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CERTIFIED MEASUREMENT & VERIFICATION SPECIALIST ★ CMVS ★

PERFORMANCE MEASUREMENT AND VERIFICATION ANALYST – PMVA

What is M&V?

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"Measurement & Verification (M&V) is the process of using measurements to reliably determine actual saving created within an individual facility by an energy management program."

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Savings

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Value,in quantifiable units,of energy consumption, demand,water,greenhouse gas emissions, or other related cost reductions is determined by comparing measured values before and after the implementation of an energy efficiency measure(s) and making suitable routine and non-routine adjustments to account for changes in conditions. Energy or other unit savings and any resulting cost savings may be reported in the form of avoided energy consumption or normalized savings.

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Static Factors

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Those characteristics of a facility that affect Energy Consumption and/or Demand within the defined Measurement Boundary, that are not expected to change, and were therefore not included as Independent Variables. While not expected to change, these static factors should be recognized and monitored, and if they change, non-routine adjustments may need to be calculated to account for these changes.

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Uncertainty in Savings

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The range of savings values in which the true savings value is estimated to lie is often given a statistical confidence level. A single value does not adequately represent savings. Uncertainty in savings is reported either as a range of values (absolute uncertainty) or as a percent of the estimated savings (relative uncertainty).

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Adjusted Baseline Energy

A model, developed using data from the baseline period and incorporating routine and non-routine adjustments, against which an energy conservation measure's actual performance is compared

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Avoided Energy Consumption

Reduction in energy consumption, demand, or related cost that occurred relative to what measured energy (or demand) would have been without the energy efficiency measure, most commonly determined under reporting period conditions. In some cases, avoided energy consumption may be determined under baseline conditions.

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Backcasting

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An infrequently employed method for calculating avoided energy consumption in which reporting period energy is adjusted to baseline period conditions

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Baseline

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A characterization of the energy use and operating conditions during a specified period of time prior to implementation

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Baseline Period

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A defined period of time is chosen to represent the operation of the facility or system before the implementation of energy efficiency measures.

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Baseline Period Energy

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Energy consumption (or demand) used within a defined measurement boundary occurring during the baseline period without adjustments

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Commissioning

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A quality-focused process for enhancing the delivery of a project includes verifying and documenting that the facility and its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the design intent.

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Confidence Level

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Confidence level refers to the probability that the quoted range contains the true value.

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Demand

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A measure of the rate at which work is done or energy is used when applied to a load

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Energy Efficiency Measure (EEM)

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An action or a set of actions designed to improve efficiency, reduce energy or water consumption, or manage demand is sometimes referred to as an Energy Conservation Measure (ECM).

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Routine Adjustment

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An adjustment to the baseline or reporting period data using mathematical and statistical methods to account for expected changes in energy consumption or demand due to changes in the independent variables affecting energy consumption within the measurement boundary

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Energy Consumption

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Quantity of energy applied to a load in a specific period of time.

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Energy Influencing Factors

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Operating conditions that can affect the energy use within a measurement boundary include static factors and independent variables.

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Energy Performance Contract

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An agreement between two or more parties where payment is based on achieving specified results, such as improvement in energy performance, reductions in GHG emissions, energy costs, or the payback of investment within a stated period.

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Energy End-Use

Application of energy for a specific purpose, which is not the production, transformation, or storage of energy. (Examples: ventilation, lighting, heating, cooling, transportation, industrial processes, production lines.)

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Estimated Value

Parameters used in savings calculations are determined through methods other than conducting measurements during the M&V period. The methods used to estimate values may range from engineering estimates derived from manufacturer ratings of equipment performance to measurements made during a different M&V period. Values derived from equipment performance tests or other measurements that are not made in situ are considered to be estimates for purposes of adherence with IPMVP.

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Greenhouse Gas (GHG) Emissions

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Carbon-containing gases such as carbon dioxide and methane are emitted through the burning of fossil fuels in the production and distribution of energy. The emissions from within a measurement boundary can be expressed as weight units of carbon dioxide equivalent and are sometimes referred to generically as carbon emissions.

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Installation Period

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A defined period of time during which the planned EEMs are installed.

