ENERGY PERFORMANCE PROTOCOL

PROJECT DEVELOPMENT SPECIFICATION

Version 1.0 – March 2016

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1.0 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.

The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are the EU's main legislation related to reducing the energy consumption of buildings (see section 4.2.5). All methodologies and procedures across all ICP protocols have taken into consideration the requirements of these key laws.

1.1 ENERGY EFFICIENCY PERFORMANCE – PROJECT DEVELOPMENT SPECIFICATION

This ICP Project Development Specification (PDS) represents a comprehensive resource designed for project developers, third-party quality assurance providers, 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.

The ICP PDS verification process can be applied either through a central authority such as a public programme, by distributed third parties such as a qualified independent engineering firm, or by an individual investor. Projects that successfully complete the ICP System and comply with the PDS 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.

This document presents commercially available, non-proprietary resources that provide standards, guidelines, tools, and other materials that can be used or referenced as part of the Project Development process. There are many additional proprietary tools available, many of which are useful in the development and review of an energy efficiency project. However, ICP does not endorse any individual product or provider, therefore some resources may be described in a general way without identifying a specific product.

This document will evolve over time. Members of the ICP invite engineers, building owners, software developers, prospective lenders, investors, and other stakeholders to assist in testing and improving these specifications by participating in ICP technical forums, sharing known resources, reviewing the protocols, and providing feedback gained during implementation of the protocols on projects.

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

1.2 USING THIS SPECIFICATION

This PDS is intended to support the elements, procedures and documentation requirements presented in the ICP Protocols. This document's structure mirrors the protocols 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 building 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. The Project Developer must be ICP accredited, and only projects with an ICP accredited Quality Assurance Provider are able to receive IREE certification.

The accredited Project Development 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 Certified Quality Assurance Provider 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 provider 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 provider 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 providers 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 provider 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.

1.3 PROJECT DEVELOPMENT PROCESS

The Energy Efficiency Project (EEP) Framework is divided into five categories that represent the entire lifecycle of a well-conceived and well-executed energy efficiency project:

1. **Baselining**
    a Core Requirements
    b Rate Analysis, Demand, Load Profile, Interval Data
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 at specific points in the development of an energy efficiency project 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 calibration of an energy model or bounding of energy savings predictions, as well as in the M&V efforts. Inaccuracies in the development of these key baseline components can affect the subsequent accuracy of the energy model, possibly resulting in over-prediction of energy savings estimates, and/or an inaccurate assessment of 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 provider, the periods within a project's development that these tasks should be performed, and under which protocols.

Project development templates are available on the ICP Europe website which will facilitate the efficient creation of key components required as part of the documentation package – see section 11 for further detail.

QUALITY ASSURANCE TASKS	Develop Baseline	Audit / ECM List	Savings Calculations / Investment Package	Design, Construction & Verification	Operations, Maintenance & Monitoring	Measurement & Verification (Post-Implementation)
PROJECT TASKS	Collect utility data	Collect building asset / performance data	Develop / calibrate energy model	Develop OPV plan	Develop OM&M procedures	Option A/B: Collect post-retrofit energy / performance data
	Develop energy end-use consumption	Collect building operational / performance data	Perform model / spreadsheet calculations	Perform OPV tasks	Set up FDD, develop RCx plan, or other monitoring method	Option A/B: Performance data analysis
	Collect utility rate info	Develop ECM descriptions	Develop costs / constructability	Develop / updated systems manual	Develop / update operator's manual	Option A/B: Verified savings calculations
	Load shape development		Develop / inform investment criteria	Perform building operators training	Perform building operators training	Option C: Post-utility data
	Develop energy consumption equation		Develop ECM bundles & packages	Develop M&V plan (before construction)		Option C: Identify / quantify non-routine adjustments
	Identify adjustments		Develop audit report			Option C: Regression based modeling
	Collect weather / occupancy data			Option A/B: Collect pre-retrofit energy / performance data (before construction)		All Options: M&V report
	Estimate any interactive effects in establishing baseline		Account for any interactive effects in savings			
QA TASKS	Review and approve data, energy consumption equation and baseline model	Review and approve asset / operational / performance data	Review and approve ECM descriptions	Review and approve OPV plan	Review and approve OM&M procedures	Review and approve data and analysis
	Review and approve energy end-use consumption		Review and approve energy model / check calibration	Review and approve M&V plan	Review and approve FDD, RCx plan, or other monitoring method	Option C: Review and approve regression based model
	Review and approve utility rates		Review and approve savings calculations	Review and approve systems manual	Review and approve operator's manual	Option A/B: Review and approve verified savings calculations
	Review and approve load shapes		Review and approve costs / constructability	Review and approve training (interview building operators)	Review and approve training (interview building operators)	Review and approve adjustments and proper application
			Review and approve ECM bundles / investment package	Option A/B: Ensure pre-retrofit energy / performance data collected		

Key	
(grey)	All protocols
(green)	Only required for Targeted protocols if relevant to ECMs
(purple)	Large protocols only
(light blue)	Large and Standard protocols only
(orange)	Standard and Targeted protocols only

2.0 ACRONYMS

ACH	Air changes per hour
AEE	Association of Energy Engineers
AFLH	Annual full load hours
ASHRAE	American Society of Heating Refrigeration and Air Conditioning Engineers
BEM	Building energy modelling
BEMP	Building energy-modelling professional
BESA	Building energy simulation analyst
BMS	Building management system
BOD	Basis of design
BPA	Bonneville Power Administration
BPI	Building Performance Institute
CAD	Computer aided drafting
CDD	Cooling degree days
CEM	Certified Energy Manager
CFR	Current facility requirements
CMVP	Certified Measurement and Verification Professional
CV	Curriculum vitae
CV[RMSE]	Coefficient of variation [root mean square error]
DDC	Direct digital control
DOE	US Department of Energy
ECM	Energy conservation measure
EE	Energy efficiency
EEPF	Energy Efficiency Project Framework
EIA	Energy Information Administration
EMS	Energy management system
ESCo	Energy service company
ESPC	Energy savings performance contract
EUI	Energy utilisation index
EVO	Efficiency Valuation Organization
FDD	Fault detection and diagnostics
FEMP	Federal Energy Management Programme (US-based)
FPT	Functional performance test
HDD	Heating degree days
HVAC	Heating, ventilation and air conditioning
ICP	Investor Confidence Project
IGA	Investment grade audit
IPMVP	International Performance Measurement and Verification Protocol

IREE	Investor ready energy efficiency
IRR	Internal rate of return
kW	kilowatt
kWh	kilowatt hour
LCCA	Lifecycle cost analysis
M&V	Measurement and Verification
NIST	National Institute of Standards and Technology (US based)
NMBE	Normalised mean bias error
NPV	Net present value
NYSERDA	New York State Energy Research Development Authority
O&M	Operations and maintenance
OM&M	Operations, maintenance and monitoring
O&P	Overhead and profit
OPV	Operational performance verification
PD	Project development
PE	Professional engineer
PFT	Pre-functional test
PDS	Project Development Specification
QA	Quality assurance
QM	Quality management
RCx	Retro-commissioning or recommissioning
RFP	Request for proposal
RFQ	Request for qualifications
SaaS	Software as a service
SIR	Savings to investment ratio
TAB	Test, adjustment and balance
TMY	Typical meteorological year
UMP	Uniform Methods Project
WYEC	Weather year for energy calculation

3.0 PROTOCOL SELECTION

There are currently six protocols available that describe a standardised approach to the development of Large, Standard and Targeted energy efficiency projects in tertiary buildings and apartment blocks. Selecting the most applicable protocol for use with development of an energy efficiency project represents a key first step in the process. Selection of the appropriate protocol to use must involve assessment of the methods that are planned to be utilised in the project's development, and the project's overall scale.

The Large Tertiary/Apartment Block protocols are intended for:

- Large Buildings - where the cost of improvements and size of savings justifies greater investment in energy development analysis;
- Whole-Building Retrofits - projects that typically involve multiple measures with interactive effects;
- Calculation Methods - projects that plan to use an energy model to estimate energy savings; and
- Measurement and Verification - projects that will apply an IPMVP Option C, *Whole Facility* approach.

It should be noted that currently ICP does not allow the use of an IPMVP Option D, *Calibrated Simulation* approach for M&V. Instead, it requires the use of IPMVP Option C to be combined with calibrated simulation as the calculation method for Large projects, rather than by measuring energy use at the utility meter level alone. This is described further in section 9.1 of this document.

The Standard Tertiary/ Apartment Block protocols are intended for:

- Standard Projects - multiple measure projects where engineering requirements must be scaled to fit performance risk;
- Calculation Methods - projects that plan to use non-dynamic energy modelling methods to estimate energy savings; and
- Measurement and Verification - projects that will apply an IPMVP Option A and/or B, *Retrofit Isolation* approach.

The Targeted Tertiary/ Apartment Block protocols are intended for:

- Targeted Projects - single or smaller sets of measures with no interactivity, applied to one or a number of buildings; the exception to this is for lighting projects where there may be interactions between the lighting measures and heating and cooling loads;
- Targeted Scope - limited engineering requirements scaled to fit performance risk;
- Calculation Methods - projects that plan to use non-energy modelling methods to estimate energy savings; and
- Measurement and Verification - projects that will apply an IPMVP Option A and/or B, *Retrofit Isolation* method.

Each project will have its own set of characteristics, as well as limitations on resources and time. Selection of the right protocol depends on many factors, and the project development team should work with the investors and Quality Assurance provider to determine the most suitable protocol to apply to any given project. The diagram below provides simplified guidance on the protocol selection process.

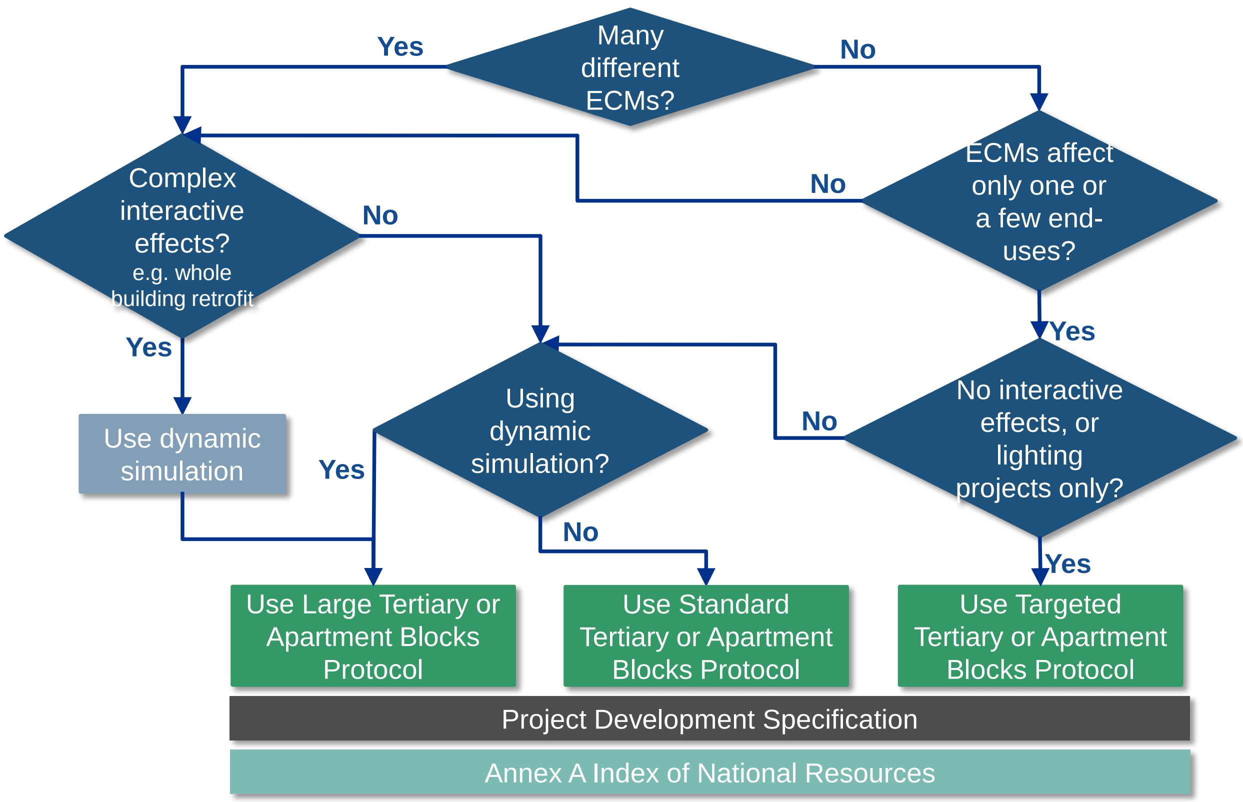

Figure 1 Protocol selection decision flowchart

3.1 DETERMINING PROJECT APPROACHES

A comprehensive project development approach should be established early in the process. A key decision relating to this is whether to use an energy model to estimate energy savings, or to use other tools, such as spreadsheet calculations to estimate savings. In general, development of an energy model requires a greater level of effort, as well as specific skills pertaining to energy modelling. However, energy modelling offers a comprehensive assessment of a building's operation, and of the interactive effects that will occur when considering multiple measures for a project. The project team should determine whether the scope of a project warrants the use of an energy model, and whether there are sufficient resources available to support development and calibration of a model.

