
APPENDIX 4

Guidelines
For Determining Energy Savings

TITLE OF THE CONTRACT: **CONTRACT ON ENERGY SERVICE FOR IMPLEMENTATION OF ENERGY EFFICIENCY IMPROVEMENT MEASURES AND REDUCTION OF OPERATING COSTS IN PUBLIC BUILDINGS**

Based on the principles of the

International Performance Measurement and Verification Protocol (IPMVP)

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1 TERMS AND DEFINITIONS FOR MEASUREMENT

For the purposes of this document, the following terms and definitions shall apply:

Accounting Period means a period of 12 calendar months during which the achieved Energy Savings and Financial Savings in the Guarantee Period are calculated.

Adjusted baseline energy consumption: means the Energy consumption in the Baseline period, adjusted to different sets of operating conditions.

Avoided energy use: means a reduction in Energy consumption occurred in the Reporting Period, with reference to the consumption that would have taken place had the Contracted Facility been equipped and operated in the same manner as during the Baseline Period, but under the Operating conditions from the Reporting Period.

Adjustments means the modifications made to the baseline values in order to neutralize routine and non-Routine alterations in Energy consumption and thus provide a reliable basis for identifying Energy Savings attributable to the ECMs implemented by the Contractor.

Baseline Energy Consumption means the consumption of Energy and associated peak demand and/or capacity of the Contracted Facility occurring during the Baseline Period.

Baseline Period means a mutually agreed period of time chosen so as to best represent operation of the Contracting Facility prior to the implementation of ECM(s). This period may be as short as the time required for measurement of a constant quantity at a given time or long enough to illustrate a full operational cycle of the Contracting Facility, including variable operational processes.

Client means a public owner [*alternatively: user*] of the Contracted Facility.

Confidence Level: means a probability that any measured value will fall within a range of readings of the stipulated accuracy.

Constant: means a term used to describe a physical parameter, which does not change during a relevant period. Minor variations may be observed in the parameter while still describing it as constant. The magnitude of variations that are deemed to be ‘minor’ must be reported in the M&V Plan.

Commissioning means the activity of putting the installed equipment, installations and/or parts of installations in Contracted Facilities into their probationary operation, for the purpose

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of verifying whether they are fully operational and ready for use. The Commissioning must be in compliance with the technical regulations and standards in respect of the construction permit or any other relevant permit for the commencement and implementation of works, so that the operating license for installed equipment, installations and/or parts of installations in the Contracted Facilities may be validly issued, if required.

Contracted Facility means a Public Facility on which the ECMs are applied and which may consist of several facilities i.e. technical and technological entities and/or systems, all used by the Client.

Cycle: means a period of time between the start of successive similar operating modes of the Contracted Facility or a piece of the equipment, whose Energy consumption varies in response to operating procedures or independent variables.

Degree-Day: means a measure for determining the annual energy demand needs for heating of a facility. The Degree-Day is determined by multiplying the number of heating days and the difference between the agreed mean air temperature in the heated area (usually 19 °C, but it depends of the use of the area) and temperature of the outside air, whereas only the days in the heating season with daily mean outside temperature below the referenced 12 °C are taken into account for the calculation. In case the outside temperature is below the reference temperature, the heating degree-days are calculated. In case the outside temperature is above the reference temperature for cooling, the cooling degree-days are calculated. Any reference temperature may be used for recording degree-days, although it is usually chosen to reflect the temperature at which a particular building no longer needs heating or cooling.

Energy: means all forms of energy, water and associated consumption/use including provisions of peak-demand/capacity.

Energy Conservation Measures (ECM) means the activities for reducing the Operating Costs in the Contracted Facility.

Energy Savings means reduction in consumption of Energy in the Contracted Facility.

Estimate: means a process of determining parameters used in savings calculation through methods other than measuring in the Baseline Period and the Reporting period. These methods may range from arbitrary assumptions to engineering estimates derived from manufacturer’s rating of equipment performance. Equipment performance tests that are not made in the place where they are used during the Reporting Period are considered estimates, for purposes of adherence to the M&V principles.

Facility: means a building or an industrial plant that may comprise several systems which are Energy users. A wing or a section of a larger facility can be treated as an independent facility if it is equipped with its own meters, which separately measure all Energy it consumes.

Financial Savings means reduction in Operating costs of the Contracted Facility as a result of ECMs, calculated on the basis on the Reference Price of Energy.

Guarantee Period means the period of time from the end of the Implementation Period up to the end of the Contractual Period.

Independent Variable means a parameter that is expected to change regularly, and which has a measurable impact on Energy consumption in the Contracted Facility.

Interactive Effects: means energy use effects created by an ECM but which are not measured within the measurement boundaries.

Measurement and Verification (M&V): means the activities and procedures conducted in order to reliably determine actual Energy Savings and Financial Savings attributable to the implementation of ECMs.

Measurement and Verification Plan (M&V Plan) means a document that presents pre-agreed activities and procedures to be conducted in order to identify the M&V activities related to the installed ECMs.

Measurement and Verification Report: means a report to be produced to demonstrate the results obtained while applying the M&V Plan.

Measurement Boundary: means a notional boundary drawn around equipment and/or 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 is consumed within or beyond such boundary.

Metering: means collection of data on Energy consumption over a period time at the Contracted Facility using measuring gauges and sensors.

Non-Routine Adjustments means adjustments, for those energy-governing factors, which are not usually expected to change. They refer to the change of any energy-governing characteristic of the Contracted Facility within the measurement boundaries, except the stated Independent Variables used for Routine Adjustments.

