Measurement and Verification Guidelines for the Seattle City Light Energy Efficiency as a Service (EEaS) Pilot Program

Seattle City Light
Customer Energy Solutions

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TABLE OF CONTENTS

1. Overview

These guidelines describe the protocols and methods to be used by an independent, third-party Measurement and Verification (M&V) Consultant to measure energy savings in Seattle City Light (City Light)'s Energy Efficiency as a Service (EEaS) pilot program, which are the basis for EEaS service fees and PPA payments as described in the EEaS Program Manual.

The EEaS program intends to encourage deep energy savings through retrofits in existing buildings and high-performance design in new construction. For the purposes of this pilot, deep energy savings are defined as savings greater than 25% of annual consumption or Seattle Energy Code baseline achieved through the implementation of energy conservation measures (ECMs). The ECMs must directly affect multiple end-uses[1] in the participating building.

Energy savings resulting from improvements in building performance will be quantified at a whole-building level, using utility meters. For existing buildings participating in this program, the M&V Consultant will rely on this meter data and independent variables (such as weather and leased square footage) to estimate baseline energy consumption and performance-based savings. For new construction[2] buildings participating in this program, the M&V Consultant will rely on the Seattle Energy Code Section C401 and the energy model provided to the SDCI Code Official (C407.6) for baselining and meter data and independent variables to estimate energy savings in the performance period.

1.1. Purpose

This document describes the savings determination methodologies and clarifies the minimum statistical criteria and approaches to estimate whole-building energy savings for participants for each billing cycle[3] in the EEaS program. The M&V Consultant will estimate avoided energy use at a building-level for individual sites, rather than the portfolio-level.

These Guidelines do not intend to restate industry-standard M&V protocols, definitions, or formulas. Rather, the M&V Consultant should consult the applicable sections of the referenced protocols to perform calculations.

In the case of a lack of clear direction from the protocols relative to this pilot, City Light has clarified methodology approaches below.

1.2. Key Metrics

Seattle City Light has chosen to use an avoided energy use metric to calculate performance-based savings for the Energy Efficiency as a Service program:

- Avoided Energy Use[4] is the reduction in energy use that occurred in the performance period, relative to what would have occurred if the facility had been equipped and operated as it was in the baseline period, *but under performance period operating conditions*.
- For new construction, the difference between the Seattle Energy Code target energy use (C401) and the participant's actual energy use shall be considered the avoided energy use.

[1] Eligible end uses include lighting, envelope, HVAC, plug load, and domestic hot water.

[2] See glossary for a definition.

[3] In this document, we will be using billing cycle and monthly period interchangeably.

[4] ASHRAE Guidelines 14-2014

2. Existing Buildings

2.1. Protocol and Compliance

The M&V Consultant should largely follow the Whole Facility approach in ASHRAE Guidelines 14-2014, section 4 and 5.1, "Whole Building Prescriptive Path" to set the baseline for existing buildings and to calculate avoided energy use. In addition, the M&V Consultant shall document compliance with this methodology (see Section C)

Participant's adjusted baseline energy use and avoided energy use shall be expressed at a monthly billing period scale, regardless if the data interval is more frequent.

2.2. Measurement Boundary and Multiple Accounts

For buildings with multiple accounts or meters, at least 90% of the electricity use of the building must be on one account, as determined in the baseline year. The remaining electricity use would be considered outside of the measurement boundary of this program and does not need to be analyzed.

2.3. Non-Electric Fuels

Per Washington State law RCW 35.92.360, Seattle City Light cannot pay for "a conversion from one energy source to another."[5] In addition, Seattle City Light cannot provide monthly EEaS payments to the owner or EE Developer for any non-electric savings as Seattle City Light is not the utility provider for these fuels. Fossil fuels shall be monitored, but not quantified as avoided energy use savings, in the EEaS program.

To participate, owners must agree to not reduce electricity use by switching services that are delivered using electricity to delivery using gas, e.g. reducing electric heating by increasing gas heating, and agree to reduce electricity consumption by 25% or more. The primary concern is fuel-switching to increase payments to the EE Developer/Participant.

- The EE Developer/Participant must proactively report to City Light when non-electric fuel increases occur, but the M&V Consultant should also scan ENERGY STAR Portfolio Manager for any changes in non-electric fuel and flag fuel-switching events.
- Not all increase in gas consumption will result in the removal of a project from enrollment. For example, in the case of lighting conversion projects that cause interactive heating and cooling effects, the lighting conversion project will have a net benefit kBTU reduction (eliminating the heat load of the lights as well as saving lighting energy). However, the M&V Consultant should estimate natural gas fuel increases due to interactive effects using engineering calculations.[6]
- Significant increase in a service provided in the building without reduction in efficiency, such as cooking, shall not adversely impact the electric savings calculated by the M&V Consultant.
- On-site generation must be City Light sub-metered and removed from the avoided energy use of the Site by the M&V Consultant.

[5] RCW 35.92.360 states "Any financing authorized under this chapter shall only be used for conservation purposes in existing structures, and such financing shall not be used for any purpose which results in a conversion from one energy source to another."

[6] CES uses gas heating factors published by the 7th Power Plan, which average as a 1.4% increase in gas heating from lighting conversions.