Similarly, the Measurement and Verification approach(es) needs to be determined and planned for. While an International Performance Measurement and Verification (IPMVP) Option C, *Whole Facility* approach, which analyses pre- and post-retrofit utility bills to verify performance, represents a comprehensive method for savings verification, it may not be appropriate for all projects. This approach requires that energy savings are significant enough to have a discernible impact on the building's overall energy consumption (typically representing greater than 10% of total energy consumption). Additionally, this approach can become complicated by non-routine adjustments that need to be quantified and incorporated into the analysis, such as changes in building occupancy, loads, etc.

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 trending through the building automation system or through the use of remote data logging equipment, tools that may not be available to a project. These approaches also require access to, and understanding of, the live savings calculations so that assumptions can be revised to reflect new observations and develop verified energy savings.

These approaches, among others, 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. These factors will also guide the project development team to the most appropriate protocol to utilise in the development of a project.

4.0 BASELINING – CORE REQUIREMENTS

4.1 OVERVIEW

A technically sound energy consumption baseline provides a critical starting point for accurate projection of potential energy savings, and is also critical for measurement and verification upon completion of a retrofit and/or retro-commissioning. These are required for Large and Standard projects.

The building baseline must establish how much energy a building can be expected to use over a representative 12 month period, as a minimum. The exception to this is the case of the Targeted protocols where only a Retrofit Isolation baseline associated with the proposed ECMs is required (see section 4.2.6).

The baseline needs to cover all energy sources and account for:

- Total electricity purchased
- Purchased or delivered steam, hot water, or chilled water
- Natural gas
- Fuel oil
- Coal
- Propane
- Biomass
- Any other resources consumed as fuel and any electricity generated on site from alternative energy systems
- Any renewable energy generated and used on site

It must also factor in the impact of independent variables such as weather, occupancy, and operating hours on the building's energy consumption.

There are currently a number of baselining and benchmarking tools and software applications that are commercially available. While not required, these tools can dramatically reduce costs compared with more ad hoc methods. These energy management software tools store, analyse, and display energy consumption or building systems data, and can be used to automate the processes involved in the baselining component of energy efficiency (EE) project development. They can also be used to automate the tasks involved with an IPMVP Option C approach to Measurement & Verification (M&V). The resources subsection describes and compares applications of energy management tools in greater detail.

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

Element	Section	Protocol		
		Large Tertiary/ Apartment Block	Standard Tertiary/ Apartment Block	Targeted Tertiary/ Apartment Block
Utility Data and Baseline Period/ Normalised Baseline Development	4.2.1	✓	✓	
Energy End-Use Consumption	4.2.2	✓	✓	
Weather Data	4.2.3	✓	✓	✓
Occupancy Data	4.2.4	✓	✓	✓
Building Asset/ Operational/ Performance Data	4.2.5	✓	✓	✓
Retrofit Isolation Baseline	4.2.6		✓	✓
Interactive Effects	4.2.7	✓	✓	✓

4.2 PROTOCOL ELEMENTS

4.2.1 Utility Data and Baseline Period / Normalised Baseline Development (Large and Standard Tertiary / Apartment Blocks)

Requirements

Historical energy consumption and cost data must be collected for electricity, on-site fuel for heating and cooling, district steam, and hot water or chilled water. It is recommended that data is collected for a three year period (or minimum of a 12 month period) over a representative period for the following information:

- Electricity consumption
  - Utility name
  - Electricity consumption (total annual kWh)
  - Peak electricity demand (maximum kW demand for each month of a twelve month period) (see section 5.2.1)
  - On-site electricity generation (total annual kWh) and method
- On-site fuel for heating or cooling
  - Fuel type(s), including renewable energy
  - Utility or provider name
  - Fuel usage (total annual kWh)

- District steam, hot water, or chilled water
    - Type
    - District steam provider
    - Usage (total annual kWh)
- Cost data in local currency
    - Total annual purchased electricity cost
    - Total purchased electricity cost per kWh
    - Total annual on-site fuel usage cost
    - Total annual on-site cost per unit of fuel used
    - Total annual cost per unit of district steam, hot water, or chilled water

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. For raw fuel delivered to the facility (e.g. fuel oil, propane), estimate monthly energy consumption based on actual consumption between fuel deliveries, or by pro-rating actual consumption between deliveries by an appropriate metric such as heating degree days.

Building energy consumption metrics should be developed using the baseline historical utility data. This should include kWh/yr, and kWh/(m^2.yr). Heating values of fuels reported on utility bills are typically adjusted for delivered heat content, elevation, and temperature. Additional corrections are typically not needed. If fuel content values are not available from the local utility, they should be estimated, using recognised calculation methods, and documented. If the building is located at higher elevations, gas heating values should be adjusted for elevation according to best practices and in consultation with the gas supplier.

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 site energy consumption, including electricity and on-site fuel or district energy) to independent variables known to significantly impact the building's energy consumption. Independent variables typically include weather (heating and cooling degree days), and may include other variables such as operating hours, occupancy or vacancy rates, and number of occupants.

The energy consumption equation can be determined using a regression analysis – the process of identifying the straight line of 'best fit' between the building's energy consumption (usually on a monthly basis) and one or more independent variables. An example of this 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 degree days kWh/°C (determined from regression analysis)

$X_{1,2,etc}$ = number of units e.g. number of degree days in °C

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.

For projects following the Standard protocols, where it is deemed that the independent variables do not have a significant effect on the baseline, then normalisation and development of the energy consumption equation is not required. However, clear justification for this approach should be provided, including an estimate of the impact on energy savings.

The regression-based energy model and the energy consumption equation should result in adjusted R^2 values of at least 0.75 and a CV[RMSE] less than 0.2. Every attempt should be made to develop a model that falls within these accepted parameters. If these criteria cannot be met due to bad or inconsistent data, or other extenuating circumstances, the reasons for this discrepancy must be noted. In this case, it is recommended that the impact (uncertainty) that these discrepancies may have on the project's outcome be quantified.

Linear Regression Example

An energy efficiency project is anticipated to impact on the heating demand of a building, and therefore the building's gas consumption needs to be normalised against weather data. In this case, the monthly gas consumption, which has been taken from the utility bills, would be plotted against heating degree day data using the form of linear regression described above – this is shown in the example below, which has been created using standard functions in Excel (using the 'least squares' method). The correlation of the gas consumption data with the degree data is checked by establishing the R^2 value – here, it is 0.8, indicating an acceptable correlation. Using the form of the energy consumption equation described above, the value of 'm', or the gradient of the line, is 2,579 kWh/°C HDD, and the y-intercept value is 181 MWh which represents the base gas demand for uses such as domestic hot water and catering. These figures can be applied together to average historical weather data (for example, 20 year average heating degree day data) to create a normalised energy consumption for each month.

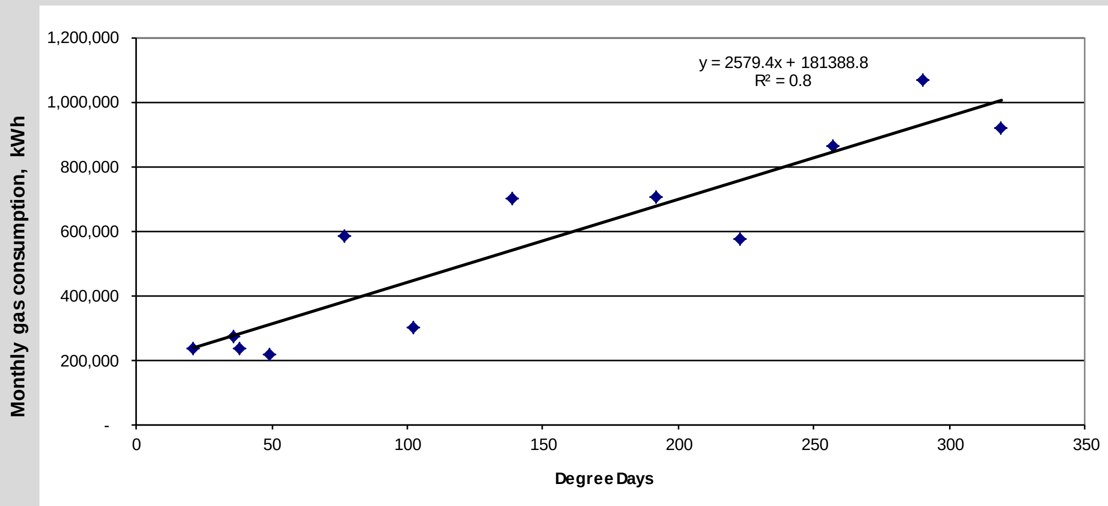

Figure 2 Example linear regression graph for gas consumption against heating degree day data

Similarly, the developed baseline should have uncertainty quantified in the form of a lower and upper bound. This can be accomplished by comparing the building's energy consumption predicted by the developed energy consumption equation to the actual utility bills for the baseline period, using the difference in energy consumption to form the error associated with the baseline. This error, combined with the standard deviation and the required confidence/precision levels, can subsequently be used to create a range around the baseline (minimum and maximum). Section B.6 of IPMVP Vol I (2012) provides an example of how ranges of predictions can be calculated.

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 also provide benchmarking capabilities, and can be used to perform IPMVP Option C M&V analysis, or to bound energy savings estimates.

The baseline data collection process should note any renovation affecting greater than 10% of building floor area, or a change that affects estimated total building energy consumption by greater than 10%, i.e. "major renovation." Where this is the case, information regarding renovations or changes to the building or its operation should be collected during the energy audit, along with the technical information relating to these changes – for example, changes to the insulation or glazing in the building and the corresponding changes to their U values. Energy consumption data from any period involving a major renovation should not be used to develop the baseline.

The report describing the baseline and its development should include the following as a minimum:

- Data on 12 months energy consumption by fuel type
- Details of all calculations carried out (e.g. calendarisation and normalisation) including any assumptions made or supporting data used (e.g. degree day data)
- Range of building energy consumption compared with the normalised baseline with lower and upper bound

Quality Assurance Methods

- ❖ Perform a review of collected data to ensure that a minimum of 12 months of contiguous data have been collected, using up to three years' worth of data. Ensure that all energy consumption data types have been accounted for. Ensure appropriate calorific values for fuels have been used.
- ❖ Ensure that the collected data does not include any periods involving major renovations.
- ❖ Review the regression-based energy model and the energy consumption equation form. Ensure that all independent variables that significantly affect energy consumption have been accounted for and are represented in the energy consumption equation. Check that adjusted R^2 values are at least 0.75 and that CV[RMSE] is less than 0.2. If the model does not fall within these parameters, check that the reasons for these discrepancies have been documented and are justifiable, and that the resulting uncertainty has been accounted for.
- ❖ Review the report (or report sections) illustrating baseline development and energy consumption results to ensure that all information and methodologies have been presented, that the results presented correspond with analysis results, and that all sources of information have been documented.

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section B-2 provides detailed guidance on regression modelling, including evaluation of regression models (R^2 and CV[RMSE]), and section B-6 provides evaluation of an example regression model.

ISO 50006:2014 Energy Management Systems – Measuring Energy Performance Using Energy Baselines and Energy Performance Indicators methodology *(Annex D)* - provides an overview of normalisation and regression modelling.

EN 16212:2012 Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods (section 5.2.3.1) – provides guidance on carrying out normalisation of climate dependent energy consumption.

ISO 16346:2013 Energy Performance of Buildings – Assessment of Overall Energy Performance (section 8.2.2) - provides guidance partial year/month data "calendarisation".

4.2.2 Energy End-Use Consumption (Large and Standard Tertiary / Apartment Blocks) Requirements

Estimating or measuring energy end-use consumption is an important component of baseline development. The results of this effort can be used to calibrate the baseline energy model, as well as to calibrate energy savings estimates.

