Regulatory and Supervisory Bureau for the Electricity and Water Sectors

Measurement and Verification Protocol

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Glossary

Term	Description
Adjustments	Calculations in the savings equation to account for changes in selected independent variables within the measurement boundary since the baseline period (so called "routine" adjustments) or to account for changes in static factors within the measurement boundary since the baseline period (so called "non-routine" adjustments).
Adjusted Baseline Energy	The energy use of the baseline period, adjusted to a different set of operating conditions.
Baseline Energy	The energy used occurring during the baseline period without adjustments.
Baseline Period	The period of time chosen to represent the operation of the facility or system before implementation of an ECM.
Cooling Degree Days (CDD)	Measure designed to reflect the demand of energy needed to cool a building, taking both the influence of temperature and time into account. CDD data is freely available online from e.g. http://www.degreedays.net/.
ECM	Energy Conservation Measure – solution / measure to improve energy performance, including both energy conservation and energy efficiency measures.
ESCO	Energy Service Company
Independent Variables	Parameters expected to change regularly and having measurable impact on the energy use of a system or facility.
Interactive Effect	Energy effects created by an ECM but not measured within the measurement boundary.
IPMVP	International Performance Measurement and Verification Protocol
M&V	Measurement & Verification; Process of using measurements to reliably determine actual savings created within an individual facility by an energy management program.
M&V Design Option	Also M&V Option – Approach selected to determine savings, i.e. Options A, B, C, D, or E as introduced in this document.
Measurement Boundary	Boundary drawn around equipment and/or systems to segregate those which are relevant to savings determination from those which are not.
Non-Routine Adjustments	Calculations in the savings equation to account for changes in static factors within the measurement boundary since the baseline period.
Operational Verification	Verification that the ECMs are installed and operating properly and have the potential to generate savings; may involve inspections, functional performance testing, and/or data trending with analysis.
Reporting Period	Period of time following the implementation of an ECM when savings reports adhere to IPMVP.
Routine Adjustments	Calculations in the savings equation to account for changes in selected independent variables within the measurement boundary since the baseline period.
Savings Equation	General equation used to compare the energy consumption during the Baseline Period and the Reporting Period that allows the quantification of the avoided energy use through an energy management program and/or project.
Savings Report	Final report after completion of the M&V process, made according to the choices and information in the M&V Plan and including the observed data during the reporting period with the justification for corrections (if any), a confirmation of the adopted estimates and assumptions, the energy price schedule that was used, all details of routine and non-routine adjustments to the baseline, and the results of the computed savings in energy and monetary units.
VFD	Also VSD – Variable Frequency Drive or Variable Speed Drive.

1. Introduction

1.1. Background

The aim of "Measurements and Verification" is to establish a standard M&V approach tailored for Dubai based on international best practices, experiences and existing protocols. Customization includes striking a balance between rigor and reasonable effort, aligning with existing metering practices, taking the most common current and future energy conservation measures into account, and aligning with the most relevant infrastructure types.

Figure 1. Standard M&V Protocol - Approach

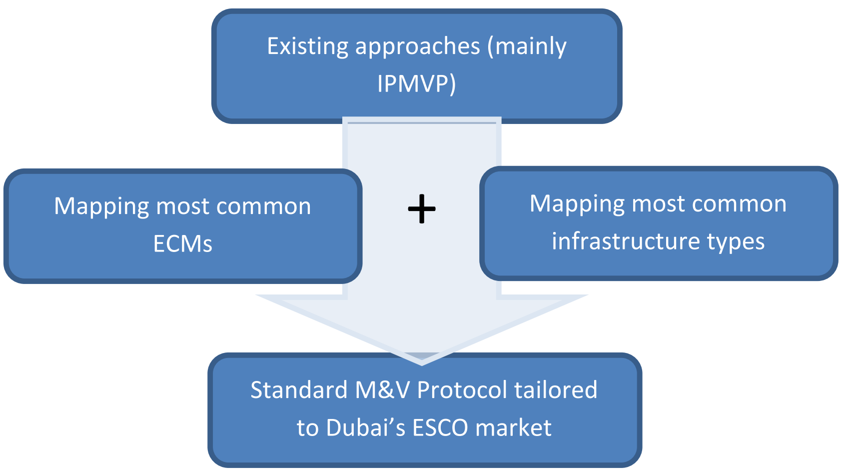


Figure 1 illustrates the different steps in the development of the Standard M&V Protocol.

The main sources of information used for this document are:

- International Performance Measurement and Verification Protocol (IPMVP Vol I; published by EVO[1] and available in multiple languages at no cost);
- M&V Guidelines for Federal Energy Projects; (published by FEMP[2], US DOE and freely available on-line);
- Information gathered during the stakeholder consultation process;
- Example M&V protocols from mainly the US market; and
- DNV KEMA's experience.

[1] EVO : Efficiency Valuation Organization (http://www.evo-world.org/)
[2] FEMP : Federal Energy Management Program(http://www1.eere.energy.gov/femp/)

In this Standard M&V Protocol, only the most essential information on M&V is summarized. The reader is referred to the two first listed sources for more detailed information.

1.2. Structure of the document

The document is structured as follows:

- Summary of basic M&V concepts;
- M&V Options;
- Key M&V steps;
- Standard cases , selected based on stakeholder (ESCOs and governmental institutions) input, for each of which the recommended M&V approach is described; and
- Guidance for non-standard M&V cases.

2. Introduction to M&V

2.1. Overview

M&V is the "*process of using measurement to reliably determine actual savings created within an individual facility by an energy management program*"[3].

Savings cannot be measured directly since they represent the absence of energy use. Instead, savings are determined in most cases by comparing measured use before and after implementation of a project and by making appropriate adjustments for changes in conditions during this process.

Depending on the type and size of the project, M&V activities include some or all of the following: development of the M&V plan, operational verification, meter installation, calibration and maintenance, data gathering and screening, development of a computation method, adoption of acceptable estimates, computations with measured data, and reporting, quality assurance, and third party verification of reports.

2.2. Objectives

The multiple purposes of M&V can include:

- Increasing energy savings[4];
- Documenting financial transactions (e.g. as part of performance-based contracts);
- Enhancing financing for efficiency projects (by increasing credibility);
- Improving engineering design and facility operations and maintenance;
- Managing energy budgets;
- Enhancing the value of emission-reductions;
- Supporting evaluation of efficiency programs; and
- Increasing public understanding of energy management.

2.3. Challenges

The following challenges are typically encountered during M&V activities:

1. Measuring the "absence of energy use", i.e. against a 'counterfactual' baseline (see also further);

[3] Source: IPMVP
[4] M&V increases the visibility of energy use and contributes to raising awareness, which, in turn, typically leads to increased savings.

2. Implementing proper adjustments for factors, such as weather, production volume, level of occupancy, etc. within & beyond control;
3. Accounting for interactive effects (for instance, when implementation of an ECM will have an influence on the energy consumption of other equipment);
4. Remaining consistent with existing standards, other projects and in time;
5. Ensuring proper trade-off between rigor (accuracy & confidence) and effort;
6. Balancing interests of all involved parties; and
7. Alignment with local market specificities.

2.4. Principles

The M&V approach adopts the following principles:

- **Accurate** – The selected M&V option and approach should produce the required accuracy in the Savings Report. At the same time, M&V costs should be acceptable and typically small relative to the monetary value of the savings being evaluated;
- **Complete** – The reporting of energy savings should consider all relevant effects of a project, quantifying all significant effects and estimating others;
- **Conservative** – Where uncertainty is encountered, the savings should be under-estimated;
- **Consistent** – Energy effectiveness monitoring and verification should be consistent between different types of energy efficiency projects, different energy management professionals, different periods of time for the same project and energy efficiency projects and new energy supply projects;
- **Relevant** – Determination of savings should measure the performance parameters of concern. Less critical or predictable parameters may be estimated; and
- **Transparent** – All aspects of the M&V activities should be clearly and fully disclosed and documented in the M&V Plan and the Savings Report.

2.5. Definitions

2.5.1. Performance & Usage

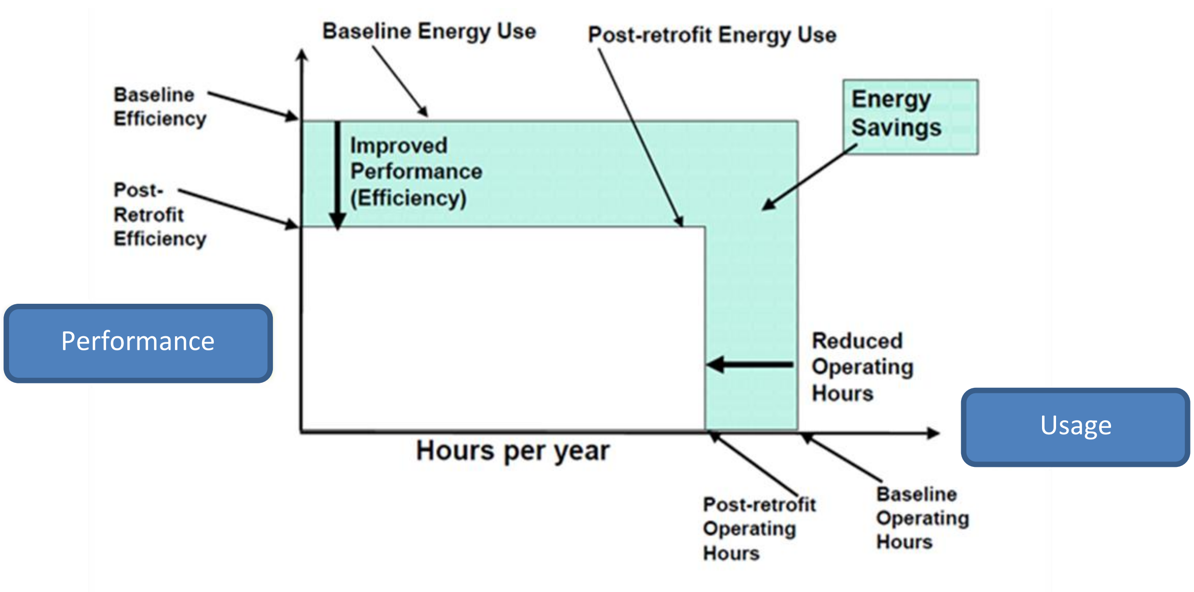
Energy savings as a result of Energy Conservation Measures (ECMs) are in most cases the consequence of an improvement in performance, a reduction in usage, or a combination of both. This principle is illustrated in *Figure 2*[5], in which the blue colored shape represents the saved energy as a combination of an improvement in performance and a reduction in operating hours.

