PROJECT DEVELOPMENT SPECIFICATION – STREET LIGHTING

VERSION 0.1 – MAY 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754056. The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EASME nor the European Commission are responsible for any use that may be made of the information contained therein.

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0.0 INVESTOR CONFIDENCE PROJECT

The Investor Confidence Project (ICP) provides a framework for energy efficiency project development, which standardises projects into verifiable project classes in order to reduce transaction costs associated with technical underwriting, and increase reliability and consistency of energy savings. The ICP Protocols and certification system provides a comprehensive framework of elements that is flexible enough to accommodate the wide range of methods and resources that are specific to individual projects.

0.1 PROJECT DEVELOPMENT SPECIFICATION

This ICP Project Development Specification (PDS) represents a comprehensive resource designed for project specialists, third-party quality assurance assessors, and investors to ensure that projects are developed in full compliance with the ICP Protocols. This document provides essential information about the protocol's requirements, best practices, quality management tasks, and references to ensure that all stakeholders are operating from a common set of requirements and practices.

Projects that successfully complete the ICP System and comply with the protocols are eligible to be certified as an ICP Investor Ready Energy Efficiency (IREE) project, which assures investors that a project conforms to ICP Protocols, has standard documentation, and has been verified by a certified third party. Therefore investors can rest assured that the project has been engineered to consistent industry best practices.

ICP is contract agnostic, and it does not guarantee energy or cost savings or set any performance requirements for projects. ICP can help reduce risks for investors on projects following ICP, but it does not itself eliminate risk. Examples of risks which are outside the scope of ICP, but which should be considered and addressed in the delivery of any well-conceived energy efficiency project include:

- Contractual risks
- Budget risks
- Programme risks/time delays
- Risks associated with third parties e.g. equipment suppliers, installers
- Selection of poor quality equipment
- Loss of income generation e.g. renewable energy generation incentives
- Risk associated with delivery of a public service

0.2 USING THIS SPECIFICATION

This PDS is intended to support the elements, procedures and documentation requirements presented in the ICP Street Lighting Protocol. This document's structure mirrors that of the protocol and utilises the same five categories that represent the lifecycle of a well-conceived and well-executed energy efficiency project. Within each category, this document presents an overview of the requirements, best practices, quality assurance tasks, and available resources.

Energy efficiency investors, which can include system owners, energy service companies, finance firms, insurance providers, and utility programmes, are exposed to performance risk but often do not have the expertise necessary to evaluate the complex technical details associated with an energy efficiency project. Regardless of the expertise and skills of the investors, transaction costs can mount when multiple investors evaluate a project with each pursuing an expensive and time consuming technical due diligence process.

For this reason, it is important that the project investor select and engage a team with established experience and skills in energy efficiency project development, which is willing to engage with and adhere to the ICP protocols. Only projects which are reviewed by members of the ICP Quality Assurance Assessor Network for Street Lighting are able to receive IREE certification.

The Project Developer team is responsible for developing a project based on sound engineering principles and best practices as outlined in this document, utilising industry standard approaches for the development of each component of the project. This PDS describes the minimum requirements and the resources that each team member should utilise in order to adhere to these industry standards and protocols, as well as best practice approaches where relevant.

The ICP Quality Assurance Assessor must be a third party to the project developer, and is responsible for reviewing the outlined components and project documentation to ensure the specifications laid out in this PDS are met. Best practice is to involve the QA assessor in the process early on during project development, so that issues can be identified and addressed as the project progresses, rather than at the end of a project when necessary information may be difficult to capture, or when changes may have far reaching (and serious financial) implications. The QA assessor should refer to the requirements for each section of this specification, and to the QA tasks listed to help guide the process of evaluating and ultimately signing off a project as compliant with the Protocols.

In general, it is not feasible or necessary for the QA assessors to recreate the entire project development process. The QA effort should involve application of available resources to review and address the areas of a project that represent the greatest level of potential uncertainty and risk. The QA assessor should take a collaborative approach, working with the project development team to resolve issues in order to develop a financially sound investment built on strong engineering and conservative assumptions.

0.3 PROJECT DEVELOPMENT PROCESS

The ICP framework is divided into five categories that represent the entire lifecycle of a well-conceived and well-executed energy efficiency project:

1. **Baselining**
2. **Savings Calculations**
3. **Design, Construction, and Verification**
4. **Operations, Maintenance, and Monitoring**
5. **Measurement and Verification (M&V)**

It is important that project development activities are performed in sequence, since the development of preceding components of a project will affect subsequent project components and results. For example, the baseline and energy end-use consumption estimates are used in the bounding of energy savings predictions, as well as in the M&V efforts. Inaccuracies in the development of these key baseline components can produce an inaccurate assessment of the verified energy savings.

The following table provides a general overview of the specific project development and quality assurance activities by that should be performed by the third-party QA assessor and the periods within a project's development that these tasks should be performed.

STAGE	Develop Baseline	Savings Calculations / Investment Package	Design, Construction & Verification	Operations, Maintenance & Monitoring	Measurement & Verification
PROJECT TASKS	Select a baselining approach	Develop initial savings estimates	Appoint an Operational Performance Verification Resource	Select and document ongoing management regime e.g. periodic inspection/aM&T	Develop an IPMVP based M&V plan
	Collect asset information, plans, drawings and utility asset registers	Establish preliminary cost estimates	Develop OPV plan	Develop OM&M plan	Appoint an M&V professional
	Work with the M&V specialist to define the measurement boundary	Ascertain preferred financial analysis metrics	Where appropriate, make provisions for the development and implementation of training	Where appropriate, make provisions for the development and implementation of operator training	Provide the M&V Plan, input data sets, assumptions and calculation to all parties
	Establish the baseline period	Develop a set of recommended ECMs	Make provisions for updating systems manual (if one already exists)	Make provisions for updating operator's manual (if one already exists)	Option A/B: Collect post-retrofit energy / performance data
	Collect hourly electricity consumption data, independent data, utility rate schedule, historical energy use data and independent variable data	Develop a project inventory for the proposed ECMs	If no systems manual exists, at minimum provide full inventory of installed equipment	Make provisions for the development and execution of instructions to notify affected stakeholders	Option A/B: Performance data analysis
	Define the project boundary	Estimate the total annual operational hours	Where appropriate, make provisions for a simple OPV report		Option A/B: Verified savings calculations
	Develop a project inventory	Calculate and document the estimated annual performance period energy consumption			Option C: Post-utility data
	Calculate estimated operational hours, power consumption and hence baseline energy consumption	Develop detailed energy savings calculations			Option C: Identify / quantify non-routine adjustments
	Cross-check the baseline energy consumption using spot measurements	Develop final investment package for ECMs			Option C: Regression based analysis
	Calendarise independent variable data	Prepare final report summarising ECMs			Develop a deemed savings plan
	Develop the baseline energy consumption model and test accuracy				
	Establish peak demand and pricing (where it is in effect)				
	Chart average daily demand (where demand charges or time-of-using pricing is in effect)				

QUALITY ASSURANCE TASKS	Review and approve selected baseline period	Review and approve credentials of individual responsible for energy model/savings calculations	Review and approve credentials of individual responsible for OPV	Review and approve OM&M plan, setting out procedures	If using a measurement based approach: Review and approve M&V plan
	Review and approve electricity data and rates, significant variable data and energy baseline	Review and approve credentials of individual responsible for designing the lighting system	Review and approve OPV plan	Review and approve selected ongoing management regime	Review and approve credentials of individual responsible for M&V
	Review and approve energy consumption model	Review and approve energy savings calculations, including supporting data	Review and approve systems manual/full inventory	Review and approve operator's manual (if one exists)	Review and approve the deemed savings plan
	Review and approve regression model when used	Review and approve annual operational hours and total annual post-retrofit energy consumption calculations	Review and approve training (interview system operators)	Review and approve training (interview system operators)	
		Review and approve project inventory			
		Review and approve investment package			
		Review and approve ECM report including final energy cost savings and pricing for each measure			

Key
All approaches
Measurement based approach
Deemed savings approach

0.4 DETERMINING PROJECT APPROACHES

There is currently a single protocol available that describes a standardised approach to the development of energy efficiency projects relating to street lighting systems. The Street Lighting Protocol is intended for projects that include:

- **Replacement of typical street lighting equipment –** for example, upgrades to lighting fixtures and central management systems
- **Installation of new ancillary equipment, including new technologies, as part of an energy efficiency project** - for example, installation of WiFi hotspot equipment or public information systems etc.