2.4. Baseline Data

The participant site's baseline data shall be used to create a baseline model equation. The M&V Consultant should document data used to determine/calculate the baseline completely and accurately, including static and independent variables. The baseline and independent variables shall be derived based on:

- Historical utility data and fuel use information for the 12 months immediately prior to the capital project (derived from City Light and ENERGY STAR Portfolio Manager).
- M&V Consultant must use NOAA Boeing Field Weather data for the baseline.
- Leased square footage data (%).
- Floor area data (gross sf).
- Space use type information.
- Detailed description of all project-related activities, dates of project start and completion, and a description of the magnitude and duration of ECM savings, provided by the EE Developer and Participant to Seattle City Light.

2.5. Model Fitness

Among the possible baseline models, the M&V Consultant shall select the simplest model with the best R Squared and CV(RSME).

The final selected model shall be from ASHRAE Guideline 14-2014 Table 5-1. The dependent variable shall be expressed as the average usage per day (UPD) for a billing period. Independent variables should be either HDD and/or CDD, unless other independent variables are necessary to reach acceptable statistical fitness.

The final equation shall be fit using a least-squares regression method[7]. In summary, the City Light will require:

- Evaluation of the baseline period for significant non-routine events and adjust as needed.
- Coefficient of variation of the root mean square error CV(RSME) shall be less than or equal to 20%.
- The model selected shall have the best R Squared value.[8]
- The t-statistic shall be >1.73 for a 90% confidence level.
- Net determination bias must be <0.005%.

If interval data is readily available and model fitness improves significantly by doing so, the M&V Consultant may develop a baseline model using more frequent data. Hourly or more frequent data shall be averaged to intervals of at least one day in length.[9]

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[7] CalTRACK 2.0 section 3.4.2 prefers weighted least squares regression for billing data.

[8] An R^2 of 0.75 is often considered a reasonable indicator of a good causal relationship amongst the energy and independent variables.

[9] ASHRAE 4.3.2.1 (h).

The M&V Consultant shall also calculate the annual fractional savings uncertainty and bias for evaluation purposes for the site and the portfolio of participants. The goal is to be less than 50% at 68% Confidence (For government-published weather-only data models, consultant may use ASHRAE equation 4-8)[10]; also see ASHRAE Guideline 14-2002 Annex B for guidance.[11]

2.6. Performance Period

EE Developers will be asked to provide a list of planned ECMs and their expected energy savings, costs, and timelines in the initial project application.

The performance period for an existing building starts after a capital upgrade specified in their ECM plan is complete *and* when the electricity savings reach at least 10% of monthly baseline energy use.

The M&V Consultant shall be responsible for collecting:

- Continuous monthly utility billing/ fuel use information (derived from ENERGY STAR Portfolio Manager and City Light).
- Weather data for the performance period measured at Boeing Field/King County Intl Airport (KBFI/BFI).
- Onsite energy generation (data provided by City Light).

The EE Developer shall provide to Seattle City Light/M&V Consultant on a quarterly basis updated forms specifying:

- ECM Plan status.
- Confirmed changes in space use, gross square footage, leased square footage, and/or implementation of non-project related capital projects and other NREs.

2.7. Savings Estimates

To calculate the Adjusted Baseline Energy had the EEaS upgrades not occurred, performance period weather and other relevant independent variables such as leased square footage data will be applied to the model as "routine adjustments". Energy savings for the site are estimated by summing the differences between the actual energy during the performance period and Baseline Model's predicted energy use.

Avoided Energy Use (or Energy Savings) = Adjusted Baseline Energy – Performance Period Energy +/- Non-Routine Adjustments

The M&V Consultant shall ensure that the Baseline Model and the actual energy use (for each billing period):

- Describe the same measurement boundary,
- Describe the same time period,
- Use the same assumptions and calculations, using weather in the performance period, and
- On-site generation is correctly removed from the avoided energy use savings.

[10] CalTrack offers a modified formula and guidance for aggregating site-level FSU data, see sections 4.3.2.3 through 4.3.2.5.

[11] This likely will require a higher model CV than 0.2 and deeper savings than 10%.

2.8. Non-Routine Events

Non-routine events are changes in a building's static factors that were not accounted for in the baseline model.

Examples of non-routine events include:

- Change in space use type, such as from retail to restaurant or vice versa.
- Expansion or destruction of conditioned building floor area.
- Addition or removal of large equipment, such as data servers, kilns, and refrigerators.
- Change in operating hours or operations.
- Fuel switching on water or space heat.
- Electric vehicle charging infrastructure (shall be sub-metered and added to the baseline).
- On-site generation (shall be sub-metered and removed from the avoided energy use of the site).
- Occupancy changes that are not captured in the baseline model, measured by leased square footage.
- Temporary, one-time, or rare events that fall outside of regular operation conditions, such as power loss or emergency operations.

Temporary events that are expected to occur in regular operating conditions, for example, normal building closures, maintenance events, or control sequence overrides, do not need to be removed from the data.

2.9. Post-Retrofit Change Detection Model

During the performance period, the M&V Consultant will establish a post-retrofit "change detection" model which will be used to predict building energy consumption in the performance period (to be compared to actual energy consumption) in order to detect non-routine events.

A performance period change detection model shall be created for participants after collecting one year of data post-retrofit or post-construction.