[5] Source : M&V Guidelines – M&V for Federal Energy Projects, FEMP, EERE, US DOE

The performance of a system or equipment relates to its energy efficiency, i.e. the output that is realized per unit of energy consumed. Examples are watt per fixture in case of lighting upgrade, and COP of a chiller.

The usage of a system or equipment expresses its operating time. Examples are operating hours of lighting, and cooling load period.

Figure 2. Performance & Usage



There are a number of ways in which energy savings can be calculated. A high level overview of the different options is provided below:

- **Option A: Retrofit Isolation - Key Parameter Measurement** – Savings are determined by field measurements of the key performance parameters.
- **Option B: Retrofit Isolation - All Parameter Measurement** – Savings are determined by field measurements of the energy use such that all performance parameters are included;
- **Option C: Whole Facility** – Savings are determined by measuring energy use at the whole facility or sub-facility level (typically relying on utility meters);
- **Option D: Calibrated Simulation** – Savings are determined through calibrated simulation of the whole facility or the sub-facility; and
- **Option E: Deemed Savings** – Savings are determined based on engineering calculations using typical equipment characteristics.

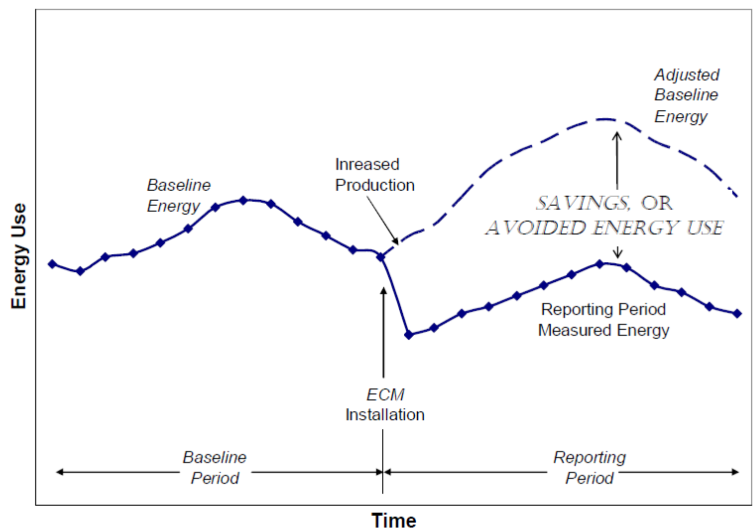
Further information on each of these options is provided in Section 4.

For M&V options that are based on estimating at least part of the key parameters, it is often useful to distinguish between performance related and usage related parameters. In case either one of these categories exhibits little variation, e.g. lighting without dimming has a nearly constant performance, it may be justified to adopt an estimate rather than to implement actual measurements.

2.5.2. Baseline & Reporting Period

Figure 3 illustrates the basic notion of M&V and introduces the concepts: Baseline Energy, Baseline Period, Reporting Period, and Adjusted Baseline Energy.

Figure 3. M&V Concept – Baseline Energy, Baseline Period, Reporting Period, Adjusted Baseline Energy



The Baseline Period constitutes the period prior to implementation of the ECM during which the Baseline Energy is recorded and documented to serve as a basis of comparison later on. The minimum length of the Baseline Period depends on the type of ECM, the type of infrastructure, and the selected M&V option but it should represent all operating modes of the facility. For retrofit isolation options (option A and B), the baseline period can be relatively short, i.e. ranging from a spot measurement to a measurement during a few weeks or months. In case of a whole facility M&V option (option C), a typical baseline period of 12 – 24 months is adopted.

As already indicated in Section 2.3, the key challenge with all M&V efforts constitutes the development of a counterfactual 'baseline', an estimate of what consumption would have been in the absence of the ECM (Adjusted Baseline Energy in *Figure 3*). Since this baseline cannot be observed directly, the rules for developing the baseline and especially the necessary adjustments to account for variations are specified in the M&V Protocol.

The Reporting Period constitutes the period following implementation of an ECM when savings reports adhere to M&V Protocol. The duration of the Reporting Period depends on the type of ECM, the type of infrastructure, and the selected M&V option. However, it should typically cover one full operating cycle of the facility. In case of a whole facility M&V option (option C), a typical reporting period of 12 months is used.

2.5.3. Savings Equation

To quantify the Savings, the energy use during the Baseline Period and during the Reporting Period (see also *Figure 3*) is compared on a consistent basis.

The following Savings Equation is used:

Savings = (Baseline Energy – Reporting Period Measured Energy or Demand) ± Adjustments

(Source: IPMVP)

i.e., in most cases savings are determined by comparing measured use before and after implementation of a project and by making appropriate adjustments for changes in conditions during this process. The period length of the baseline and reporting-period will be equal. These adjustments are essential to ensure that energy use during both periods (baseline and reporting) is considered for a common set of conditions, i.e. comparing 'apples to apples'. As shown in the next section, "routine" and "non-routine" adjustments are discerned.

Depending on the common set of conditions that are selected to perform the calculation, different versions of the savings equation can be used. The principle of the calculation remains the same and more details are available in the IPMVP.

2.5.4. Routine Adjustments & Energy Governing Factors

Routine Adjustments are made to take into account the "normal' fluctuations of Energy Governing Factors, i.e. parameters expected to change regularly and having a measurable impact. Typical examples are weather, production volume, occupancy of a hotel, etc.

In practice, Routine Adjustments might take the shape of a constant in the savings equation or, in more complex cases, a statistical or engineering (energy) model based on regression or principles.

2.5.5. Non-Routine Adjustments & Static Factors

Non-Routine Adjustments are needed for variations in energy governing factors that are usually not expected to change, i.e. so called Static Factors. Typical examples of Static Factors are facility size or use, changes in occupancy types or product range, changes in production shifts, etc.

2.5.6. Interactive Effects

In certain cases, the implementation of an ECM on a specific piece of equipment or system will also have a significant influence on the energy consumption of other equipment or systems, known as Interactive Effects. Depending on the M&V scope, it can be required to include or exclude this influence, which, obviously, will have an impact on the selection of the M&V option.

The influence of replacing incandescent lights by fluorescent lights on the cooling load of the space in which the replacement is executed is a typical example.

The relevant application of the above mentioned concepts is further explained within the sections below.

3. M&V Steps

The M&V process involves multiple activities (see also Section 2.1). However, as a minimum three main steps should be followed:

- M&V Plan;
- Operational Verification; and
- Savings Report.

This section provides an overview of each of these steps.

3.1. M&V Plan

M&V Plan is a recommended part of savings determination. Advance planning ensures that all data needed for savings determination will be available after implementation of the ECM(s), within an acceptable budget.

The development and establishment of the M&V Plan constitutes the first step in the M&V process and should be initiated as early as possible in the project. In any case, it should be completed before the implementation of the ECM is started. The M&V Plan should constitute an integral part of the ECM implementation or energy performance improvement plan and should document all steps in the M&V process.

While the content, length, and level of detail of the M&V Plan depends on the type of ECM or energy improvement program, the type of infrastructure, and the selected M&V Option, the following topics should be addressed:

1. *ECM or Program Description & Objective*; including intended results;
2. *Selected M&V Option*; including motivation, description of measurement boundary, and interactive effects;
3. *Operational Verification Requirements & Procedure;*
4. *Baseline Period, Energy, and Conditions*; including documentation of baseline conditions, i.e. identification of energy governing factors (linked to potential routine adjustments), static factors (linked to potential non-routine adjustments), and the operating cycle;
5. *Reporting Period*;
6. *Basis for Adjustments*; including selection of reference conditions for the calculation of the savings, i.e. avoided energy or normalized savings;
7. *Analysis Procedure*; including mathematical models or algorithms for e.g. routine and non-routine adjustments;
8. *Energy Prices;* including potential assumptions with respect to future evolution;

9. *Meter Specifications;* including the type & duration (permanent / temporary) and the requirements (accuracy, metering frequency, data format).
10. *Monitoring Responsibilities*; including project team with responsibilities and contact details;
11. *Expected / Required Accuracy*; including an a-priori uncertainty analysis if necessary;
12. *Budget*;
13. *Savings Report Format*; and
14. *Quality Assurance*; including QA procedures during the M&V process.

For specific M&V Options, the plan will be extended with for example:

- List and justification of estimates, assumptions and hypotheses (Options A & E)
- Description and frequency of periodic inspections (Options A & E)
- Software name, input and output that will be used (Option D)
- Calibration Procedure of the software (Option D)

Several examples of M&V Plans are available on-line, e.g. from the Lawrence Berkeley National Lab (http://mnv.lbl.gov/keyMnVDocs/mnvplan), and from the FEMP (http://www1.eere.energy.gov/femp/pdfs/sample_mv_plan.pdf).

A1 contains a typical Table of Content for an M&V Plan for an energy improvement program comprising a set of multiple ECMs. The first part of the Table of Content contains project level components, i.e. information applicable to all ECMs, and the second part consists of a series of similar ECM specific components, i.e. information that is specific to particular ECMs.

3.2. Operational Verification

Operational Verification constitutes an important part of almost all M&V Options and serves as a low-cost initial step in the M&V process for nearly all types of ECMs and infrastructures. Activities of Operational Verification include visual inspection, sample or spot measurements, short-term performance measurements (i.e. when the performance of ECM varies depending on actual load and controls, for instance, day lighting sensors and lighting dimming controls, in such cases tests will need to be conducted to capture component performance of a period of time to characterize the full range of operation); data trending (when the performance of ECM varies depending on actual load and controls, for instance, when the component is controlled through building automation system data trends can be set up to characterize overall performance) and longer-term reviews (review of component performance over an extended period). The appropriate timing, frequency, and type of Operational Verification depend mainly on the type of ECM and the selected M&V Option. Typically, Operational Verification activities will take place both during the Baseline Period as well as during the Reporting Period (also known as 'Post-Installation Verification').