Normalized savings: means reductions in energy consumption or costs incurred in the Reporting Period, relative to the energy use or costs that might have been incurred had the facility been equipped and operated as if it were in the Baseline Period, reduced to a normal set of conditions. These normal conditions may refer to a long-term average, or any other mean value related to the chosen period of time, other than the Reporting Period. Normal conditions may also be set as those prevailing during the Baseline Period, especially if they were used as the basis for predicting the Savings.

Operating Cost means current expenditures for Energy use and maintenance of the Contracted Facility.

Operational Verification: means verification that the ECMs are installed and operating properly and have the potential to generate savings. The Operational Verification may involve inspections, functional performance testing, and/or monitoring of data trending with relevant analysis.

Peak Energy Demand: means the highest (or peak) energy demand/capacity measured or expected in the Contracted Facility at any point of time that defines the required Energy demand/capacity.

Precision: means the amount by which a measured value is expected to deviate from the true value. Precision is expressed as a "±" tolerance. Any precision statement about a measured value should include a confidence level, which is the probability that any measured value will fall within a stated range of accuracy.

Reference Price of Energy means a net price as defined in the tender documents for every form of Energy, including specific prices for units of consumption and peak-demand or capacity, as deemed necessary, excluding VAT but including all fees and other costs included in the energy price calculations by the Energy supplier.

Regression Analysis: means a mathematical method that extracts parameters from a set of data to determine the correlation of measured independent variables and dependent variables (usually energy data). .

Reporting Period means any period of time following implementation of an ECMs for which savings reports are prepared in line with Appendix 4 (Guidance for Determining Energy Savings). This period may be as short as the time for an instantaneous measurement of a constant quantity or long enough to reflect all normal operating modes of a system or facility with variable operations. It can be the length of the Guarantee Period; the duration of a performance measurement period (on annual level an equivalent to the Accounting Period) in accordance with this Contract, or indefinite.

Routine Adjustments means any adjustment for any factors, related to expected changes of Independent Variables that influence the consumption of Energy during the Guarantee Period.

Savings: means reductions in Energy consumption attributable to the implemented ECMs. Such physical savings may also be expressed as “avoided energy use” or “normalized savings”, depending on the selected approach used for the adjustments.

Static Factors: mean those characteristics of a facility that affect energy consumption, 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.

All terms used in this document and referring to a term defined in the Contract shall have the meaning explained therein.

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2 MEASUREMENT AND VERIFICATION (M&V) FRAMEWORK

2.1 OPERATIONAL VERIFICATION

Operational verification is performed as a part of the M&V Plan for each project. It serves as an initial step for assessing the Savings potential and should precede the Savings verification activities. A range of Operational verification approaches can be applied, as outlined in Table 1. The selection of a given approach depends on the ECM's characteristics, as noted below.

Table 1 — Operational Verification Approach

Operational Verification Approach	Typical ECM Application	Activities
Visual Inspection	ECM will perform as anticipated when properly installed. Direct measurement of ECM performance is not possible.	View and verify the physical installation of the ECM.
Sample Spot Measurements	Achieved ECM performance can vary from published data based on installation details or component load.	Measure single or multiple-key energy–use parameters for a representative sample of the ECMs installed.
Short-Term Performance Testing	ECM performance may vary depending on actual load, controls or inter-operability of components.	Test for functionality and proper control. Measure key Energy-use parameters. It may involve conducting a test designed to capture the component operating over its full range or performance data collection over sufficient period of time to characterize the full range of operation.

Data Trending and Control-logic Review	ECM performance may vary depending on actual load and controls. A component or system is being monitored and controlled through Building Automation System (BAS) or can be monitored through independent meters.	Set up trends and review data and control logic. Measurement period may last from a few days to a few weeks, depending of the period required to capture the full range of performance.

Operational verification activities can also be applied following the Reporting Period to support Energy Savings persistence. While not formally a part of the M&V process, such a practice is beneficial for an organization, which has improved its energy efficiency. It reduces the risk of adverse shifts in performance associated with the ECMs that yield no results, fade or can be bypassed.

2.2 SAVINGS VERIFICATION

2.2.1 Measurement Boundary

Savings may be determined for the entire Contracted Facility or simply for a portion of it, depending upon the purpose of the reporting.

- If the purpose of reporting is to help manage only the equipment affected by the savings program, a measurement boundary should be drawn around that equipment. After that, significant energy requirements of the equipment within the boundary can be determined. The approach used is the retrofit-isolation option, (Options A or B), further detailed in Chapter 3 below.
- If the purpose of reporting is to help manage whole-building data for energy performance, the meters measuring the supply of energy to the whole facility can be used for the performance and Savings assessment. The measurement boundary in this case encompasses the whole Contracted Facility. The approach used is the Whole-Building Data Analysis, Option C, described in chapter 3.
- Some of the energy requirements of the systems or equipment being assessed may arise outside the defined measurement boundary. Nevertheless, energy effects of the ECM(s) should be taken into account. The energy effects that are significant should be determined based on the measurements, while other ones should be either estimated or ignored.

Any energy effects occurring beyond the notional measurement boundary are called interactive effects or “leakages”. It is necessary to find a way to estimate the magnitude of these interactive effects in order to determine the Savings. Alternatively, they may be ignored as long as the M&V Plan includes an analysis of each effect and its likely magnitude.