Sub-metering represents an accurate method to measure energy end-use consumption. For weather dependent end-uses, or end-uses that vary based on other independent variables, the metering period should cover a period that will capture both minimum and maximum loads. Regression analysis can then be used to estimate annual energy consumption for each end-use. Similar to the methodology described in the total building energy baseline development effort, this regression analysis requires the development of an energy consumption equation, which relates the dependent variable to independent variables known to impact the end-use energy consumption.

A bottom up (calculated) approach to estimated energy end-use consumption may also be employed. This involves using the information collected during the energy audit to calculate energy consumption associated with each end-use. This includes lighting inventories, mechanical schedules, plug load inventories, domestic hot water inventories, etc., combined with associated operating schedules. For example, the total demand (kW) associated with the lighting fixtures can be multiplied by the annual full load hours (AFLHs) of the lighting fixtures to develop the lighting energy end-use consumption.

A third and simpler approach to energy end-use consumption estimation involves the use of national sources of data on typical building energy characteristics. Where no national resources exist, European-wide resources should be used, such as the *Buildings Performance Institute Europe's Data Hub for the Energy Performance of Buildings (see [http://www.buildingsdata.eu/)](http://www.buildingsdata.eu/).* Based on building type, age and country, the appropriate estimated end-use consumption percentages can be applied to the total historical energy consumption of the building. While not as accurate as the aforementioned methods, this method can provide a cost-effective alternative when more detailed methods are cost or resource prohibitive.

Once developed, the energy end-use consumption estimates can be used to calibrate the energy end-use consumption predicted by an energy model or spreadsheet calculation for the base year, allowing the individual developing the baseline to work within realistic expectations of energy consumption. Similarly, energy savings estimates associated with a specific end-use can be compared to the total energy consumption of that end-use to develop reasonable and realistic estimates of energy savings.

Quality Assurance Methods

- Review energy end-use consumption estimation methods and results for reasonableness.
  - Sub-metering estimates: ensure that adequate monitoring periods capture minimum and maximum energy consumption, and are regressed based on appropriate independent variables adhering to the methodologies described in the baseline development section.
  - Energy end-use consumption calculation method: check equipment inventories for completeness, and check estimates of AFLHs to ensure that end-use consumption calculations are accurate and reasonable.
  - National or European data resource application: check that the selected building end-use consumption percentages applied to the total building energy consumption are appropriate for the region and building characteristics (building type, system types, building/system age, etc.)
- Energy end-use consumption estimates should be used to calibrate end-use consumptions for energy models and energy conservation measure (ECM) savings calculations.

Resources

Buildings Performance Institute Europe's Data Hub for the Energy Performance of Buildings (see http://www.buildingsdata.eu/) – European data set which can be used to develop high level energy end-use consumption estimates.

4.2.3 Weather Data (All Protocols)

Requirements

Use weather data representative of the area where the building is located, including three years of monthly heating degree days (minimum of 12 consecutive months), and three years of monthly cooling degree days (minimum of 12 consecutive months) where there is a significant cooling load, all corresponding to the baseline period.

Keep in mind that the relationship between temperature and energy consumption may vary based on time of year. Similarly, the relationship between energy consumption and weather may not be linear. These factors may need to be considered when developing an energy consumption equation for baseline development or Option C M&V purposes.

Weather used for baseline development or savings calculations is typically based on average historical weather files. However, weather data used for energy-modelling calibration purposes or data analysis will require actual weather data corresponding to the period covered by the historical utility billing information, or for the period of data collection.

If on-site measurements of temperature are used, the data should be recorded in the pre- and post-retrofit periods using the same measurement equipment at the same location. It is also recommended that the collected measurements be periodically checked against local weather stations to look for measurement inaccuracies or equipment failure.

Quality Assurance Methods

- Check that the weather data was collected from a weather station in close proximity to the building, and that an alternative weather station is not more representative of the weather in the building's area.
- Check that actual weather data corresponding to the period covered by the historical utility billing information is used for energy-modelling calibration purposes or data analysis.

Resources

Degree Days.net *(BizEE)* - degree day data resource aimed at energy efficiency professionals.

4.2.4 Occupancy Data (All Protocols)

Requirements

For Large and Standard projects, collect monthly occupancy (or vacancy) rates corresponding to the baseline period for three years, with a one year minimum, not including periods of major renovation. Indicate occupancy types, space types, and occupancy schedules for all spaces within the building where these are relevant to the baseline.

Changes in occupancy, occupancy schedules, or space types may warrant non-routine adjustments to the baseline. Changes that will have a significant (typically greater than 3-5%) effect on overall building energy consumption should be considered. If post-retrofit occupancy and space use differ from baseline conditions, adjustments should be made to account for the corresponding changes in building heating or cooling loads due to these variations, as well as how these impact the energy consumption of the heating or cooling equipment serving these spaces.

For Targeted projects, the above approach should be taken where occupancy significantly affects the baseline energy consumption. In this case, occupancy information corresponding to the measurement period need only be collected.

Quality Assurance Methods

- Ensure that occupancy data, occupancy types, space types, and occupancy schedules were collected and documented.
- Note any significant deviations from "normal" occupancy, occupancy schedules, or space types. These deviations may warrant adjustments to the baseline (non-routine adjustments), and should be accounted for in the baseline development if they pose a significant influence on building energy consumption.

Resources

EN 16247-2 Energy Audits – Part 2: Buildings (section 5.3.2) – provides guidance on information required relating to occupancy as part of an energy audit.

4.2.5 Building Asset / Operational / Performance Data

Requirements

Collection of accurate building asset, operational and performance data is critical to the decision making process. This data provides the foundation for all important investment decisions, including: building performance tracking, assessment of energy efficiency opportunities, and ECM investment implementation and performance tracking.

Information regarding the building, its operation and system performance should be collected by conducting an energy audit of the building(s) that are to have ECMs installed. Energy audits are required for all projects. However, for Targeted projects, where numerous sites may be involved, a sampling approach to auditing may be adopted, provided an explanation is given for the selection of sites to be audited in the context of all the sites in the project and an estimate made of any associated uncertainty.

European Directives and the ICP

The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are the EU's main legislation related to reducing the energy consumption of buildings.

The Energy Performance of Buildings Directive (EPBD) sets out the following requirements:

- Energy performance certificates are to be included in all advertisements for the sale or rental of buildings
- EU countries must establish inspection schemes for heating and air conditioning systems or put in place measures with equivalent effect
- All new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018)
- EU countries must set minimum energy performance requirements for new buildings, for the major renovation of buildings and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls, etc.)
- EU countries have to draw up lists of national financial measures to improve the energy efficiency of buildings

The Energy Efficiency Directive (EED) includes a number of requirements – some of the most relevant ones include EU governments to:

- Set national energy efficiency targets, taking into account national circumstances (Article 3)
- Draw-up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans (Article 4)
- Make energy efficient renovations to at least 3% of buildings owned and occupied by central government; only purchase public buildings which are highly energy efficient (Article 5)
- Promote high quality, cost effective audits to SMEs, and ensure that large companies are subject to regular energy audits at least every four years (Article 8)
- EU governments to ensure that competitively priced individual meters are provided to customers of electricity, gas, and district heating and cooling; building level and individual meters must be installed in multi-occupancy buildings with central heating or district heating and/or cooling or hot water (Article 9)
- Ensure the availability of certification, accreditation and/or qualification for providers of energy audits and energy managers (Article 16)
- Promote the energy services market and support it by providing information on available energy service contracts, financial instruments and incentives (Article 18)
- Evaluate and remove regulatory and non-regulatory barriers to energy efficiency, and take measures to remove these – this includes the issue of split of incentives between building owners and tenants (Article 19)

Of particular relevance to the ICP process is the requirement for energy auditing, which are required to produce EPCs under the EPBD and are mandatory for large business under the EED, and regular inspections of heating and air conditioning systems, required under EPBD. These requirements should be taken into account at the start of the project to identify whether there is any overlap between these requirements and the ICP process requirements.

Information to be collected can include: site observations and plant nameplate data; building as-built drawings; interviews with facility personnel, maintenance personnel, manufacturer's representatives, service providers and occupants; commissioning and re-commissioning reports; sequences of operation;

commissioning reports; spot measurements or short-term monitored data; or previous energy audits. A checklist of key building information that should be collected as a minimum is provided below:

1. Building information
    a. General building information, such as building location, type, age
    b. Energy performance certificate, if available
    c. Air conditioning inspection reports, if available
    d. As built plans
    e. Building floor area, including a description of how this has been calculated – the calculation should include all conditioned parts of the building, the latter as defined by the EPBD or national authorities, and should exclude non-habitable areas
    f. Details of car parking - including whether or not it is enclosed and mechanically ventilated, and associated floor areas
    g. Description of tenant type(s), area in m^2 of building occupied, and details of their lease agreement
    h. Energy related data (see section 4.2.1) – including details of the building's energy supply and metering arrangements, including details of any sub-meters (drawings, schedules)
    i. Variables affecting energy consumption e.g. weather data, occupancy patterns
    j. Information on changes made to the building in the last 3 years that may affect energy consumption related to the energy baseline or ECMs, such as physical changes to the building or its systems, or changes related to occupancy
2. Systems and equipment information, where relevant to the ECMs
    a. Overview of systems description e.g. from Operation and Maintenance manuals
    b. Building services schematics – mechanical and electrical
    c. Details of the energy consuming systems, plant and equipment for relevant areas of the building, including type, number, capacity, hours of operation, location, areas served, and controls, including:
        i. Heating and hot water, including heat recovery
        ii. Mechanical ventilation
        iii. Air conditioning
        iv. Lighting – internal and external
        v. Motors and drives
        vi. Low and zero carbon technologies e.g. solar photovoltaics, combined heat and power etc.
        vii. Lifts and escalators
        viii. Information Technology and small power equipment
        ix. Specialist equipment e.g. commercial refrigeration, compressed air
3. Controls and Building Management System
    a. Information on how the building is controlled including key data such as set points and time

clock settings

4. Building fabric details where relevant to the proposed ECMs

It is important to collect this information in a consistent and standardised way. Therefore the data collection process must utilise standardised forms and methods, or tablet-based applications designed for energy audit data collection. The collection of information must be thorough, as well as specific to the building and system types. Equipment schedules, tables, and building and system descriptions must be developed in order to compile this information in a way that can be easily and clearly referenced in associated project development tasks. The underlying concept is that energy auditors with different 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.

While collection of complete and accurate building data is important, of equal importance is the proper and thorough documentation of this data and its sources. These resources can then be easily referenced, shared, and used in all subsequent project development efforts, including: energy conservation measure (ECM) descriptions; energy model development; 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 energy audit report must include building asset, performance, and operational data. The report must also note the sources of the information, and a description of how the information was collected. As a minimum, the report should include:

- Summary, including technical and non-technical overview
- Background to the building, its systems and its operation (see earlier in this section)
- Any key observations made during the audit
- Historical energy consumption analysis (see section 4.2.1) and including details of energy costs (see section 5.0)
- Energy efficiency opportunities identified, and description of proposed ECMs – including anticipated savings and cost (see section 6)

The format of the report should also satisfy the project’s requirements (i.e. client or stakeholder’s expectations).

Quality Assurance Methods

- ❖ Review data collection methods and tools (interview questions, data collection forms, tablet applications) to ensure that they are comprehensive and consistent with required standards.
- ❖ Review collected data; perform spot check comparisons of resources to data collected (e.g.

compare building drawings to equipment inventories) to ensure that data was collected accurately, and that the sources of this data are documented.
- ❖ Review operational and performance data (spot measurements, short-term monitoring, functional performance tests) analysis results. Ensure that conclusions regarding system performance correspond to and are consistent with analysis results.
- ❖ Review report (or report sections) to ensure that building asset, operational, and performance data have been properly represented, and the sources of this data are well documented.

Resources

EN 16247-2 Energy Audits – Part 2: Buildings (section 5.3.2 and Annex D) – provides guidance on information required as part of an energy audit.

EN 16247-2 Energy audits – Part 2: Buildings (section 5.6) – provides guidance on industry standard for reporting.

4.2.6 Retrofit Isolation Baseline (Standard and Targeted Tertiary / Apartment Blocks)

Requirements

A retrofit isolation baseline presents a baseline specific to proposed ECMs, and is best applied when applying an IPMVP Option A or B M&V approach. The development of the retrofit isolation baseline(s) should follow a similar procedure to that described in the previous baseline development section (section 4.2.1). It should be informed by, and be consistent with, all collected field data that describes operation of the facility and systems.

Development of the retrofit isolation baseline should include a clear definition of the measurement boundary. The boundary can be defined around a specific piece of equipment, a combination of equipment comprising a building subsystem, or a specific end-use. The measurement boundary should also account for whether the equipment or end-use is a constant or variable load, or a constant or variable schedule.