The M&V Consultant shall use interval data for the change-detection model, depending on model statistics and data availability.

2.10. Detection of Non-Routine Events

Non-routine events should be identified and reported by both the EE Developer/Participant and the M&V Consultant.

Based on quarterly reporting and site interactions, the EE Developer/Participant will be responsible for flagging potential non-routine events and reporting them to City Light.

The M&V Consultant will be responsible for flagging potential non-routine events they see in the data and proactively reporting them to City Light. The M&V Consultant may use the following approaches to investigate non-routine events, as needed and available:

- Anomalies in monthly billing reports.

- Assessment of interval meter data.
- Information from the EE Developer/Participant, direct knowledge of the building, or direction from City Light.
- Tracking of model residuals over time.
- Visual observations of outliers on a model scatter chart.
- Calculations of the z-scores or t-scores for data points.

2.11. Characterization of NREs

Once identified, the M&V Consultant should characterize each non-routine event based on:

- The time period in which it occurred.
- Whether it is a temporary or permanent change.
- Constant or variable load.
- Added or removed load.

This characterization will help estimate the event's impact and duration, whether using engineering calculations or data analysis.

The M&V Consultant will compile relevant information including detailed description of the non-routine event, duration, and the operational condition going forward. The M&V Consultant shall work with City Light to request further information about the event from the EE Developer/Participant.

2.12. Non-Routine Adjustments

If the NREs warrant a non-routine adjustment, the M&V Consultant will propose a recommended non-routine adjustment to City Light for approval. Ideally these adjustments will be based on verified sub-metered data.

Otherwise, the M&V Consultant may estimate non-routine adjustments with statistical or engineering methods. When they use engineering calculations, the calculations should be documented clearly and reside in the same place as the regression model so that the adjustments can easily be reviewed.

If the building increases in building size or changes use type during the performance period, City Light may choose to pivot the baseline to a new construction methodology described below, as the baseline model is no longer representative of how much energy the building would have used had no ECMs occurred. The new baseline shall be based on the Target Performance Path Energy Use Intensities (EUIs) in the Seattle Energy Code adopted at the time of construction or renovation, or the most recent Seattle Energy Code with a Target Performance EUI.

- Additions or substantial remodels that change the use type must be electric-only.
- The original footprint of the building may continue to use non-electric fuels and an adjusted Baseline Model Equation.

Procedures around non-routine adjustments may be updated during the EEaS Pilot Program to reflect best industry practice (including Efficiency Valuation Organization (EVO) M&V 2.0 & NRE subcommittee's recommendation) on how and when to identify and apply non-routine adjustments, tracking and calculating them, and estimating the uncertainty in the presence of non-routine adjustments.

2.13. Measurement and Verification Reports

The M&V Consultant will provide a monthly report per building to City Light on:

(1) Monthly avoided energy use per site

  (a) kWh savings total and percent (compared to baseline)

  (b) Gas use, including weather-adjusted changes relative to previous years

(2) Identify ECMs completed per site in the data

(3) Flag NREs at each site

The M&V Consultant will provide an annual report per building to City Light, every 12 months after the start of its performance period, on:

(1) Monthly and annual avoided energy use per site

  (a) kWh savings total and percent (compared to baseline)

  (b) Gas use, including weather-adjusted changes relative to previous years

(2) Identify ECMs completed per site in the data

(3) Summary of flagged and verified NREs per site

(4) Inventory of permanent and temporary NRAs recommended and made at each site, and adjustments to Baseline Model Equation, per the summary table[12] below:

Non-Routine Adjustment & Baseline Model Equation Revision History				
Date	Revision/Adjustment	Permanent or Temporary?	Justification	New Baseline Model Equation (if permanent)

[12] More detail shall be provided as necessary in a M&V report.

3. New Construction

For New Construction, the Seattle Energy Code C401 and Code Official requirements shall guide the development of the Adjusted Baseline Energy. Routine adjustments will be made annually to the baseline model or total allowable EUI and shall be based on code allowances and/or actual monthly data (rather than a recalibration of the model itself).

To be eligible for the pilot, new construction projects must pursue the Target Performance Path (C401) as means of compliance with Seattle Energy Code. The participant site's annual baseline is set by the energy use targets required in the SEC Target Performance Path (C401). Eligible building types and energy use target EUI (in kBTU/ft^2/year)[13] include:

- Office (40 kBTU/ft^2/yr)
- Medical Office (50 kBTU/ft^2/yr)
- Retail (60 kBTU/ft^2/yr)
- Master-metered Group R-2 multifamily (35 kBTU/ ft^2/yr)

The target EUIs may also include partial loads from:

- Data centers as allowed in C401.3.2.1
- Parking garages (6 kBTU/ ft^2/yr for open garages, 10 kBTU/ ft^2/yr for enclosed)

3.1. Measurement Boundary and Multiple Accounts

For buildings with multiple accounts or meters, at least 90% of the electricity use of the building must be on one account, as determined in the baseline year. The remaining electricity use would be considered outside of the measurement boundary of this program and does not need to be analyzed.

3.2. Non-Electric Fuels

City Light-provided electricity is the sole fuel source for all end-uses in New Construction projects, with the following exceptions:

- Generator fuel use is allowed but must be reported accurately and consistently in ENERGY STAR.
- On-site generation must be City Light sub-metered and energy production shall be calculated separately by City Light and removed from the avoided energy use of the Site by the M&V Consultant.