2.2.2 Measurement Period Selection

2.2.2.1 Baseline Period

The Baseline Period should be selected with utmost care. The Baseline Period should be established to:

- Fully represent operating modes of the Contracted Facility. This period should span a full operating Cycle from maximum Energy use to minimum consumption;

- fairly represent operating conditions of a normal operating cycle;
- include only such time periods for which fixed or variable Energy-governing facts are known about the facility. An extension to the baseline period back in time in order to include multiple cycles of operation requires equal knowledge of Energy-governing factors throughout a longer baseline period in order to properly derive Routine and Non-routine adjustments after the ECM installation;
- coincide with the period immediately before the commitment to implement the ECMs. A period further back in time would not reflect the conditions existing before the implementation of the ECM and may therefore not provide a proper baseline for measuring exclusively the ECM effects.
- EMC planning may require a study over a longer period of time than the one chosen as the Baseline period. Longer study periods assist the planner in understanding the Contracted Facility's performance and determining the true duration of a normal (standard) cycle.

2.2.2.2 Reporting Period

The Contractor and the Client should jointly determine the length of the Reporting Period, which should encompass at least one normal operating Cycle of the equipment or the Contracted Facility, in order to fully characterize the Savings effectiveness under normal operating modes.

The length of any Reporting period should be determined with due consideration of the lifetime of the ECM and the likelihood of degradation of originally achieved Savings over time.

Regardless of the length of the Reporting Period, metering devices may be left in place to provide a feedback on operating data for routine management purposes, and specifically to detect subsequent adverse changes in performance.

The Client may wish to continue with the reporting even after the expiry of the Contract for his own needs.

2.2.2.3 Adjacent Measurement Periods (on/off test)

When an ECM can be turned on and off easily, the Baseline and the Reporting Period may be selected as adjacent time periods. A change in control logic is an example

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of an EMC that can often be easily halted and then reinstated without affecting the Contracting Facility.

Such "on/off tests" involve Energy measurements with the ECM in effect, and immediately thereafter with the ECM turned off so that pre-ECM (baseline) conditions are reinstated. The difference in Energy use between the two adjacent measurement periods represents the Savings created as a result of the implemented ECM. The Savings are calculated without adjustments if the Energy-governing factors are the same in the two consecutive periods.

Energy Savings = (Energy use in the Baseline period - Energy use in the Reporting period).

This technique can be applied under both retrofit-isolation and whole-Contracted Facility options. However, measurement boundaries must be determined so that it is possible to readily detect a significant difference in metered Energy use when the equipment or systems are turned on and off, respectively.

The adjacent periods used for the on/off test should be long enough to represent stable operation. Such periods should also cover the range of normal operations of the Contracted Facility. In order to cover a normal range of operations, the on/off tests may have to be repeated under different operating modes, such as during different seasons or production rates.

Due attention should also be paid to the fact that the EMCs, which may be turned off for testing purposes are also at risk of being accidently or maliciously turned off, although due to be active.

2.2.3 Basis for Adjustment

The adjustments should be computed from identifiable energy consumption governing factors within the measurement boundary. Two types of adjustments are possible:

a) Routine adjustments – for any Energy-governing factors, expected to change routinely during the Reporting Period, such as weather conditions or production output. A variety of techniques can be used to define the adjustment methodology. Techniques may be as simple as using a constant value (no adjustment) or as complex as a several multiple parameter non-linear equations, each correlating

Energy consumption with one or more independent variables. Valid mathematical techniques must be used in order to define the adjustment method for each M&V Plan.

b) Non-routine adjustments – for those Energy-governing factors which are not usually expected to change, such as: the Contracted Facility size, the design and operation of installed equipment, the number of weekly production shifts, or the type of occupants. These static factors must be monitored for changes throughout the Reporting period.

Therefore, the Savings are more accurately expressed as:

Energy Savings = (Baseline energy use –Energy use in the Reporting period) ± Routine adjustments ± Non-routine adjustments

The adjustments are used to express both sets of measured Energy consumption data under the same set of conditions. The mechanism of the adjustment depends upon whether the Savings are to be reported on the basis of the conditions of the Reporting Period, or normalized to some other fixed set of conditions.

2.2.4 Savings Based on the conditions from the Reporting Period or Avoided Energy Use

When Savings are reported under the terms of the Reporting Period, they can also be termed “Avoided Energy Use” in the Reporting Period. Avoided Energy use quantifies Savings in the Reporting Period relative to what the Energy consumption would have been without the ECM(s) applied. When reporting on the Savings under the terms of the Reporting Period, energy in the Baseline Period must be adjusted to the conditions of the Reporting Period. This commonly used method of reporting of the Savings may be expressed as:

Energy Savings (avoided Energy use) = (Baseline Energy use ± Routine adjustments to Reporting Period conditions ± Non-routine adjustments to Reporting Period conditions) – Reporting Period Energy use

This equation is often simplified to:

Energy Savings (Avoided Energy Use) = adjusted Baseline Energy use – Reporting Period Energy use ± Non-routine adjustments to the Reporting Period conditions

Adjusted Baseline Energy consumption in the Baseline Period is defined as the Baseline energy use plus/minus any Routine and Non-routine adjustments required to adjust it to the conditions of the Reporting Period.

The adjusted baseline Energy use is usually calculated by firstly developing a mathematical model which correlates with the actual Baseline Energy use data with

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appropriate Independent Variable(s) in the Baseline Period. Each Reporting Period's Independent Variable(s) are then inserted into this baseline mathematical model to produce the adjusted Baseline Energy use.

2.2.5 Avoided Energy Use or Normalized Savings?

Factors to be considered when choosing between Avoided Energy Use and Normalized Savings:

a) Avoided Energy use style of Savings:

- are dependent upon the Reporting Period's operating conditions. Even though the Savings can be properly adjusted for phenomena such as weather conditions, the level of reported Savings depends on actual weather conditions, which cannot be directly compared to the Savings predicted under the baseline conditions.

b) Normalized Savings:

- are Savings unaffected by the Reporting Period conditions since once established fixed set of conditions cannot be changed;
- can be directly compared to the Savings predicted under the same set of fixed conditions;
- can only be reported after a full Cycle of Energy use in the Reporting Period, so that the mathematical correlation between the Reporting Period Energy use and the operating conditions can be derived.