However two different approaches to baselining, savings calculations and M&V are permitted under this protocol. Selecting the most applicable method for use when developing a street lighting energy efficiency project is the key first step in the process. Selection of the most appropriate method to use must involve assessment of the asset information and variable data available, and the project's overall scale.

The baselining, savings calculations and M&V approaches permitted are:

- **International Performance Measurement and Verification (IPMVP) compliant measurement-based approach:** Options A, B or C may be appropriate. This approach involves direct monitoring (metering) of energy consumption, and calculation of energy savings based on IPMVP.
- **Deemed savings approach:** where asset information is used to develop energy consumption estimates. This approach involves estimating the system's pre and post project consumption based on deemed values of registered assets, and then providing a calculated energy saving based on the difference between these estimates.

Each project will have its own set of characteristics, as well as limitations on resources and time. The Project Developer should work with the investors and Quality Assurance Assessor to determine the most suitable approach to apply to any given project. The measurement-based approach is considered to represent best practice, and is more closely aligned with the required methods under other ICP protocols. Where the electricity utility bills for the street lighting system are based on metered consumption, or where energy monitoring forms part of an existing management system, the measurement-based approach should ideally be used.

However, in many cases street lighting systems are powered by unmetered supplies, with billing based on a register of asset charge codes. In these circumstances, the deemed savings approach provides an acceptable alternative and should be used in compliance with the procedures defined in the Street Lighting Protocol.

If the IPMVP compliant measurement-based approach is selected, the Measurement and Verification approach(es) needs to be determined and planned for as early on in the process as is feasible. An IPMVP Option C, *Whole Facility* approach, which analyses pre- and post-retrofit utility bills to verify performance, represents a comprehensive method for savings verification, but it may not be appropriate for all projects. This approach requires that energy savings are significant enough to have a discernible impact on the system's overall energy consumption (typically representing greater than 10% of total energy consumption). Most projects that involve the upgrade of existing luminaires to LEDs will be expected to achieve a higher saving than this, but where outdoor lighting forms part of a wider system containing non-lighting loads, Option C may not be the most appropriate method. Additionally, this approach can become complicated by non-routine adjustments that need to be quantified and incorporated into the analysis.

IPMVP Option A and/or B approaches, which deal with key or all parameter measurement of a *Retrofit Isolation*, can isolate the performance of individual measures and may be more appropriate for some projects. However, these approaches require parameter measurements, which will require monitoring through the system's integrated management system, or through the use of remote data logging equipment, tools that may not be available to all projects. These approaches, alongside the deemed savings approach, should be evaluated and incorporated into an overall plan that takes into account the scope of the measures, their potential interactive effects, and the available resources.

1.0 BASELINING

1.1 OVERVIEW

A technically sound energy consumption baseline provides the starting point for accurate projection of energy savings, and is critical for measurement and verification upon completion of a retrofit and/or retro-commissioning. The street lighting system baseline must establish how much energy can be expected to be used over a representative time period. For projects using IPMVP Option C, this will usually be a period of 12 months. The baseline needs to cover all energy consumed within the measurement boundary:

- Total electricity purchased
- Any other resources consumed as fuel and any electricity generated on site from alternative energy systems
- Any renewable energy generated and used by the system

It must also factor in the impact of independent variables such as hours of operation and changes to illuminance levels on the system's energy consumption.

The process of data collection, compilation, analysis, and reporting should be consistent, transparent, and practical. While in-house tools for performing these tasks represent a reasonable approach, there are also a myriad of available proprietary tools that automate many of these tasks that should be considered as part of the project development process. These tools can download data automatically from the energy provider, perform regressions, provide visualisation of the data, and typically include reporting and exporting features. Many of these applications can be used to perform IPMVP Option C M&V analysis, or to bound energy savings estimates.

The following table indicates which elements described in this document apply to each baselining approach:

Element	Section	Measurement-based approach	Deemed Savings approach
Baseline Operational/Performance Data	1.1		
Electricity Consumption Data	1.2		
Asset Information	1.3		
Independent Variable Data	1.4		
Project Inventory	1.5		
Estimated Annual Baseline Energy Consumption	1.6		
Regression Analysis	1.7		

1.1 BASELINE OPERATIONAL/PERFORMANCE DATA

Acquiring system performance data is critical to the decision making process around informed solution designs and energy savings calculations. The system data may be collected through on-site inspections/surveys, reviews of system documentation, observations, and short-term field monitoring or measurements.

Information to be collected can include: up-to-date equipment inventories; technical specifications for equipment; site drawings; condition surveys; power distribution diagrams; control or operation descriptions.

The data collection process must utilise standardised forms and methods. The collection of information must be thorough, as well as specific to the system itself, and information should be captured in a way that can be easily and clearly referenced in subsequent project development tasks. These resources can then be easily referenced, shared, and used in all subsequent project development efforts, including: energy conservation measure (ECM) descriptions; ECM savings calculations; cost estimation; design and construction; operational performance verification; operations, maintenance and monitoring (OM&M); and M&V efforts. Without these sources of data collection, other project development tasks can be hindered.

The collection procedure should follow the requirements set out in:

- *EN 16247-1 Energy audits - General requirements*
- *ISO 50002 Energy audits - Requirements with guidance for use.*

The underlying concept is that energy professionals with different (but reasonable) levels of skill or experience should be able to follow a specific process and utilise standardised tools such that each one would gather the same information independently in a comprehensive and accurate manner.

1.2 ELECTRICITY CONSUMPTION DATA

Collecting electricity consumption data is an important component of baseline development for street lighting projects. All electricity consumption entering or leaving the defined measurement boundary should be accounted for, and used to inform the baseline and savings calculations.

Sub-metering is an accurate method to measure energy end-use consumption. For end-uses that vary based on independent variables, the metering period should cover a period that will capture both minimum and maximum loads. Energy for lighting will obviously be the main end use, with the key independent variable typically being hours of darkness. Regression analysis can then be used to estimate annual energy consumption for end-use.

When gathering historical energy use, the goal should be to account for 100% of electricity consumption. If electricity bills are based on estimated meter consumption, meter readings should be taken directly (manually or automatically). These data should be used as the basis for an analysis that is adherent with the requirements of IPMVP. Either exclude or adjust the baseline accordingly to account for any data which is not representative of typical operating conditions.

Data that does not correspond to calendar month periods (such as for two partial months) should be converted to calendar months. Determine average daily consumption during each partial month, and multiply the daily average consumption by the total number of days in the calendar month.

1.3 ASSET INFORMATION

Collection of accurate building asset, operational and performance data is critical to the decision-making process. These data provide the foundation for all important investment decisions, including building performance tracking, assessment of energy efficiency opportunities, ECM investment implementation and performance tracking. The extent of the street lighting system, which relates to the physical scope of the proposed project, should be determined and recorded using plans and drawings, utility asset registers and physical inspection as necessary.