For the proposed ECMs, load and hours-of-use components, and whether these components are constant or variable should be documented. The measured and estimated parameters should be defined based on the characteristics of the proposed ECMs. When these have been identified, the measurement period should be selected, ensuring that it is appropriate to the measured parameters identified and the associated operating conditions relating to the ECM.

The developed baseline(s) should be informed by all available information, including equipment inventories and operating performance, and should be compared to simple estimation efforts or previous energy savings estimates to ensure reasonability. These baselines should be used to bound savings estimates, and subsequently to verify achieved energy savings.

Quality Assurance Methods

- Ensure that retrofit isolation baseline(s) are developed following a similar approach to that outlined in section 4.2.1 of this specification. Baseline should be informed by, and be consistent with available data, and should correspond to end-use energy consumption calculations.
- Ensure that baselines document load and hours-of-use components, and whether these components are constant or variable.
- Ensure that a suitable measurement boundary has been clearly identified, as well as measured and estimated parameters and the measurement period.
- Ensure that developed baseline(s) are used to bound savings estimates, and are used for IPMVP Option A or B M&V efforts.

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section 4.5.1 provides guidance on identifying the measurement boundary.

4.2.7 Interactive Effects (All Protocols)

Requirements

Interactive effects are secondary energy effects occurring as a result of ECMs, usually associated with heating and cooling.

These must be considered for all types of projects. For guidance on dealing with interactive effects for Large projects, see section 6.2.3, and for Standard projects, see section 6.2.5.

For the Targeted protocols, there should be no interactive effects between measures. The exception to this applies to lighting retrofit projects where there may be interactions between the lighting-related measures, and the heating and cooling loads – that is, a significant improvement in lighting efficiency in a building will reduce heat gains and therefore potentially reduce cooling loads and/or increase heating loads.

Where this type of project is planned, one of the following approaches should be adopted:

a. The impact on heating and cooling loads must be estimated for each season of the year, using conventional heating and cooling calculations. The result should be presented as a proportion of the lighting energy savings, and the total energy savings should be adjusted accordingly; or
b. The impact on heating and cooling loads must be estimated using the simplified methodology outlined below. The result should be presented as a proportion of the lighting energy savings, and the total energy savings should be adjusted accordingly; or
c. The measurement boundary should be expanded to include the interactive effects (see section 4.2.6).

Where Option ‘a’ above is chosen, the following should be taken into account:

- Lamp or lighting fixture efficiency improvement
- Annual full load hours of operation
- HVAC system type
- HVAC system efficiencies
- Climate

Option ‘b’ should be carried out as follows:

1. Estimate the reduction in lighting load in kW and the change in annual full load operating hours, and multiply together to provide a total energy change in kWh.
2. Estimate number of hours in the year when the building is in heating or cooling mode, if applicable. This should be based on sub-metered data for the operation of the boilers and chillers, if available. Present as percentages of the year.
3. Apply percentages to the total energy change to provide the increase in heat demand and

reduction in cooling demand in kWh, unless the energy change is less than 5% of the predicted lighting energy savings where the interactive effect may be ignored.

4. Apply plant efficiencies (i.e. boiler efficiency or chiller COP) to calculate primary energy consumption change. Plant efficiencies should be documented and their sources clearly identified.

Quality Assurance Methods

- Ensure that all potential interactive effects resulting from proposed ECMs are considered.
- Where lighting projects are proposed, ensure either the impact on heating and cooling is documented or that the measurement boundary is shown to include interactive effects.
- Review estimated heating and cooling loads to ensure that they are accurate and reasonable.

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section 4 describes interactive effects and how they may be addressed under an IPMVP compliant approach.

5.0 BASELINING - RATE ANALYSIS, DEMAND, LOAD PROFILE, INTERVAL DATA

5.1 OVERVIEW

Depending upon the location of the building in question, the time of day at which energy is saved can have a significant impact on the monetary value of the savings achieved. Where demand charges or time-of-use pricing are in effect, load profiles must be provided to show the pattern of daily demand. An annual electrical load profile must be constructed for peak demand (kW) as recorded and billed by the utility. Where there are charges for a minimum proportion of annual peak demand throughout the year, these must be identified. The same procedure must be followed for any other energy source that is sold with a peak demand charge separate from energy consumption.

While analysis of whole-building monthly energy consumption and demand data helps quantify and bound projected savings, and facilitates M&V efforts, analysis of interval data and the development of load profiles can provide additional insight into building operation, load disaggregation, end-use benchmarking, and potential energy saving opportunities. The increased availability of energy consumption data at resolutions of one hour or less (due largely to recent increases in smart or time-of-use metering) provides greater resources to perform this level of analysis on energy efficiency projects.

5.2 PROTOCOL ELEMENTS

5.2.1 ANNUAL / AVERAGE DAILY LOAD PROFILES

Requirements

Note that the following requirements relate to Targeted projects only where they are relevant to the proposed project.

Describe how the facility purchases energy, including the pricing that applies to peak and off-peak energy, for all energy types, and present at least one bill for electricity, as well as each fuel. The price schedule should be obtained from the energy supplier. This price schedule should include all elements that are affected by metered amounts, such as consumption charges, demand charges, transformer credits, power factor, minimum demand charges, fuel price adjustments, early payment discounts and taxes. Average or blended prices should never be used to calculate cost savings, other than for early stage feasibility assessments.

The price schedule used for the purposes of M&V will need to be determined - whether energy-cost savings are verified using the price schedule which corresponds to the baseline or reporting period. Typically, the price schedule associated with the reporting period is used to calculate verified costs savings so that they are a function of demand changes rather than a mix of demand and price/tariff changes.

If interval data is available, it can be used to develop load shapes. Interval data may also be referred to as "interval meter data," "demand interval data," "kW interval data," or "electricity interval data." Common forms of interval data include 15-minute data and half-hourly data.

As a minimum, monthly load profiles, showing peak demand, should be developed using monthly data. Where this data is not available, explain why, and describe any potential impacts this may have on the baseline and savings calculations, and how these issues will be addressed.

Where demand charges or time-of-use pricing is in effect, load profiles should be developed using available interval data for typical weekday and weekend days in the spring, summer, autumn and winter. Time should be charted on the x-axis and appropriate energy units (such as kWh or MBtu) on the y-axis.

The developed load profiles can indicate excessive energy consumption during normally unoccupied periods (such as evenings or weekend days). The load profiles can also show peak periods of demand, which represent potential opportunities for demand reduction or demand limiting efforts. Load profiles can also be used to assist with energy model calibration efforts.

Quality Assurance Methods

- Ensure that all price schedules have been provided, and that the price schedule to be used for the purpose of calculating verified cost savings has been identified.
- Review developed load shapes (if interval data is available), and how they were used to inform identification of ECMs or energy-modelling calibration efforts.

Resources

Energy Charting and Metrics Tool *(PNNL/DOE)* - ECAM+ is an add-on for Microsoft Excel® which facilitates the analysis of data from the building (energy and other data). Key features of ECAM+ include: creation of charts to help re-tuning, creation of schedules and day-type information using time series data; filtering data from months, years, days, day-type, day of week, day of month, occupancy, temperature binned weather data, pre/post comparisons after retrofits or retro-commissioning; normalising data and creating metrics based on consumption or equipment; creation of various load profiles or scatter charts for data selected by the user; new additions to the PNNL re-tuning charts; and new M&V for meter data.

6.0 SAVINGS CALCULATIONS

6.1 OVERVIEW

Savings calculations can be performed using detailed energy modelling, spreadsheet calculations, or other methods, depending on the requirements of the project and protocol. Regardless of the method employed, the procedure should be transparent and well documented. For Large and Standard projects, calculation methods must be based on sound engineering methods, and be consistent with the IPMVP approach (refer to IPMVP section 4.5). 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 should be thorough, documenting existing conditions, the proposed retrofit, and potential interactive effects. The descriptions should provide enough detail so that they can be used to develop accurate scopes of work and informed cost estimates.

For Large and Standard projects, the results of the savings calculations must be calibrated to estimated or known end-use energy consumption.

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

Element	Section	Protocol		
		Large Tertiary/ Apartment Block	Standard Tertiary/ Apartment Block	Targeted Tertiary/ Apartment Block
ECM Descriptions	6.2.1	✓	✓	✓
Dynamic Energy Modelling (Model Data, Calibration, Process Description)	6.2.2	✓		
ECM Modelling	6.2.3	✓		
ECM Calculations (Measure Calculation Tools, Calculation Data, Measure Calibration, Calculation Process Description)	6.2.4		✓	✓
Interactive Effects	6.2.5		✓	✓ (Lighting ECMs only)
Cost Estimates	6.2.6	✓	✓	✓
Investment Criteria	6.2.7	✓	✓	✓
Reporting	6.2.8	✓	✓	✓

6.2 PROTOCOL ELEMENTS

6.2.1 ECM Descriptions

Requirements

The results of the energy audit 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 6.2.6), and therefore detailed descriptions of the measures must be developed so that these estimates can be accurately developed.

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

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

A best practice approach would also include:

- Risk of equipment failure
- Schedule for implementation
- Summary of specific maintenance requirements or considerations associated with the ECMs, particularly any impacts on maintenance costs
- Interaction with other end uses and ECMs (see section 6.2.5)
- Potential issues which may prevent successful completion
- Organisations and individuals involved in implementing this action or improvement, and their responsibilities
- Staff effort required

Quality Assurance Methods

❖ Review the ECM descriptions to ensure that they contain sufficient information, as described above.

6.2.2 Dynamic Energy Modelling (Large Tertiary / Apartment blocks)

Requirements

Dynamic energy modelling is best suited to projects with a large number of potentially interactive ECMs being considered, and where there is a higher level of performance risk associated with the project. Development of an accurate energy model, calibrated to historical utility bills, is critical for the accurate estimation of energy savings associated with the ECMs. The energy model used should be developed using public domain or commercially available software that meets the current nationally or internationally recognised specifications for 8760 hour annual simulation of building energy consumption. Internationally recognised specifications include *ISO 13790:2008 Energy performance of buildings – Calculation of energy use for space heating and cooling* and *ASHRAE Standard 140-2011 Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programmes.*

The modelling process starts with complete descriptions of the facility, building envelope, mechanical systems, service water heating, and electrical systems, and also includes climate data and utility rate information. The following are specific components that need to be input into the energy model:

- Building location and orientation
- Descriptions of all building envelope assemblies, including exterior walls, windows, doors, roofs, underground walls and floors, as well as component dimensions and orientations
- Space use classifications that best match the uses within the building or individual spaces, as well as space sizes (volume). These classifications determine default occupant density, plug loads, service water heating, minimum outdoor ventilation air, operating schedule, and lighting assumptions when this information is unknown
- Internal loads associated with each space, including occupant density, plug loads, process loads, infiltration, thermal mass, refrigeration equipment, cooking equipment, miscellaneous equipment, elevators and escalators, and lighting, as well as associated schedules and controls
- Zones representing areas of the building served by a single thermostat. Zones may be combined to simplify the energy model, assuming these zones are served by the same HVAC system or system type, have similar conditioning requirements, similar minimum airflows, and similar loads
- Information on all HVAC systems and equipment, including which systems serve which zones. All information regarding the system type, efficiency, performance curves and operation needs to be inputted into the model. This includes setpoints, control strategies, ventilation, and schedules
- Domestic hot water systems and associated schedules or controls
- Exterior lighting and associated schedules or controls
- Swimming pools and other miscellaneous gas or electricity using equipment
- Climate data - see section 4.2.3
- Utility rate information – see section 5

When developing an energy model, it is often necessary to make assumptions about how the building is being operated, or about the loads or schedules pertaining to the building. Reliance on assumptions should be minimised, but may be necessary due to lack of resources or available information. Assumptions may include thermostat settings, number of occupants, plug loads, process loads, hot water loads, as well as schedules of operation for HVAC systems, lighting systems and other systems.

Assumptions should always be conservative, and clearly documented.

While every reasonable attempt should be made to determine these inputs through the energy auditing activities, other resources can be used to generate reasonable assumptions to use in place of unknown data, such as nationally recognised sources of design data. One such resource includes the Commercial Energy Services Network (COMNET), which provides guidance regarding defaults for these items.

Calibration of the energy model to the baseline utility bill analysis represents a critical step toward ensuring accurate estimates of the building's energy performance and energy savings for proposed ECMs. The calibration process requires development of a custom weather file conforming to the selected baseline period (not the use of averaged weather data). When creating a custom weather file, the weather data parameters that the building simulation programme requires must be determined. This weather data may in some cases need to be collected from different weather stations.