Obviously, M&V Options that rely more on assumptions & estimations and less on measurements will require more Operational Verification to properly manage the risks related to the project, e.g. simple visual inspection is sufficient for Option B while more in-depth inspection at several moments in time is recommended for Option A – even more so for Option E.

Measurement and Verification inspection during the Operational Verification stage is normally conducted by the ESCO under the supervision of the client, but can also be conducted entirely by the client or by a third independent party if so preferred by the client.

3.3. Savings Report

After implementation of the ECM and typically at the end of the Reporting Period, a Savings Report is made following the choices and information in the M&V Plan. In case of extended Reporting Periods and also in case a follow-up of the ECM or improvement program is required over several years, multiple Savings Reports are recommended, e.g. on an annual basis.

The report includes the observed data during the Reporting Period with the justification for corrections (if any), a confirmation of the adopted estimates and assumptions, the energy price schedule that was used, all details of Routine and Non-Routine Adjustments to the baseline, and the results of the computed savings in energy and monetary units.

The Savings Report(s) typically constitute(s) the last step in the M&V process.

In addition to the M&V Plan, the Savings Report will include:

- Observed data during the Reporting Period, results and documentation of performance measurements and inspections;
- Confirmation or correction of the adopted Energy Price Schedule;
- Final list of assumptions (e.g. for Options A and E);
- Details of Routine and Non-Routine Adjustments;
- Summary of O&M activities conducted (if any); and
- Computed savings in energy and monetary units, and comparison of actual savings to the guaranteed and/or predicted amounts.

Appendix 2 contains a typical table of content for a Savings Report. Also in this case, the first part of the report contains a general section, which is followed by detailed parts for the ECMs.

4. M&V Options

The energy savings estimated to be delivered by the project can be measured using several techniques. Depending on the program or the project, which in turn depends on the actual ECM and the infrastructure type, a certain option to determine savings is more applicable than another. The following M&V options shall be used to determine savings:

- Option A: Retrofit Isolation – Key Parameter Measurement;
- Option B: Retrofit Isolation – All Parameter Measurement;
- Option C: Whole Facility;
- Option D: Calibrated Simulation; and
- Option E: Deemed Savings

This section provides an overview of each option and provides a recommendation in which case it is most appropriate to use each option when considering Dubai's market specifics.

4.1. Option A – Retrofit Isolation / Key Parameter Measurement (RI / KPM)

For Option A, savings are determined by field measurements (spot / short-term measurements at component / system level during baseline & reporting period) of the key performance parameters. Wherever a parameter, known to vary independently, is not measured, it can be estimated. Typically, those estimates are based on historical and/or manufacturer's data.

Selection of key parameters is guided by their contribution to the overall uncertainty of the reported savings. Estimates should only be used where it can be shown that the combined uncertainty from these estimates will not significantly affect the overall reported savings.

When using M&V Option A, there is typically no need for adjustments such that the savings equation simplifies to:

Savings (Option A) = Estimated Value x (Baseline Period measured parameters – Reporting Period measured parameters)

A typical example of Option A is a lighting retrofit where the power drawn by the corresponding fixture(s) is a key performance parameter that is measured periodically and the operating hours are estimated based on facility schedules and occupant behavior.

On average, the cost of Option A ranges between 1 – 5% of the total project cost, which means that it is a relatively inexpensive approach. In terms of Retrofit Isolation methods, due to the estimations that are needed, it is typically less accurate than Option B.

Option A should generally be considered:

- In case of ECMs with readily assignable savings that amount to below 10% - 20%[6] of the energy consumption that is measured on a facility or sub-facility level, and for which at least part of the performance or usage parameters are (nearly) constant and can be estimated with acceptable certainty and accuracy; and
- For M&V scopes in which interactive effects can be estimated or ignored.

Since most facilities in Dubai are equipped with utility meters only, Option A should be considered for all projects in which the expected savings are below 10% - 20% of the total facility consumption and, at the same time, some performance and/or usage parameters are relatively constant. Measurement of the key parameters, i.e. those for which estimations are not acceptable, will typically be short-term and should be documented in detail in the M&V plan.

Consequently, Option A is the preferred option for the Dubai ESCO market for relatively small projects (savings below 10% - 20% of total facility consumption) in which relevant performance and/or usage parameters can be estimated, e.g. in case of a lighting upgrade in which existing lamps are replaced by high efficiency versions, the consumption per lamp can usually be estimated with sufficient accuracy and reliability.

4.2. Option B – Retrofit Isolation / All Parameter Measurement (RI / APM)

For Option B, savings are determined by field measurements of the energy use such that all performance parameters (directly or via proxies) at component / system level are included.

In many cases, depending on the location of the measurement boundary and the timing of the Baseline and the Reporting Period, no adjustments will be required, thereby allowing the savings equation to be simplified to:

Savings (Option B) = Baseline Period Energy – Reporting Period Energy

A typical example of Option B concerns the application of a Variable Speed Drive (VSD) to a motor. The key performance parameter is the power drawn by the motor and is measured by a kW meter, reading the power every minute, for one week during the Baseline Period (i.e. prior to installation) and at least one full operating cycle during the Reporting Period (i.e. after installation).

Typical cost of Option B ranges between 3 – 10% and is therefore higher than that of Option A. However, Option B will produce more certain results where load and/or savings patterns are variable.

[6] The window between 10% and 20% is indicated as there isn't one specific value that holds for all cases since the suitability of the utility meter to monitor and verify the savings due to a particular ECM depends on many factors such as the type of ECM, the type of infrastructure, the type of utility meter, etc.

Option B should generally be considered:

- In case of ECMs with readily assignable savings that amount to below 10% - 20% of the energy consumption that is measured on a facility or sub-facility level, and for which all relevant performance or usage parameters vary to such a degree that estimates cannot be done with acceptable reliability and accuracy;
- For M&V scopes in which interactive effects can be estimated or ignored; and
- If meters added for isolation purposes will be used for other purposes such as operational feedback or tenant billing.

Option B should be considered for projects in which the expected savings are below 10% - 20% of the total facility consumption and none of the performance and usage parameters are sufficiently constant to allow estimation. Measurement of the key parameters will typically be short-term and should be documented in detail in the M&V plan.

Consequently, Option B is the preferred option for the current Dubai ESCO market for relatively small projects (savings below 20% of total facility consumption) in which all relevant performance and usage parameters must be measured, e.g. in case of a lighting upgrade in which existing lights are equipped with motion sensors and/or automatic dimmer control, the actual performance and usage will need to be measured to provide sufficient accuracy and reliability.

4.3. Option C – Whole Facility (WF)

For Option C, savings are determined by measuring energy use at the whole facility or sub-facility level, depending on the degree of utility sub-metering. Since whole-facility meters are used, effects of non-ECM changes made in the facility will also be recorded and will often necessitate routine and non-routine adjustments. Consequently, the full Savings Equation (see Section 2.5.3) will be utilized. Identifying changes that necessitate non-routine adjustments is an important challenge associated with Option C. Periodic inspections should therefore be made of all equipment and operations during the Reporting Period. Typical Baseline and Reporting Period duration is 12 – 24 months and at least 9 – 12 months, respectively.

A typical example for which Option C is used constitutes a multifaceted energy management program affecting multiple systems and leading to a consolidated saving in excess of 20% of the total facility energy consumption.

Option C's cost depends on the source of the energy data, the availability of suitable utility meters, and the difficulty of tracking static factors within the measurement boundary. Typically, it ranges between 1% and 3% of the total project cost and is therefore, relatively speaking, similar to Option A in terms of cost.

Option C should generally be considered:

- In case of one large or multiple ECMs or programs without readily assignable savings (e.g. building envelope upgrades) in excess of 10% - 20%[7] of the energy consumption that is measured on a facility or sub-facility level;
- For M&V scopes in which interactive effects must be taken into account;
- The energy performance of the whole facility will be assessed, not just the ECMs; and
- When Options A or B are excessively complex, e.g. when interactive effects or interactions between ECMs are substantial and cannot be estimated.

Since most facilities in Dubai are equipped with utility meters only and given the trust that facility owners and operators have in these meters, Option C is the preferred approach for all cases in which sufficiently large energy savings (in MWh or equivalent) are expected and therefore acceptable accuracy and reliability can be attained. Utilizing longer Baseline and Reporting Periods generally improves accuracy and reliability and should therefore be considered.

4.4. Option D – Calibrated Simulation (CS)

For Option D, savings are determined through calibrated simulation of the whole facility or the sub-facility by means of a building energy model. The calibration of the simulation is required to ensure that the predicted energy pattern approximately matches actual metered data. Option D can be used as a Whole Facility or a Retrofit Isolation method. Advanced building simulation software is available from e.g. Department of Energy (DOE) of the U.S. (e.g. eQuest[8]) at little or no cost, but skilled resources are needed to conduct the calculations. When properly using such simulation software, accuracy will depend mainly on the calibration process.

The standard Savings Equation is applied but the energy consumption during either the Baseline Period or the Reporting Period is generated by means of the calibrated simulation.

A typical example of Option D concerns a multifaceted energy management program for a new construction, i.e. the Baseline Energy data is not available.

[7] The window between 10% and 20% is indicated as there isn't one specific value that holds for all cases since the suitability of the utility meter to monitor and verify the savings due to a particular ECM depends on many factors such as the type of ECM, the type of infrastructure, the type of utility meter, etc.

[8] US DOE, www.doe2.com/equest/

Since Option D generally involves intricate and lengthy calculations as well as measurements to generate the calibration data, its cost ranges from 3 to 10% of total project cost.