3.3. Baseline Data and Model

Step 1. Determine the baseline EUI and EEaS EUI (which requires a 25% improvement relative to code). For instance, if the SEC allowed EUI for an office building is 40 kBTU/ft^2/ year, then the 25% EEaS EUI is 30 kBTU/ft^2/year.

For mixed-use buildings, use a floor area-weighted kBTU/ft^{2}to calculate the baseline EUI, as shown below.

[13] Based on the energy model and the densities allowed in section C401.3.4, the total allowable EUI may be greater than these specific targets.

Example 1 – Office Building

	Square Feet by Use Type (ft^2)	*Baseline EUI (401.3.2 Code) (kBTU/ft2/yr)*	*EEaS EUI* (kBTU/ft^2/yr)
Office	100,000	40	
Enclosed Parking	15,000	10	
Total/ Weighted	115,000	36.09	27.07

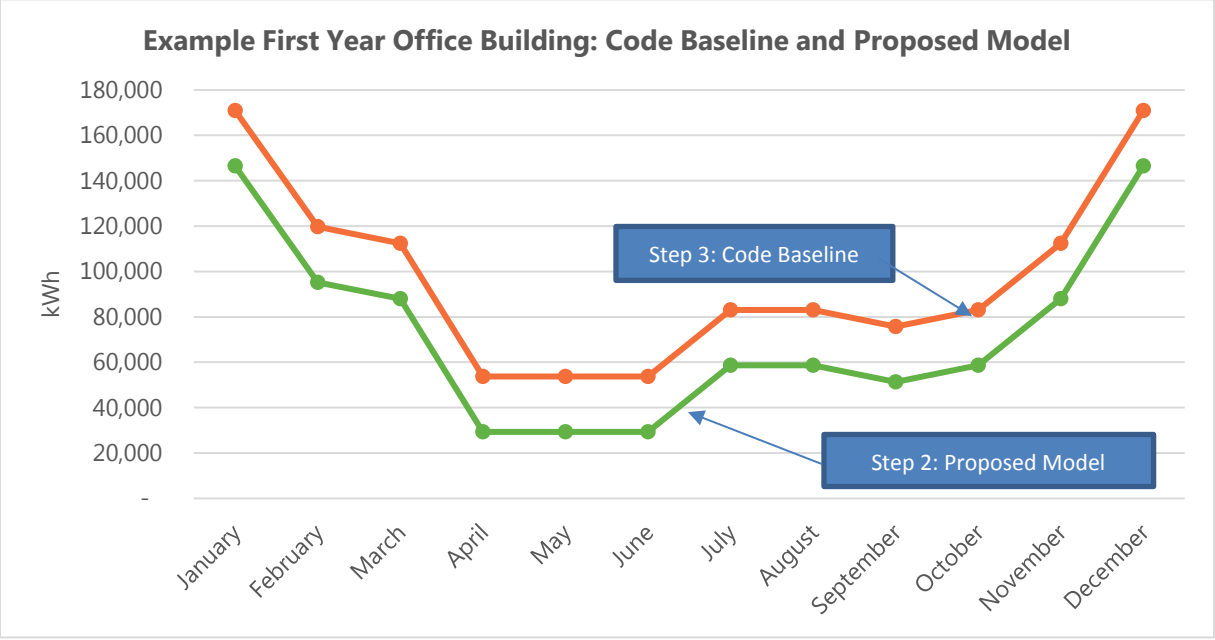
Note: Total Weighted EUIs shall contain four significant figures.

Example 2 – Mixed Use Building

	Square Feet by Use Type (ft^2)	*Baseline EUI (401.3.2 Code) (kBTU/ft2/yr)*	*EEaS EUI* (kBTU/ft^2/yr)
Office	100,000	40	
Medical Office	50,000	50	
Retail	25,000	60	
Total / Weighted	175,000	45.71	34.28

Step 2 and 3. The M&V Consultant will use the participant's energy model (proposed model) submitted to the SDCI Code Official to create the month-by-month energy use profile (step #2 on chart below). The M&V Consultant will then determine the baseline energy use profile to match the EUI target set by code (step #3 on the chart below).

The difference between the code baseline and the participant's actual energy use shall be considered the avoided energy use and the transactable monthly energy allowance.



Step 4. After the first performance year, use actual data make changes to the month-by-month energy use profile and any code adjustments to the baseline allowance for the next year, if necessary. The total allowable annual baseline EUI will be based on the code baseline, adjusted for any

data center, occupancy, cold years, or retail operating hours as allowed by SEC sections C401.3.2.1, C401.3.8, C401.3.9, and C401.3.10.

Step 5. Repeat Step 4 for each subsequent year.

3.4. Performance Period

For new construction use cases, the performance period will begin when the building has reached at least 75% occupancy (as specified in SEC C401.3.6), as reported by the EE Developer.

At a minimum, the M&V Consultant will use the following information in its modeling and savings calculations for New Construction projects:

- Continuous monthly utility billing/ fuel-use information (derived from ENERGY STAR Portfolio Manager and City Light).
- Weather data measured at Boeing Field/King County Intl Airport (KBFI/BFI).
- Sub-metered loads, if applicable.