IPMVP *Core Concepts* (2016) (section 6.6.3) sets out the steps associated with calibrating the simulation:

1. Collect and document detailed operating data e.g. occupancy, weather, equipment ratings and operating hours. It may be necessary to carry out short or medium term monitoring for inputs which may vary in practice and which have a significant impact on results e.g. lighting loads, equipment efficiency.
2. Collect real weather data covering the baseline period. However, in some cases, obtaining and preparing actual weather data for use with a simulation may be time-consuming and expensive. If this is found to be the case, then it may be acceptable to adjust an average weather file using valid statistical methods – in this instance, justification should be provided on why this approach is necessary.
3. Run the simulation and verify that it predicts operating parameters such as temperature and humidity.
4. Compare the simulated energy results with the metered energy data from the calibration period, on a monthly, daily, or even hourly basis. Monitored data of systems, subsystems or end uses can also inform the modelling and calibration process. Daily load profiles can also be used to assist in this process, if available.
5. Determine the calibration accuracy. The calibrated model results should give a Mean Bias Error (MBE) of ±5% and CV(RMSE) of 15% relative to monthly calibration data. The accuracy of the estimate can further be assessed using standard error of the estimate and the associated value of the t-statistic. IPMVP Volume 1 provides guidance on how these measures are calculated.
6. Optimise the model by adjusting any unknown input data to bring predicted results within the required tolerance set out above. Adjustments to unknown or assumed inputs should be conservative, and within reasonable defined parameters. Collect more actual operating data from the facility to meet the calibration specification if necessary. The calibration process should not include the adjustment of any known model inputs.

All modelling inputs and assumptions should be well documented in the form of a report that describes the modelling process. The report should include key modelling inputs and outputs, as well as full disclosure of any modelling warnings or errors.

Quality Assurance Methods

- Review modelling inputs, to ensure that they correspond to field data collected during the audit. If spot checking items, which is common, review inputs that have the greatest potential impact on building energy performance, or ones that are directly related to the proposed ECMs. Check that assumptions used for unknown variables are conservative.
- Check that the proper energy cost rate schedule(s) have been used in the energy model.
- Review model errors or warnings, and make corrections/amendments to the model where necessary.
- Review output reports, and compare metrics to typical comparable metrics (such as Energy Consumption Intensity in kWh.m^2.year, ventilation rates, load densities, etc.).
- Review calibration methods to ensure that adjustments to the model are reasonable. Calibration efforts should utilise a local weather file for the time period corresponding to the baseline. Calibration results should result in a MBE of ±5% and a CV(RMSE) of 15% relative to monthly calibration data.

Resources

International Performance Measurement and Verification Protocol: Core Concepts (EVO), 2016 – section 6.6.3 sets out how to use computer simulation to predict building energy consumption.

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 – section 4.9 sets out how to use computer simulation to predict building energy consumption, and includes details of how to calibrate models; Appendix B explains how to calculate uncertainty, with MBE and CV(RMSE) covered in section B-2.2.2.

EN ISO 13790:2008 Energy performance of buildings – Calculation of energy use for space heating and cooling – sets out the calculation procedures for detailed dynamic simulation methods for energy consumption associated with space heating and cooling.

EN 15265:2007 Energy performance of buildings – Calculation of energy needs for space heating and cooling using dynamic methods – General criteria and validation procedures – sets out validation criteria for dynamic modelling.

ASHRAE Standard 140-2011 Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programmes - specifies test procedures for evaluating the technical capabilities and ranges of applicability of computer programmes that calculate the thermal performance of buildings and their

HVAC systems.

COMNET (IMT/NBI) - A US quality assurance initiative to standardise building energy modelling, by creating consistent baselines relative to various energy codes and standards. COMNET extends and supports existing systems for assessing and rating the energy efficiency of new commercial and multifamily buildings in the United States. The core component of COMNET comprises a set of guidelines and procedures that governs this standardization.

6.2.3 ECM Modelling (Large Tertiary / Residential)

Requirements

The calibrated baseline model, developed using dynamic energy modelling software, should be updated to include the proposed ECMs and to estimate the resulting energy savings. In order to account for interactive effects, the measures can be modelled iteratively, effectively creating a "rolling" baseline that includes all previously modelled ECMs in subsequent runs, with the final run representing the package of all proposed measures. Measures that affect the building's loads (envelope improvements or lighting retrofits) should be modelled first, followed by those that impact schedules. Subsequent ECMs should include those that affect HVAC subsystems, followed by those that affect the central plant. This approach is best applied when all of the ECMs are being considered, such that the final run represents a bundle of all proposed ECMs and their potential interactive effects.

If ECMs are not modelled to include previous measures, and are modelled in isolation, it is important to keep in mind that these model runs do not capture the interactive effects between measures, and savings will not therefore be additive (the sum of the parts will be greater than the whole). Instead, final packaged runs, representing multiple ECM bundles, will need to be performed so that the interactive effects can be quantified for each package of measures being considered.

The manner in which measures are modelled should be documented, including the key parameters or programming that was performed to model the measures, as well as the assumptions used and their sources. As with all ECM energy savings calculations, assumptions should be conservative. The resulting energy savings estimates should be compared to baseline and end-use energy consumption, previous project results, or simple estimation methods to ensure that energy savings are realistic and in line with other sources.

Quality Assurance Methods

- Check ECM modelling parameters and programming logic, as well as assumptions used, to ensure that they are conservative and documented.
- Ensure that savings estimates are reasonable, as compared to baseline and end-use energy consumption, previous project results, or simple estimation methods.
- Check that interactive effects have been accounted for in the form of iterative modelling or the

modelling of packages (bundles) of ECMs.

Resources

See Section 6.2.2, *Energy Modelling*, for associated resources.

6.2.4 ECM Calculations (Standard and Targeted Tertiary / Apartment Blocks)

Best Practices

Calculation methods other than dynamic energy modelling, such as regression analysis, are a practical and effective method for estimating energy savings associated with proposed ECMs. Any calculation methods used should be based on sound engineering principles and methodologies. Inputs should be derived from weather data, system design information, manufacturer specifications, and operational data from on-site monitoring. For each ECM, the calculation methodology, formulas, inputs, assumptions and their sources need to be clearly documented.

References such as the IPMVP Volume 1 and the US' Uniform Methods Project (UMP) 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. 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 description such that (with the necessary input information) a reviewer can reconstruct the calculations. This description should include documentation of the formulas used, as well as any assumptions and their sources.

Inputs for the savings calculations are derived from the outputs of the energy audit. Each of these inputs is critical to the accurate estimation of energy savings, and should always be conservative, especially if not well defined or unknown. Operational and performance data also provide key inputs to inform and bound the savings calculations. This data can be obtained from functional performance tests or short-term monitored data, supplemented by driving variables (such as occupancy or weather), and can help define or demonstrate opportunities or deficiencies in operation or performance.

Interactions are also an important part of the energy savings calculation process. Savings calculations should always take into account the potential effects of other proposed ECMs. For example, a measure that involves replacement of a piece of equipment with a higher efficiency unit may need to account for a reduced operating schedule associated with another ECM. As with more complex energy modelling, it is best to calculate savings for ECMs affecting schedules or building loads first, then zone-level equipment, and finally plant-level equipment. This method allows for effectively "carrying through" the characteristics of the earlier measures through to the later measures.

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, independent testing results of the application, and the like. 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. Estimated energy savings should also be compared to simple estimation efforts or previous energy savings estimates. This ensures figures are credible and provides a first level of quality assurance.

Quality Assurance Methods

- ❖ Ensure that appropriate calculation methodology has been applied, and that no constants or assumptions have been embedded as numbers within cell formulas. When dealing with spreadsheet calculations, typically the best way to check the calculations is to begin with the savings estimate result, and work back through the formulas and methodologies to look for any errors.
- ❖ Check that all assumptions and inputs are reasonable and documented, and that they match the results of the field investigation or data analysis. If assumptions are used, check that they are conservative.
- ❖ Check that the appropriate weather file has been used, as well as the appropriate operating schedule for the equipment being affected by the measure. Constants used in calculations should also be appropriate for the region or elevation (density of air, energy content of fuel, etc.).
- ❖ Check that the results have been compared to end-use energy consumption or simple calculation methods, and appear reasonable.
- ❖ If third-party proprietary calculation tools are used for any ECM, ensure that the application is well documented and provides unbiased results.

Resources

EN 16212 Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods, section 6.2 – provides general guidance on calculating energy savings using a bottom-up approach

Uniform Methods Project (National Renewable Energy Laboratory) – US resource which provides detailed guidelines for calculation methods and best practices.

US Department of Energy (DOE) Federal Energy Management Program (FEMP) - Calculators and tools that can be used or referred to as models for calculation methods.

6.2.5 Interactive Effects (Standard and Targeted Tertiary / Apartment Blocks)

Requirements

For Standard projects, calculations should take into account measure interactions with building heating and cooling loads (e.g. lighting retrofit), as well as interactions between measures. Interactive effects may be ignored where the estimated adjustment required for each measure can be shown to be less than 5% of the predicted saving for the measure. This should be clearly documented, including a description of each interactive effect and how the estimated impact has been made.

For example, for a lighting retrofit project, the reduced heat gains from the lighting system may affect the energy savings by increasing the heating demand but also decreasing the cooling demand. If the overall interactive effect is expected to have a significant impact on the savings, conventional heating and cooling calculations would be used to determine the appropriate fraction(s) for each season. However, if the measurement boundary can be expanded to encompass interactive effects during the baseline period, there is no need to estimate them.

For Targeted projects, refer to section 4.2.7 on how interactive effects should be taken into account.

Quality Assurance Methods

- Ensure that measure interactions have been taken into account in the appropriate manner.

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section 4 describes interactive effects and how they may be addressed under an IPMVP compliant approach.

6.2.6 Cost Estimates

Requirements

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 (see section 6.2.7).

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 any contractors familiar to the building owner. Alternatively, cost estimates may be based upon the engineer’s experience with previous projects. 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 the facility, access points for bringing in any large equipment, major removals (demolition), permits required, and possible environmental issues (i.e. asbestos, hazardous materials, or other issues that impact indoor air quality).
- Categories and multiple line items for all necessary trades, i.e. civil (structural and site work, demolition, rigging), mechanical, plumbing, electrical, architectural (finishes), 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.
- Cost estimates 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.
- Lifecycle Cost Analysis (LCCA) is not required, but may be included where there are benefits of the proposed retrofit other than energy-cost savings. Refer to ISO 15686-5:2008 Buildings & constructed assets – Service life planning – Part 5: Life cycle costing.
- Estimated equipment useful life expectancy and equipment degradation are not required (although some projects may require this when assessing the investment term), but may be included to assess the overall economic performance of proposed retrofits. These estimates should be conservative and based on accepted values.

Quality Assurance Methods

- ❖ Check that a construction feasibility review was performed and that all subsequent cost estimate components have been accounted for and accurately reflect the scope of work involved with the proposed ECMs.
- ❖ Ensure that cost estimates are conservative and reasonable.
- ❖ Ensure that cost estimates have been split if necessary (total cost and incremental cost).
- ❖ If LCCA is performed, ensure that the proper assumptions were used in the analysis.

Resources

ISO 15686-5:2008 Buildings & constructed assets – Service life planning – Part 5: Life cycle costing – guide to the LCC methodology and criteria for the economic evaluation of energy projects.

6.2.7 Investment Criteria

Requirements

Different programmes and projects will each have their own financial metrics and specific financial inputs that meet their expectations or criteria. The ICP's goal is to create confidence in project energy performance, but does not take a position on what financial metrics or criteria should be used to evaluate a potential investment. Determining which financial metrics are important to the investors when assessing the financial performance of a proposed project represents the first step in the investment criteria process.

Different financial metrics will be more or less valuable depending on the needs and requirements of the investors, therefore the relevant financial metrics should be developed by the investing parties. This should include selection of the appropriate discount rate which will be critical to the financial analysis and the selection of the ECMs. It is then the responsibility of the project development team to provide the data and calculations necessary to allow the investors to evaluate the project's potential. The metrics used should be properly defined and calculated using 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.

The following are common metrics used to assess the financial performance of a proposed energy efficiency project. In general, use of the simple payback method as the sole criterion for evaluation of a capital investment is discouraged. Instead, projects should consider using additional methods such as net present value, internal rate of return, or savings to investment ratio, to incorporate the time value of money and more complex cash flows.

Savings to Investment Ratio (SIR) - the ratio of the present value of an energy saving stream with respect to the present value of the cost of making the energy efficiency improvements. Divide the total savings over the project's useful life by the cost of the project. The SIR is a measure of how many times an investment is recouped over the life of a project. A number above 1 indicates the project is savings money over the life of the project, while a number below 1 indicates the investment will not be recouped. The major limitation with this metric is that this is a relative measure rather than an absolute measure of the size of the savings from the project.