Option D should generally be considered:

- For large or multiple ECMs or programs with expected savings in excess of 10% - 20% of the facility's energy consumption but where reliable Baseline or Reporting Period data is unavailable;
- In cases where savings associated with individual ECMs are required, but measurements with Options A or B are too difficult or costly; and
- In cases that the Baseline or Reporting Period data is not available, Option D will need to be used. As explained elsewhere, given the limited track record with this option in the region, it is recommended to engage an independent expert to manage the M&V process.

At least until an initial track record has been established in the region with Option D, it is to be considered as a last resort, i.e. when other options are not feasible, e.g. in cases where no reliable Baseline or Reporting Period data is available. In such cases, the involvement of an independent party to review or conduct the simulation can provide an approach in which sufficient acceptance is obtained.

4.5. Option E – Deemed Savings (DS)

For Option E, which is not covered in IPMVP and not regarded as an M&V Option in some literature, savings are determined based on engineering calculations using typical equipment characteristics and operating schedules without field testing or metering. Instead, verification may consist of checking units installed & confirmation of proper operation of the equipment / measure. Given the absence of direct verification of energy savings, the risks related to the ECM are placed virtually entirely with the client.

The Savings Equation depends strongly on the type of ECM and could be:

Savings (Option E) = Number of ECM related equipment installed x
Operating time of ECM related equipment x
Calculated typical saving per ECM related equipment

Typical examples for Option E concern relatively inexpensive ECMs such as e.g. the application of window films.

Since no actual measurements or complex calculations are required, Option E is the least expensive with a typical cost of less than 1% of the total project cost. At the same time, the accuracy obtained from Option E is typically lower than other options.

Option E should generally be considered:

- For ECMs or programs with relatively low expected savings, typically less than 10% of the facility's total energy consumption, that can be calculated sufficiently accurately based on constant performance and usage parameters (e.g. expected performance improvement and assumed / known operating hours of the ECM related equipment). Often this requires the availability of reliable, accurate and validated engineering calculations to determine the expected savings per ECM related equipment / change; and
- The size and cost of the ECM is too small to justify the cost of an IPMVP-guided M&V activity.

In case of Dubai's ESCO market, Option E is attractive since it provides a low-cost and low-risk M&V option that is likely to enhance market growth. At the same time, Option E should only be considered in the case where the corresponding risk remains acceptable for the building owner or facility operator.

5. Standard M&V Cases

In this section, a series of standard M&V cases is discussed. The cases are split by i) types of facilities most likely to participate and ii) most common types of ECMs. A standard M&V approach is presented for each of the cases, in line with the previous sections of this Standard M&V Protocol and with market specificities and local conditions in Dubai.

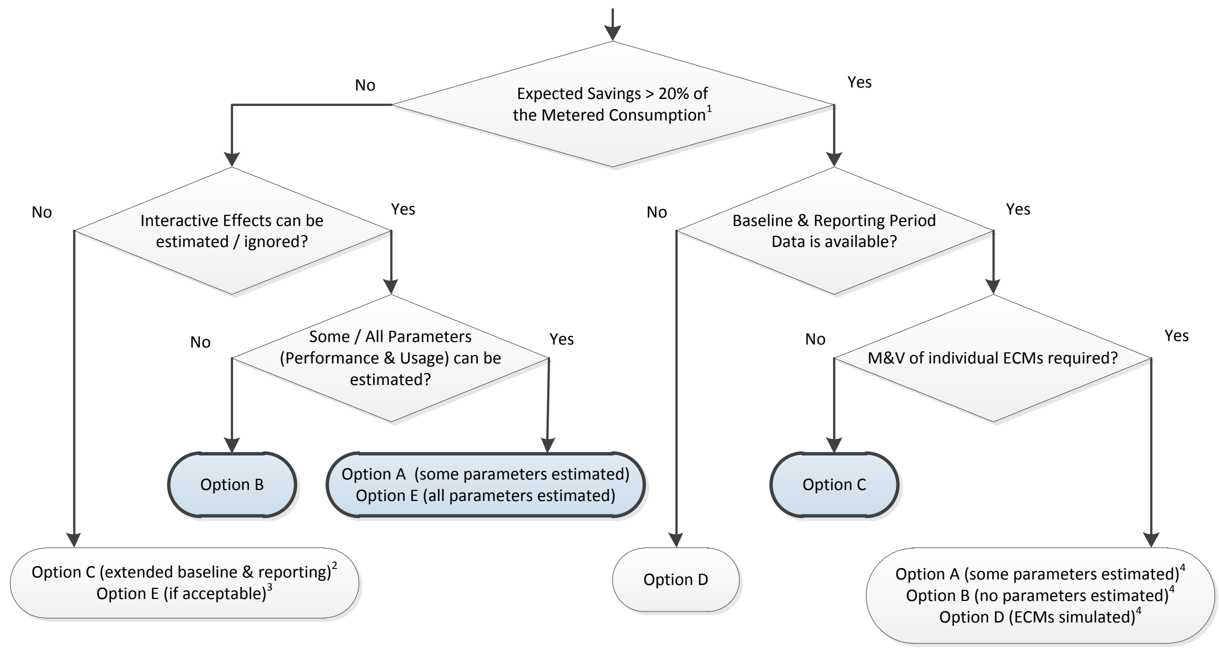
Prior to looking at the standard cases, relevant guidelines for selecting M&V Options are discussed.

5.1. M&V Option selection guidelines

The selection of M&V Options is generally driven by the balance between *required rigor* (i.e. accuracy and certainty of the M&V process) and *acceptable effort* (i.e. cost and time of the M&V process). Both considerations are directly influenced by the type of ECM or improvement program, the type of infrastructure, and the expected energy savings. Consequently, while the development of generic selection guidelines for the M&V Options is possible to a certain degree, there will be cases for which a customized evaluation is required. Such a customized approach will be required in case the outcome of the generic guidelines (i.e. the selected M&V Option) is not satisfactory in terms of accuracy and reliability and/or in terms of required effort.

For the Dubai ESCO market, generic selection guidelines as illustrated in Figure 4 are proposed. The most common cases for Dubai's ESCO market are highlighted in green. Figure 4 provides generic guidance for the selection of M&V Options for common cases. In absence of reliable Baseline or Reporting Period data, Option D will have to be applied. In these cases, the involvement of a third party would probably be required to execute or verify the calibrated simulations and to provide quality assurance of the results. It is certain that specific cases will necessitate deviations from this generic approach. These cases will be characterized by the fact that the application of the guidelines of Figure 4 does not lead to an acceptable balance of required rigor and acceptable effort.

Figure 4. Generic Selection Guidelines



Notes:

1. Given the absence of sub-metering in the Dubai market, the 'metered consumption' in most cases will correspond to the total facility consumption as recorded by the utility meters. In case reliable and accurate sub-meters are available on a sub-facility level, the 'metered consumption' for these sub-facility levels can be considered, which, in turn, will make Option C feasible in more cases.
2. In order to improve accuracy and reliability of Option C for cases with relatively low expected savings (i.e. less than 20% of the metered consumption), it can be considered to extend the Baseline and / or the Reporting Period.
3. Option E should be considered for relatively inexpensive ECMs with a diffuse impact, e.g. application of window film to reduce solar heat gain.
4. To determine the impact of individual ECMs, dedicated estimations and/or measurement campaigns need to be conducted (Option A or Option B). In cases with relatively large number of ECMs, a calibrated building simulation, allowing the calculation of the impact of individual ECMs might be more cost effective (Option D).

The remainder of this section contains eight Standard M&V Cases to which the selection guidelines in *Figure 4* have been applied. Standard M&V Cases were developed using standard ECMs and the infrastructure types in Dubai as listed in *Table 1* and *Table 2* below. In *Table 2*, infrastructure types with similar operating routine and occupancy characteristics have been clustered, e.g. a shopping center and an office building.

Table 1. ECMs considered for Standard M&V Cases

#	Description
1	HVAC – upgrade (e.g. VSD retrofit, heat/cold recovery retrofit, air distribution optimization, chiller optimization, etc.)
2	HVAC – installing programmable thermostats
3	Lighting – lamp and / or fixture upgrade
4	Lighting – control upgrade (e.g. motion sensors, dimmers, timers, etc.)
5	Building envelope upgrade (e.g. improved insulation, fenestration, etc.)

Table 2. Infrastructure types considered for Standard M&V Cases

#	Infrastructure Type	Operating Routine	Occupancy / Use
1	Shopping Centre Office Building	6 d/wk ; 10h/d 5 - 6 d/wk ; 8h/d	Variable Variable
2	Hotel / Apartment Block	Variable	Variable
3	School	5 - 6 d/wk ; 8h/d	Variable
4	Hospital	7 d/wk ; 24h/d	Fixed
5	Government Building	5 - 6 d/wk ; 8h/d	Fixed

Based on the Generic Selection Guidelines in Figure 4 and in line with the Standard M&V Cases elaborated on later in this section, a Guidance Matrix has been established for the ECMs and Infrastructure types of Table 1 and Table 2, respectively. This Guidance Matrix is shown in Table 3.

Table 3. Guidance Matrix

	HVAC Upgrade	HVAC – programmable thermostats	Lighting – Lamp and/or fixture upgrade	Lighting – control upgrade	Building envelope upgrade
Shopping Centre Office Building	**B**	B / E	**A** / E	A / **B**	**C**
Hotel / Apartment Block	**B**	B **/ E**	A / E	A / B	**C**
School	**B**	**B**	E	A / B	**C**
Hospital	**B**	B	**E**	A / B	**C**
Government Building	**B**	B	E	**A** / B	**C**

The cases covered by the Standard M&V Cases in the remainder of this section are indicated in **bold** in Table 3 above.