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3 ACCEPTABLE OPTIONS FOR MEASUREMENT

3.1 OVERVIEW OF ACCEPTABLE OPTIONS

One or several of the following techniques can be applied to measure the Energy quantities in several forms of Savings equations:

a) utility or fuel supplier invoices or reading utility meters and making the same adjustments to the readings that the utility companies make;

b) special or control meters isolating an ECM or portion of the Contracted Facility from the rest of the Contracted Facility. Measurements may be periodic for short intervals or continuous throughout the Baseline Period or the Reporting Period;

c) separate or control measurements of parameters used in computing the Energy use;

d) measurement of proven proxies for Energy use;

e) if the energy value is already known with adequate accuracy or when it is more costly to measure than justified by the circumstances, then the measurement of Energy use may not be necessary or appropriate. In such cases, estimates may be made of some ECM parameters, but other parameters must be measured (only in case of Option A);

f) three options for determining the Savings (A, B, and C) are deemed acceptable within the present international practice. The choice among the three options involves many considerations including the location of the measurement boundary. Table 2 summarizes the three options that are detailed in this section.

Table 2 — Overview of Acceptable Options

Option	How the Savings Are Calculated	Typical Applications
A. Retrofit Isolation: Key Parameter Measurement Savings are determined by field measurement of the key performance parameter(s), which define the Energy use of the ECM's affected system(s) or the success of the project. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameter, and the length of the Reporting Period. Parameters not selected for field measurements are estimated. Estimates can be based on historical data, manufacturer's specifications, or engineering judgment. Documentation of the source or justification of the estimated parameter is required. The plausible Savings' error arising from estimation rather than measurement is also evaluated.	Engineering calculation of Energy use in the Baseline and the Reporting Period based on: — short-term or continuous measurements of key operating parameter(s); and — estimated values. Routine and Non-routine adjustments, as required.	A lighting retrofit where power draw is the key performance parameter that is measured periodically. Estimate operating hours of the lights based on the occupancy schedule and occupant's behavior in the Contracted Facility.
B. Retrofit Isolation: All parameter Measurement Savings are determined by field measurement of Energy use of the ECM affected system. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the Savings and the length of the Reporting period.	Short-term or continuous measurements of Energy in the Baseline Period and in the Reporting Periods or engineering computations using measurements of proxies of Energy uses. Routine and Non-routine adjustments, as required.	Application of a variable speed drive and controls to a motor to adjust the pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, with readings of power displayed every minute. In the Baseline Period this meter remains in place for a week to verify constant loading. The meter is in place throughout the Reporting Period to track variations in power use.

C. Whole Facility Savings are determined by measuring Energy use at the whole Contracted Facility or Contracted Sub-Facility level. Continuous measurements of the entire Contracted Facility's Energy use are taken throughout the Reporting Period.	Analysis of data using (utility) meter data for the whole Contracted Facility in the Baseline Period and in the Reporting Period. Routine adjustments, as required, use techniques such as simple comparison or regression analysis. Non-routine adjustments, as required.	Multifaceted Energy management program affecting many systems in the Contracted Facility. Measurements of Energy use using utility gauges (water meters, gas and electric utility meters, heat measuring devices) for a twelve-month Baseline Period and throughout the entire Reporting Period.

3.2 OPTION A: RETROFIT-ISOLATION

3.2.1 General

The retrofit isolation allows the narrowing of the measurement boundary in order to reduce the effort required to monitor independent variables and static factors, when retrofits affect only a portion of the Contracted Facility. However, boundaries smaller than the total Contracted Facility usually require additional meters at the measurement boundary. Narrow measurement boundaries also introduce the possibility of 'leakage' through unmeasured interactive effects.

Since measurement is performed at sub-facility, the results of retrofit isolation techniques cannot be correlated to the facility's total Energy use of the Contracted Facility as shown on the utility bills. The Contracted Facility's change beyond the measurement boundary but unrelated to the ECM will not be reported by retrofit-isolation techniques but will be included in the utility's metered consumption or demand.

Two Options are presented for isolating the Energy use of the equipment affected by an ECM from the Energy use of the rest of the Contracted Facility:

› Option A: Retrofit Isolation: Key Parameter Measurement

› Option B: Retrofit Isolation: All Parameter Measurement (please see below).

Additional control and measuring devices are placed at the measurement boundary between the equipment affected by the ECM and the equipment which remains unaffected by it.

When drawing a measurement boundary, care should be taken to consider any energy flows affected by the ECM, but beyond the boundary. A method must be derived for estimating such interactive effects.

Apart from small estimated interactive effects, the measurement boundary defines the metering points and the scope of any adjustments, which may be used in various forms of Savings equations. Only changes to energy systems and operating variables within the measurement boundary must be monitored to prepare the adjustments term(s) of the equation.

Parameters may be continuously measured or periodically measured for short periods. The expected amount of variation in the parameter will govern the decision of whether to measure continuously or periodically. Where a parameter is not expected to change it may be measured immediately after the ECM installation and checked occasionally throughout the Reporting Period. The frequency of this checking can be determined by beginning with frequent measurements to verify that the parameter is constant. Once proven constant, the frequency of measurement may be reduced. To maintain control on Savings as measurement frequency drops, more frequent inspections or other tests might be undertaken to verify proper functioning.

Continuous metering provides greater certainty in reported Savings and more data about equipment operation. The information can be used to improve or optimize the operation of the equipment on a real-time basis, thereby improving the benefit of the ECM itself.