The EE Developer shall provide to Seattle City Light/M&V Consultant on a quarterly basis updated forms specifying:

- Changes in space use, square footage, or occupied square footage.
- Data Center IT Energy Use.

3.5. Savings Estimates

The M&V Consultant should take care to ensure that the baseline and performance models:

- Describe the same measurement boundary,
- Describe the same time period (normalizing to billing data)
- Use the same assumptions and calculations
- Onsite generation is correctly removed from the avoided energy use savings.

For any weather adjustments, the M&V Consultant shall adjust the EUI baseline per Seattle Energy Code C401.3.9.

3.6. Annual Routine Adjustments in New Construction

Each year, the Participant's Baseline Model shall be adjusted in the following ways.

1. Using actual energy use data, change the shape of the baseline curve for the next year if necessary. The baseline EUI will be the product of code**.**
2. Adjust the baseline EUI for any data center, occupancy, cold years, or retail operating hours as allowed by SEC sections C401.3.2.1, C401.3.8, C401.3.9, and C401.3.10.

Any other types of adjustments will follow the Non-Routine Event and Non-Routine Adjustment sections below.

3.7. Non-Routine Events (NREs) and Adjustments in New Construction

Non-routine events are changes in a building's static factors that were not accounted for in the baseline model.

The EE Developers are responsible for flagging to City Light what appear to be non-routine events in quarterly reports, which City Light will share with the M&V Consultant.

Non-routine events for New Construction include:

- Change in space use type or space type mix, such as from retail to restaurant or vice versa.
- Expansion or destruction of conditioned building floor area.
- Changes in leased square footage that drop the building below 75% occupied.
- Electric vehicle charging infrastructure (shall be sub-metered and added to the baseline).
- Onsite generation (shall be sub-metered and removed from the avoided energy use of the Site).

The M&V Consultant will notify City Light of all suspected Non-routine events as evidenced by the data.

3.8. Detection of Non-Routine Events

Related to the NRE's listed in 3.7, the M&V Consultant may use the following approaches to investigate non-routine events, as needed and available:

- Anomalies in monthly billing reports
- Direct knowledge of the building or direction from City Light
- Change Detection Model

3.9. Non-Routine Adjustments (NRAs)

For new construction projects, only these few NREs listed above will trigger a non-routine adjustment. If and when these NREs are significant, the M&V Consultant will recommend City Light make a non-routine adjustment to the participant's code baseline.

Leased square footage changes between 100% and 75% in new construction use cases do not require a non-routine adjustment. Below 75% leased square footage, the Participant and EE Developer will need to resubmit their SDCI proposed model to adjust for leasing changes.

If there is an addition or building use type change during the performance period, City Light may choose to pivot the baseline model to another code baseline, as the baseline model is no longer representative of how much energy the building would have used had no improvements occurred. The new baseline shall reference be based on the Target Performance Path EUIs in the Seattle Energy Code adopted at the time of construction or renovation, or the most recent SEC Seattle Energy Code with a Target Performance EUI.

3.10. Measurement and Verification Reports

The M&V Consultant will provide a monthly report to City Light on:

(1) Monthly avoided energy use per site

(a) kWh savings total and percent (compared to EUI baseline)

(2) Flag NREs per site

The M&V Consultant will provide an annual report to City Light describing:

(3) Monthly and annual avoided energy use per site

(a) kWh savings total and percent (compared to baseline)

(4) Summary of flagged and verified NREs per site

(5) Annual baseline energy use and adjustments (e.g. transactable energy allowances) per the summary table[14] below:

Monthly Baseline (Allowable) Energy Consumption (kWh)													
Year	1	2	3	4	5	6	7	8	9	10	11	12	**Total**
2020													
2021													
2022													
2023													
2024													
2025													
2026													
2027													
2028													
2029													
2030													
2031													
2032													
2033													
2034													
2035													
2036													
2037													
2038													
2039													

[14] The Participant's energy model may also be referenced with this table.

A. Glossary of Terms

Accuracy: An indication of how close a singled measured value is to the true value of the quantity in question.

Addition: An extension or increase in the conditioned space floor area or height of a building or structure.

Adjusted Baseline Energy: What the baseline energy use would have been if the project ECMs had never been installed, under the same set of post-retrofit conditions.

Avoided Energy Use: The reduction in energy use that occurred in the performance period, relative to what would have occurred if the facility had been equipped and operated as it was in the baseline period, but under performance period operating conditions.

Avoided Energy Use (or Energy Savings) = Adjusted Baseline Energy - Performance Period Energy +/- Non-Routine Adjustments

For new construction, the difference between the Seattle Energy Code target energy use (C401) and the Participant's actual energy use shall be considered the avoided energy use.

Balance Point: A balance point temperature selected to calculate degree days, or the point at which heating or cooling is required due to heat loss or heat gain. For the baseline model equation, the balance point may be fixed or variable. The Uniform Methods Project recommends 60 F for heating degree days and 70 F for cooling degree days for billing period methods. A variable balance point range shall be 30 to 90 degrees. A cooling balance point must be greater than or equal to the heating balance point.

Baseline Data: The measurements and facts describing facility operations and design during the baseline period. This will include energy use and parameters of facility operation that govern energy use.