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Independent Variable

A parameter that is expected to change regularly and has a measurable impact on energy consumption and/or demand for a system or facility

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Interactive Effects

Any energy impacts created by an energy efficiency measure that occur outside of the measurement boundary of the EEM and are not captured in the energy measurements

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Key Parameter(s)

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Critical variable(s) identified to have a significant impact on the energy savings associated with installing an energy efficiency measure

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Measurement and Verification (M&V)

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The process of planning, measuring, collecting, and analyzing data to verify and report energy savings within a facility or facilities resulting from the implementation of EEMs Savings commonly quantified include electricity consumption, electric demand, natural gas consumption, carbon emissions, and water consumption, and may include utilities such as steam, energy generated, or other items to be verified as part of a sustainability or efficiency project.

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Facility

Building or industrial site containing several energy-using systems. A wing or section of a larger facility can be treated as a facility if it has meters that separately measure all of its energy.

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M&V Periods

Time period of interest for an M&V project, including the baseline, installation, and reporting periods.

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Measurement Boundary

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Notional boundaries are drawn around equipment, systems, or facilities to segregate those that are relevant to savings determination from those that are not. All energy consumption and/or demand for equipment or systems used or generated within the boundary must be measured or estimated.

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Metering

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The process of using meters to collect energy consumption, demand data, or key parameter data over time using measurements

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Non-Routine Adjustment

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Individually engineered calculations to account for the energy effects within the measurement boundary due to changes in the static factors

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Non-Routine Event

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Variations in energy consumption within the measurement boundary caused by changes in static factors that are not accounted for in the energy savings calculations and are unrelated to the energy project in question.

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Normalized Savings

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Reduction in energy use, demand, or cost that occurred in the reporting 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 fixed set of normal conditions. These normal conditions may be a long-term average or those of any other chosen period of time (other than the baseline or reporting period), which result in avoided energy use instead of normalized savings. Normalization involves using a statistically valid means of adjusting baseline and reporting period energy to a common set of meaningful conditions.

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Operational Verification

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- Verification that the Energy Efficiency Measures (EEMs) are installed and operating as intended and have the potential to generate savings
- Operational verification may involve inspections, measurements, functional performance testing, and/or data trending with analysis.

- Verification that the Energy Efficiency Measures (EEMs) are installed and operating as intended and have the potential to generate savings
- Operational verification may involve inspections, measurements, functional performance testing, and/or data trending with analysis.

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Performance Indicator

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A measurable factor related to operating conditions is used to assess the function of an EEM or system.

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Reporting Period

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A defined period of time is chosen to verify and quantify savings after the implementation of an energy efficiency measure(s). M&V may be performed over one or more reporting periods during which individual savings reports are prepared. The reporting period may be the total period on which the M&V is performed after EEMs are installed (e.g., the duration of a performance-based contract) or just the duration of time covered by an individual saving report.

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Reporting Period Energy

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Energy consumption and/or demand used within a defined measurement boundary occurring during the reporting period without adjustments

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Advanced M&V methods are characterized by the use of energy data in short time increments, typically daily, hourly or sub-hourly data collected from whole building utility meters, and the use of software tools that allow advanced data analysis and modeling strategies to be applied.

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True

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Baseline adjustments

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The non-routine adjustments arising during the post-retrofit period that cannot be anticipated and which require custom engineering analysis

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Base year Conditions

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The set of conditions that gave rise to the energy use and demand of the base year

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Base year Energy Data

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The energy consumption or demand during the base year.

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Base year

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A defined period of any length before implementation of the ECM(s)

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Degree Day

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Degree day (Kelvin day): the difference in temperature between the outdoor mean temperature over a 24-hour period and a given base temperature, used in estimating heating and cooling energy use. For any one day, there are as many degree days (Kelvin-days) as there are degrees Fahrenheit (degrees Celsius) of departure of the mean temperature for the day from the base temperature.

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Energy Conservation Measure (ECM)

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A set of activities designed to increase the energy efficiency of a facility Several ECMs may be carried out in a facility at one time, each with a different thrust. An ECM may involve one or more of: physical changes to facility equipment; revisions to operating and maintenance procedures; software changes; or new means of training or managing users of the space or operations and maintenance staff.

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EMS or Energy Management System

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A computer that can be programmed to control and/or monitor the operations of energy-consuming equipment in a facility

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Hourly building simulation models

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Estimate hourly energy savings by estimating consumption with and without the EE project or measure in place for each hour of a standard year, based on detailed specifications of building characteristics and operating conditions.