If the measurement is not continuous and meters are removed between the readings, the points of measurement and the specifications of the measuring device should be recorded in the M&V Plan, along with the procedure for calibrating the meter being used. Where a parameter is expected to be constant, measurement intervals can be short and occasional.

Where a parameter may vary daily or hourly, as in most building heating or cooling systems, continuous metering may be the simplest. For weather dependent Energy use, measurements may be taken over a long enough period to adequately characterize the load patterns through all parts of its normal annual cycle (i.e. each season, and weekday/weekend) and repeated as necessary through the Reporting Period.

Where multiple versions of the same ECM installation are included within the measurement boundary, statistically valid samples may be used as valid measurements of the total parameter.

Portable meters may be used if only short-term metering is required. The costs of portable meters can be shared with measurements for other objectives. However, permanently installed meters also provide a feedback to operating staff or automated control equipment for optimization of the systems. Added meters may also enable Energy invoicing for individual users or departments in the Contracted Facility.

Retrofit isolation techniques are best applied where:

- only the performance of the systems affected by the ECM is of concern, either due to the responsibilities assigned to the Contracting Parties, or due to the savings of the ECM being too small to be detected in the time available, when using Option C;
- interactive effects of the ECM on the Energy use of other Contracted Facility equipment can be reasonably estimated, or assumed to be insignificant;
- possible changes to the Contracted Facility, beyond the measurement boundary, would be difficult to identify or assess;
- the Independent variables, which affect Energy use, are not excessively difficult or expensive to monitor;
- control meters already exist to isolate Energy use of systems;
- meters added at the measurement boundary can be used for other purposes such as operational feedback or tenant billing;
- long term testing is not warranted;
- there is no need to directly reconcile savings reports with changes in payments to Energy suppliers.

3.2.2 Retrofit Isolation: Key Parameter Measurement

The energy quantities in the equation

Energy Savings = (Baseline Energy use – Reporting period Energy use) ± Routine adjustments ± Non-routine adjustments

can be derived from a computation using a combination of measurements of some parameters and estimates of the others. Such estimates should only be used where it can be shown that the combined uncertainty from all such estimates will not significantly affect the overall reported Savings. It should be decided which parameters are to be measured and which will be estimated by considering each parameter's contribution to the overall uncertainty of the reported Savings. The estimated values and analysis of their significance

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should be included in the M&V Plan. Estimates may be based on historical data such as recorded operating hours from the Baseline Period; equipment manufacturer's published ratings, laboratory tests, or typical weather data.

If a parameter, such as hours of use is known to be constant and not expected to be impacted by the ECM, then its measurement in the Reporting Period is sufficient. The Reporting Period measurement of such constant parameter can also be considered a measurement of its baseline value.

Wherever a parameter, known to vary independently, is not measured in the Contracted Facility during both the Baseline and Reporting Periods, the parameter should be treated as an Estimate.

Engineering calculations and mathematical modeling may be used to assess the significance of the errors in estimating any parameter in the Reported Savings. The combined effect of estimations should be assessed before determining whether sufficient measurement is in place.

The choice of the factor(s) to be measured may also be considered relative to the objectives of the project or the duties of the Contractor undertaking some ECM-performance risk. Where a factor is significant for performance assessment, it should be measured. Other factors beyond the Contractor's control can be estimated.

If a Savings computation involves subtracting a measured parameter from an estimated parameter, the result is an estimate.

Generally, conditions of variable load or variable operating hours require more rigorous measurement and computations.

3.2.3 Calculations

However, under Option A, there may be no need for adjustments, either Routine or Non-routine, depending upon the location of the measurement boundary, the nature of any estimated values, the length of the Reporting Period, or the amount of time between Baseline measurements and Reporting-period measurements.

Similarly, Baseline or Reporting-period Energy measurements involve measurement of only one parameter under Option A, and estimation of the other. Therefore the proper equation reads:

Option A Energy Savings = Estimated Energy use x (Baseline-Period, measured parameter – Reporting-period, measured parameter)

For example, the key parameters in a lighting replacement ECM are the power of the lights and the operating hours. In the Option A methodology, the operating hours are estimated and the power is measured.

3.2.4 Installation Verification

Since some values may be estimated under Option A, great care is required to review the engineering design and installation to ensure that the Estimates are realistic, achievable, and based on the equipment that should truly produce Savings as intended.

At defined intervals during the Reporting Period, the installation should be re-inspected to verify continued existence of the equipment and its proper operation and maintenance. Such re-inspections will ensure continuation of the potential to generate predicted Savings and validate estimated parameters. The frequency of these re-inspections is determined by the likelihood of performance changes. Such likelihood can be established through frequent initial inspections to establish the stability of equipment existence and performance.

3.2.5 Cost

Energy Savings determinations under Option A can be less costly than under other Options, since the cost of estimating a parameter is often significantly less than the cost of measurement. However, in some situations where Estimation is the only possible route, a good Estimate may be costlier than possible direct measurement. Cost planning for Option A should consider all elements: analysis, Estimation, meter installation, and the ongoing cost to read and record data.

3.2.6 Best Applications

Option A is best applied where:

- Estimation of non-key parameters may avoid possibly difficult Non-routine adjustments when future changes happen within the measurement boundary;
- uncertainty created by Estimations is acceptable;
- continued effectiveness of the ECM can be assessed by simple routine re-testing of key parameters;

- Estimation of some parameters is less costly than their respective measurement according to Option B, below;
- key parameter(s) used to judge a project's or Contractor's performance in computing savings can be readily identified.

3.3 OPTION B: RETROFIT-ISOLATION

ALL PARAMETER MEASUREMENT

3.3.1 General

Option B Retrofit Isolation with all parameter measurement, requires measurement of Energy quantities, or parameters required to compute Energy for the equation below.