Key system information that should be collected if available, where relevant to ECMs, is provided below:

1) Overview of system description e.g. from Operation and Maintenance manuals
2) System schematics and other installation drawings/diagrams

3) Details of energy consuming components and equipment, including type, number, capacity, hours of operation, location, areas served, and controls, including:
   a) Lighting fixtures
   b) Ballasts or drivers
   c) Power supply including cable losses
   d) Sensors including presence detection and light level detection
   e) Any ancillary equipment e.g. mobile phone cell sites, pollution monitoring sensors etc.
4) Central Management System
   a) Information on how the systems is controlled including key data such as set points and time clock settings
   b) Information on associated communications modules

Where the deemed savings approach is being used, note that there is an additional requirement for a detailed project inventory, defined in section 1.5.

1.4 INDEPENDENT VARIABLE DATA

When using a measurement-based approach and for the defined baseline period, where relevant to ECMs and to identified variations in energy use within the measurement boundary, acquire any available data on relevant independent variables. For example, weather conditions, or number of lamp burn-outs may be required to achieve an accurate regression model.

1.5 PROJECT INVENTORY

For projects following a deemed savings approach, once asset information has been acquired, a project inventory should be developed for all the assets being removed or replaced. Depending on the country or location where the project is taking place, ideally a street lighting inventory should contain information regarding: the position of the fixture, its location on the street, street/road name, mounting height and the equipment type. It may also contain any associated codes used to manage the street lighting system.

Assess the number of each type of asset, including any assets which are not operational, and establish the associated power consumption for each (see section 1.6).

1.6 ANNUAL BASELINE ENERGY CONSUMPTION

1) **Estimate total annual operational hours ('burn hours') of lamps to be upgraded** – this should be based on a nationally/internationally recognised approach that accounts for any effects which may impact hours of operation. Any inventory or asset register should contain information regarding burn hours and may be used as a source for this estimate. In cases where such a standardised figure

is not available, either carry out on-site measurement, or a conservative estimate of burn hours should be derived and agreed with the system operator.

2) **Calculate the estimated power consumption** – using the appropriate power consumption for each piece of equipment and estimated hours of operation within the project boundary. Where information on power consumption is not available from manufacturer's data, from the official asset register (database) used for utility billing purposes, or from nationally recognised reference documents, on-site measurements must be carried out. A sampling or spot-measurement approach may be used provided there is a description of how the sample size has been determined and along with the associated precision. There will usually be a trade-off between sampling error and the cost of measurement. Guidance on sampling can be found in *IPMVP: Statistics and Uncertainty for IPMVP, 2014 (section 3).* Care should be taken where dimmable lamps are concerned. Estimates of power consumption at various levels of dimming should be derived from the same source. For any cases where the dimming level is determined by local conditions (such as daylight sensing, presence detection of people or traffic, etc), estimates of power consumption should be conservative and consistent across the project.
3) **Calculate the estimated annual baseline energy consumption** – multiply the annual hours of operation by the power consumption for each type of equipment within the project boundary and then by the number of each piece of equipment to achieve the estimated baseline energy consumption.

Checks should be performed to ascertain relative accuracy of the estimated baseline. These should be done, where possible, by comparing results to existing nationally recognised benchmark data.

1.7 REGRESSION ANALYSIS

Normalisation is used to analyse, predict and compare energy performance under equivalent conditions. Regression-based energy modelling is a specific type of normalisation, and involves the development of an energy consumption equation, which relates the dependent variable (total system/equipment energy consumption) to independent variables known to significantly impact the system or equipments energy consumption. Independent variables typically include weather-related data, and may include other variables such as operating hours.

Under an IPMVP Option C approach, a regression model is usually required to develop the baseline energy consumption model. Under an IPMVP Option A or B approach, this is the Retrofit Isolation Baseline, which may also require regression analysis depending on the relationship between the energy consumption data and the independent variables.

The energy consumption equation can be determined using a regression analysis – the process of identifying the straight line of 'best fit' between the system's energy consumption and one or more independent variables. An example of linear regression is shown below:

Energy consumption (kWh) = $m_1X_1 + m_2X_2 + C$

Where

C = energy baseload in kWh (determined from regression analysis)

$m_{1,2,etc}$ = energy consumption in kWh per unit e.g. energy consumption per piece of equipment

$X_{1,2,etc}$ = number of units e.g. number of lighting fixtures etc.

Further variables can also be included – this is known as multiple-linear regression. More complex regression techniques may also be employed – where these are required, the reasoning and calculation details must be provided. It is unlikely that such techniques will be required for most street lighting projects, where a simple correlation with operating hours, or a proxy such as daylight hours, may be established.

For projects following IPMVP Option C, in rare cases it may be deemed that variation in baseline energy use is not correlated with the independent variables, and therefore that normalisation and development of the energy consumption equation is not required. In such cases, clear justification for the omission of an energy consumption equation should be provided.

As part of an initial evaluation of the regression-based energy model and the energy consumption equation, an assessment should be made of the coefficient of correlation (R^2). Regression models should be evaluated on the basis of the predicted savings, which must be greater than twice the standard error of the baseline value, as set out in IPMVP - see *IPMVP: Statistics and Uncertainty for IPMVP, 2014 (section 1).* Guidance for developing and evaluating regression models can be found in *IPMVP: Statistics and Uncertainty for IPMVP, 2014 (section 2)*. IPMVP sets outs alternative approaches that should be considered where the baseline model criterion is not met:

- More precise measurement equipment
- more independent variables in the energy consumption model
- Larger sample sizes
- An alternative IPMVP Option that is less affected by unknown variables

Generally, a value of 0.75 or more, and a CV[RMSE] of less than 0.2 would usually indicate a good relationship.

2.0 SAVINGS CALCULATIONS

2.1 OVERVIEW

Savings calculations can be performed using spreadsheet calculations, but the use of proprietary tools may be required to carry out supporting calculations. Regardless of the method employed, the procedure should be transparent and well documented. Calculation methods must be based on sound engineering methods, and assumptions must be based on observations, field measurements, monitored data, or documented resources. In all cases, these assumptions should be conservative, transparent, and documented.

ECM descriptions submitted for Quality Assurance review should be thorough, documenting the existing system and the proposed retrofit. The descriptions should provide enough detail to demonstrate to the Quality Assurance Assessor that the design has been developed to a sufficient level of detail so as to develop accurate scopes of work and informed costings.

The results of the savings calculations must be calibrated to estimated or known energy end-use consumption. Under a deemed savings approach, estimates should be compared to benchmark data or experience from other street lighting projects.

The table below indicates which elements described in this document apply to each protocol:

Element	Section	Measurement-based Approach	Deemed Savings Approach
Develop a recommended set of ECMs	2.2		
ECM Savings Calculations: Energy consumption data	2.3		
ECM Savings Calculations: Estimated annual performance period energy consumption	2.4		
Financial Savings Calculations based on Energy Tariff	2.5		
Investment Criteria and Package	2.6		
Reporting	2.7		

2.2 DEVELOPING THE RECOMMENDED SET OF ECMS

Under a best practice approach, the results of an energy audit, alongside the experience of the engineers involved, lighting design specialist, system owner preferences, observed condition and operation of existing systems, preliminary calculations, and contractor recommendations, will provide a list of ECMs that can include low-cost and no-cost measures, operations and maintenance (O&M) improvements, and capital cost items. Estimates of annual energy savings and implementation costs are key components of the financial evaluation of an EE project (see section 2.5). Detailed descriptions of the measures must be developed so as to aid in the development of these estimates.

As a minimum, documentation for each recommended measure should include the following information:

- The present condition of the system
- Recommended action or improvement.