Internal Rate of Return (IRR) - a rate of return used in capital budgeting to measure and compare the profitability of investments. The IRR of an investment is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment. IRR calculations are commonly used to evaluate the desirability of investments or projects. The higher a project's IRR, the more desirable it is to undertake the project. Assuming all projects require the same amount of up-front investment, the project with the highest IRR would be considered the best and undertaken first. This metric is a relative measure rather than an absolute measure of the size of the savings from the project, and is suitable for comparing projects of different scales.

Net Present Value (NPV) - the "difference amount" between the sums of discounted cash inflows and cash outflows. It compares the present value of money today to the present value of money in the future, taking inflation and returns into account. Essentially, it sums up the present values of money going in or going out each year to see what the sum would be. This sum represents the cost of "doing nothing." If positive, it can be compared to other project's NPVs to see if it is a worthy investment. This metric is an absolute measure rather than a relative measure, and is best used when comparing the profitability between projects of a similar scale to give a more straightforward comparison.

Simple Payback (SPB) - the investment of a project divided by the annual savings (first year). The simple payback is a measure of how much time in years it takes to recoup an investment based on the first year annual savings. This metric should only be used in conjunction with other metrics.

Quality Assurance Methods

- Determine through interviews with the investors that the financial metrics used to evaluate the project meet the needs of the investors.
- Ensure that the financial metrics, as they are defined in this specification, are being applied properly to the project. The metrics used should be calculated using 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.

Resources

Building Life Cycle Costs (National Institute of Standards and Technology) – US programme to provide computational support for the analysis of capital investments in buildings.

International Energy Efficiency Financing Protocol, 2009 (EVO) - The global "blueprint" for educating and training on the special intricacies, benefits and risks associated with financing EE projects. Intended to serve as a growing set of best practices, resource materials, case studies, standardised tools and guidelines to support economic and financial evaluation of EE projects.

RETScreen Financial Analysis Workbook - workbook used to analyse financial performance and viability of an EE project.

6.2.8 Reporting

An industry-accepted format should be used for reporting results and for compilation of methods and underlying data used for individual ECM calculations as well as for the package of recommended measures. At present, the industry standard for report presentation of ECM, building, and energy consumption data is *EN 16247-2 Energy audits – Part 2: Buildings (section 5.6)*. Additionally, annual energy savings by fuel type shall be documented in terms of energy units, a percentage of the total consumption of each fuel, and as cost savings using the correct marginal rate for that energy type.

The report should be written in such a way as to be relevant to both technical and executive personnel. As a minimum, the report should cover the following key areas:

1. Executive summary
    - Overview of building energy consumption and performance
    - Ranked ECMs including ECM summary table
    - Recommended opportunities and overall timeframe for implementation
2. Introduction:
    - Background, description/scope of the building audit carried out and methodology
    - Contact details of parties involved (investor, auditor, etc)
    - Investor objectives
3. Building energy usage
    - Summary of building energy consumption and details of associated costs - see sections 4 and 5
    - A simple analysis of building energy performance and/or energy performance indicators
4. Building information
    - Description of the building
    - Description of the existing building and its systems i.e. building asset and operational information - see section 4.2.5
5. Energy conservation measures
    - Description of the ECMs under consideration – see section 6.2.1
    - Cost estimates – see section 6.2.6
    - Financial analysis – see section 6.2.7
    - Details of all assumptions made
    - ECM summary table of measures, including capital cost, energy and cost savings; measures should be ranked according to attractiveness based on the financial metrics used
    - Recommendations and suggested implementation programme
6. Building and ECM modelling details (Large Tertiary and Apartment Blocks only)
    - See section 6.2.2 and 6.2.3
    - Details of the software used
    - Description of the calculation process, with necessary inputs and all assumptions made
    - Model outputs
    - Model accuracy/calibration details
7. Savings calculations (Standard and Targeted Tertiary and Apartment Blocks only)
    - See section 6.2.4
    - Details of the calculation tool used
    - Description of the calculation process, with necessary inputs, and all assumptions made
    - Calculation outputs

- Calculation accuracy details
- Description of any measure interactions and how these have been addressed – see section 6.2.5

8. Conclusions and recommendations
    - Any recommendations for implementation
    - Any recommendations for monitoring and verification to assist in developing the M&V plan
9. Appendix
    - Details of any supporting information, such as manufacturer's information
    - Any measured data or monitoring results

Quality Assurance Methods

- ❖ Ensure that the report is clear and that it covers all the required elements; identify any gaps
- ❖ Ensure that the investor's objectives are clearly set out, and that the ECMs identified meet these objectives

Resources

EN 16247-2 Energy audits – Part 2: Buildings - section 5.6 and Annex J set out the content required for energy audit reports, including an example table of contents for a comprehensive building energy audit.

ISO 50002:2014 Energy audits – Requirements with guidance for use – section 5.8.2 sets out the topics that an energy audit report should cover.

7.0 DESIGN, CONSTRUCTION AND VERIFICATION

7.1 OVERVIEW

This part of the process focusses 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 focusses on the commissioning activities specific to the EE upgrades and ECMs, rather than involving the commissioning of all building systems and components.

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

A qualified OPV Specialist 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. See section 10.1 for further detail on this.

Overall, the 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 provider 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 table below indicates which elements described in this document apply to each protocol.

Element	Section	Protocol		
		Large Tertiary/ Apartment Block	Standard Tertiary/ Apartment Block	Targeted Tertiary/ Apartment Block
Operational Performance Verification Plan	7.2.1	✓	✓	
Operational Performance Verification and Report	7.2.1	✓	✓	✓
Training	7.2.2	✓	✓	✓
Systems Manual	7.2.3	✓	✓	

7.2 PROTOCOL ELEMENTS

7.2.1 OPERATIONAL PERFORMANCE VERIFICATION (ALL PROTOCOLS)

Requirements

For Large and Standard projects, the OPV effort begins with the development of an OPV plan – the submission of a formally developed plan is optional for Targeted projects. The plan should be developed pre-construction, and should describe the verification activities, target energy budgets and key performance indicators associated with the project and the individual ECMs. Performance indicators should be used to identify underperformance, although these are optional under the Targeted protocols.

The plan should also describe the data logging, control system trending (analysis of historical data and using it to predict future performance, usually using the BMS), functional performance tests, spot measurements, or observations that will be used to establish both baseline operation as well as post-construction operation, to demonstrate that operations and performance have improved and have the ability to perform over time.

The OPV process itself, led by the OPV Specialist, should include consultation with the energy audit team, 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 in an issue log. 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 the 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 considerably certain may only warrant installation verification. That is, visual inspection to ensure that the measures have been implemented properly – for example, wall insulation and windows. Measures with greater savings at risk or greater uncertainty will require a greater depth of OPV, such as sample spot measurements (for example, lighting fixtures and lamps, pumps), short term performance testing (for example, fans fitted with variable speed drives), and the collection and analysis of post-installation performance data (for example, more complex projects with multiple ECMs).

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 more simple 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.
- Trending and data logging – set up BMS trending or install data logging equipment and analyse data, and/or review control logic; applied when ECM performance may vary depending on controls or 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 for all projects. This documentation should be continuously updated during the course of a project.

Quality Assurance Methods

- ❖ Review OPV plan (where required) to ensure that it describes the OPV activities, target energy budgets and key performance indicators associated with the project and the individual ECMs.
- ❖ Review OPV report, including results of any analysis and tests carried out, and the issues log, and ensure that appropriate actions are being taken to resolve issues or revise savings estimates.

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section 4.4 contains information regarding the operational performance verification general process.

7.2.2 Training (All Protocols)

Requirements

Training of the facility staff and building operators may be one of the most important factors in determining the operational performance and persistence of energy savings. Without proper understanding of the new 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 building operating staff should be involved with all 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.

A well-developed training plan should be created, supported by comprehensive and useful building documentation. As a best practice approach, and where appropriate, video recorded training sessions should also be provided. The training sessions should cover the changes arising from the energy efficiency project and the implemented ECMs. They should be developed/contributed to and performed by the consultants, vendors, and contractors.

The training associated with the OPV activities should 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 the 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 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 and building users with respect to the ECMs
- Energy performance targets
- Key performance indicators
- 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)
- Staff 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 warranty

Quality Assurance Methods

- Review training plan to ensure that key items listed above have been addressed.
- Interview building operators to ensure that training efforts met their needs, that they understand the ECMs installed and how to operate and diagnose their operation, and that roles and responsibilities and the associated response network are defined and understood.

Resources

EN 15331:2011 Criteria for design, management and control of maintenance services for buildings – describes the criteria and general methods that can be used in the planning, management and control of maintenance in buildings

ASHRAE Guideline 0-2005, The Commissioning Process - section 6.2.7 and Annex P describe requirements for training and identifies needs for the Training / Systems Manual.

7.2.3 Systems Manual (Large and Standard Tertiary / Apartment Blocks)

Requirements

In general, a Systems Manual contains information and documentation regarding building design and construction, commissioning, operational requirements, maintenance requirements and procedures, training, and testing. The document is intended to support building operations and maintenance, and to optimise the facility systems over their useful lives. Specifically, it includes technical instructions to ensure systems, plant 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.

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

- *Facility design and construction*: owner's project requirements (OPR) / current facility requirements (CFR); basis of design (BOD); and construction / project record documents
- *Facility, systems and assemblies information*: specifications; approved submittals; coordination drawings e.g. system schematics, circuit diagrams, plantroom drawings; assets register; manufacturer's operation and maintenance data; warranties; as well as contractor / supplier listing (including components lists and spare parts lists) and contact information
- *Facility operations*: operating plan; organisational structure, including roles and responsibilities; building and equipment operating schedules; set points and ranges; 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 facility 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.

Quality Assurance Methods

- ❖ Compare the contents of the Systems Manual to the content requirements described in *EN 13460:2009 Maintenance – Documents for maintenance.*
- ❖ Through interviews with operations and maintenance personnel, ensure that the Systems Manual has been developed so that it meets the needs of the facility staff responsible for the energy-efficient operation of the new systems and equipment.
- ❖ Ensure that the Systems Manual contains details regarding ongoing optimisation of the systems, and a clear process and responsibility matrix for addressing issues.

Resources

EN 13460:2009 Maintenance – Documents for maintenance - section 5 and Annex A, contain information about Systems Manuals and contents.

8.0 OPERATIONS, MAINTENANCE AND MONITORING

8.1 OVERVIEW

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, building re-tuning, or periodic inspections.

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

Element	Section	Protocol		
		Large Tertiary/ Apartment Block	Standard Tertiary/ Apartment Block	Targeted Tertiary/ Apartment Block
Operator's Manual	8.2.2	✓	✓	✓
Training on OM&M Procedures	8.2.3	✓	✓	✓
Operations, Maintenance and Monitoring Procedures (including Performance Indicators)	8.2.1	✓	✓	✓
Tenant Outreach	8.2.4	✓	✓	✓

8.2 PROTOCOL ELEMENTS

8.2.1 Operations, Maintenance & Monitoring Procedures (Large and Standard Tertiary / Apartment Blocks)

Requirements

Operations, Maintenance & Monitoring (OM&M) and building performance tracking is a process of continuous improvement, and involves tracking, analysing, diagnosing and resolving issues involving building HVAC, lighting or other energy-consuming systems. While the focus from an energy efficiency project perspective is on building system energy performance, it is important to consider and efficiently maintain the building occupants' needs, including comfortable temperatures and humidity levels, ventilation requirements, and lighting requirements.

Good OM&M processes involve a proactive strategy for achieving occupant comfort while optimising energy performance. A common problem that often arises in tertiary buildings is due to the fact that building operators first responsibility is to provide occupant comfort, essentially responding to and resolving "hot and cold" complaints. This directive is often counter-productive to a building's energy efficiency performance. Development of specific OM&M procedures can provide more clear direction to the facility's operations and maintenance staff, empowering them and providing specific methods for identifying, analysing, and resolving issues over time.

The overall OM&M process should involve the following key components:

1. *Data collection and performance tracking* - HVAC, lighting, and other energy-consuming equipment performance data is tracked along with energy consumption data. Various tools are available to support this process, and typically multiple tools are employed as part of the overall management strategy.
2. *Detection of performance issues* - use of automated tools to perform real-time analysis and identification of issues (fault detection and diagnostics), or the use of tools to present information in a way that facilitates identification of problems manually.
3. *Diagnosing issues and identifying solutions* - while automated tools can help facilitate issue diagnostics and the development of solutions, the skill, knowledge and training of building operators, supplemented by the assistance of service contractors or consultants, are critical components in diagnosing issues successfully and identifying appropriate solutions.
4. *Resolve issues and verify results* - issues should be resolved in a manner that addresses indoor conditions and occupant comfort, 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 and metrics (the performance indicators).