Notes:

- Option D is not considered at this stage due to the lack of established track record of it in the region. As mentioned, Option D should be considered as a last resort when all the other options are not feasible.
- In addition to the Infrastructure type, the choice of M&V Option for the implementation of programmable thermostats (column 3) depends on the type of HVAC system that is implemented, i.e. a centralized or a distributed system. In case of centralized systems, predominantly used in hotels, schools, hospitals and government buildings, a relatively limited number of dedicated electrical consumption meters are required and Option B is feasible. For distributed systems, such as possibly used in shopping centers and apartment blocks, the cost of dedicated power meters would be excessive and Option E is recommended. This difference is further illustrated by the Standard M&V Cases 2 and 3 below.
- The choice of M&V Option for the lighting control upgrade (column 5) depends on the type of lighting control that is implemented, which is illustrated by means of the Standard M&V Cases 6 and 7 below.

For the selection of the M&V Option for the remaining cases, the Generic Selection Guidelines of Figure 4 have been followed and whilst the proposed M&V Options in Table 3 constitute a generic approach, real case scenarios would need to be evaluated and confirmed and/or modified for specific cases.

5.2. Standard Case 1 – HVAC Upgrade

The ECM regards the upgrade of the existing centralized HVAC system of a facility, comprising a series of separate improvements to the system such as, for example, VSD retrofits, heat/cold recovery retrofit, air distribution optimization, and chiller optimization. Since the approach is the same for all types of facilities, the infrastructure type is not specified. The total expected savings from the ECM are less than 10% of the facility's electricity bill and no other metering is available except for the utility meters. For simplicity's sake and given the climate in Dubai, it is assumed that the HVAC system is used only for cooling (i.e. no heating during winter). If the system is also used for heating, the proposed approach can readily be extended to include this.

The Performance and Usage parameters of the ECM constitute the electrical power consumption and the operating hours of the centralized HVAC system, respectively. Both parameters are heavily influenced by seasonal variations and therefore need to be measured during the Baseline and the Reporting Period. Since the expected savings are less than 10% of the total electricity consumption of the facility, a dedicated electrical power meter needs to be installed during the Baseline and the Reporting Period in order to ensure sufficiently accurate and reliable data. It is assumed that interactive effects can be ignored in this case. Thus all parameters will be measured rather than estimated. The operating cycle is clearly determined by seasonal variations and has therefore a typical duration of 1 year.

Potential Static Factors include changes in occupancy of the facility, in type of activity in the facility, in cooling strategy of the facility, in building envelope characteristics that influence e.g. solar heat gain, etc. Therefore, certain adjustments would need to be accounted for.

The proposed standard M&V approach is documented by means of Table 4.

Table 4. M&V Details – Standard Case 1 – HVAC Upgrade

M&V Option	**Option B**
- Estimated parameters	None
- Measured parameters	Electrical power consumption and operating hours of the facility's centralized HVAC system.
Baseline Period	
- Duration	Sufficiently long to cover at least one operating cycle prior to the implementation of the ECM. Given the importance of seasonal effects, a Baseline Period of at least 12 months and preferably 24 months is recommended.
- Actions	Operational verification during the Baseline Period includes a site visit to

	inspect and document the existing centralized HVAC system. During the Baseline Period, a dedicated electrical power meter is to be installed to record the consumption of the centralized HVAC system. In addition, Cooling Degree Day (CDD)[9] data is to be collected.
- **Conditions**	The main Energy Governing Factor during the Baseline Period constitutes the CDD data for the location of the facility.
Reporting Period	
- **Duration**	Sufficiently long to cover at least one operating cycle after the implementation of the ECM. Given the importance of seasonal effects, a Reporting Period of at least 12 months is recommended.
- **Actions**	Operational verification during the Reporting Period includes a site visit to inspect and document the upgraded centralized HVAC system. During the Reporting Period, a dedicated electrical power meter is to be installed to record the consumption of the centralized HVAC system. In addition, Cooling Degree Day (CDD) data is to be collected.
- **Conditions**	The main Energy Governing Factor during the Reporting Period constitutes the CDD data for the location of the facility.
Savings Equation / Calculation Methodology	Savings (Option B) = Baseline Period Energy – Reporting Period Energy ± Adjustments (if required)
Interactive Effects	Interactive effects are not taken into account since a dedicated electrical power meter for the centralized HVAC system will be used.
Adjustments	
- **Routine**	Routine Adjustments for the electricity consumption for the centralized HVAC system of the facility are to be made based on the recorded CDD data during the Baseline and the Reporting Period. In most cases, a linear relation between HVAC consumption and CDD suffices to determine the collective impact of the different upgrades to the HVAC system[10].

[9] Cooling Degree Days (CDD) is a measure designed to reflect the demand of energy needed to cool a building, taking both the influence of temperature and time into account. CDD data is freely available online from e.g. http://www.degreedays.net/.
[10] The linear relation is to be established by means of a regression analysis and will contain in some cases also a fixed component (i.e. a baseload that is present even if the value of the CDD is zero). Typical examples of applications resulting in a baseload are server rooms that need to be cooled, irrespective of the outside temperature.

- Non-Routine	Non-Routine Adjustments may be required in case of changes in occupancy of the facility, in type of activity in the facility, in cooling strategy of the facility, in building envelope characteristics that influence e.g. solar heat gain, etc.
Expected Cost Range	3% - 10% of the total project cost

Notes:

- For cases where strong correlations between the HVAC energy use and CDD data are observed during the Baseline Period, e.g. coefficients of determination (R^2) above 0.95, a reduction of the duration of the Baseline and Reporting Period can be considered. In such cases, a single cooling season, e.g. 6 – 8 months can be considered for the Baseline Period and half the subsequent cooling season e.g. 3 – 4 months can be considered for the Reporting Period.
- For certain types of facilities, the expected savings from a HVAC upgrade may exceed 10% of the total facility electricity consumption. In such cases, the use of M&V Option C is to be considered (similar approach as the Building Envelope Upgrade, see Section 5.9).
- If important Interactive Effects are to be included in the M&V process, again M&V Option C is to be considered with possibly an extended Baseline and Reporting Period in order to improve accuracy and reliability.

5.3. Standard Case 2 – Programmable Thermostats in a School

The ECM regards the replacement of conventional thermostats for the control of a school's three centralized HVAC systems with advanced programmable thermostats. Features of the new thermostats include, for example, time-based control, automatic override of manual adjustments at start of the next program period, pre-programmed settings, adaptive recovery, and dead band control. The total expected savings from the ECM are less than 10% of the facility's electricity bill and no other metering is available except for the utility meters. For simplicity's sake, it is assumed that the HVAC systems are used only for cooling during the summer months (i.e. no heating during winter). In case heating is used during a significant period, which is deemed unlikely given the climate in Dubai, the presented approach can readily be extended by using Heating Degree Days (HDD) during that period.

The Performance and Usage parameters of the ECM constitute the electrical power consumption and the operating hours of the three centralized HVAC systems, respectively. Both parameters will be heavily influenced by seasonal variations and therefore need to be measured during the Baseline and the Reporting Period.

As the expected savings are less than 10% of the total electricity consumption of the facility, a dedicated electrical power meter needs to be installed for each of the centralized HVAC units during the Baseline and the Reporting Period in order to ensure sufficiently accurate and reliable data. The recordings from these dedicated electrical power meters will provide sufficient information on both the Performance and the Usage parameter of the systems.

It is assumed that interactive effects can be ignored in this case.

Potential Static Factors include changes in occupancy of the facility, in type of activity in the facility, in cooling strategy of the facility, in building envelope characteristics that influence e.g. solar heat gain, etc. Therefore, certain adjustments would need to be accounted for.

The proposed standard M&V approach is documented by means of Table 5.

Table 5. M&V Details – Standard Case 2 – Programmable Thermostats in a School

M&V Option	Option B
- **Estimated parameters**	None
- **Measured parameters**	Electrical power consumption and operating hours of the HVAC units
Baseline Period	
- **Duration**	Sufficiently long to cover at least one operating cycle prior to the implementation of the ECM. Given the importance of seasonal effects, a Baseline Period of at least 12 months and preferably 24 months is recommended.
- **Actions**	Operational verification during the Baseline Period includes a site visit to inspect and document the existing thermostats of the centralized HVAC systems. During the Baseline Period, one dedicated electrical power meter per centralized HVAC system is to be installed to record the consumption. In addition, Cooling Degree Day (CDD) data is to be collected.
- **Conditions**	The main Energy Governing Factor during the Baseline Period is the CDD data for the location of the facility.
Reporting Period	
- **Duration**	Sufficiently long to cover at least one operating cycle after the implementation of the ECM. Given the importance of seasonal effects, a Reporting Period of at least 12 months is recommended.
- **Actions**	Operational verification during the Reporting Period includes a site visit to inspect and document the programmable thermostats of the centralized HVAC systems. During the Reporting Period, one dedicated electrical power meter per

	centralized HVAC system is to be installed to record the consumption. In addition, Cooling Degree Day (CDD) data is to be collected.
- Conditions	The main Energy Governing Factor during the Reporting Period constitutes the CDD data for the location of the facility.
Savings Equation / Calculation Methodology	Savings (Option B) = Baseline Period Energy – Reporting Period Energy ± Adjustments (if required)
Interactive Effects	Interactive effects are not taken into account since a dedicated electric al power meter for the centralized HVAC system will be used.
Adjustments	
- Routine	Routine adjustments for the electricity consumption for the centralized HVAC systems of the facility are to be made based on the recorded CDD data during the Baseline and the Reporting Period. In most cases, a linear relation between HVAC consumption and CDD suffices to determine the collective impact of the implementation of the programmable thermostats[10].
- Non-Routine	Non-routine adjustments may be necessary in case of changes in occupancy of the facility, in type of activity in the facility, in cooling strategy of the facility, in building envelope characteristics that influence e.g. solar heat gain, etc.
Expected Cost Range	3% - 10% of the total project cost

Notes:

- For cases where strong correlations between the HVAC energy use and CDD data are observed during the Baseline Period, e.g. coefficients of determination (R^2) above 0.95, a reduction of the duration of the Baseline and Reporting Period can be considered. In such cases, a single cooling season, e.g. 6 – 8 months can be considered for the Baseline Period and half the subsequent cooling season e.g. 3 – 4 months can be considered for the Reporting Period.
- For certain types of facilities, the expected savings from a HVAC upgrade may exceed 10% of the total facility electricity consumption. In such cases, the use of M&V Option C is to be considered (similar approach as the Building Envelope Upgrade, see Section 5.9).
- If important Interactive Effects are to be included in the M&V process, again M&V Option C is to be considered with possibly an extended Baseline and Reporting Period in order to improve accuracy and reliability.

