	100%

Square Footage

The research team also collected information on facility square footage during the installation of loggers. Table 3-13 shows the square footage by facility type, for the 134 sites where this information was available. For the remaining sites, facility contacts were not able to provide the size of the facility.

Square footage is not used in this study; however, it is useful for consideration of how the sample relates to the population. Compared to the average square footage for all commercial buildings of those types, the office and retail facilities in the study are small; the Buildings Energy Data

Book estimates an average of 14,800 square feet on average for offices and 9,700 square feet for retail facilities (non-mall).¹⁰ Also, the warehouse facilities in the study are larger than the national average of 16,900 square feet. These differences could indicate a difference between Michigan and the national average or they could indicate sample bias towards smaller offices and retail facilities and larger warehouse spaces. In our experience, larger office and retail facilities are more difficult to recruit for studies, as the key site contacts are difficult to reach. Larger offices and retail spaces may be open longer hours, thus indicating the potential for estimates in this study to be conservative.

Table 3-13. Square Footage by Facility Type in Wave 1

Facility Type	Count	Mean	S.D.
Apartments	9	3,644	3,880
Assembly (e.g., churches)	7	36,000	67,863
Industry	9	14,759	18,528
Medical	7	3,986	3,040
Office	24	4,337	5,700
Other	11	8,059	12,816
Restaurant	6	3,029	943
Retail	52	5,857	8,088
School (K-12)	1	38,000	NA
Warehouse	8	29,288	63,371
Total	134	14,696	23,845

As mentioned earlier, the square footage of the average office space is below the national average. To confirm that our sample was representative, the research team compared our sample against several data sources. These included data from DTE Energy's customer database, Consumers Energy's customer database, and the ENERGY STAR Building Performance Database. All three of these sources confirmed that Michigan offices are smaller than the national average and provided estimate of office square footage in-line with our sample. In addition, analysis of HOU and square footage data from our research indicates a weak and statistically not significant relationship, suggesting that even if our sample is not representative of larger offices, this would not bias our HOU estimates.

¹⁰ Department of Energy. 2011. Buildings Energy Data Book. Table 3.2.8. Retrieved from: <http://buildingsdatabook.eren.doe.gov/DataBooks.aspx>

3.3 Heating and Cooling Equipment

Finally, the research team collected data on heating and cooling system types for the inventoried spaces during the on-site visits for Wave 1 (3,249 spaces). The distribution of heating systems is summarized in Table 3-14. The study indicates that more than half of the inventoried sites use some type of gas furnace heating system.

Table 3-14. Heating Type Inventory by Space in Wave 1

Heating Type	Number of Spaces	Percent
Boiler (Hot Water)	631	19.4%
Boiler (Steam)	170	5.2%
Electric Resistance	24	0.7%
Gas Furnace	1,584	48.8%
Gas Furnace (Condensing)	171	5.3%
Heat Pump (Air)	3	0.1%
Heat Pump (Geothermal)	174	5.4%
None	70	2.2%
Other	112	3.4%
Radiant	11	0.3%
Unknown	299	9.2%
Total	3,249	100.0%

The research team also recorded heating equipment efficiency during the on-sites. Table 3-15 presents the recorded system efficiency values by system type across 2,768 spaces where the information was available.

Table 3-15. Recorded Heating Equipment Efficiency (n=2,768)

Heating Type	Value	Units	Count
Boiler Hot Water	0.80	-	631
Boiler Steam	0.75	-	170
Electric Resistance	1.00	-	24
Gas Furnace	0.80	-	1,584
Gas Furnace Condensing	0.93	-	171
Heat Pump Air	3.10	COP	3
Heat Pump Geothermal	3.60	COP	174
Radiant	0.80	-	11

Similarly, the research team collected data on cooling system types during the on-sites. The distribution of cooling systems is summarized in **Table 3-16**. Just over half of the inventoried sites use direct expansion (DX) cooling.

Table 3-16. Cooling Type Inventory by Space

Cooling Type	Number of Spaces	Percent
Chiller Air Cooled	47	1.4%
Chiller Centrifugal	123	3.8%
Chiller Scroll	38	1.2%
Direct Expansion	1,710	52.6%
Heat Pump Air	3	0.1%
Heat Pump Geo	175	5.4%
None	771	23.7%
Other	71	2.2%
Unknown	311	9.6%
Total	3,249	100.0%

Finally, the research team recorded the cooling equipment efficiency during the on-sites. Table 3-17 presents the recorded system efficiency by system type across 784 spaces where the information was available.