Identifying energy performance indicators will depend on the ECMs proposed, and the associated energy consumption characteristics, and the factors affecting this. They can be applied at an equipment, system or whole building level, and are usually directly measured (e.g. kWh), calculated using a ratio of measured values (e.g. efficiency), or a calculated or modelled relationship between energy consumption and relevant variables (e.g. linear regression modelling to determine kWh/degree day). A performance indicator for a lighting system could be energy consumption kWh/occupant-hour and peak power draw in kW.

Automated energy management systems (EMS) can be incorporated into the OM&M management regime, and provide a method for tracking, analysing, and assessing energy performance against savings projections and benchmarks. These tools can be used at the project development and implementation stages to support the Baselining and M&V activities.

Data collection systems are used to collect energy data and transmit this data to the EMS. This data is typically collected in intervals of between one minute and one hour, and can track either whole-building energy consumption, or the energy consumption of specific systems or end-uses. The EMS aggregates this data, identifies errors, analyses the data, and provides graphical representations of the data or reports used to assess the energy performance of the building in real time.

While EMS tools provide the ability to identify underperformance or problems, they cannot diagnose the cause of these problems. Trending and analysis through the use of the building management system (BMS), or the use of automated fault detection and diagnostic (FDD) tools, provide system tracking methods that can pinpoint problems with system operation and performance in real time.

Use of the BMS to track key performance metrics can present a cost-effective method for tracking and identifying building performance improvements. Trended metrics can be plotted and reviewed on a regular basis to identify abnormal changes in values that might indicate problems. Long term patterns, averages, and minimum or maximum values can also be used to identify issues and track energy efficiency and system performance. Performance metrics typically include zone temperatures, equipment efficiencies, system efficiencies, and ventilation rates.

While use of the BMS to track performance metrics provides a useful, manual method to track system performance, FDD tools provide functionality beyond these manual judgment methods. FDD tools utilise system-level performance data to automatically detect, and in some cases, quantify issues and report problems in real time.

FDD tools utilise existing BMS points, and in some cases additional dedicated sensors external to the BMS, and analyse the data using fault detection algorithms. These algorithms are typically proprietary, but some tools allow for customisation or programming of additional fault detection routines. FDD tools are typically installed by a third party, and their features, diagnostic levels and associated costs can vary significantly.

Retro-commissioning or recommissioning (RCx) can provide an additional or alternative method for providing OM&M on a periodic basis. RCx is a cost-effective means to improve the performance of existing buildings with the goals of reducing energy consumption and peak demand consumption, improving system performance, improving occupant comfort, and reducing maintenance issues and costs. RCx involves a review of the building's systems and their operation (a "building tune-up") that identifies problems due to system operation deficiencies or design flaws that occurred during the original construction. RCx also identifies problems that may have developed during the building's existence. Typical energy efficiency measures identified during the RCx process focus on improving control of existing equipment or correcting hardware and sensor malfunctions.

Quality Assurance Methods

- Ensure that the ongoing management regime selected is appropriate given the scope of the ECM project, complexity of systems, and the skill level of the facility staff. Review the plan for fault detection and remediation, and the content of periodic performance reports.
- Ensure that key performance indicators have been selected are SMART – i.e. specific, measurable, achievable, realistic and trackable - and will provide adequate representation of system operation and energy performance. If appropriate, review the monitoring points, interval and duration, and functionality of the automated tools used for issue detection and analysis.
- Ensure that the management regime and hierarchy are well defined, with clear roles and responsibilities, and plans of action for response and issue resolution. Review reporting processes, and ensure that accountability is factored into the management regime.

Resources

ISO 50001 Energy management systems – Requirements with guidance for use – sets out a management approach for organisations to improve energy performance, including energy efficiency, use and consumption, based on the Plan – Do – Check – Act continual improvement framework.

ISO 50006:2014 Energy Management Systems – Measuring Energy Performance Using Energy Baselines and Energy Performance Indicators methodology – section 4.3 and Annex C provide detailed guidance on identifying energy performance indicators, with examples.

Building Performance Tracking Handbook *(CCC)* - Outlines the steps needed to continually manage building performance, describes the complex array of building performance tracking tools available, and provides guidance on selecting the most appropriate tracking strategy.

O&M Best Practices Guide to Achieving Operational Efficiency (PNNL) - Guide with information regarding O&M management, technologies, energy efficiency, and cost-reduction strategies.

8.2.2 Operator's Manual (All Protocols)

Requirements

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 7.2.3 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; balance reports; equipment locations; control system logic; O&M instructions; training materials.

Quality Assurance Methods

- Review the Operator's Manual, or O&M sections of the Systems Manual, to ensure that it meets the needs of the facility staff responsible for the energy-efficient operation of the new systems and equipment.

8.2.3 Training on OM&M Procedures (All Protocols)

Requirements

The OM&M specific training practices described here should be combined with the training efforts and best practices described in Section 7.2.2.

Proper operation, maintenance practices, and monitoring are tasks critical to the ongoing energy-efficient performance of the building's systems. Overriding of system setpoints or 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. Training of the building 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, a well-developed training plan should be created specific to the OM&M tasks. The OM&M training sessions should be video recorded and supported by comprehensive and useful building documentation. The training should, at a minimum, cover the following OM&M components (under the Targeted protocols, some components may not be relevant, such as automated management, and therefore need not be provided):

- *Management structure* - Development and structure of the management, responsibility and reporting structure and its components, including operations, maintenance, engineering, training, and administration.
- *Performance metrics* - Development and analysis methods to evaluate maintenance, operational and energy performance of the building's systems. This should also include review of the M&V plan.
- *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 all of the following should be considered for inclusion in the O&M management structure, with associated training: vibration monitoring/analysis, lubricant and fuel analysis, wear particle analysis, bearing and temperature analysis, performance monitoring, ultrasonic noise detection, ultrasonic flow, infrared thermography, non-destructive testing (thickness), visual inspection, insulation resistance, motor current signature analysis, motor circuit analysis, polarization index, and electrical monitoring.

The OM&M activities will include a method to monitor and assess the ongoing performance of the installed ECMs. This may include ongoing commissioning, monitoring-based commissioning, performance-based monitoring (fault detection and diagnostics), periodic recommissioning, building re-tuning, or periodic inspections. As part of the training curriculum, the building operators must be trained on how to utilise and interpret systems in place to monitor the ECMs and associated building systems, and how to respond to issues identified as a part of this process. The building 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 building operators on the proper operation and maintenance of building systems. Facility staff should be encouraged to pursue and obtain relevant education and certifications, which will enhance their ability to provide comfortable, energy efficient and environmentally friendly workplaces.

Quality Assurance Methods

- Review training plan to ensure that key items previously described in this section and section 7.2.2 have been addressed.
- Interview building operators to ensure that training efforts met their needs, that they understand the ECMs installed and how to operate, maintain and monitor their operation, and that roles and responsibilities and the associated response network are defined and understood.

Resources

EN 15331:2011 Criteria for design, management and control of maintenance services for buildings – describes the criteria and general methods that can be used in the planning, management and control of maintenance in buildings.

8.2.4 Tenant Outreach (Targeted Tertiary / Apartment Blocks)

Requirements

Tenant behaviour can be critical to the success of the ECM project. Ensuring tenants understand the impact of their behaviour on building energy consumption and, particularly, the new ECMs is integral to this. Energy awareness may take the form of poster campaigns, flyer distribution, or training sessions for building occupants. Consideration should also be given to involving tenants in design of the ECMs, if this is deemed appropriate.

Quality Assurance Methods

- Ensure tenants have been notified of improvements made in the building, and any appropriate behaviour modifications have been communicated to them.

9.0 MEASUREMENT AND VERIFICATION

9.1 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 ICP protocols support 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.

Currently, ICP does not allow the use of an IPMVP Option D, *Calibrated Simulation* approach for M&V. Instead, it requires the use of IPMVP Option C to be combined with calibrated simulation as the calculation method for Large projects, rather than by measuring energy use at the utility meter level alone. Option D is primarily intended for new construction projects, in which there is no baseline data available, whilst the ICP is designed to address the retrofit of existing buildings that have utility data which can be used to develop a baseline.

For most M&V efforts, non-routine adjustments need to be made to the baseline to reflect unanticipated changes in the building's energy use after the retrofits have been completed, such as increased occupancy, new internal loads, added floor area, etc. These items affect heating and cooling loads, and other building energy uses, and 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 in an Option C approach.

Calculation of the effects of these adjustments on the building's energy use can be challenging, especially adjustments that affect the loads in the building, and have potentially complex interactive effects with the building's HVAC systems. The calibrated energy model can subsequently be used to estimate these effects on energy use, in a more comprehensive and accurate manner than spreadsheet calculations or other methods.

Table 1 Overview of M&V Options[1]

IPMVP Option	How Savings Are Calculated	Typical Applications
A. Retrofit Isolation: Key Parameter Measurement Savings are determined by field measurement of the key performance parameter(s) which define the energy use of the ECM's affected system(s) and/or the success of the project. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameter, and the length of the reporting period. Parameters not selected for field measurement are estimated. Estimates can based on historical data, manufacturer's specifications, or engineering judgment. Documentation of the source or justification of the estimated parameter is required. The plausible savings error arising from estimation rather than measurement is evaluated.	Engineering calculation of baseline and reporting-period energy from: - short-term or continuous measurements of key operating parameter(s); and - estimated values. Routine and non-routine adjustments as required.	A lighting retrofit where power draw is the key performance parameter that is measured periodically. Estimate operating hours of the lights based on facility schedules and occupant behaviour.

[1] Courtesy of *IPMVP, Volume I* (2012)

IPMVP Option	How Savings Are Calculated	Typical Applications
B. Retrofit Isolation: All Parameter Measurement Savings are determined by field measurement of the energy consumption of the ECM-affected system. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the savings and the length of the reporting period.	Short-term or continuous measurements of baseline and reporting-period energy, and/or engineering computations using measurements of proxies of energy consumption. Routine and non-routine adjustments as required.	Application of a variable speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to track variations in power consumption.
C. Whole Facility Savings are determined by measuring energy consumption at the whole facility or sub-facility level. Continuous measurements of the entire facility's energy consumption are taken throughout the reporting period.	Analysis of whole facility baseline and reporting-period (utility) meter data. Routine adjustments as required, using techniques such as simple comparison or regression analysis. Non-routine adjustments as required.	Multifaceted energy management programme affecting many systems in a facility. Measure energy consumption with the gas and electric utility meters for a twelve month baseline period and throughout the reporting period.

In general, the QA process involves review of the M&V Plan, 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 and baseline adjustments will also be necessary throughout the duration of the performance period.

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

Element	Section	Protocol		
		Large Tertiary/ Apartment Block	Standard Tertiary/ Apartment Block	Targeted Tertiary/ Apartment Block
M&V Plan and Implementation	9.2.1	✓	✓	✓
Energy Data	9.2.2	✓	✓	✓
Regression-Based Model: IPMVP Option C	9.2.3	✓	May be optionally applied	
Estimated Parameters: IPMVP Option A	9.2.4		✓	✓
Revised Calculations: IPMVP Options A and B	9.2.5		✓	✓

9.2 PROTOCOL ELEMENTS

9.2.1 M&V PLAN AND IMPLEMENTATION (ALL PROTOCOLS)

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 in Sections 4 and 5 of 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 weather data (not averaged weather data) 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 Chapter 5 of the IPMVP, Volume I (2012)). 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 7 of this specification. The fourth step involves data collection, which must be performed both before and after the planned retrofit, details of which are covered in the following subsection (9.2.2).

The fifth step involves determination of verified energy savings. Savings may be determined for the entire facility (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 building. The measurement periods should adhere to the guidance set out in IPMVP Volume I (2012) section 4.5.2, and must include at a minimum a representative 12 month period for both pre- and post-retrofit utility data.

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 (most commonly weather) 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 facility size, operation of installed equipment, conditioning of previously unconditioned spaces, number of occupants, 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 building owner and facility personnel, 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 (refer to sections 4.2.7 and 6.2.5). 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.

Quality Assurance Methods

- Review of the M&V Plan for adherence to the IPMVP.
- Ensure that operational performance verification (as described in Section 7) was performed and documented.
- Baseline development review, according to the QA methods described in Section 4.2.1.
- Ensure that appropriate measurement boundaries are defined, and that appropriate interactive effects are being considered and/or quantified.
- Ensure that appropriate measurement periods that will reflect equipment operation through its full operating cycle have been selected (for both the baseline and reporting periods). The baseline period should coincide with the period immediately before commitment to undertake the retrofit.
- Ensure that all appropriate adjustments were considered affecting energy performance of the building or measures, and review proper application of adjustments (routine and non-routine) to ensure they have been conservatively applied.