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Energy Savings

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Actual reduction in electricity use (kWh), electric demand (kW), or thermal units (Btu).

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Heating degree days (HDD)

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For any one day, when the mean temperature is less than the local or country-specific common temperature base, Annual HDDs are the sum of the HDDs over a calendar year.

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Option A – Retrofit Isolation: Key Parameter Measurement

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This approach requires the field measurement of the key performance parameters that define the energy use of systems affected by energy conservation measures (ECM). The energy savings are calculated using the field measurements of key parameters and the estimation of other parameters. These estimates can be based on historical data or the manufacturer's specifications.

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Option B – Retrofit Isolation: All Parameter Measurement

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Similar to option A, except that all parameters necessary for calculating EEM energy savings must be measured.

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Option C – Whole Facility

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For this approach, the energy savings are determined by measuring energy use at the whole facility or sub-facility level. The gas and electric utility meters from energy suppliers are used for the savings calculations to determine the baseline.

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Option D – Calibrated Simulation

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This approach uses a calibrated simulation using professional software and applies to the whole facility or sub-facility. The software models the building's performance and calibrated simulations are used to determine the targeted system's energy use.

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Entire Building Approach

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This approach uses the main utility meter, usually installed by the electricity, gas, oil, or hot water supplier. The energy savings measures can affect one or more of the building's subsystems. The use of the billing history is often necessary to define the baseline.

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Retrofit Isolation

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This strategy makes use of measurement tools to identify the energy consumption of the subsystems that are subject to the energy conservation measure. The baseline is determined using measurements noted before the installation of the ECM. All parameters must be measured.

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Calibrated Simulation of the Entire Building

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This method applies to an entire building and uses computer simulation software to create a consumption and energy demand model for the building. The parameters affected by the ECM are changed in this model to obtain the resulting energy savings.

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ESPC or Energy Savings Performance Contract

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A term used in the United States is equivalent to an energy performance contract.

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Cooling load

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Amount of cooling per unit time required by the conditioned space or product; heat that a cooling system must remove from a controlled system over tim

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ASHRAE

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American Society of Heating, Refrigerating and Air-Conditioning Engineers.

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Metering

Collection of energy and water consumption data over time at a facility through the use of measurement devices.

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Monitoring

The collection of data at a facility over time for the purpose of savings analysis (i.e., energy and water consumption, temperature, humidity, hours of operation, etc.)

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M&V Option

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One of four generic M&V approaches defined herein for energy savings determination.

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Post-Retrofit Period

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Any period of time following the commissioning of the ECM.

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Regression Model

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Inverse mathematical model that requires data to extract parameters describing the correlation of independent and dependent variables

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RMSE

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Root mean square error

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Simulation Model

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An assembly of algorithms that calculate energy use based on engineering equations and user-defined parameters.

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Verification

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The process of examining the reports of others to comment on their suitability for the intended purpose

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Operating conditions

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the conditions in which the EE project, measure, or facility is operated, including but not limited to weather, occupancy, and hours of operation.

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Monitoring and Targeting

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This is a management technique that can—and should—be utilized with or without specific facility retrofits in order to keep operations efficient and to monitor utility costs. These are management strategies designed to drive energy costs downward as a continuous improvement cycle.

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Energy use

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Energy is used within the measurement boundary.

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Key parameters

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Data sources relating to energy use and independent variables that are measured or estimated form the basis for savings calculations.

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Purchased energy rates

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Purchased energy rates are the costs of units of energy or power purchased at the building site. These costs may include energy costs as well as costs for power demand

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Statistically valid sample

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Randomly selected sample where the actual uncertainty of the sample measurements is equal to or less than the targeted precision for the specified confidence interval.

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The terms advanced M&V or M&V 2.0 are increasingly used to refer to the use of automated analytics in combination with higher granularity data to quantify project or program energy savings

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True

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Performance

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Output performance is affected by the ECM.

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Energy Savings Equation

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Energy Savings = *Adjusted Baseline Energy* – *Actual Energy*

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Adjusted Baseline Energy Equation

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Adjusted Baseline Energy = *Baseline Energy* ± *Routine Adjustments*

where:

± *Non Routine Adjustments*

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Precision

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Precision is defined as “the amount by which a measured value is expected to deviate from the true value”. Precision is expressed as a ± tolerance (e.g., ±2.7% or ±340 kWh).