Energy Savings = (Baseline-Period Energy Use - Reporting-Period Energy Use) ± Adjustments

The Energy Savings created by most types of ECMs can be determined according to Option B. However, the degree of difficulty and costs increase as metering complexity increases. Option B methods will generally be more difficult and costly than those of Option A. However, Option B will produce more certain results where load or Savings patterns are variable. These additional costs may be justifiable if the Contractor is responsible for factors affecting Energy savings.

3.3.2 Calculations

The equation: Energy Savings = (Baseline-Period Energy Use - Reporting-Period Energy Use) ± Adjustments

is used in adherent computations. However, under Option B, there may be no need for adjustments, either Routine or Non-routine, depending upon the location of the measurement boundary, the length of the Reporting Period, or the amount of time between Baseline and Reporting period measurements. Therefore, Option B may be simplified down to:

Option B Savings = Baseline Energy Use- Reporting-Period Energy Use

3.3.3 Measurement Issues

Retrofit isolation usually requires the addition of special meters, on either a short term or permanent basis. These meters may be installed during an energy audit to help characterize Energy use before design of the ECM. Otherwise, meters may be installed to measures baseline performance for an M&V Plan.

Follow good measurement practices to enable calculation of Energy savings with reasonable accuracy and repeatability. Measurement practices are continually evolving as metering equipment improves.

3.3.3.1 Electricity Measurements

The rate of power input and/or capacity is measured in the same manner at the same time the electricity distribution system operator determines the peak demand for its billing. This measurement usually requires continuous recording of the peak demand at additional control meters. From this record, the additional control meter's demand can be read for the time when the power distribution company reports that the peak demand was recorded on its meter.

The method of measuring rate of power input and/or capacity on additional control meter should replicate the method the power distribution company uses for the relevant billing.

However, due care should be taken to ensure that the Contracted Facility does not contain unusual combinations of equipment that generate high one-minute peak loads which may show up differently in a moving interval, than in a fixed interval. After processing the data into intervals used by the power distribution company, it is necessary to convert it to hourly data for archiving and further analysis.

3.3.3.2 Calibration

Meters should be calibrated according to the recommendation by the equipment manufacturer, and in compliance with the procedures of accredited laboratories. Whenever possible, use reference standards and reference measuring equipment guaranteeing traceability to national and international reference standards. Sensors and metering equipment should be selected based in partly according to the ease of calibration and the ability to maintain the referenced calibration.

3.3.4 Best Applications

Option B is best applied where:

- additional control meters added for isolation purposes will be used for other purposes such as operational feedback or tenant billing;
- Savings or operations within the measurement boundary are variable.

3.4 OPTION C: WHOLE-FACILITY

3.4.1 General

Option C involves the use of utility meters for the whole Contracted Facility or additional control meters to assess the energy performance of the total Contracted Facility. The measurement boundary encompasses either the whole Contracted Facility or its major section. This Option determines the collective savings of ECMs applied to the part of the Contracted Facility monitored by the Energy meter. Also, since whole-Contracted Facility meters are used, the Savings reported under Option C include the positive or negative effects of any non-ECM changes made in the Contracted Facility.

Option C is intended for projects where expected Savings are large as compared to the random or unexplained Energy use variations, which occur at the whole-Contracted Facility level. If Savings are large compared to the unexplained variations in the Baseline-Energy data, then identifying Savings will be easy. Also, the longer the period of Savings analysis after the ECM installation, the less significant is the impact of short-term unexplained variations. Standard Savings should exceed 10% of the Baseline Energy use if the Savings are distinguished from the Baseline Period Data.

Identifying changes in the Contracted Facility that will require Non-routine adjustments is the primary challenge associated with Option C, particularly when the Savings are monitored for longer periods of time. Therefore, it is necessary to perform periodic inspections of all equipment and operations in the Contracted Facility during the Reporting period. These inspections will identify changes in the Static factors with respect to the baseline conditions. Such inspections may be part of regular monitoring to ensure that the intended operating methods are still being followed.

3.4.2 Energy Data Issues

Where Energy supply is only measured at a central point in a group of facilities, which are part of the Contracted Facility, additional control meters are required at each facility or group of facilities for which individual performance is assessed.

For measuring the flow of one Energy type into the Contracted Facility, several meters can be applied. If a meter measures the supply of Energy to a system that interacts with other energy systems, directly or indirectly, this meter’s data should be included in the whole-Contracted Facility Savings determination.

Meters serving non-interacting Energy flows, for which Savings are not to be determined, can be ignored.

It is necessary to determine Savings separately for each meter or additional control meter serving Contracted Facility or for separately metered parts of the facility so that

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performance changes can be assessed. However, where a meter measures only a small fraction of one Energy type's total use, it may be totaled with the larger meter(s) to reduce data-management tasks. When electrical meters are combined this way, it should be recognized that small consumption meters often do not have demand data associated with them so that the totalized consumption data will no longer provide meaningful load factor information.

If several different meters are read on separate days, then each meter having a unique billing period should be separately analyzed. The resultant Savings can be combined after analysis of each individual meter, if the dates are reported.

If any of the Energy data are missing from the Reporting Period, a Reporting-period mathematical model can be created to fill in the missing data. However, the reported Savings for the missing period should identify these savings as "missing data."