Baseline Model: A mathematical representation or calculation procedure that is used to predict the energy use in a building or facility (or Adjusted Baseline Energy) had no ECMs been implemented. Models may be based on equations that specifically represent the physical processes or may be the result of statistical analysis of energy-use data.

Baseline Model Equation: The specific mathematical representation or equation governing the prediction of energy use (or Adjusted Baseline Energy) had no ECMs been implemented at the Site.

Coefficient of Variation of the Root-Mean Squared Error [CV(RMSE)]: A measure that describes how much variation or randomness there is between the data and the model, calculated by dividing the root-mean squared error (RMSE) by the average y-value.

Confidence Interval: Uncertainty is associated with a given confidence level or probability – for example "we are 90% confident the true value lies between 1,000 and 1,200."

Confidence Level: Confidence intervals define the range – an uncertainty band – that is expected to band the true regression, with a certain probability. For example, it may be reported as 1,000 kWh ±200 at the 90% confidence level.

Adjusted Baseline Energy: What the baseline energy use would have been if the project ECMs had never been installed, under the same set of post-retrofit conditions.

Degree Day (heating degree day, cooling degree day): A degree-day is a measure of the heating or cooling load on a facility created by outdoor temperature. When the mean daily outdoor temperature is one degree below a stated reference, or balance point, temperature such as 64°F, for one day, it is defined that there is one heating degree day. If this temperature difference prevailed for ten days, there would be

ten heating degree-days counted for the total period. If the temperature difference were to be 12 degrees for ten days, 120 heating degree-days would be counted. When the ambient temperature is below the balance point temperature, it is defined that heating degree-days are counted. When ambient temperatures are above the balance point, cooling degree-days are counted. Any balance point temperature may be used for recording degree-days, though it is usually chosen to reflect the temperature at which a particular building no longer needs heating or cooling.

Dependent Variable: The variable that changes in relationship to alterations of the independent variable. In energy efficiency, energy usage is typically treated as the dependent variable, responsive to the manipulation of conditions (independent variables). In the case of Energy Efficiency as a Service, the dependent variable shall be expressed as the average usage per day (UPD) for a billing period.

Efficiency Energy: The calculated avoided energy use harvested at the site by the EE Developer, which is quantified by the M&V Consultant. This is an energy efficiency resource.

Energy Conservation Measure (ECM): An ECM is any type of energy efficiency or energy conservation project or activity conducted, related to the installation, repair, or replacement of energy-efficient equipment or building systems, implementation of capital projects, operational & maintenance (O&M) improvements, or new means of training or managing users of the space, intended to improve the energy productivity of or generate Efficiency Energy at the Site.

Energy Consumption: The amount of energy consumed in the form in which it is acquired by the user. The term excludes electrical generation and distribution losses.

Energy Efficiency Developer (EE Developer): The party who holds this Power Purchase Agreement with the City for the sale of the Efficiency Energy to the City from the avoided energy use at the site.

Estimate: The average, or expected, y-value, given a specific x-value. The uncertainty in a regression estimate is a confidence interval.

Fractional Savings Uncertainty: The uncertainty divided by the savings. It must always specify the confidence level associated with the savings, where uncertainty is measured as the quantity of savings from the upper confidence limit to the lower confidence limit surrounding a savings estimate.

Independent Variable: Also termed an explanatory or exogenous variable; a factor that is expected to have a measurable impact on the dependent, or outcome variable (e.g., energy use of a system or facility). In the case of Energy Efficiency as a Service, independent variables should be either HDD and/or CDD, unless other independent variables are necessary to reach acceptable statistical fitness.

International Performance Measurement and Verification Protocol (IPMVP): The IPMVP provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities. It may also be used by facility operators to assess and improve facility performance. The IPMVP is the leading international standard in Measurement and Verification protocols. It has been translated into ten languages and is used in more than 40 countries.

M&V Plan: A well-defined and implemented M&V Plan encourages comprehensive project design by including all M&V costs in the project's economics. It increases the transparency and credibility of reports on the outcome of efficiency investments and can be the basis for documenting performance in a transparent manner and subjected to independent verification.

Measure: 1) (noun) an action or system modification intended to reduce energy use. 2) (verb) the process of quantifying a physical parameter using instruments.

Measurement and Verification (M&V): The process of using measurements to reliably determine actual savings created within an individual facility by an energy management program. Savings cannot be directly measured, since they represent the absence of energy use. Instead savings are determined by comparing measured use before and after implementation of a project, making appropriate adjustments for changes in conditions.

Measurement Boundary: A boundary drawn around whole-building meters and systems to segregate those which are relevant to savings determination from those which are not. All energy uses of equipment or systems within the measurement boundary must be measured or estimated, whether the energy uses are within the boundary or not.

Measurement and Verification Consultant (M&V Consultant): An independent third-party who will develop and implement an approach to use data-driven models with meter data and other variables to estimate baseline energy consumption, which will be used to will be used to determine the Avoided Energy Use of the Site.

Net Determination Bias (NDB): The ratio of summation of differences between model-predicated and actual dependent variable values to summation of actual dependent variable values.

Net Determination Bias Test: Savings resulting from applying the baseline period's independent variable data to algorithms for savings determination. Data so applied must reflect all exclusions or adjustments to actual measured data as documented for the baseline model.

New Construction: (1) construction of a new building or structure, (2) an extension or increase in the conditioned floor area or height of a building or structure, or (3) major changes in space use type.