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Confidence

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Confidence level is defined as “the probability that any measured value will fall within a stated range of precision”. That is, our confidence that the true value lies within the stated tolerance Confidence is expressed as a percentage (e.g., 95%).

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Why measure and verify?

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Effective M&V helps businesses to:

- Increase energy savings;
- Reduce the cost of financing projects;
- Encourage better project engineering; and
- Help demonstrate and capture the value of reduced emissions from energy efficiency and renewable energy investments.

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Instrumentation Error

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The magnitude of instrumentation errors is given by manufacturer's specifications. Typically instrumentation errors are small, and are not the major source of error in estimating savings.

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Modeling Error

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Modeling error refers to errors in the models used to estimate parameters of interest from the data collection.

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Why is measurement and verification important?

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Energy efficiency projects sometimes fail for various reasons. Thus, calculating energy savings is crucial. Metering and sub-metering facilities and equipment help. Correctly interpreting metered data requires adjusting for temperature changes, building occupancy and use, and energy-consuming equipment installation or removal. Energy savings are calculated by comparing final energy consumption to an accurate baseline.

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Adjustments, Nonroutine & Routine

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Changes made to the baseline and/or the performance period energy use to account for changes Routine adjustments are used to account for expected variations in independent variables; nonroutine adjustments are used to compensate for unexpected changes unrelated to the energ conservation measures (ECMs).

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Annual Report

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A report issued annually, typically on the anniversary of project acceptance, documents the execution and results of the M&V activities prescribed in the M&V plan. This documentation verifies the continued operation of the ECMs, provides the associated energy savings estimates, demonstrates proper maintenance, and provides M&V results. In an ESPC, the energy savings documented in the report serve as the basis for the ESCO's invoice after the regular interval report has been reviewed and approved by the customer.

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Avoided Energy Use

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The reductions in energy use that occurred during the performance period were relative to what would have been used during the baseline period, using actual operating conditions experienced during that period. This may require baseline energy use to be adjusted to actual conditions. This approach is different than calculating normalized savings.

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Baseline Conditions

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Physical conditions that existed before implementation of the energy savings measures (such as equipment inventory and conditions, occupancy, nameplate data, energy consumption rate, and control strategies), which are determined through surveys, inspections, spot measurements, and short-term metering activities. Baseline conditions are established for the purpose of estimating savings and are also used to account for any changes that may occur during the post-installation period, which may require adjustments to baseline energy use.

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Expected Savings

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Expected savings are those reported in the post-installation report. They are based on as-built conditions and post-installation verification activities and are the savings expected for year 1 of the project.

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Independent Variable

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A parameter that is expected to change regularly and have a measurable effect on the energy use of a building or system.

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Insolation

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A measure of solar radiation energy received on a given surface area in a given time

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Good practice requires that M&V is well integrated into the process of identifying, developing, procuring, installing and operating energy conservation measures.

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True

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Investment Grade Audit (IGA)

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A comprehensive assessment of a facility's energy and water use characteristics, identifying and analyzing energy conservation measures It may also be referred to as a feasibility study.

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Measurement and Verification (M&V) Approach

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An evaluation procedure for determining energy and cost savings. M&V techniques discussed in this document include engineering calculations, metering, utility billing analysis, and computer simulation.

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If quantification of equivalent greenhouse gas emissions is required in the reported M&V results, then the applicable GHG equivalence factors are determined for the measurement boundary and measurement period.

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True

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M&V Plan

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The M&V plan is a document that defines project-specific M&V methods and techniques that will be used to determine savings resulting from a specific energy conservation project.

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Measurements, Continuous

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Measurements were repeated at regular intervals over the baseline period or post-installation period.

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Measurements, Long- Term

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Measurements were taken over a period of several years.

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Measurements, Short- Term

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Measurements were taken for several hours, weeks, or months.

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Measurements, Spot

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Measurements taken one time; snap-shot measurements

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Normalized Savings

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The reductions in energy use that occurred during the performance period relative to what would have been used during the baseline period were adjusted to a normal set of conditions (such as typical weather conditions).