3.4.3 Energy Invoice Issues

Energy use data for Option C are often derived from utility meters, either through direct reading of the meter, or from utility invoices. Where utility bills are the source of data, it should be recognized that a utility's need for regular meter reading is not usually as great as the needs of the M&V. Utility bills sometimes contain estimated data, especially for small accounts. Sometimes it cannot be determined from the bill itself whether the data came from an Estimate or an actual meter reading. Unreported estimated meter readings create unknown errors for estimated month(s) and also for the subsequent month of the actual meter reading. However, the first invoice with an actual reading after one or more Estimates will correct the previous errors in Energy quantities. Savings reports should note when Estimates are derived from the utility bill.

Energy may be supplied indirectly to the Contracted Facility, through on-site storage facilities, such as for oil, propane or coal storages. In these situations, the energy supplier's shipment invoices do not represent the Contracted Facility's actual consumption during the period between shipments. Ideally a meter downstream of the storage facility should measure the Energy use. However, where there is no downstream meter, inventory-level adjustments for each invoiced period should supplement the invoices.

3.4.4 Independent Variables

Mathematical modeling can assess independent variables if they are cyclical. Regression analysis and other forms of mathematical modeling can determine the number of

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Independent variables to be considered in the baseline data. Parameters, which have a significant effect on the Baseline Energy use, should be included in the Routine adjustments when determining Savings using one of the following equations:

> **Energy Savings = (Baseline Energy Use – Reporting period Energy Use) ± Routine adjustments ± Non-routine adjustments**
>
> **Avoided Energy Use (or Savings) = Adjusted-Baseline Energy Use – Reporting-Period Energy Use ± Non- Routine Adjustments of Baseline Energy Use to Reporting-period conditions**
>
> **Normalized Energy Savings = (Baseline Energy Use ± Routine Adjustments of Energy Use to fixed conditions ± Non-Routine Adjustments of Energy Use to fixed conditions) - (Reporting Period Energy Use ± Routine Adjustments to fixed conditions ± Non-Routine Adjustments to fixed conditions)**

Independent variables should be measured and recorded at the same time as the Energy data.

3.4.5 Calculations and Mathematical Models

For Option C, the routine adjustments term in

> **Energy Savings = (Baseline Energy Use – Reporting period Energy Use) ± Routine adjustments ± Non-routine adjustments**

is calculated by developing a valid mathematical model of each meter's Energy-use. A model may be as simple as an ordered list of twelve measured monthly Energy quantities without any adjustments. However, the model often includes factors derived from regression analysis, which correlates Energy to one or more Independent variables such as outdoor temperature, Degree-days, metering period length, production, occupancy, or operating mode. Models can also include a different set of regression parameters for each range of conditions, such as summer or winter operation modality of the Contracted Facility with seasonal Energy use variations.

Option C should use complete years (twelve, twenty-four, or thirty-six months) of continuous data, during the Baseline period, and continuous data during the Reporting Period. Models, which use other numbers of months, (nine, ten, thirteen, or eighteen months) can create statistical bias by under or over- representing normal modes of operation.

Meter data can be hourly, daily or monthly whole-Contracted Facility data. Hourly data should be combined into daily data to limit the number of Independent variables required to produce a reasonable baseline model, without significantly increasing the uncertainty in

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computed Savings. Variation in the daily data often results from the weekly Cycle of most facilities.

Many mathematical models are appropriate for Option C. To select the one most suited to the application, statistical-evaluation indices, such as R^2 and t or models from the literature should be considered.

3.4.6 Metering

Whole-Contracted Facility Energy measurements can use the communal utility's meters. Communal utility-meter data is considered 100% accurate for determining the Savings because these data define the payment for Energy, only provided the meter is certified. Communal utility-meter data are subject to national regulations for a specific type of meter.

The Energy supplier's meter(s) may be equipped or modified to provide an electrical pulse output that can be recorded by the Contracted Facility's monitoring equipment. The "energy-per-pulse constant" of the pulse transmitter should be calibrated against a known reference such as similar data recorded by the utility meter.

Separate meters installed by the Contracted Facility owner or user can measure whole-facility Energy. The accuracy of these meters should be considered in the M&V Plan, together with a way of comparing its readings with the utility meter readings.

3.4.7 Best Applications

Option C is best applied where:

- energy performance of the whole Contracted Facility will be assessed, not just the individual ECMs;
- there are many types of ECMs in one Contracted Facility;
- ECMs involve activities whose individual Energy use is difficult to measure separately;
- Savings are large compared to the variance in the baseline data, during the Reporting Period;
- retrofit-isolation techniques (Option A or B) are excessively complex;

- significant future changes to the Contracted Facility are not expected during the Reporting Period;
- system of tracking Static factors can be established to enable possible future Non-routine adjustment;
- reasonable correlations can be found between Energy use and other Independent variables.

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4 MEASUREMENT AND VERIFICATION PLAN

Based on the selection of the approach for the implementation of M&V for a specific project, the M&V plans will have to be prepared. Each plan will have to include the following:

4.1 ECM INTENT

Describe the ECM, its intended result, and the operational verification procedures that will be used to verify successful implementation of each ECM and identify any planned changes to conditions of the baseline values, such as temperature settings in unoccupied parts of the Contracted Facility.

4.2 SELECTED OPTION AND MEASUREMENT BOUNDARY

The selected Option will be used to determine the Savings within the identified measurement boundary of the Savings determination. The boundary may be as narrow as the flow of Energy through a pipe or wire, or as broad as the total Energy use of one or many facilities. Also, the nature of any interactive effects beyond the measurement boundary should be described together with their possible effects.

4.3 BASELINE: PERIOD, ENERGY USE AND CONDITIONS

The Contracted facility's baseline conditions and Energy use data, within the measurement boundary must be documented.