Non-Routine Adjustments (NRAs): Adjustments to the baseline to account for changes in energy consumption, which occurred during the performance period and that cannot be modeled using the considered independent variables.

Non-Routine Events (NREs): Changes in building energy use that are not attributable to changes in the independent variables used in the baseline model nor to the efficiency measures that were installed. In the case of an NRE, the avoided energy use may be adjusted by making non-routine adjustments.

Normalized Savings: The reduction in energy use or cost that occurred in the performance period, relative to what would have occurred if the facility had been equipped and operated as it was in the baseline period, but under a normal set of conditions. These normal conditions may be a long-term average or those of any other chosen period of time other than the performance period. Normal conditions may also be set as those prevailing during the baseline period, especially if they were used as the basis for predicting savings. If conditions are those of the performance period, the term avoided energy use, or just savings, is used instead of normalized savings.

Occupancy: In the case of Energy Efficiency as a Service, "occupancy" specifically means leased square footage of the total available leasable space. It is not adjustments for weekly occupancy schedule or holiday schedule, nor number of employees.

Participant: The party who owns the Site or an entity working as their agent, granted authority by the site owner to enter into the Participation Agreement.

Performance Period: The period of time after the EE Developer has implemented initial energy conservation measures at the Site resulting in a reduction of monthly energy consumption at least 10% relative to the baseline model.

Precision: The indication of the closeness of agreement among repeated measurements; a measure of the repeatability of a process. Any precision statement about a measured value must include a confidence

level. A precision of 10% at 90% confidence means that we are 90% certain the measured values are drawn from samples that represent the population and that the "true" value is within ±10% of the measured value. Because precision does not account for bias or instrumentation error, it is an indicator of predicted accuracy only given the proper design of a study or experiment.

Precision, Relative, as applied to a savings estimate: The ±uncertainty in savings divided by the savings. If the savings are 10,000, and the uncertainty is ±1,000 at an 80% confidence level, the relative precision is 1,000 ÷ 10,000 = 10% at the 80% confidence level.

Prediction: The specific y-value that may accompany a specific x-value. The uncertainty in a regression prediction is a prediction interval.

Projected Baseline: The baseline energy use applied to the post-retrofit period and conditions.

R Squared: A measure of the extent to which variations in the dependent variable from its mean value are explained by the regression model.

Regression Analysis: A mathematical technique that extracts parameters from a set of data to describe the correlation of measured independent variables and dependent variables.

Regression Model: A mathematical model based on statistical analysis where the dependent variable is regressed on the independent variables which are said to determine its value. In so doing, the relationship between the variables is estimated from the data used.

Retrofit: Energy conservation measure or measures installed and/or implemented as a single project at a specific time in an existing facility.

Residual: The difference between the predicted and actual value of the dependent variable, i.e. the portion of energy use that is not explained by the model.

Root Mean Squared Error (RMSE): (Also known as the Standard Error of the Estimate.) An indicator of the scatter, or random variability, in the data, and hence is an average of how much an actual y-value differs from the predicted y-value. It is the standard deviation of errors of prediction about the regression line.

Site: The actual building location that the energy efficiency work will take place. The project boundary shall be the utility account and corresponding meters, which make up at least 90% of the site's electricity consumption

Standardized Residual: A residual divided by its Standard Error (RMSE). This is a regression analog for a z-score, the number of standard deviations a value is away from the sample mean.

Static factors: The characteristics of a facility that affect energy use within the chosen measurement boundary, but which are not used as the basis for any routine adjustments. These characteristics include fixed, environmental, operational, and maintenance characteristics. They may be constant or varying. This includes conditions such as operating schedules, occupied square footage levels or density, setpoints, condition space and volume, control strategies, etc.

t-statistic: A measure of the probability that the value (or difference between two values) is statistically valid. The calculated t-statistic can be compared to critical t-values from a t-table. The t-statistic is inversely related to the p-value; a high t-statistic (t>2) indicates a low probability that random chance has introduced an erroneous result. Within regression, the t-statistic is a measure of the significance for each coefficient, (and, therefore, of each independent variable) in the model. The larger the t-statistic, the more significant the coefficient is to estimating the dependent variable.

Uncertainty (e.g. of Savings): The range or interval of doubt surrounding a measured or calculated value within which the true value is expected to fall within some stated degree of confidence. Uncertainty in regression analysis can come from multiple sources, including measurement uncertainty and regression uncertainty.

Whole Building Metered Approach: The savings measurement approach defined in ASHRAE Guideline 14 that determines energy and demand savings using whole facility energy (end-use) data, which may be measured by utility meters.

z-statistic: (Also known as the Standard Score.) The z-statistic indicates how many standard deviations an observation or datum is above or below the mean. It is a dimensionless quantity derived by subtracting the population mean from an individual raw score and then dividing the difference by the population standard deviation.

$$z = \frac{x - \mu}{\sigma}$$

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C. Methodology Compliance Checklist

M&V Consultants should use this list to verify that the models developed for retrofits meet data standards. Where the M&V Consultant feels it necessary to depart from these standards, they should document the rationale for City Light review and approval.