5.4. Standard Case 3 – Programmable Thermostats in an Apartment Block

The ECM regards the replacement of conventional thermostats for the control of the distributed HVAC units in all apartments of a serviced apartment block. Features of the new thermostats include, for example, remote control, adaptive recovery, and dead band control. The total expected savings from the ECM are less than 10% of the apartment block's electricity bill and no other metering is available except for the overall utility meters. As the expected savings are less than 10% of the total electricity consumption of the apartment block, utility meter data provides insufficient accuracy for M&V purposes. Interactive effects can be ignored in this case.

The Performance and Usage parameters of the ECM constitute the electrical power consumption and the operating hours of the distributed HVAC units, respectively. On the one hand, the Performance parameter is influenced by seasonal variations and, on the other hand, the Usage parameter depends on the occupancy level of the apartments. Therefore all of the parameters will need to be estimated rather than measured. The operating cycle is determined by seasonal variations and has therefore a typical duration of 1 year.

Potential Static Factors include changes in the number of rooms, in the purpose of some of the rooms, in building envelope characteristics that influence e.g. solar heat gain, etc.

The proposed standard M&V approach is documented by means of Table 6.

Table 6. M&V Details – Standard Case 3 – Programmable Thermostats in an Apartment Block

M&V Option	**Option E**
- Estimated parameters	Expected relative electricity savings per distributed HVAC unit when replacing a conventional thermostat by a programmable thermostat.
- Measured parameters	None
Baseline Period	
- Duration	None
- Actions	Assuming that the expected relative electricity savings per distributed HVAC unit can be estimated with sufficient accuracy and reliability, no measurements are required. If this is not the case, the estimate can be established or improved by conducting measurements on a sample of representative apartments (see notes). Operational verification includes a site visit prior to the implementation of the ECM during which a sample of the existing thermostats is inspected.
- Conditions	Not relevant (absence of Baseline Period)

Reporting Period	
- **Duration**	None
- **Actions**	Assuming that the expected relative electricity savings per distributed HVAC unit can be estimated with sufficient accuracy and reliability, no measurements are required. If this is not the case, the estimate can be established or improved by conducting measurements on a sample of representative apartments (see notes). Operational verification includes a site visit after the implementation of the ECM during which a sample of the existing thermostats is inspected.
- **Conditions**	Not relevant (absence of Reporting Period).
Savings Equation / Calculation Methodology	Savings (Option E) = Number of replaced thermostats x expected relative electricity savings per replaced thermostats x estimated electricity consumption of distributed HVAC units
Interactive Effects	Interactive effects are not taken into account.
Adjustments	
- **Routine**	The use of a relative energy savings eliminates the need for Routine Adjustments.
- **Non-Routine**	Non-Routine Adjustments may be required in case of changes in the number of apartments, in the purpose of some of the apartments, in building envelope characteristics that influence e.g. solar heat gain, etc.
Expected Cost Range	Less than 1% of the total project cost

Notes:

- In case a sufficiently accurate and reliable estimate of the expected relative electricity savings per replaced thermostat is not available, a dedicated measurement campaign on a relevant sample of apartments needs to be conducted. For this measurement campaign, a Baseline Period and a Reporting Period of each 12 months is recommended. The measurement campaign requires equipping the distributed HVAC units of the selected apartments with electrical power meters during the Baseline and the Reporting Period. Based on the data gathered, a relatively accurate and reliable estimate of the expected relative electricity savings per replaced thermostat should be able to be established.
- If the expected savings is near to 10% or between 10% and 20%, M&V Option C with extended Baseline and Reporting Period should be considered, with Routine Adjustment for the occupancy levels in the hotel and CDD profiles.

5.5. Standard Case 4 – Lighting Upgrade in a Hospital

The ECM regards the replacement of existing light fixtures with more efficient versions on an application without advanced lighting control systems such as motion sensors, timers, or dimmers. This may involve replacing only the lamps but also the fixtures itself and the ballasts. The total expected savings from the ECM are less than 10% of the facility's electricity bill and no other metering is available except for the utility meters.

This scenario constitutes a potential interactive effect, namely the influence of the lighting replacement on the HVAC load of the affected spaces. This effect can be estimated, and will depend on the type of lighting before and after the retrofit.

The Performance parameter of the ECM is the electrical power consumption per fixture, which is assumed to be constant before and after the replacement and known from e.g. test documents of the supplier. If this is not the case, spot measurements may be required during the Baseline and the Reporting Period (depending on the size of the expected savings of the ECM) – see also the note at the end of this section. The Usage parameter is the operating hours per fixture, which depends on the infrastructure characteristics, i.e. operating routine and occupancy. For a hospital, it can be assumed that the lighting remains on all the time and thus also the Usage parameter is constant, i.e. 8760 hours / year. Therefore all of the parameters are estimated.

Since both parameters are constant (performance and usage), there is no operating cycle and there are no Energy Governing Factors. Potential Static Factors include changes in occupancy type of specific parts of the hospital, in the size and lighting strategy of hospital wings, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc.

The proposed standard M&V approach is documented by means of Table 7.

Table 7. M&V Details – Standard Case 4 – Lighting Upgrade in a Hospital

M&V Option	**Option E**
- Estimated parameters	Power consumption per fixture, number of fixtures, operating hours per fixture.
- Measured parameters	None
Baseline Period	
- Duration	None
- Actions	Assuming that the performance and usage parameters are known with sufficient accuracy and reliability, no measurements are required. Operational verification includes a site visit prior to the implementation of the ECM during which the existing lighting system is inspected. The type, number,

	and operating hours of the system should be documented (including at least an estimate of the fraction of burnt-out or inoperative lights). For larger lighting systems, statistical sampling will need to be applied during the operational verification.
- Conditions	Not relevant (due to absence of an operating cycle)
Reporting Period	
- Duration	None
- Actions	Assuming that the performance and usage parameters are known with sufficient accuracy and reliability, no measurements are required. Operational verification includes a site visit after the implementation of the ECM during which the new lighting system is inspected. The type, number, and operating hours of the system should be documented (including at least an estimate of the fraction of burnt-out or inoperative lights). For larger lighting systems, statistical sampling will need to be applied during the operational verification.
- Conditions	Not relevant (due to absence of an operating cycle)
Savings Equation / Calculation Methodology	Savings (Option E) = Number of replaced lighting fixtures x operating time of the affected lighting fixtures x calculated saving per replaced lighting fixture
Interactive Effects	The most important potential Interactive Effect constitutes the influence of the lighting replacement on the HVAC load of the affected spaces. The relevance of this depends on the type of lighting before and after the retrofit.
Adjustments	
- Routine	None
- Non-Routine	Non-Routine Adjustments may be required in case of changes in e.g. occupancy type of specific parts of the hospital, in the size and lighting strategy of hospital wings, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc.
Expected Cost Range	Less than 1% of the total project cost

Notes:

- In case of uncertainty or insufficient accuracy regarding the performance parameter of the ECM, i.e. the electricity consumption per fixture, a spot or short-term electrical power measurements on a representative sample of the affected fixtures should be organized during the Baseline

Period and the Reporting Period to replace the estimated values based on supplier data. In this case, M&V Option A would be chosen over M&V Option E.

- In case Interactive Effects with respect to e.g. HVAC are anticipated, dedicated measurements during the Baseline Period and the Reporting Period will need to be organized to determine the actual impact. For some cases, an estimate of the impact of the Interactive Effects may be acceptable.
- In case some of the existing fixtures are not replaced and taken out of service (e.g. because the new system provides more light output per fixture), the Savings Equation needs to be modified to take this effect into account.

5.6. Standard Case 5 – Lighting Upgrade in a Shopping Centre / Office Building

The ECM regards the replacement of existing light fixtures with more efficient versions on an application without advanced lighting control systems such as motion sensors, timers, or dimmers. This may involve replacing only the lamps but also the fixtures itself and the ballasts. The total expected savings from the ECM are less than 10% of the facility's electricity bill and no other metering is available except for the utility meters.

This scenario constitutes a potential interactive effect, namely the influence of the lighting replacement on the HVAC load of the affected spaces. This effect can be estimated, and will depend on the type of lighting before and after the retrofit.

The Performance parameter of the ECM is the electrical power consumption per fixture, which is assumed to be constant before and after the replacement and known from e.g. test documents of the supplier. If this is not the case, spot measurements may be required during the Baseline and the Reporting Period (depending on the size of the expected savings of the ECM) – see also the note at the end of this section.

The Usage parameter is the operating hours per fixture, which depends on the infrastructure characteristics, i.e. operating routine and occupancy. For a Shopping Centre or an Office Building (see Table 2), the operating routine and occupancy are variable and cannot be estimated with sufficient certainty and reliability. Given this variability of the Usage Parameter, a measurement throughout the operating cycle is required to reliably and accurately perform the M&V. The operating cycle depends on the operating routine and occupancy of the infrastructure with e.g. shop and office hours as Energy Governing Factors. Therefore, there are some parameters that are estimated and that can be measured.

Potential Static Factors include changes in occupancy type of specific parts of the Shopping Centre or Office Building, in the size and lighting strategy of parts of the facility, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc. Therefore adjustments would need to be taken into account.

The proposed standard M&V approach is documented by means of Table 8.

