Technical Specification: Quantifying energy and emissions savings for lighting upgrades using pre and post measurements

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Foreword

This document has been prepared by the OpenEAC Alliance, a collaborative group of energy engineering and measurement and verification professionals focused on creating transparent and standardized methods to measure the environmental impacts of demand side interventions. These methodologies are designed to align with best practices and reflect input from industry experts. The OpenEAC Alliance aims to enhance accountability and consistency in documenting energy and carbon savings from distributed energy resources (DERs).

About the OpenEAC Alliance

The OpenEAC Alliance is an organization of professionals dedicated to standardizing the measurement and verification of DERs. By focusing on clarity and rigor, the Alliance aims to overcome challenges that have hindered the proper valuation of DERs for their climate benefits. Central to this effort is the Energy Attribute Certificate (EAC), a tool that provides a detailed, auditable record of energy project impacts, including attributes such as type, timing, and location of energy production or reduction.

The OpenEAC Alliance collaborates to develop open-source methodologies, ensuring that DER projects can be accurately measured, verified, and valued in a way that promotes trust and drives market adoption.

Introduction

The purpose of this methodology is to estimate the energy and related carbon impact of lighting projects in commercial buildings. Specifically, the methodology looks to measure the number of hourly useful EACs, avoided emissions, and the generated grid emissions from installing more efficient light fixtures with controls.

Scope

To quantify energy savings achieved through the replacement of existing lighting systems with energy-efficient LED fixtures. The project will involve data collection, energy savings calculation, and measurement and verification (M&V) to ensure the accuracy and persistence of reported savings.

Normative References

The following documents are essential for the application of this specification. For references with no date, the latest edition applies:

- **ASHRAE Guideline 14-2022**: *Measurement of Energy, Demand, and Water Savings*
- Includes statistical methods for verifying energy savings and calculating sample sizes in the context of energy efficiency projects.
- **IPMVP (International Performance Measurement and Verification Protocol)**: *Concepts and Options for Determining Energy and Water Savings, Volume 1*
- ***ANSI/IES RP-29-20****: Recommended Practice for Lighting for Industrial and Commercial Facilities (Illuminating Engineering Society)*

Terms and Definitions

- **Fixture:** A complete lighting unit consisting of a lamp or lamps (or LED module) and components designed to distribute light, position and protect the lamps, and connect them to the power supply.
- **Line-by-Line Audit:** A detailed inventory of lighting systems, documenting individual fixture characteristics such as location, type, wattage, and hours of operation.
- $W_{pre}[i]$: pre-retrofit wattage for each lighting fixture *i* in the line-by-line audit
- $W_{post}[i]$: post-retrofit wattage for each lighting fixture *i* in the line-by-line audit
- **EFLH**: effective full load-hours are a sort of compound unit like watt-hours, they are a proxy for energy consumed by a lighting fixture, in that they are the # of hours over a period of time assuming the lighting load is at full capacity. EFLH/hour is similar to Wh/h, where it can be seen either as a percent of the time the lights are at full load or a percent of the load that was on for that hour (similar to thinking of Wh/h as energy consumed within the hour or average wattage over the course of the hour). Since we will be using this term exclusively hourly, we can colloquially think of it as "% of lights turned on".

Data Requirement Definitions

- Line-by-Line Audit documenting all fixtures to be included in the analysis.
- For estimating the pre-retrofit EFLH, one of:
  - >1 day of Pre-Retrofit Measured Consumption Data
  - Citable simulated results of pre-retrofit annual EFLH for each lighting fixture i
- For the post-retrofit measurement data, one of:
  - Hourly measured reporting data that covers 100% of lighting fixtures

- Hourly measured reporting data that covers at least X% of lighting fixtures and one of:
  - A list of all lighting fixtures that are being measured so the total measured wattage is known
  - >= 1 month of minute-level measured reporting data for the X% of lighting fixtures that are measured, so that a static peak wattage analysis can be conducted.

Methodology

This methodology can be used for an individual light fixture or set of light fixtures depending on lighting consumption measurement constraints.

1. Decarbonization Impact Calculation

1.1. Sum the total power of the pre-retrofit and post-retrofit lighting fixtures based on the line-by-line audit

1.1.1. **:** $W_{pre} = \sum W_{pre}[i]$

1.1.2. $W_{post} = \sum W_{post}[i]$

1.2. Calculate the Post-Retrofit (Actual) Reporting Period EFLH and Consumption

1.2.1. If 100% of Post-Retrofit is Measured:

1.2.1.1. The total measured energy consumption timeseries represents the full reporting period.

1.2.1.2. $kWh_{reporting}(t) = kWh_{reporting,\,measured}(t)$

1.2.2. If < 100% of Post-Retrofit is measured:

1.2.2.1. *Assumption: The usage behavior of the measured fixtures is representative of that of all fixtures.*

1.2.2.2. Use the sampling method in **Appendix 1** to determine the minimum wattage of fixtures to be measured.

1.2.2.3. Calculate the $W_{post,measured}$ based on adding up the wattages of the lighting fixtures that are measured. If the specific fixtures being measured are not labeled, then use the Static Peak Wattage Analysis, described in section **2.1**.

1.3. Calculate Pre-Retrofit (Counterfactual) Reporting Period Consumption:

Consumption: To calculate the reporting period consumption, a model that can predict the EFLH for a given hour must be constructed.