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Periodic M&V reports are prepared as a means to document the overall performance of the measure and project using procedures outlined in the M&V plan

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True

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Performance Period

In an ESPC, the time period spanning from acceptance of ECMs to the end of the contract term or a specific time frame, such as 1 year, within that period

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Performance Period Energy Use or Demand

The calculated energy use (or demand) by a piece of equipment or a site after implementation of the project

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Post-Installation Conditions

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The physical and operational conditions present during the time period following the installation of an energy conservation project

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Post-Installation Report

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The report provides results of post-installation M&V activities, documents any changes in the project scope that may have occurred during project implementation, and provides energy savings estimates for the first year of performance.

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Preliminary Assessment

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High-level assessment of whether or not a viable project exists at a site.

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Energy Efficiency Project

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The implementation of energy efficiency services at a federal facility or group of facilities

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Project-Specific M&V Plan

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The plan provides details on how a specific project's savings will be verified based on the general M&V options described in this document.

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Proposed Savings

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Proposed savings are those estimated in the contract before project implementation and determined from metering and/or calculations performed in accordance with the provisions of the approved M&V plan.

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Regression Analysis

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A technique used to develop a mathematical model from a set of data that describes the correlation of measured variables

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Sampling

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A process of selecting random pieces of similar equipment for monitoring in order to characterize some feature of an entire population of equipment This strategy is used when it is unrealistic to measure all affected equipment.

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Usage Group

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A collection of equipment (e.g., motors or rooms with light fixtures) with similar characteristics (e.g., operating schedule)

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Utility Energy Service Contract (UESC)

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A limited-source contract between a federal agency and its serving utility for energy- and water-efficiency improvements and demand-reduction services

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Verified Savings

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For a federal ESPC project, verified savings are those reported in the annual report for the project. They are based on verification activities conducted during the performance period and are the savings calculated for that specific year of the project.

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Energy Services Company (ESCO)

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A company that designs, finances, acquires, installs, and potentially maintains one or more ECMs or systems at a facility or facilities, typically under the terms of a performance contract or task order.

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Mean Bias Error (MBE)

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An indication of overall bias in a regression model

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What is IPMVP?

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It provides a framework and standard for M&V and has become the most widely recognized protocol in the world. So what exactly is IPMVP and why should your facility be participating?

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Evaluators are able to determine the relationship between cause and effect between interventions and outcomes by using counterfactual analysis.

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True

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Benefits of IPMVP

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The purpose of IPMVP is to increase certainty, reliability and the level of savings, while also reducing the level of transaction costs by providing a measurement and verification plan. It aims to provide a basis for negotiating the contractual terms to ensure that an energy efficiency project achieves its goals of improving efficiency and increasing energy savings. Overall, it simplifies the M&V process and improves the credibility and attractiveness of energy efficiency projects.

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ISO 50015:2014

Energy management systems — Measurement and verification of energy performance of organizations — General principles and guidance

©Beyond Smart Cities Private Limited

ISO 50001:2018

Energy management systems — Requirements with guidance for use

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Combined coefficient of performance

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A ratio of the total cooling in one year divided by the total energy from active, standby, and off modes.

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Budget building design

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A computer representation of a hypothetical design based on the actual proposed design This representation is used as the basis for calculating the energy budget.

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Confidence Interval

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Confidence Intervalis the range within which the true value is expected to occur at a specified confidence level (equivalent to twice the savings uncertainty)

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Ongoing Commissioning (OCx)

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Ongoing Commissioning (OCx) provides the means and process to optimize and sustain building performance on an ongoing basis through investigating, analyzing, and monitoring the performance of building systems.

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CMVP

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Certified measurement and verification professional

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Monitoring-based commissioning

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Monitoring-based commissioning, or MBCx, is a process that utilizes automated data analytics to continuously monitor the performance of systems over the life of a building.

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Utility meter

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meter used by a utility to measure billing determinants to calculate monthly charges for energy, demand, and/or water at a facility. More than one utility meter may be installed at a facility. If a utility combines data from several meters to calculate a single bill, the meters may be treated as a single meter.

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Counterfactual method

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the comparison of actual post-implementation performance to "what would have happened" had the project not been implemented.

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CV (RMSE)

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Coefficient of variation of root-mean squared error In a regression analysis of energy data, CV (RMSE) indicates the model's predictive capabilities.

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Deemed savings

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Predetermined estimates of the avoided energy use achieved by energy conservation measures

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Dependent variable

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A variable presumed to be influenced by an independent variable

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Descriptive statistics

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"the process of analyzing data in a dataset in order to describe and offer meaningful information about the data, including possible relationships among data points.