Modified from CalTrack 2.0[15]

M&V Methodology Checklist	**CalTrack 2.0 Section Reference**
The baseline must be 365 days immediately prior to the intervention start date	3.1.3
Unless fitting baseline models using interval methods, the number of days of consumption and temperature data missing should not exceed 37 (10%).	2.2.1.2
CDD balance point range has been limited to between 30 and 90 degrees	3.2.1.1
HDD balance point range has been limited to between 30 and 90 degrees	3.2.1.2
Cooling balance point must be greater than or equal to the heating balance point	3.2.2.1
Balance point search must check at least every 3 degrees (or fewer) within the range	3.2.3
Regression model dependent variable is average usage per day.	
Daily Average Usage has been correctly specified	3.3.3.1
Cooling degree days have been correctly specified	3.3.4.1.1
Heating degree days have been correctly specified	3.3.5.1.1
Daily models are fit using ordinary least squares regression	3.4.1
Billing models are fit using weighted least squares regression	3.4.2
All combinations of candidate balance points are tried	3.4.3.1
Only include candidate models where each parameter estimate is not negative	3.4.3.2
Select the candidate model with the highest adjusted R-squared	3.4.3.3
If a day in the reporting period is missing a temperature value, the corresponding consumption value for the day should be masked	3.5.1.1
If a day in the reporting period is missing a consumption value, the corresponding counterfactual for that day should be masked	3.5.2.1
Avoided energy use should not be calculated when consumption data is missing	3.5.4.1
For daily and billing methods, avoided energy use should be calculated using ASHRAE 5-1 formulas.	N/A
A CVRMSE value should be used to define building-level model uncertainty	4.3.2.1
CVRMSE should be calculated using the following form: CV(RMSE)=∑Pp=1(Up−Up^)2P−c¯¯¯¯¯¯¯¯√U———	4.3.2.2

[15] See: https://www.caltrack.org/caltrack-compliance.html

Weather station information is Boeing Field/King County Intl. Airport	2.1.2.3
Weather station information must include observed dry-bulb temperature data	2.1.2.7
Weather data should be converted to hourly intervals using interpolation and downsampling	2.3.4
Hourly or more frequent data shall be averaged to intervals of at least one day in length	N/A
Consumption data frequency must be specified	2.1.1.1
If data from multiple meters is combined, must be noted	2.1.1.2
All consumption data must be converted to units of energy consumption	2.1.1.3
Project data must include a project start date	2.1.3.1.1
Project data must include an Intervention completion date	2.1.3.1.2
Project data must include a baseline period end	2.1.3.1.4
If data is marked as NULL, NaN, or similar, it is considered missing	2.2.1.3
Values of zero (0) are considered missing for electricity data, but not gas data	2.2.1.4
If periods are estimated, they should be combined with subsequent periods	2.2.2.2
When using billing data, estimated periods should be combined with the next period up to a 70 day limit. Estimated periods are counted as missing data for the purpose of determining data sufficiency.	2.2.3.1
Excessively long Billing Periods have been removed (>70 days)	2.2.3.4
Excessively short Billing Periods have been removed (< 25 days)	2.2.3.4
Projects should be flagged if net metering status changes during baseline or reporting period	
Projects should be flagged if electric vehicle charging is installed during the baseline or reporting period	2.2.7
If using billing data and the date provided is impossible (e.g., January 32nd), use the first of the month	2.3.1.1
If using billing data and the month or year is impossible, flag the date and remove it from the dataset	2.3.1.2
Where two time series overlap, combine into a single time series by dropping duplicate records, using the most complete version possible. If timestamps conflict, flag for review. If multiple meters present, may be aggregated.	2.3.2.1
Ensure daylight savings consistency across meter and temperature data	2.3.3
Presence of negative meter data should be flagged as possible unreported net metering	2.3.5
Extreme values (more than 3 interquartile ranges larger than the median) should be flagged as outliers for manual review.	2.3.6
CDDs are not used as a variable in the calculation for gas data.	3.2.1.1
To aggregate single project results from individual time periods, the following should be calculated: $AEU_{total,P}=\sum_{p=1}^{P}(AEU_{p,i})$	4.1.1
To aggregate multiple project results from the same time periods, the following should be calculated: $AEU_{p,S}=\sum_{i=1}^{S}(AEU_{p,i})$	4.2.1

A Fractional Savings Uncertainty value should be used to define portfolio-level uncertainty	4.3.2.3
Fractional Savings Uncertainty is calculated using the following form: $FSU_i = \frac{\Delta U_{save,Qi}}{U_{save,Qi}} = t(aM^2 + bM + d)CV(RMSE) * PP'(1 + 2P')\frac{1}{Q}}F$	4.3.2.4
Portfolio Fractional Savings Uncertainty should be calculated using the following form: $FSU_{portfolio} = \frac{\sqrt{\sum_{i=1}^{N}(\Delta U_{save,Qi})^2}}{\sum_{i=1}^{N} U_{save,Qi}}$	4.3.2.5
Site level Bias should be calculated using the following form: $MB_i = \frac{1}{P}\sum_{p=1}^{P}(y_p - \hat{y_p})$	4.3.2.6.1
Portfolio level Bias should be calculated using the following form: $FBE_{portfolio} = \frac{\sum_{i=1}^{N}(MB_i)^2}{\sum_{i=1}^{N} U_{save,Qi}}$	4.3.2.6.1