Table 8. M&V Details – Standard Case 5 – Lighting Upgrade in a Shopping Centre / Office

M&V Option	**Option A**
- Estimated parameters	Power consumption per fixture, number of fixtures
- Measured parameters	Operating hours per fixture
Baseline Period	
- Duration	Sufficiently long to cover at least one operating cycle prior to the implementation of the ECM. For a Shopping Centre or Office Building, care should be taken to include seasonal variations, e.g. vacations, Ramadan, etc. With this in mind, a standard Baseline Period of 1 year is proposed. If a limited number of characteristic periods can be identified, e.g. normal operation and vacation, several shorter Baseline Periods (e.g. each time 1 month) can be considered.
- Actions	Operational verification during the Baseline Period includes a site visit to inspect the existing lighting system. If necessary (see note) a spot measurement of the power consumption per fixture should be organized. During the Baseline Period, the operating hours of the affected light fixtures are measured and recorded directly (e.g. light sensors / logging of lighting patterns) or indirectly (e.g. electrical current to the fixtures).
- Conditions	The main Energy Governing Factor during the Baseline Period constitutes the operating hours of the system.
Reporting Period	
- Duration	Sufficiently long to cover at least one operating cycle after implementation of the ECM. For a Shopping Centre or Office Building, care should be taken to include seasonal variations, e.g. vacations, Ramadan, etc. With this in mind, a standard Reporting Period of 1 year is proposed. If a limited number of characteristic periods can be identified, e.g. normal operation and vacation, several shorter Reporting Periods (e.g. each time 1 month) can be considered.
- Actions	Operational verification during the Reporting Period includes a site visit to inspect the new lighting system. If necessary (see note) a spot measurement of the power consumption per fixture should be organized.

	During the Reporting Period, the operating hours of the light fixtures are measured and recorded directly (e.g. mobile light sensors / logging of lighting patterns) or indirectly (e.g. electrical current to the fixtures).
- **Conditions**	The main Energy Governing Factor during the Reporting Period constitutes the operating hours of the system.
Savings Equation / Calculation Methodology	Savings (Option A) = (Measured operating hours x power consumption per fixture x number of fixtures)$_{\text{Baseline Period}}$ – (Measured operating hours x power consumption per fixture x number of fixtures)$_{\text{Reporting Period}}$ ± Adjustments (if required)
Interactive Effects	The most important potential Interactive Effect constitutes the influence of the lighting replacement on the HVAC load of the affected spaces. The relevance of this depends on the type of lighting before and after the retrofit.
Adjustments	
- **Routine**	None
- **Non-Routine**	Non-Routine Adjustments may be required in case of changes in e.g. occupancy type of specific parts of the Shopping Centre or Office Building, in the size and lighting strategy of parts of the facility, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc.
Expected Cost Range	1% - 5% of the total project cost

Notes:

- In case of uncertainty or insufficient accuracy regarding the performance parameter of the ECM, i.e. the electricity consumption per fixture, a spot or short-term electrical power measurement on a representative sample of the replaced fixtures should be organized to replace the estimated values based on supplier data. In this case, M&V Option B would be chosen over M&V Option A.
- In case Interactive Effects with respect to e.g. HVAC are anticipated, dedicated measurements during the Baseline and the Reporting Period will need to be organized to determine the actual impact. For some cases, an estimate of the impact of the Interactive Effects may be acceptable.

5.7. Standard Case 6 – Lighting Control Upgrade (type 1) in a Governmental Building

The ECM regards the upgrade of the lighting control system of an existing lighting system in a Governmental Building. In practice, the upgrade constitutes the implementation of a series of motion sensors in infrequently occupied spaces (meeting rooms, cafeterias, and toilets) as well as timers in hallways and corridors. No changes are made to the actual lighting system, i.e. fixture, lamp and ballast.

The total expected savings from the ECM are less than 10% of the facility's electricity bill and no other metering is available except for the utility meters.

This scenario constitutes a potential interactive effect, namely the influence of the lighting replacement on the HVAC load of the affected spaces. This effect can be estimated, and will depend on the type of lighting before and after the retrofit.

The Performance parameter of the ECM is the electrical power consumption per fixture, which is not impacted by the implementation of the ECM and which is assumed to be known from e.g. test documents of the supplier. If this is not the case, spot measurements may be required during the Baseline or the Reporting Period.

The Usage parameter is the operating hours per fixture, which is expected to decrease significantly as a result of the ECM. Since the actual decrease depends on the occupancy and usage of the affected spaces and areas, a measurement throughout the operating cycle is required during the Baseline and the Reporting Period. The operating cycle depends on the activities in the Governmental Building and should be chosen either as one extended period or as a number of shorter periods such that all characteristic operating modes are covered (e.g. normal operation, Ramadan, vacation, etc.). Therefore, there are some parameters that are estimated and that can be measured.

Potential Static Factors include changes in occupancy type of specific parts of the building, in the size and lighting strategy of parts of the facility, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc. Therefore adjustments would need to be taken into account.

The proposed standard M&V approach is documented by means of Table 9.

Table 9. M&V Details – Standard Case 6 – Lighting Control Upgrade (type 1) in a Governmental Building

M&V Option	**Option A**
- Estimated parameters	Power consumption of affected fixtures, number of affected fixtures.
- Measured parameters	Operating hours of affected fixtures.
Baseline Period	
- Duration	Sufficiently long to cover at least one operating cycle prior to the implementation of the ECM. Care should be taken to include seasonal variations, e.g. vacations, Ramadan, etc. With this in mind, a standard Baseline Period of 1 year is proposed. If a limited number of characteristic periods can be identified, e.g. normal operation and vacation, several shorter Baseline Periods (e.g. each time 1 month) can be

	considered. Note that this will reduce the measurement cost but not the duration of the Baseline Period.
- Actions	Operational verification during the Baseline Period includes a site visit to inspect the existing lighting control system. If necessary (see note) a spot measurement of the power consumption for the affected fixtures should be organized. During the Baseline Period, the actual operating hours of the affected light fixtures are measured and recorded directly (e.g. light sensors / logging of lighting patterns) or indirectly (e.g. electrical current to the fixtures).
- Conditions	The main Energy Governing Factor during the Baseline Period constitutes the operating hours of the system.
Reporting Period	
- Duration	Sufficiently long to cover at least one operating cycle after implementation of the ECM. Care should be taken to include seasonal variations, e.g. vacations, Ramadan, etc. With this in mind, a standard Reporting Period of 1 year is proposed. If a limited number of characteristic periods can be identified, e.g. normal operation and vacation, several shorter Reporting Periods (e.g. each time 1 month) can be considered. Note that this will reduce the measurement cost but not the duration of the Reporting Period.
- Actions	Operational verification during the Reporting Period includes a site visit to inspect the new lighting control system. If necessary (see note) a spot measurement of the power consumption of the affected fixtures should be organized. During the Reporting Period, the operating hours of the affected light fixtures are measured and recorded directly (e.g. mobile light sensors / logging of lighting patterns) or indirectly (e.g. electrical current to the fixtures).
- Conditions	The main Energy Governing Factor during the Reporting Period constitutes the operating hours of the system.
Savings Equation / Calculation Methodology	Savings (Option A) = (Measured operating hours x power consumption of affected fixtures x number of affected fixtures)$_{\text{Baseline Period}}$ – (Measured operating hours x power consumption of affected fixtures x number of affected fixtures)$_{\text{Reporting Period}}$ ± Adjustments
Interactive Effects	The most important potential Interactive Effect constitutes the influence of the lighting replacement on the HVAC load of the affected spaces. The relevance of this depends on the type of lighting before and after the retrofit.
Adjustments	

- **Routine**	Routine Adjustments are required to take differences in operating routine and occupancy levels into account. This is done by measurement and calculation based on the actual operating hours during the Baseline and the Reporting Period.
- **Non-Routine**	Non-Routine Adjustments may be required in case of changes in e.g. occupancy type of specific parts of the building, in the size and lighting strategy of parts of the facility, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc.
Expected Cost Range	1% - 3% of the total project cost

Notes:

- In case of uncertainty or insufficient accuracy regarding the performance parameter of the ECM, i.e. the electricity consumption per fixture, a spot or short-term electrical power measurement on a representative sample of the replaced fixtures should be organized to replace the estimated values based on supplier data. In this case, M&V Option B would be recommended over M&V Option A.
- In case Interactive Effects with respect to e.g. HVAC, are anticipated, dedicated measurements during the Baseline and the Reporting Period will need to be organized to determine the actual impact. For some cases, an estimate of the impact of the Interactive Effects may be acceptable.

5.8. Standard Case 7 – Lighting Control Upgrade (type 2) in an Office Building

The ECM regards the upgrade of the lighting control system of an existing lighting system in an Office Building. In practice, the upgrade constitutes the implementation of a series of motion sensors in infrequently occupied spaces (meeting rooms, cafeterias, and toilets), timers in hallways and corridors, and automatic daylight dimmers for areas with significant amounts of natural light. These dimmers reduce lighting power by up to 50% during times of maximal entrance of natural light. No changes are made to the actual lighting system, i.e. fixture, lamp and ballast. The total expected savings from the ECM are less than 10% of the facility’s electricity bill and no other metering is available except for the utility meters.

This scenario constitutes a potential interactive effect, namely the influence of the lighting replacement on the HVAC load of the affected spaces. This effect can be estimated, and will depend on the type of lighting before and after the retrofit.

The Performance parameter of the ECM is the electrical power consumption of the affected fixtures, which is variable for the areas in which automatic daylight dimmers are installed. Consequently, at least during the Reporting Period, the electrical power consumption of the affected fixtures will need to be measured throughout the operating cycle.

The Usage parameter is the operating hours of the affected fixtures, which is expected to decrease significantly as a result of the ECM. Since the actual decrease depends on the occupancy and usage of the affected spaces and areas, a measurement throughout the operating cycle is required during the Baseline and the Reporting Period. The operating cycle depends on the activities in the building and should be chosen either as one extended period or as a number of shorter periods such that all characteristic operating modes are covered (e.g. normal operation, Ramadan, vacation, etc.). Therefore, there are no estimated parameters since all of the parameters can be measured.

Potential Static Factors include changes in occupancy type of specific parts of the building, in the size and lighting strategy of parts of the facility, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc.

The proposed standard M&V approach is documented by means of Table 10.