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ECM

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Energy Conservation Measure

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EM&V

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Evaluation, measurement, and verification Refers to program-level or portfolio-level activities rather than project-level activities, as in M&V.

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EMCS

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Energy Management Control System

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Counterfactual methods underpin all M&V methods. This method estimates the energy savings from an energy efficiency project.

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True

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EVO

Efficiency Valuation Organization A nonprofit organisation whose flagship product is IPMVP, the International Performance Measurement and Verification Protocol.

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FEMP

The Federal Energy Management Program Independent variable: a variable presumed to exert influence on a dependent variable

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ISO

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International Organization for Standardization

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Utility

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supplier of energy or water to a facility. For the purposes of this guideline, a utility includes all entities responsible for providing both the commodity (energy and/or water) and services related to delivering the commodity to the facility, which may include storage, transmission, distribution, and metering. This includes regulated utilities, commodity suppliers, and internal groups that supply steam, hot water, c chilled water.

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Operational verification

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The process of periodically verifying that an ECM is operating as intended through equipment inspection, review of operational logs, or other means

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Physical model

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Also known as a simulation or a causal, physics-based, or first-principles model. A model that tries to represent the dynamics of underlying systems.

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Portfolio

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A collection of energy efficiency programs sponsored by an organization, such as a utility or government agency, employing various technologies across a range of contexts

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Program

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A series of related energy efficiency projects sponsored by an organization such as a utility or government agency

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Regression

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An analysis of the relationship between independent and dependent variables

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Risk structure

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The distribution of risk among project stakeholders.

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Routine adjustment

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An adjustment that reflects expected changes in independent variables—changes in weather from season to season, for instance. ' Flukes occur often during the reporting period.

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Simulation

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Also known as a physical, causal, physics-based, or first-principles model. A model that tries to represent the dynamics of underlying systems.

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Standard deviation

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A statistical measure of how dispersed the data in a dataset is relative to the mean

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Staticfactor

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An element of the baseline was not expected to change during the reporting.

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Whole facility analysis

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An approach to measurement and verification that measures the total energy consumption of a building or facility.

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Avoided costs

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Baseline period energy use is adjusted to reflect reporting period operating conditions.

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Net determination bias test

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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.

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Standard error of the estimate

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A metric is used to establish the reliability of a prediction when a model is used to predict a value for a given independent variable. The standard error of the estimate serves as a measure of the prediction's reliability.

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Weather data are the most prevalent independent variable affecting energy consumption and demand.

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True

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Missing data may be estimated or interpolated from measured data using statistically valid engineering techniques, provided that the subsequent calculation of the level of uncertainty in the reported energy use and/or savings reflects the appropriate change in uncertainty.

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True

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The amount of money saved is found by comparing the energy flows and intensities of the baseline model and the model after the retrofit, using the right weather file.

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True

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Indoor environment quality (IEQ)

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A perceived indoor experience of the building's indoor environment that includes aspects of the design, analysis, and operation of energy-efficient, healthy, and comfortable buildings. Fields of specialization include architecture, HVAC design, thermal comfort, indoor air quality (IAQ), lighting, acoustics, and control systems. See indoor air quality (IAQ).

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Facility guide

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A basic building systems description and operating plan with general procedures and confirmed facility operating conditions, set points, schedules, and operating procedures to properly operate the facility

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Energy efficiency

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(1) ratio of net cooling capacity in Btu/h to total rate of
ratio (EER) electric input in watts under designated operating conditions; (2) ratio of the net total cooling capacity to the effective power input at any given set of rating conditions, in watts per watt

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Owner's project requirement (OPR)

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A written document that details the functional requirements of a project and the expectations of how it will be used and operated These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

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Systems manual

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A system-focused composite document that includes the operation manual, maintenance manual, and additional information of use to the owner during the occupancy and operations phase

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Return air

Air is removed from a space to be recirculated or exhausted. Air extracted from a space and totally or partially returned to an air conditioner, furnace, or other heating, cooling, or ventilating system

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Direct digital control (DDC)

Direct digital control (DDC) is a type of control where controlled and monitored analog or binary data (e.g., temperature, contact closures) are converted to digital format for manipulation and calculations by a digital computer or microprocessor, then converted back to analog or binary form to control physical devices.

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