A best practice approach would also include:

- Design of the lighting solution for the street scene according to industry best practice, avoiding over-lighting
- A condition survey of existing street lighting assets
- Where existing supports are to be used, confirmation that these are suitable for any proposed new luminaires, which may have different dimensions or weight
- Risk of lamp failure, and integration of reasonable assumptions into the project business case
- Schedule for implementation
- Summary of specific maintenance requirements or considerations associated with the ECMs, particularly any impacts on maintenance costs
- Potential issues which may prevent successful completion
- Individuals and teams involved in implementing the project, and their responsibilities
- Engagement of external organisations involved including contractors and local electricity supply companies

2.3 ECM SAVINGS CALCULATIONS: ENERGY CONSUMPTION DATA

Calculation methods such as regression analysis or open-book methods are a practical and effective method for estimating energy savings associated with proposed ECMs for street lighting projects.

When preparing savings estimates for a list of proposed ECMs, the adopted calculation methods should be based on sound engineering principles and methodologies. Input values should be derived from measured data, system design information, equipment suppliers, engineering or maintenance teams and on-site observations. For each ECM, the calculation methodology, formulas, inputs, assumptions and their sources need to be clearly documented.

References such as the IPMVP Guidance and *EN 16212:2012 Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods (section 6)* provide detailed guidelines for calculation methods and best practices. Vetted resources for calculation tools, particularly those that are nationally recognised, can be used or referred to as models for calculation methods.

When developing spreadsheet-based savings calculations, assumptions and values should never be "embedded" in formulas. The formulas should use cell references for constants, assumptions and other inputs. These inputs should be clearly defined, calculations explained, and associated units noted elsewhere in the spreadsheet. This clear, consistent, "open book" approach is critical to the quality assurance process.

Each ECM calculation should contain sufficient explanation such that (with the necessary input information) a reviewer can reconstruct the calculations. This explanation should include documentation of the formulas used, as well as any assumptions and their sources.

Inputs for the savings calculations may be derived from the outputs of an energy audit. However these are determined, each of these inputs is critical to the accurate estimation of energy savings and should always be conservative, especially if they are less well defined or unknown. Operational and performance data also provide key inputs to inform and bound the savings calculations. These data can be obtained from functional performance tests or short-term monitored data, and can help define or demonstrate opportunities or deficiencies in operation or performance.

If third-party proprietary calculation tools are used, sufficient documentation must be included to validate unbiased assessment of energy savings estimates. This documentation should include sources such as calculation methodology, white papers and independent testing results of the application. Caution should be applied when using any tools provided by a retailer or manufacturer to estimate the energy savings associated with their product.

Estimated energy savings should always be compared to estimated or measured energy end-use consumption to ensure that the estimated energy savings are reasonable. They should also be compared to simple estimation efforts or previous energy savings estimates. This ensures figures are credible and provides an elementary level of quality assurance.

2.4 ECM SAVINGS CALCULATIONS: ESTIMATED ANNUAL PERFORMANCE PERIOD ENERGY CONSUMPTION

When preparing savings estimates for a list of proposed ECMs, the adopted calculation methods should be based on sound engineering principles and methodologies. This is also true for savings calculations produced using a deemed savings approach.

Deemed savings should be calculated following the method outlined in section 1.6, using a proposed project inventory and total annual operational hours calculated under the proposed operation of the new scheme. The final output should be a calculated and well documented estimated annual performance period energy consumption.

Each ECM calculation should contain sufficient explanation such that (with the necessary input information) a reviewer can reconstruct the calculations. This explanation should include documentation of any formulas used, as well as any assumptions and their sources.

Estimated energy savings should be compared to benchmark data or rules of thumb to ensure that the estimated energy savings are reasonable. They should also be compared to simple estimation efforts or previous energy savings estimates. This ensures figures are credible and provides an elementary level of quality assurance.

2.5 FINANCIAL SAVINGS CALCULATION BASED ON ENERGY TARIFF

Conversion from energy savings to cost savings must be based on the appropriate local utility rate schedule in effect at the time:

- Measurement-based approach: where time-of-use charges are in effect, ensure each rate is applied to the appropriate portion of energy consumption, in order to develop cost savings
- Deemed savings approach: where time-of-use charges are in effect, apply each rate to the appropriate portion of energy consumption, in order to develop cost savings.

2.6 INVESTMENT CRITERIA AND PACKAGE

Different owners, investors, and programs will each have their own financial metrics, criteria, and requirements in order to help ensure that their investment goals are met. ICP's goal is to create confidence in project energy performance but does not take a position on which financial metrics or criteria should be used to evaluate a potential investment. ICP also does not require or promote any specific financial "hurdle rate" such as a specific payback or Savings to Investment Ratio.

Determining which financial metrics are important to the investors when assessing the financial performance of a proposed project should be the first step in the investment criteria process. In these discussions, the project team should also attempt to discover any specific metric requirements (such as payback less than 5 years or an Savings to Investment Ratio of greater than 1) as well as figures that are required for calculations such as discount rates. Once these preferences are uncovered, it is then the responsibility of the project development team to provide the necessary data and calculations that will allow the investors to evaluate the project's potential according to their preferences. The metrics used should be properly defined and calculated using accurate implementation costs, estimated savings, available incentives, effective useful life, escalation rates, interest rates, discount rates, cost of capital, lease terms, and other appropriate financial inputs.

Accurate cost estimation for the proposed ECMs represents a critical component that is used to financially evaluate a proposed EE project. Sound cost estimates are the basis for developing return on investment criteria and to prepare a clear, realistic financial package.

At the feasibility stage, initial quotes may be obtained from the contractor, provided a minimum of three are used. It is recommended that the project use contractors experienced in street lighting system upgrades. Alternatively, cost estimates may be based upon the engineer's experience with previous projects of similar nature and scope. Either of these approaches can be used to rank improvements and determine which measures will be included in a final bid package.

Ultimately, however, the final investment package should have pricing based upon bids that represent the price for which a contractor has committed to make the improvements. Cost estimates during the calculation phase must include as applicable:

- A construction feasibility review indicating which measures will be included, description of construction methods, allowable working hours, impacts on public access and safety, access points for bringing in any large equipment, permits required, and possible environmental issues.
- Categories and multiple line items for all necessary trades, i.e. civil (structural and site work), electrical, environmental (hazardous material mitigation), provision of temporary services as necessary. Underlying lists or spreadsheets which include cost information must be submitted.
- All lines by trade must include labour and materials. "Labour" can be specified by budgetary allowance rather than by hours and hourly rates.
- Operation and maintenance costs throughout the life of the project.
- Line items for professional fees, engineering, commissioning, construction management, permitting, measurement & verification, contractor overhead and profit (O&P), and contingency. These are typically estimated as percentages of the total implementation costs.
- Costs may need to be split into total cost and incremental cost, depending on the audience and the investment contemplated. The incremental cost is the additional cost of installing the energy efficient system or piece of equipment compared to the baseline cost, or non-energy-related investment. For example, utility incentives are often based on incremental cost.

- Estimated equipment useful life expectancy and equipment degradation are required, and should be included to assess the overall economic performance of proposed retrofits. These estimates should be conservative and based on accepted values.

2.7 REPORTING

An industry-accepted format should be used for reporting project analysis results should be set out in such a way that the methods used - with regards to data collection, site survey approach, inclusion/exclusion of ECMs, savings calculations - are clearly set out and justified. The report should be clearly written, and contain an executive summary which ideally contains technical and non-technical sections, background and context for the audit, facility energy use summary, ranked ECM list, conclusions and recommendations.