This Baseline documentation should include:

- identification of the Baseline Period;
- Baseline energy consumption and demand/capacity data;
- Independent variable data coinciding with the Energy data (e.g. production data, ambient temperature);
- Static factors coinciding with the Energy data:
  - number of user, method and periods of use;
  - operating conditions for each baseline operating period and season, other than the independent variables;
  - description of any baseline conditions that fall short of the required conditions.

- details of Adjustments that are necessary to the Baseline Energy data to reflect the energy management program's expected improvement from the baseline conditions;
- area, type and insulation of any relevant Contracted facility envelope elements such as walls, roofs, doors, windows;
- equipment inventory;
- data on equipment use;
- data about projects, installation, calibration and all special measurement equipment that is required under the M&V Plan;
- significant equipment problems or outages during the Baseline Period;
- the baseline documentation typically requires well-documented short term metering activities. The extent of this information is determined by the measurement boundary chosen or the scope of the savings determination;
- if the whole-Contracted Facility M&V methods are employed, all Contracted Facility equipment and conditions should be documented.

4.4 REPORTING PERIOD

Period of time following the implementation of an ECM for which savings reports are prepared in line with Appendix 4 (Guidelines for Determining Energy Savings). This period may be as short as the time for an instantaneous measurement of a constant quantity; long enough to reflect all normal operating modes of a system or facility with variable operations; the length of the Guarantee Period; the duration of a performance measurement period (on a yearly base equivalent to the Accounting period) under this Contract; or indefinite.

4.5 BASIS FOR ADJUSTMENT

It is necessary to declare the set of conditions to which Energy measurements will be adjusted. The conditions may be those of the Reporting Period or some other set of fixed conditions. The conditions for the basis of the adjustment determine whether the Savings are reported as avoided Energy or as normalized Savings.

4.6 ANALYSIS PROCEDURE

It is necessary to specify the exact data analysis procedures, algorithms and assumptions to be used in each Savings report. For each mathematical model used, it is necessary to report the terms, and range of Independent variables over which it is valid.

4.7 ENERGY PRICES

It is necessary to specify the Energy prices that will be used to value the savings.

4.8 METERING SPECIFICATIONS

It is necessary to specify the metering points and periods, if the metering is not continuous. For non-utility meters, specify:

- meter characteristics;
- meter reading and witnessing protocol;
- meter commissioning or calibration procedure;
- routine calibration process;
- method of dealing with lost data and data transfer.

4.9 MONITORING RESPONSIBILITIES

It is necessary to assign responsibilities for reporting and recording during the Reporting Period for:

- Energy data;
- Independent variables;
- Static factors within the measurement boundary.

4.10 EXPECTED ACCURACY

Evaluate the expected accuracy associated with the measurement, data capture, sampling and data analysis. This assessment should include qualitative and any feasible quantitative measures of the level of uncertainty in the measurements and adjustments to be used in the planned Savings report.

4.11 BUDGET

Define the budget and the resources required for the Savings determination, both initial setup costs and on- going costs throughout the Reporting Period.

4.12 REPORT FORMAT

It is necessary to specify how the results obtained will be reported and documented.

4.13 QUALITY ASSURANCE

It is necessary to specify quality-assurance procedures that will be used for Savings reports and any interim steps in preparing the reports.

4.14 ADDITIONAL M&V PLAN REQUIREMENTS FOR OPTION A

4.14.1 Justification of Estimates

It is necessary to stipulate the values to be used for estimated values. Explain the source of these estimated values. Show the overall significance of these estimates to the total expected Savings by reporting the range of possible Savings associated with the range of plausible values of the estimated parameters.

4.14.2 Periodic Inspections

It is necessary to define the periodic inspections that will be performed in the Reporting Period to verify that equipment is still in place an operating as assumed, when determining the estimated values.

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5 MEASURMENT AND VERIFICATION (M&V) REPORTS

The M&V reports will have to be prepared as defined by the M&V Plan. The report will include, at a minimum, the following:

- considered needs of the user of the planned M&V report(s);
  - if the user is focused on the overall cost control, the whole Contracted Facility methods may be the most suited,
  - if the user is focused on particular ECMs, retrofit isolation techniques may be most suited,
- observed data of the Reporting Period;
  - the measurement period start and end point in time,
  - the Energy data,
  - the values of the Independent variables,
- description and justification for any corrections made to observed data;
- for option A, the agreed estimated values;
- Energy price schedule used;
- details of any baseline Non-routine adjustments;
- computed Energy Savings;
- computed Savings in monetary units;
- input data from the review of the report with the facility’s operating staff.

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6 PRINCIPLES

M&V plans and reports always have to respect the following principles:

6.1 ACCURATE

M&V should be as accurate as the M&V budget will allow. The M&V costs should normally be small relative to the monetary value of the Savings being evaluated. The M&V expenditures should also be consistent with the financial implications of over- or under-reporting of a project's performance. Accuracy trade-offs should be accompanied by increased conservativeness in any Estimations or judgments.

6.2 COMPLETE

The reporting of Energy Savings should consider interactive effects of a project. The M&V activities should use measurements to quantify the significant effects, while estimating others.

6.3 CONSERVATIVE

Where judgments are made about uncertain quantities, the M&V procedures should be designed to underestimate the Savings.

6.4 CONSISTENT

The reporting of a project's energy efficiency should be consistent with:

- different types of energy efficiency projects;
- different energy management professionals for any one project;
- different periods of time for the same project; and
- energy efficiency projects and new Energy supply projects.

6.5 RELEVANT

The determination of the Savings should measure the performance parameters of concern, or least well known, while other less critical or predictable parameters may be estimated.

6.6 TRANSPARENT

All M&V activities should be clearly and fully disclosed. Full disclosure should include presentation of all of the elements defined for the contents of an M&V Plan and a Savings report, respectively.