Table 10. M&V Details – Standard Case 7 – Lighting Control Upgrade (type 2) in an Office Building

M&V Option	**Option B**
- **Estimated parameters**	None
- **Measured parameters**	Power consumption of the affected fixtures, operating hours of affected fixtures.
Baseline Period	
- **Duration**	Sufficiently long to cover at least one operating cycle prior to the implementation of the ECM. Care should be taken to include seasonal variations, e.g. vacations, Ramadan, etc. With this in mind, a standard Baseline Period of 1 year is proposed. If a limited number of characteristic periods can be identified, e.g. normal operation and vacation, several shorter Baseline Periods (e.g. each time 1 month) can be considered.
- **Actions**	Operational verification during the Baseline Period includes a site visit to inspect the existing lighting control system. If necessary (see note) a spot measurement of the power consumption for the affected fixtures should be organized. During the Baseline Period, the actual operating hours of the affected light fixtures are measured and recorded directly (e.g. light sensors / logging of lighting patterns) or indirectly (e.g. electrical current to the fixtures).
- **Conditions**	The main Energy Governing Factors during the Baseline Period constitute the electrical power consumption of the affected fixtures and the operating hours of the affected fixtures.

Reporting Period	
- **Duration**	Sufficiently long to cover at least one operating cycle after implementation of the ECM. Care should be taken to include seasonal variations, e.g. vacations, Ramadan, etc. With the implementation of daylight dimmers, seasonal effects will be stronger during the Reporting Period than during the Baseline Period. With this in mind, a standard Reporting Period of 1 year is proposed.
- **Actions**	Operational verification during the Reporting Period includes a site visit to inspect the new lighting control system During the Reporting Period, both the electrical power consumption of the affected fixtures and the operating hours of the affected fixtures are measured and recorded. Possibly, a distinction can be made between fixtures with and without daylight dimming. For the former, it is imperative that the electrical power consumption is measured throughout the Reporting Period. For the latter, it can be accepted that the electrical power consumption is estimated based on test documents or spot-/short-term measurements.
- **Conditions**	The main Energy Governing Factors during the Reporting Period constitute the electrical power consumption of the affected fixtures and the operating hours of the affected fixtures.
Savings Equation / Calculation Methodology	Savings (Option B) = Baseline Period Energy – Reporting Period Energy ± Adjustments (if required)
Interactive Effects	The most important potential Interactive Effect constitutes the influence of the lighting replacement on the HVAC load of the affected spaces. The relevance of this depends on the type of lighting before and after the retrofit.
Adjustments	
- **Routine**	Routine Adjustments are required to take differences in electrical power consumption per fixture and operating hours into account. This is done by measurement of the actual electrical power consumption per fixture and operating hours during the Baseline and the Reporting Period.
- **Non-Routine**	Non-Routine Adjustments may be required in case of changes in e.g. occupancy type of specific parts of the building, in the size and lighting strategy of parts of the facility, in the fraction of the burnt-out or inoperative lights, in operations & maintenance procedures regarding lighting, etc.
Expected Cost Range	3% - 10% of the total project cost

Notes:

- In case Interactive Effects with respect to e.g. HVAC are anticipated, dedicated measurements during the Baseline and the Reporting Period will need to be organized to determine the actual impact. For some cases, an estimate of the impact of the Interactive Effects may be acceptable.

5.9. Standard Case 8 – Building Envelope Upgrade

The ECM regards the upgrade of the building envelope of a facility, comprising a series of improvements to the insulation, fenestration, and doors. Since the approach is the same for all types of facilities, the infrastructure type is not specified. The total expected savings from the ECM are in excess of 20% of the facility's electricity bill and no other metering is available except for the utility meters. Given the climate in Dubai, the HVAC system is used only for cooling during the summer months (i.e. no heating during winter).

The Performance and Usage parameters of the ECM constitute the electrical power consumption and the operating hours of the HVAC, respectively. Both parameters are heavily influenced by seasonal variations and therefore need to be measured during the Baseline and the Reporting Period. Since the expected savings exceed 20% of the total electricity consumption of the facility, the impact of the ECM can be sufficiently accurately and reliably assessed based on utility meter data. Therefore baseline and reporting period data is available in this case.

The total impact of the improvements on the electrical consumption of the facility's HVAC is the scope of the M&V process (rather than assessing the impact of individual measures).

The operating cycle is clearly determined by seasonal variations and has therefore a typical duration of 1 year.

Potential Static Factors include changes in occupancy of the facility, in type of activity in the facility, in cooling strategy of the facility, etc. Therefore adjustments will need to be taken into account.

The proposed standard M&V approach is documented by means of Table 11.

Table 11. M&V Details – Standard Case 8 – Building Envelope Upgrade

M&V Option	**Option C**
- Estimated parameters	None
- Measured parameters	Electrical power consumption of the facility (based on the available utility meter).
Baseline Period	

- **Duration**	Sufficiently long to cover at least one operating cycle prior to the implementation of the ECM. Given the importance of seasonal effects, a Baseline Period of at least 12 months and preferably 24 months is recommended.
- **Actions**	Operational verification during the Baseline Period includes a site visit to inspect and document the existing building envelope elements that will be upgraded. During the Baseline Period, the utility meter readings and Cooling Degree Day (CDD) data is to be collected.
- **Conditions**	The main Energy Governing Factors during the Baseline Period constitute the CDD for the location of the facility.
Reporting Period	
- **Duration**	Sufficiently long to cover at least one operating cycle after implementation of the ECM. Given the importance of seasonal effects, a Reporting Period of at least 12 months is proposed.
- **Actions**	Operational verification during the Reporting Period includes a site visit to inspect and document the upgraded building envelope elements. During the Reporting Period, the utility meter readings and Cooling Degree Day (CDD) data is to be collected.
- **Conditions**	The main Energy Governing Factors during the Reporting Period constitute the CDD for the location of the facility.
Savings Equation / Calculation Methodology	Savings (Option C) = Baseline Period Energy – Reporting Period Energy ± Adjustments
Interactive Effects	Since utility meter data is used, interactive effects are properly taken into account.
Adjustments	
- **Routine**	Routine adjustments for the electricity consumption for the HVAC system of the facility are to be made based on the recorded CDD data during the Baseline and the Reporting Period. In most cases, a linear relation between HVAC consumption and CDD suffices to determine the collective impact of the different upgrades to the building envelope.
- **Non-Routine**	Potential Static Factors include changes in occupancy of the facility, in activity in the facility, in cooling strategy of the facility, etc.

Expected Cost Range	1% - 3% of the total project cost

Notes:

- In case Baseline Period or Reporting Period data is not available, M&V Option C will need to be replaced by Option D.

6. Non-Standard M&V

For cases which are not covered explicitly by the previous section, the reader is invited to explore analogies between the case at hand and the standard cases (see Section **Error! Reference source not ound.**) in terms of the type of ECM and the type of infrastructure. On the basis of these analogies, i.e. concerning variability of performance and usage parameters, operating routine, and occupancy, and by means of the guidelines in Figure 4, it is expected that the selection of the proper M&V Option will be straightforward in most cases. Proper selection of the M&V Option will result in an associated cost along the lines as specified in Section 4.5 and in a good balance between rigor and effort.

If no satisfactory solution in terms of the M&V process can be established based on the current Standard M&V Protocol, it is recommended to consult the IPMVP text and/or the FEMP M&V Guidelines, two comprehensive internationally accepted protocols upon which the current protocol has been developed. In these cases, also the involvement of a third party can be considered, e.g. an independent consultant specialized in M&V of energy and/or water savings projects. The third party will be able to provide advice regarding the M&V process and will improve assurance and confidence of all parties involved, i.e. the client, the ESCO, and the financial institution (if applicable). In addition to resolving M&V issues, the third party can also clarify the understanding of end-users and play a valuable role as impartial expert in case of disputes. Clearly, however, the third party role does not necessarily cover the full project and could be limited to specific stages, e.g. establishing or reviewing the M&V plan, reviewing the (annual) Savings Reports, etc.

A1. M&V Plan - Table of Contents Example

1. Executive Summary
    1.1. Proposed Annual Savings Overview
    1.2. M&V Plan Summary
2. Whole Project Data / Global Assumptions
    2.1. Risk & Responsibility
    2.2. Energy, (Water), and O&M Rate Data
    2.3. Schedule & Reporting for Verification Activities
    2.4. Operations, Preventive Maintenance, Repair, and Replacement Reporting Requirements
    2.5. Construction Period Savings
    2.6. Status of Rebates
    2.7. Dispute Resolution
3. ECM 1 - M&V Plan and Savings Calculation Method
    3.1. Overview of ECM, M&V Plan, and Savings Calculation
    3.2. Energy (and Water) Baseline Development
    3.3. Proposed Energy & Water Savings Calculations and Methodology
    3.4. Operations and Maintenance and Other Cost Savings
    3.5. Proposed Annual Savings for ECM
    3.6. Post-Installation M&V Activities
    3.7. Performance Period Verification Activities
4. ECM 2 - M&V Plan and Savings Calculation Method
    4.1. Overview of ECM, M&V Plan, and Savings Calculation
    4.2. Energy (and Water) Baseline Development
    4.3. Proposed Energy & Water Savings Calculations and Methodology
    4.4. Operations and Maintenance and Other Cost Savings
    4.5. Proposed Annual Savings for ECM
    4.6. Post-Installation M&V Activities
    4.7. Performance-Period Verification Activities
5. ECM 3 …

A2. Savings Report – Table of Contents Example

1. Executive Summary
    1.1. Project Background
    1.2. Brief Project & ECM Descriptions
    1.3. Summary of Proposed and Verified Energy and Cost Savings
    1.4. Savings Adjustments
    1.5. Performance and O&M Issues
    1.6. Energy, (Water), and O&M Rate Data
    1.7. Verified Savings To Date
2. Details for ECM 1
    2.1. Brief Description of ECM 1
    2.2. M&V Activities Conducted
    2.3. Verified Savings Calculations and Methodology
    2.4. Details of O&M and Other Savings
    2.5. O&M and Other Activities
3. Details for ECM 2
    3.1. Brief Description of ECM 1
    3.2. M&V Activities Conducted
    3.3. Verified Savings Calculations and Methodology
    3.4. Details of O&M and Other Savings
    3.5. O&M and Other Activities
4. Details for ECM 3
    4.1. …