3.0 DESIGN, CONSTRUCTION AND VERIFICATION

3.1 OVERVIEW

This part of the process focuses on the engineering, implementation and operational performance verification phase of the project. The key objectives here are to ensure that the project is designed and implemented as intended by providing oversight to the design as well as general oversight during construction. The submission of designs, equipment, performance specifications and installation plans should all be carefully reviewed to ensure compliance with the proposed project and the stakeholder's requirements.

The term "operational performance verification" (OPV) is used specifically for retrofit or energy efficiency upgrade projects to distinguish the activity from "comprehensive" commissioning. OPV focuses on the commissioning activities specific to the ECMs, rather than involving the commissioning of the entire system.

An important part of the OPV process is ensuring that roles, responsibilities, expectations, timelines, communication and access requirements have been established. Furthermore, it should be confirmed that arrangements have been made regarding inspections, operational performance verification activities, testing, training, acceptance criteria, operations, maintenance and monitoring requirements, and that M&V guidelines are being met where required.

A qualified OPV Specialist who meets the qualification or experience requirements set out in the protocol should be appointed to manage the process, either under an in-house role or using a third party. Although there are advantages to appointing an in-house representative, the use of a third party is recommended to avoid conflicts of interest and to take advantage of specialised skills.

The quality assurance (QA) process should provide unbiased recommendations for fast and fair resolution of any project related issues that might arise during design and/or construction. The QA assessor should work closely with the OPV Specialist, stakeholders and project development/construction teams to ensure that the project is completed on time and within budget.

The following elements apply to both the measured-based and deemed savings variants of the protocol:

Element	Section	Protocol
Operational Performance Verification Plan	3.2	
Training	3.3	
Systems Manual (if one already exists)	3.4	

3.2 OPERATIONAL PERFORMANCE VERIFICATION PLAN

The OPV effort begins with the development of an OPV plan. The plan should be developed pre-construction, and should describe the verification activities and target energy budgets associated with the project and the individual ECMs.

The plan should also describe any data logging, control system trending (analysis of historical data and using it to predict future performance), functional performance tests, spot measurements, or observations that will be used to establish both baseline operation as well as post-construction operation, to demonstrate post-project and ongoing performance improvements.

The OPV process itself, led by the OPV Specialist, should include consultation with the energy audit team (if used), monitoring of designs, submittals and project changes, and inspections of the implemented changes. It also includes the responsibility for and means of reporting deviations from design and projected energy savings to the project owner. If the collected post-installation data, testing results, or other observations indicate underperformance or a lack of potential continued performance, the OPV Specialist needs to:

- Help the customer / project development team fully install the measure properly and then re-verify its performance; or
- Work with the project development team to revise the ECM savings estimates using any actual post-installation data and associated inputs.

Successful OPV is achieved by applying traditional commissioning methods to the measures and affected systems involved in the project, and supplementing these methods with more data-driven activities, such as data logging, trending, and functional performance testing, as appropriate.

The level of effort required to verify proposed ECMs will vary. Measures that are well-known or have relatively low expected savings, and measures whose savings are fairly certain may only warrant installation verification. That is, visual inspection to ensure that the measures have been implemented properly. Measures with greater savings at risk or greater uncertainty will require a greater depth of OPV, such as sample spot measurements of upgraded lamps, short term performance testing, and the collection and analysis of post-installation performance data.

Where a deemed savings approach is being taken, a visual inspection of installed assets will suffice. For projects using a measurement-based approach, the M&V method being employed may also affect the OPV approach taken. That is to say, if an Option B M&V approach is being employed, where all key parameters associated with the ECM are to be measured, then a simpler visual inspection may suffice for OPV. However, if an Option A or Option C approach is being employed, then a more thorough OPV approach should be utilised to verify ECM functionality.

Typical OPV approaches include:

- Visual inspection - verify the physical installation of the ECM; applied when ECM operation is well understood and uncertainty or anticipated relative savings are low.
- Spot measurements - measure key energy consumption parameters for ECMs or a sample of ECMs; applied when ECM performance may vary from published data based on installation details or load, or anticipated relative savings are low.
- Functional performance testing - test functionality and proper control; applied when ECM performance may vary depending on load, controls, or interoperability of other systems or components, and savings or uncertainty are high.
- Monitoring/data logging – install temporary or permanent monitoring or data logging equipment and analyse data; applied when ECM performance may vary depending on loads, and savings or uncertainty are high.

Concise documentation should be provided that details activities completed as part of the OPV process and significant findings from those activities – this is the OPV report, and is required where appropriate to the scale and nature of the proposed project. If required, this documentation should be continuously updated during the course of a project.

3.3 TRAINING

Training of the system operators may be one of the most important factors in determining the operational performance and persistence of energy savings. Without proper understanding of any new central management systems, the skills to operate the systems correctly, and a plan regarding how to resolve or report issues, it will be impossible for an energy efficiency project to succeed and perform optimally over time.

The operating staff should be involved with all relevant OPV activities, from planning through to implementation. Assisting with the OPV process provides critical on-the-job training, and ensures familiarity with the new systems and installed ECMs.

Where appropriate to the nature of the proposed ECMs, the OPV plan should contain provisions for the training of the operating staff. A well-developed training plan should then be created during the Performance Period, and supported by comprehensive system documentation. This should extend to any Central Management System (CMS) installed, and any interaction with ancillary (non-lighting) equipment (shown in table 1 in the street lighting protocol.) The training sessions should cover the changes arising from the energy efficiency project and the implemented ECMs. They should be developed and delivered by the consultants, vendors, and contractors.

The training associated with the OPV activities can be combined with the training performed as part of the OM&M efforts. Taken as a whole, they will provide a thorough understanding of the proper operation of any new systems and how to diagnose and respond to issues that may arise over time. Key points to be covered by the OPV and OM&M training may include:

- Thorough descriptions of the ECMs implemented, and descriptions of improved performance generated by these ECMs
- Review of the OPV plan (where required)
- Objectives for the investor with respect to the ECMs
- Energy performance targets
- Operating schedules and owner's operating requirements
- Ongoing data analysis, and investigation process and methods used to identify issues and deficiencies in performance – this should include the use of diagnostic methods and instruments for maintenance associated with the ECMs, and the means for collecting, analysing and storing data
- O&M requirements needed to ensure persistence of performance and savings (service, corrective maintenance and preventative maintenance tasks, and associated schedule of these tasks)
- Operator roles and responsibilities to maintain persistence of performance and savings, and methods for responding to or reporting issues
- Relevant health and safety issues and concerns
- Special issues to maintain warranties

3.4 SYSTEMS MANUAL

In general, a Systems Manual contains information and documentation regarding system design and construction, commissioning, operational requirements, maintenance requirements and procedures, training, and testing. The document is intended to support system operation and maintenance, and to optimise the systems over their useful lives. Specifically, it includes technical instructions to ensure systems and equipment reach their optimum performance according to their technical specifications, and to ensure that they are preserved in, or restored to, a state where they can function in their optimum state.

Provisions for updating an existing Systems Manual should be included in the OPV plan developed during the Certification Period. If one does not exist, then a new manual is not required. However, provisions must be made to provide a full inventory of the installed equipment, as a minimum.