1.3.1. If baseline period data is available,

1.3.1.1. If < 1 week is available: Use section **2.2.1** for matching to the reporting period.

1.3.1.2. Else if < 12 months of data available: Use section **2.2.2** for matching to the reporting period.

1.3.1.3. Else: Use section **2.2.3** for matching to the reporting period.

1.3.2. If baseline data is not available:

1.3.2.1. Calculate an EFLH adjustment to apply to the post-retrofit data.

1.3.2.1.1. Deemed per Lighting Fixture using Onsite Analysis

1.3.2.1.1.a. Based on the description for the pre-retrofit lighting fixtures, estimate the annual pre-retrofit EFLH.

1.3.2.1.1.b. Based on the annual pre-retrofit EFLH divide this by 8760 to get the average EFLHpre/hour.

1.3.2.1.1.c. Then, calculate the average EFLHpost/hour based on the EFLHpost,measured(t) timeseries.

1.3.2.1.1.d. Calculate the adjustment from the difference between the post and pre average EFLH/hour:

$$EFLH_{adjustment} = \overline{EFLH}_{pre} - \overline{EFLH}_{post}$$

1.3.2.1.1.e. Add this value to each element of the EFLHpost,measure(t) timeseries to get the pre-retrofit reporting period timeseries.

$$EFLH_{pre,\,reporting}(t) = EFLH_{adjustment} + EFLH_{post,\,reporting}(t)$$

1.3.2.1.2. Deemed By Average EFLH of similar buildings in NREL Comstock

1.3.2.1.2.a. Use the NREL ComStock database Warehouse building type and normalize the internal_lighting load in the baseline so that it gives a % of max, which will represent an 8760 EFLH loadshape. This loadshape can be used to predict the EFLH when given an hour of week and week number. Apply the EFLH model to each hour of the reporting period to get the $EFLH_{pre,\,reporting}(t)$.

1.3.2.2. If this process leads to any $EFLH_{pre,\,reporting}(t)$ values that are greater than 1, then a more complex apportionment of the $EFLH_{adjustment}$ will need to be conducted. This scenario will be addressed in a future version of this methodology.

1.3.2.3. Multiply the pre-retrofit EFLH reporting timeseries by the pre-retrofit total Wattage to get the counterfactual consumption time series: $kWh_{pre,\,reporting}(t) = EFLH_{pre,\,reporting}(t) * W_{pre}$

1.4. Calculate Electricity Savings

1.4.1. Subtract the counterfactual consumption time series by the measured energy consumption timeseries to calculate the energy savings timeseries:

$$kWh_{savings, reporting}(t) = kWh_{pre, reporting}(t) - kWh_{post, reporting}(t)$$

1.5. **Calculate Decarbonization Impact:** The decarbonization impact for a given hour is the avoided emissions minus the generated emissions for that hour.

1.5.1. Avoided Emissions: Match the electricity savings to the carbon intensity of the grid at that hour, following the guidelines here.

2. Other Helper Methods

2.1. Static Peak Wattage Analysis

2.1.1. Using the reporting period minute-level data, find the total maximum wattage consumed by the measured lighting fixtures. Use this as an estimate for $W_{post,measured}$.

2.1.2. The Static Peak Wattage analysis assumes that there is a minute within this subset of reporting period data where all of the lights are simultaneously on (and therefore the total wattage can be measured). This analysis is inherently conservative, as there may not be a minute where this takes place. This conservative approach means that the end savings may be lower than what they otherwise would be if the total measured Wattage was known.

2.1.3. Calculate the post-retrofit EFLH for each hour in the reporting period by dividing the energy consumed for that hour by the total wattage of the measured light fixtures:

$$EFLH_{post, reporting}(t) = kWh_{reporting, measured}(t)/W_{post,measured}$$

2.1.4. Then multiply this EFLH by the total post-retrofit wattage Wpost to estimate the total energy
consumption timeseries:

$$kWh_{post, reporting}(t) = EFLH_{post, reporting}(t) * W_{post}$$

2.2. Loadshape Time-Matching

2.2.1. Hour of Day: Calculate the average EFLH for each hour of the day (0-23) and match to a reporting period date time based on the hour.

2.2.2. Hour of Week, Month: Calculate the average EFLH for each hour of the week (0-167) for each month. Then apply this EFLH to the reporting period, matching on the hour of the week and month.

2.2.3. Hour of Day, Day of Week, ISO Week Number: Calculate the average EFLH or each hour of the year. Then apply this EFLH to the reporting period, matching on the hour of the week and week number of the year.

Appendix

Appendix 1: Lighting Fixture Minimum Sample Calculation

Sampling method:

- *n*: Wattage of Sampled Fixtures
- *N*: Total Wattage of Fixtures
- *Z*: The z-statistic for the desired level of confidence. Equal to 1.645 for a confidence level of 90%
- *CV*: assumed coefficient of variation (0.5)
- *P*: desired precision (10%)
- *n**: adjusted sample size (actual minimum sample fixtures)

Use the following formulas to determine the initial sample size and then adjust based on the population:

$$n = \frac{Z^2 * CV^2}{P^2}$$

$$n^* = \frac{N * n}{N + n}$$

This calculation results in the following minimum sample sizes based on total fixtures to achieve a 10% precision at 90% confidence:

A: Total Fixture Wattage Retrofit (N)	**B: Minimum Sample Fixture Wattage (n*)**
3	3
5	5
10	9
25	19
50	29
100	41
250	54
500	60
1000	64

2500	66
5000	67
≥7500	68