Table 3-17. Recorded Cooling Equipment Efficiency (n=784)

Cooling Type	Value	Units	Count
Chiller Air Cooled	4.50	COP	25
Chiller Centrifugal	4.90	COP	123
Chiller Scroll	4.50	COP	38
Direct Expansion*	9.29	EER	246
Direct Expansion*	11.90	SEER	309
Heat Pump Air	9.10	EER	3
Heat Pump Geothermal	-	-	-
*For Direct Expansion, efficiencies were recorded as either EER or SEER. They are reported according to recorded units.			

APPENDIX A: FACILITY-TYPE WEIGHTING

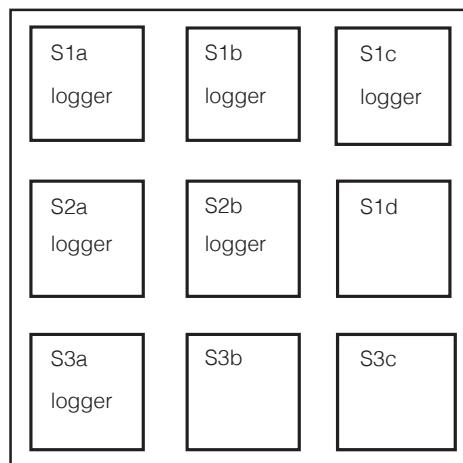
Objective:

Determine Facility Type mean (μ) for HOU and CF, using data from metered subset of spaces within facilities

Given:

- Facility Type, F
 - F1a, F1b are two facilities of the same facility type F1 (see diagram)
- Space Type, S
 - S1, S2, S3, S4 are spaces of different types; S1a and S1b are different spaces of the same type (see diagram)
 - A space of a given space type may or may not be metered (“logger” in diagram)

Facility 1a



Facility 1b



Summary of approach:

To extrapolate to the population of C&I facilities of a given facility type, the evaluation team weighted logger data values to account for how much of a facility’s space type is represented by the logger (steps 1,2 below), how much of the facility is represented by each space type (step 3), and how much each facility type is represented by each facility (step 4).

1. For each Facility Space Type in a given facility (F1a), calculate metered space type watts and total space type watts
 - a. $Metered(S1watts) = S1a,watts + S1b,watts + S1c,watts$
 - b. $Total(S1watts) = S1a,watts + S1b,watts + S1c,watts + S1d,watts$
2. For each **Facility Space Type** in a given facility (F1a), calculate the mean (μ) of the observed values (v) of HOU or CF where loggers were installed
 - a. $S1\mu = \frac{S1a,watts}{Metered(S1watts)} \times S1a,v + \frac{S1b,watts}{Metered(S1watts)} \times S1b,v + \frac{S1c,watts}{Metered(S1watts)} \times S1c,v$
 - b. $S2\mu = \frac{S2a,watts}{Metered(S2watts)} \times S2a,v + \frac{S2b,watts}{Metered(S2watts)} \times S2b,v$
 - c. $S3\mu = \frac{S3a,watts}{Metered(S3watts)} \times S3a,v$
3. For each **Facility (F1a)**, calculate total facility watts and facility mean (μ) of value (v) of HOU or CF

- a. $Total(F1a, watts) = Total(F1a, S1watts) + Total(F1a, S2watts) + Total(F1a, S3watts)$
- b. $F1a, \mu = \frac{Total(S1watts)}{Total(F1a, watts)} \times S1\mu + \frac{Total(S2watts)}{Total(F1a, watts)} \times S2\mu + \frac{Total(S3watts)}{Total(F1a, watts)} \times S3\mu$
4. For each **Facility Type (F1)**, calculate total facility type watts and mean (μ) of value (v) of HOU or CF
- a. $Total(F1watts) = F1a, watts + F1b, watts$
- b. $F1, \mu = \frac{F1a, watts}{Total(F1, watts)} \times F1a, \mu + \frac{F1b, watts}{Total(F1, watts)} \times F1b, \mu$