The Systems Manual, which will be updated during the Performance Period, should document the modified systems and equipment involved with the energy efficiency project as well as being comprehensive yet concise so that it is usable to the involved personnel. It should also include the following information as appropriate (defined in more detail in *EN 13460:2009 Maintenance – Documents for maintenance*):

- System design and installation: owner's project requirements (OPR) / current system requirements; basis of design (BOD); and installation / project record documents
- System information: specifications; approved submittals; coordination drawings e.g. system schematics, circuit diagrams; asset inventory; manufacturer's operation and maintenance information; warranties; as well as contractor / supplier listing (including components lists and spare parts lists) and contact information
- System operations: operating plan; organisational structure, including roles and responsibilities; system and equipment operating schedules; sequences of operation; limitations and emergency procedures actions; maintenance procedures, checklists and records; maintenance schedules; record of maintenance costs; instrument/meter calibration procedures and logs; ongoing commissioning procedures; cleaning plans and procedures; utility measurement and reporting
- Training: plans and materials; training records; training for ongoing system manual updating
- Commissioning process report: commissioning (or OPV) plan; design and submittal review reports; testing reports, permits and inspections, and certificates; commissioning (or OPV) progress reports; issues and resolution logs; item resolution and open items

The development of the manual should be coordinated with operations and maintenance personnel so that it best serves their needs. In addition to containing system operating procedures associated with the equipment, the manual should also provide details regarding ongoing optimisation of the systems, and a clear process and responsibility matrix for addressing issues.

4.0 OPERATIONS, MAINTENANCE AND MONITORING

4.1 OVERVIEW

The primary objective of the Operations, Maintenance and Monitoring stage is to ensure the savings associated with the ECM persist over the lifetime of the project. The QA process must ensure that an appropriate and reasonable practice has been selected and developed to monitor energy system performance, and that corrective action plans have been developed to ensure “in specification” energy performance. This OM&M practice can vary in scope, and may involve ongoing commissioning, monitoring-based commissioning, performance-based monitoring (fault detection and diagnostics), periodic recommissioning, system or equipment re-tuning, or periodic inspections.

General guidance on Operations and Maintenance can be found in *Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency, Federal Energy Management Program, 2010*. This document sets out five key principles associated with integrated, successful O&M: operations, maintenance, engineering, training and administration. The document also provides guidance on best practice O&M for lighting technologies, including how to ensure persistence of energy savings for them.

General guidance on monitoring and reporting on energy performance, including types of monitoring methods and reports, and types of energy performance indicator targets, can be found in *ISO 50006:2014 Energy Management Systems – Measuring Energy Performance Using Energy Baselines and Energy Performance Indicators.* More specific guidance can be found in *CIE Technical Report 154:2003: The maintenance of outdoor lighting systems.*

The following elements apply to both the measured-based and deemed savings variants of the protocol:

Element	Section	Protocol
Operations, Maintenance and Monitoring Procedures	4.2	
Training on OM&M Procedures	4.3	
Operator’s Manual (if one already exists)	4.4	

4.2 OPERATIONS, MAINTENANCE AND MONITORING PROCEDURES

Operations, Maintenance & Monitoring (OM&M) and system performance tracking are a process of continuous improvement, and involve tracking, analysing, diagnosing and resolving issues involving energy-consuming systems. While the focus from an energy efficiency project perspective is on energy performance, good OM&M processes involve a proactive strategy for maintaining system functionality while optimising energy performance. Development of specific OM&M procedures can provide clear direction to the system's operations and maintenance staff, empowering them and providing specific methods for identifying, analysing, and resolving issues.

An OM&M plan needs to be developed during the Certification Period. The plan needs to address the overall OM&M process which should involve the following key components:

1. *Data collection and performance tracking* - energy-consuming system performance data is tracked along with energy consumption data. This may be automated through a Central Management System (CMS), or may be a product of manual inspections of the system.
2. *Diagnosing issues and identifying solutions* - while automated tools can help facilitate issue diagnostics and the development of solutions, the skill, knowledge and training of operational personnel, supplemented by the assistance of service contractors, are critical components in diagnosing issues successfully and identifying appropriate solutions.
3. *Resolve issues and verify results* - issues should be resolved in a manner that addresses risks to functionality, and also considers and optimises energy performance.

A strong OM&M management framework needs to clearly set out how automated or manual tools or processes are to be used, and provide the guidance, training and support necessary to extract, interpret and act on the data and analysis results. This management framework should dedicate resources to the OM&M effort by establishing roles and responsibilities and assigning them to the appropriate team member. The framework must set quantifiable performance goals, determine accountability, and define the performance tracking methods.

4.3 TRAINING ON OM&M PROCEDURES

The OM&M specific training practices described here should be combined with the training efforts and best practices described in section 3.3.

Proper operation, maintenance practices, and monitoring are essential to the ongoing energy-efficient performance of the street lighting system. For example, the overriding of controls due to lack of understanding, or diminished performance due to improper maintenance, are common issues that can affect system energy performance over time, and jeopardise the financial performance of an energy efficiency project. The proper training of the system operators represents a critical component of the OM&M process, and helps avoid these issues.

In conjunction with the training associated with the OPV efforts, provisions to develop a training plan must be included in the OM&M plan developed during the Certification Period. It should be specific to the OM&M tasks, and appropriate to the nature of the proposed ECMs. The training should, at a minimum, cover the following OM&M components where appropriate to the nature of the proposed ECMs:

- *Management structure* - Development and structure of the management, responsibility and reporting structure and its components, including operations, maintenance, engineering, training, and administration.
- *ECM maintenance* - Responsibility for the operation, maintenance, repair and replacement of each ECM.
- *Reporting* - Reporting requirements for O&M activities and their frequency, including submission of ECM-specific O&M checklists.
- *Manuals* - Review of the Operator's/Systems Manual(s).
- *Automated management* - Integration of the ECMs into a computerised maintenance management system.
- *Issue resolution* - Discussion of potential issues that can adversely affect operation or savings persistence, and a review of the process to address or report identified issues.

A properly designed O&M programme, and associated training, must include predictive maintenance best practices. Predictive maintenance attempts to detect the onset of a degradation mechanism with the goal of correcting that degradation prior to significant deterioration in the component or equipment. Training as it is applied to predictive maintenance is particularly important, as it is continuously becoming more sophisticated and technology-driven.

Predictive maintenance can incorporate many different approaches, and the following should be considered for inclusion in the O&M management structure, with associated training: performance monitoring, visual inspection and electrical monitoring. A Central Management System (CMS) may provide some of this functionality.

The OM&M activities will include a method to monitor and assess the ongoing performance of the installed ECMs. This may include periodic inspections, or remote management and monitoring systems. As part of the training curriculum, the system operators must be trained on how to utilise and interpret systems in place to monitor the ECMs and associated systems, and how to respond to issues identified as a part of this process. The system operators represent the "first line of defence" against performance degradation, and their proper understanding of the monitoring systems and analysis tools represent key contributors to an energy efficiency project's success.

Where available, nationally recognised competency-based training and certification programmes should be used to formally educate system operators on the proper operation and maintenance of systems in place. Staff should be encouraged to pursue and obtain relevant education and certifications.

4.4 OPERATOR'S MANUAL

For street lighting projects, any existing Operator's Manual should be updated; if one does not exist, then a new manual is not required. Provisions for the updating of an Operator's Manual must be included in the OM&M plan developed during the Certification Period. In many cases, the Operator's

Manual and Systems Manual can be combined into one document to be used by the operations and maintenance personnel. In this case, the requirements described in section 3.4 of this Specification should be adhered to for development of this document. Otherwise, these two Manuals can be developed as two separate documents.

The Operations and Maintenance sections of the Systems Manual, or the separate Operator's Manual, should contain the following information as appropriate:

- Photographs
- Reduced-size as-built drawings and schematics
- List of major equipment
- Invoices for major equipment purchases and repairs
- Equipment locations
- Control system logic
- O&M instructions; training materials

5.0 MEASUREMENT AND VERIFICATION

5.1 OVERVIEW

All Measurement & Verification (M&V) efforts involve reliably quantifying the savings from energy conservation projects (or individual ECMs) by comparing the established baseline with the post-installation energy performance and use, normalised to reflect the same set of conditions.

The measurement-based variant of the ICP Street Lighting protocol (see section 1.0) supports the use of Option A (*Retrofit Isolation: Key Parameter Measurement*), Option B (*Retrofit Isolation: All Parameter Measurement*), and Option C (*Whole Facility*), as defined by the IPMVP, as well as a compliant deemed savings methodology.

For most M&V efforts, non-routine adjustments need to be made to the baseline to reflect unanticipated changes in energy use due to factors other than the installed ECMs after the retrofits have been completed. These items need to be calculated and subtracted from or added to the baseline, so that it can be accurately compared to the post-retrofit energy use.

The QA Assessor will review the M&V Plan during the Certification Period. Under a best practice approach, the QA Assessor will continue their role during the Performance Period - activities will include verification inspections, baseline development review, review of proper application of adjustments (routine and non-routine), review of monitoring equipment, collected data review, and review of the calculations performed to quantify verified savings. Review of M&V reports, baseline adjustments and Deemed Savings plans will also be necessary throughout the duration of the Performance Period.

While the deemed savings variant of the protocol is not based on the IPMVP, many of the same principles and procedures apply in successfully implementing the deemed savings method. The table below indicates which elements described in this document apply to each approach:

Element	Section	Measurement-based Approach	Deemed Savings Approach
IPMVP based M&V Plan and Implementation	5.2		
Regression-Based Model: IPMVP Option C	5.3		
Estimated Parameters: IPMVP Option A	5.4		
Revised Calculations: IPMVP Options A and B	5.5		
Deemed Savings Plan and Implementation	5.6		

5.2 IPMVP BASED M&V PLAN AND IMPLEMENTATION

Requirements

The M&V process can be simply broken down into the following fundamental activities:

1. Document baseline energy
2. Plan and coordinate M&V activities (M&V Plan)
3. Verify operations
4. Gather data
5. Verify savings
6. Report results

The first step in the M&V process, the development and documentation of the baseline, is covered earlier in this specification. The level of uncertainty should be quantified as part of this process. This can be performed by using the energy consumption equation and actual data on explanatory independent variables to determine the monthly baseline energy consumption, and comparing the results to the actual historical energy consumption associated with the baseline period. The difference, or error, in the calculated baseline can then be combined with the standard deviation and the confidence/precision levels to develop the uncertainty in the energy consumption equation.

The second step in the process involves planning and coordinating the M&V activities, the foundation of which is formed by the development of the M&V Plan.

M&V Plan

The M&V Plan should be developed shortly after the energy efficiency project has been defined. Early development of the plan will ensure that all data needed for the savings calculations during the baseline period will be collected and available. This is particularly important in an Option A or B approach, in which pre-retrofit data is needed to establish the baseline operation of systems affected by the proposed ECMs. Early development of the M&V Plan will also allow for coordination with Operational Performance Verification activities.

The M&V Plan itself should be adherent to the IPMVP, which defines in detail the components the Plan needs to contain and consider (defined in *IPMVP Core Concepts-2016, section 7*). In summary, the M&V Plan should address the following topics:

- Descriptions of the ECMs and operational performance verification procedures
- Definition of the measurement boundary, and discussion of potential interactive effects
- Documentation of the baseline period, energy use, and conditions; include descriptions of

independent variable data coinciding with the energy data, and static factors coinciding with the energy data (the routine and non-routine adjustments)
- Definition of the reporting period (typically the length of time required to recover the investment costs associated with the energy efficiency project)
- Descriptions of the basis for adjustments (routine and non-routine – see later in this section)
- Description of the analysis procedures, including algorithms and assumptions to be used for savings verification
- Definition of energy prices used to value the energy-cost savings, and future adjustments to energy prices
- Description of the proposed metering plan and meter specifications, including methods for handling the data, and responsibilities for reporting and recording the data
- Qualitative (and, if feasible, quantitative) descriptions of expected accuracy
- Definition of the budget and resources required for the M&V process (initial and ongoing)
- Description of the M&V reporting format and schedule
- Description of quality assurance procedures applicable to the M&V process

The third step in the M&V process involves operational performance verification, which provides a means for realising savings potential, and is covered in Section 3 of this specification. The fourth step involves data collection, which must be performed both before and after the planned retrofit.

The fifth step involves determination of verified energy savings. Savings may be determined for the entire system (Option C) or for portions of it (Options A and B). In all cases, the determination of verified savings involves consideration of the measurement boundaries, interactive effects, selection of appropriate measurement periods, and basis for adjustments.

Verified Energy Savings - Option C

Requirements

For Option C approaches, the measurement boundary will include the entire system. The measurement periods should adhere to the guidance set out in *IPMVP Core Concepts-2016,* and must include at a minimum a representative time period for both pre- and post-retrofit utility data. For Option C, this will usually be a period of 12 months.

Adjustments to the baseline must be well defined and applied conservatively. The “adjustments” term is commonly used to restate the baseline energy consumption in terms of the reporting-period conditions. The verified savings equation expressed in the IPMVP is defined as:

Savings = (*Baseline Energy* +/- *Routine Adjustments* to reporting-period conditions +/- *Non-Routine Adjustments* to reporting-period conditions) - *Reporting-Period Energy*

Routine adjustments which are expected to change routinely can be accounted for through regressions or other techniques to adjust both the baseline and reporting periods to the same set of conditions. This allows for accurate comparison between the two measurement periods.

Non-routine adjustments include factors which affect energy consumption that were not expected to change such as system size, operation of installed equipment, or load changes. The first step is to identify these changes in the reporting period, but specifically, to pinpoint those adjustments that present a reasonable effect on energy consumption. This can be accomplished through interviews with the system operators, periodic site visits, observation of unexpected energy consumption patterns, or other methods.

Accurate and conservative calculation of the effects these non-routine adjustments have on energy consumption is critical. Sometimes these effects can be estimated within the energy-modelling software that was used to calculate the energy savings for the project. In other cases side calculation methods need to be employed, in which case applying the appropriate level of rigour and sound engineering principles is key. This includes accurately determining any assumptions used in these calculations.

In all cases, the application of adjustments needs to be handled with care. Only adjustments that are expected to have a relatively significant impact on energy consumption should be considered. And assumptions used within the adjustments need to be conservative and based on actual measurements, field observations, or well vetted and documented sources.

Verified Energy Savings - Options A and B

Requirements

For Option A or B approaches, the measurement boundary must be considered and defined. The measurement boundary should be drawn around the equipment or systems affected by the ECMs, and all significant energy requirements of the equipment within the boundary should be determined. Determination of the energy performance of the equipment can be accomplished by direct measurement of the energy flow, or through direct measurement of proxies of energy consumption that provide an indication of energy consumption.

All energy effects of the ECMs should be considered and measured if possible. In particular, interactive effects of the measures beyond the measurement boundary should be evaluated to determine if their effects warrant quantification, or if these effects can be reasonably ignored. The M&V Plan should still include a discussion of each effect, and its likely magnitude.

Both the baseline period and the post-retrofit (reporting) period need to be determined early on in the project development so that appropriate and adequate baseline data can be captured. The measurement periods need to collect data that reflect equipment operation through its full operating cycle (maximum energy consumption to minimum). The data should represent all operating conditions, and the baseline period should ideally coincide with the period immediately before commitment to undertake the retrofit.

5.3 REGRESSION-BASED MODEL: IPMVP OPTION C

Requirements

In some cases, Option C may be considered the most appropriate – this may be driven by the nature of the measures or the availability of data.

Under IPMVP Option C, a regression-based energy model is likely to be required. This involves the development of an energy consumption equation, which relates the dependent variable (total system energy consumption, including electricity) to independent variables known to significantly impact the system's energy consumption. Independent variables typically include weather and may include other variables such as operating hours.

Regression is described in more detail in section 1.7.

The energy consumption equation can be determined using a least squares regression. Where there is more than one dependent variable, multiple-linear regression can be used. This approach enables the comparison and analysis of the system's energy consumption as a function of the independent variable(s) that vary monthly.

There are many commercially available software tools that can be used to automate an IPMVP Option C approach to M&V. Keep in mind that while many applications or tools can help automate the Option C M&V process, they all still require a level of engineering expertise. A solid understanding of IPMVP principles, analysis techniques, and application of routine and non-routine adjustments are essential skills that the M&V agent should have when performing this analysis, even with the aid of automated software tools.

5.4 ESTIMATED PARAMETERS: IPMVP OPTION A

Requirements

Option A can be applied to a single measure or at the system level for M&V assessment. The approach is intended for retrofits where key performance factors such as power, or operational factors such as lighting operational hours can be spot-measured or short-term-measured during the baseline and post-retrofit periods. Under Option A, any factor not measured is estimated based on assumptions, analysis of historical data, or manufacturer's data.

While Option A can provide a more economical approach to M&V than Option B, it should only be applied to "simpler" measures. This would include measures in which at least one of the parameters is expected to be fairly constant or consistent, and can therefore be estimated.

When considering an Option A approach, and what variables to estimate, consideration should be given to the amount of variation in baseline energy consumption or the energy impact that variables have on the ECMs before establishing which variables to estimate. Estimates should be based on reliable, documentable sources, with a high degree of confidence. These estimates should never be based on "rules-of-thumb," proprietary sources ("black box"), or "engineering estimates."

Key parameters that are not consistent (and should therefore not be estimated), must be measured. This typically includes parameters such as capacity, efficiency, or operation - essentially, any parameters that represent a significant portion of the savings uncertainty.

The amount that the key parameter is expected to vary will determine the frequency of measurement - i.e. continuously or periodically.

5.5 REVISED CALCULATIONS: IPMVP OPTIONS A AND B

Following the installation of the ECMs, application of an Option A or B approach will require revisions to the original savings calculations to determine verified energy savings for the associated ECMs. Spot or short-term measurements and observations of post-retrofit operation should provide the inputs to the assumptions originally used in the savings calculations, so that accurate (verified) savings associated with the actual operation of the measures can be calculated. The measurement plan and process to apply the results to the verified savings calculations should be documented in the M&V Plan and adhered to for these efforts.

As with the original savings calculations, all inputs and assumptions should be transparent and well documented through data analysis, pictures, CMS screenshots, or other resources used to inform the verified savings calculations.

5.6 DEEMED SAVINGS PLAN AND IMPLEMENTATION

The Deemed Savings Plan should be developed shortly after the energy efficiency project has been defined. Early development of the plan will ensure that all asset information, as-installed data and material specifications/inventories needed for the estimated savings calculations during the Certification Period will be collected and available. Early development of the Deemed Savings Plan will also allow for coordination with Operational Performance Verification activities.

The Deemed Savings Plan itself does not need to be compliant with the IPMVP process and does not need to be written by a qualified M&V professional. However the Deemed Savings Plan should at minimum include and address the following:

- Documentation of the planned process for establishing the deemed energy savings
- All calculations and supporting documents required by sections 1 and 2 of this document

The realised energy savings are given by the following calculation:

Energy savings (kWh) = Estimated annual baseline energy consumption MINUS Estimated post-upgrade energy consumption

The procedure to be used to obtain the energy consumption figures to be used in this calculation is given in sections 1.5 and 1.6 of this document and this procedure should be the basis for the documentation in the Deemed Savings Plan.

6.0 DOCUMENTATION REQUIRED

Table 2 Documentation Required

Protocol Section	ICP Section	Documentation Required	Comments
1	Baselining	Statement of basis for the baselining approach	
1	Baselining – measurement-based approach	Full energy data	Should be a computer-readable file that includes: Raw meter readings, where duration matches the defined baseline period. An explanation of how periods are consolidated to the integer years/months periods applied.
1	Baselining – measurement-based approach	Description of baseline period	Include start/end dates and why that period was chosen. Include how the independent variable(s) relate to the energy use cycle.
1	Baselining – measurement-based approach	Regression analysis data	Could include hours of darkness, weather or traffic data. Corresponds to the baseline period.
1	Baselining – measurement-based approach	Analysis carried out on the baseline data	Include outcomes of any models or statistical validity tests.
1	Baselining - measurement-based approach	List of project-specific routine adjustment factors	To be included in the M&V plan
1	Baselining – deemed savings approach	Inventory List	Include all equipment contained in the project boundary.
1	Baselining – deemed savings approach	Power Consumptions	Relating to all equipment contained in the project boundary. Include sources of information.
1	Baselining – deemed savings approach	Calculations relating to total annual baseline energy consumption	Include the total annual operational hours calculation or measurement and the results of any cross-check exercises carried out.
1	Baselining	Street lighting system ancillary equipment	Include any energy uses which are not associated with lighting the luminaire, where relevant.
1	Baselining	System asset / operational / performance data	System or equipment drawings, equipment inventories, system and material specifications, field survey results, observations, short-term monitored data, spot measurements, and functional performance test results as appropriate and where available.
1	Baselining	Utility rate structure	As published by the utility, including a breakdown of distribution costs, demand charges, taxes, and time-of-day variability for each of these elements.
1	Baselining	Copy of a bill, or equivalent	Include a description of the tariff structure and any fixed charges

Protocol Section	ICP Section	Documentation Required	Comments
2	Savings Calculations	Savings calculator qualifications	
2	Savings Calculations	Lighting system designer qualifications	
2	Savings Calculations	ECM savings results	Workbooks, spreadsheets and other open-source calculation tools. Calculation process description.
2	Savings Calculations	ECM savings results from third-party software	Include input and output files alongside descriptions.
2	Savings Calculations	Report	Include annual predicted energy savings and cost savings.
2	Savings Calculations	Detailed cost breakdown	Include line-items for each of the major project elements.
2	Savings Calculations – Deemed approach	Inventory list	Include all equipment contained in the project boundary
2	Savings Calculations – Deemed approach	Calculations relating to total annual performance period energy consumption, and total predicted savings	Include the total annual operational hours and the results of any cross-check exercises carried out.
3	Design, Const & Verification	OPV authority qualifications	
3	Design, Const & Verification	OPV Plan	
3	Design, Const & Verification	Provisions for training	Where appropriate to the nature of the ECMs.
3	Design, Const & Verification	Provisions to update Systems Manual(s)	If no systems manual exists, a full inventory of the installed equipment should be provided.
4	OM&M	OM&M plan	
4	OM&M	Provisions for training	Where appropriate to the nature of the ECMs.
4	OM&M	Provisions to update Operator's Manual and Organisational chart	If no operator's manual exists, a new manual is not required. The organisational chart should contain information on persons involved with OM&M, and responsibilities for monitoring and response
Protocol Section	ICP Section	Documentation Required	Comments

5	M&V – Measurement-based approach	M&V Plan	
5	M&V – Measurement-based approach	Routine adjustments	
5	M&V – Measurement-based approach	Non-routine adjustments	Define the principles upon which any unknown routine adjustments will be based
5	M&V – Measurement-based approach	Description of the calculation basis of any baseline model	
5	M&V - Measurement-based approach	Regression-based baseline model	Used in the Option C analysis
5	M&V – Deemed savings approach	Deemed savings plan	Include all calculations and supporting documents.