Resources

International Performance Measurement and Verification Protocols *(EVO)* - Volume I defines basic terminology used in the M&V field. It defines general procedures to achieve reliable and cost-effective determination of savings. Verification of actual savings is performed relative to an M&V Plan for each project. Volume III provides guidance on application and specific M&V issues.

ISO 50015 Energy management systems – Measurement and verification of energy performance of organisations – General principles and guidance – provides an overview of the general principles and guidelines for the process of M&V of energy performance of an organisation or its components.

9.2.2 Energy Data (All Protocols)

Requirements

Data collection can be performed through the use of metering equipment, remote data logging equipment, trending through the BMS, or other methods. It is important to ensure that all equipment used for data collection is calibrated, and that the calibration is documented. Sensor placement should also be considered carefully for measurements such as temperature or airflow.

Issues such as reducing computer processing speeds, consuming excess communication bandwidth, storage limitations, or security and access issues should be considered and resolved before any data collection plan is implemented.

Data collection requirements and methods will vary, and there will almost always be issues arising from erroneous or missing data. Methods and procedures for dealing with such issues, as well as their potential effect on accuracy and uncertainty, should be detailed before the data collection process.

Erroneous or missing data can be managed through interpolation of the data, changing the baseline or reporting periods, omission, adjustment through recalibration, or adjustment to a nominal value. The allowable or applied methods for error remediation should be well documented as part of the M&V plan. This should also establish a maximum acceptable rate of data loss, as part of the overall acceptable level of accuracy, and how it will be measured.

Tools are available that can be used to automatically manage data errors, as well as to perform interpolation or time and interval correction.

Quality Assurance Methods

- ❖ Review of monitoring equipment (calibration, proper installation) and collected data.
- ❖ Ensure that erroneous or missing data have been identified and managed through interpolation, changing the baseline or reporting periods, omission, adjustment through recalibration, or adjustment to a nominal value, and that the method for management has been documented.

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section 10.2 contains information regarding sensors, calibration techniques, lab standards for measurements, and test methods.

ISO 50015 Energy management systems – Measurement and verification of energy performance of organisations – General principles and guidance – section 5.9 describes data collection and associated considerations. Section 7 provides an overview of assessing uncertainty in M&V results, with examples of measurement uncertainty given in Annex B.

Measurement and Verification Operational Guides *(Nexant)* - A collection of M&V operational guides to translate M&V theory into successful M&V projects. Materials include guides for practitioners new to the M&V process as well as experienced practitioners, application-specific guidebooks, and project planning templates.

9.2.3 Regression-Based Model: IPMVP Option C (Large and Standard Tertiary / Apartment Blocks)

Requirements

IPMVP Option C will always be required under the Large protocols. Under the Standard protocols, IPMVP Option A or B will usually be most appropriate, but in some cases, Option C may be considered more 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 site energy consumption, including electricity and on-site fuel or district energy) to independent variables known to significantly impact the building's energy consumption. Independent variables typically include weather (heating and cooling degree days) and may include other variables such as operating hours, occupancy or vacancy rates, and number of occupants.

Regression is described in more detail in section 4.2.1.

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 building's energy consumption as a function of the independent variable(s) that vary monthly.

More complex regression techniques may also be employed. The IPMVP provides descriptions of various techniques that may be employed to develop these regression-based energy models, including an overview of non-linear regression techniques. General guidance regarding choosing an appropriate model can also be found in Section 4.2.2 of the FEMP M&V Guidelines.

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.

Quality Assurance Methods

- Inspect the energy consumption equation (model) to ensure that the appropriate independent variable(s) that affect energy consumption have been considered and incorporated into the equation, and that the independent variable(s) selected are truly independent.
- Ensure that statistical results meet appropriate standards. Suggested standards include:
  - Coefficient of determination (R squared) > 0.75 [lower R squared values may indicate independent variables missing, or the need for more data]
  - Coefficient of variation of root mean square error CV(RSME) < 15% [indicates overall uncertainty in the model]
  - Mean bias error (MBE) +/- 7% [indicates whether model over or under predicts values]
  - t-statistic (t-stat) > 2.0 [value greater than 2.0 indicates that independent variables are significant]

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section B-2 provides detailed guidance on regression modelling, including evaluation of regression models (R^2 and CV[RMSE]), and section B-6 provides evaluation of an example regression model.

ISO 50006:2014 Energy Management Systems – Measuring Energy Performance Using Energy Baselines and Energy Performance Indicators methodology *(Annex D)* - provides an overview of normalisation and regression modelling.

EN 16212:2012 Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods (section 5.2.3.1) – provides guidance on carrying out normalisation of climate dependent energy consumption.

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section B-2 describes regression modelling, and section B-6 provides evaluation of an example regression model.

Federal Energy Management Program M&V Guidelines *(Nexant)* - Guidelines and methods for measuring and verifying energy, water, and cost savings associated with US federal energy savings performance contracts.

9.2.4 Estimated Parameters: IPMVP Option A (Standard and Targeted Tertiary / Apartment Blocks)

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 end-use capacity, demand, power, or operational factors such as lighting operational hours or pumping power 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.

As described in section 9.2.1, the amount that the key parameter is expected to vary will determine the frequency of measurement - i.e. continuously or periodically.

Resources

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - section 4.7 sets out the considerations to be taken into account when determining the measurement boundary and frequency of measurement.

Quality Assurance Methods

- Ensure that Option A is appropriate for the measures it is being applied to (simpler measures, or measures with parameters that are fairly constant or consistent).
- Ensure that estimated parameters do not include variables that are typically not consistent.
- Check source and reasonableness of estimated (estimated) parameters.

9.2.5 Revised Calculations: IPMVP Options A and B (Standard and Targeted Tertiary / Apartment Blocks)

Requirements

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, BMS screenshots, or other resources used to inform the verified savings calculations.

Quality Assurance Methods

- Review of the calculations performed to quantify verified savings.
- Check all revised assumptions, to ensure that they reflect observations and data analysis conclusions, and that they have been well documented.

10.0 OTHER PROJECT DEVELOPMENT TOPICS

10.1 THIRD-PARTY INVOLVEMENT

Energy efficiency projects can be inherently complex, with numerous components and activities that need to be developed and performed including baselining, savings calculation estimates, operational performance verification, and M&V, among others. A well-developed project needs to ensure that each component is developed by experienced professionals using well-established tools and practices.

Selecting an experienced, reputable energy efficiency project development team is critically important to the success of any project. Of equal importance is the involvement of an owner's representative, in the form of a third party, to provide oversight to the development of the project, and to help ensure that the owner's best interests are being represented.

Provision of third party OPV and M&V services

Operational performance verification and M&V services provide the opportunity to stabilise and enhance an energy efficiency project, as well as the opportunity for unbiased and specialised evaluation of system and energy performance by third-party providers or reviewers. The benefits of operational performance verification and M&V services, and the specialised skills and unbiased approach afforded through the use of third-party providers, can help ensure performance and financial stability of a project over time.

Performance of operational performance verification and M&V tasks in house has many advantages, including the project team's familiarity with the building and ECMs. However, conflicts of interest may arise during both of these activities, since the project development team may have a financial or reputational stake in the project's success. For these reasons, although this is not an ICP requirement, it is recommended that a third-party consultant, hired directly by the building owner or investor, be engaged to either perform these two project tasks, or provide oversight to these tasks. This would include review of the operational performance verification plan and M&V plan, as well as review of all activities, calculations, and results developed as part of these processes.

Third party Quality Assurance Provider

Engagement of a third party Quality Assurance Provider is required in order to obtain IREE certification. It is important that in all cases the QA Provider is hired at the very beginning of the process. This will allow them to ensure the appropriate protocol has been selected, and to review documentation in parallel with the project development process. Their input at these early stages can help avoid issues that may not otherwise become evident until late in the project, when addressing them may be difficult or impossible.

10.2 UNCERTAINTY AND RISK

Requirements

The estimated energy cost savings and implementation costs associated with the ECMs and package of measures are critical values for investors considering EE projects. Unfortunately, savings estimates and implementation costs are typically calculated as a single number and do not indicate a probable range or an estimated uncertainty. Failure to provide information about uncertainty leaves the financial analyst with no means to price the appropriate rate of return. This causes the financial analyst to increase the required rate of return or to de-rate the savings before applying the financial model. This practice undermines the viability of energy projects (Mills et al. 2003).

Uncertainty can occur from a variety of sources, including:

- Instrumentation equipment errors
- Modelling errors
- Statistical sampling
- Interactive effects
- Inaccuracy of assumptions (estimations)

Each of these sources of error can be minimised by using more sophisticated analysis methods, measurement equipment, sample sizes, and accurate assumptions. However, it must also be recognised that more certain savings estimates can come at an increased cost, with diminishing returns.

For most uncertainty analysis methods, the inputs (assumptions) need to be specified as ranges, and their distribution type specified (such as normal, lognormal, uniform, log-uniform, etc.). A statistical sampling method is then applied to develop sets of parameter values for the assumptions, representative of all possible combinations. The calculations are then performed with these sample sets, and a probability distribution function can be developed and reported, indicating the uncertainty.

Specification of the accuracy of an estimate requires both the definition of the absolute or relative bounds, but also the level of confidence that the actual values fall within these defined bounds. In general, a 90/10 standard is typically accepted for energy efficiency projects, meaning that the level of accuracy reflects a 10% relative precision at a 90% confidence level.

For projects utilising spreadsheet calculation methods, automated calculation tools can be employed, such as the Monte Carlo simulation method or the Latin Hypercube sampling method, or a combination of the two. During a Monte Carlo simulation, values are sampled at random from the input probability distributions. Each set of samples is called an iteration, and the resulting outcome from that sample is recorded. Monte Carlo simulation does this hundreds or thousands of times, and results in a probability distribution of possible outcomes. Various applications are commercially available that can be applied as an add-in to Excel, and used to automate this Monte Carlo simulation approach.

In contrast, the Latin Hypercube sampling method stratifies the input probability distributions. Variables are sampled using an even sampling method, and then randomly combined sets of these variables are used for one calculation of the target function. To perform the stratified sampling, the cumulative probability (100%) is divided into segments, one for each iteration. A probability is randomly picked within each segment using a uniform distribution, and then mapped to the correct representative value in the variable's actual distribution. Once each variable has been sampled using this method, a random grouping of variables is selected for each calculation. Independent uniform selection is performed on each of the variable's generated values, and each value must only be used once. Latin hypercube sampling is capable of reducing the number of runs necessary to stabilise a Monte Carlo simulation.

For projects utilising an energy model, a similar approach can be applied. Values are sampled from the developed input probability distributions (using Latin Hypercube and Monte Carlo sampling techniques), and then multiple iterations of the energy model are performed. While automated or standardised approaches to this uncertainty analysis have yet to penetrate the energy-modelling field, work is currently underway to develop options for completing uncertainty analysis. In particular, the next release of OpenStudio, a US-developed open-source application suite and software development kit which supports whole-building modelling using EnergyPlus and daylight analysis using Radiance, will feature uncertainty analysis tools and methods. OpenStudio will specifically draw from the DAKOTA project, an engineering optimization and uncertainty analysis modelling library developed by Sandia National Laboratories in the USA. This functionality will allow the assessment of sensitivity of the output to the input parameters, those parameters that contribute the most variance, and how they interact with each other.

While it is important to a financial investor to understand the uncertainty involved in an EE project, in many cases resources and time may not be available to fully quantify the uncertainty associated with a proposed project. A cost-effective alternative to quantifying uncertainty is to reduce risk. This is accomplished by:

- Reducing the number of assumptions used in the savings calculation and cost estimation efforts.
- Utilising conservative assumptions when these inputs are necessary.
- Reducing random errors by increasing sample sizes, using more efficient sample design, or applying sophisticated measurement techniques.
- Applying best practices to all components of project development.
- Properly applying design, delivery, and operational processes.
- Training facility staff adequately.
- Performing operational performance verification.
- Providing systems and methods to monitor and track performance on an ongoing basis, and providing an adequate managerial and recognition / response plan.
- Performing a comprehensive quality assurance process on all components of the project development, avoiding bias at all costs.

Recognising that quantifying uncertainty is not always possible, reducing risk provides a cost-effective means for providing increased investor confidence. For this reason, it is recommended that these risk reduction activities be performed for every project.

Resources

ASHRAE Guideline 14-2002 - Technical document focused on calculating energy and demand savings using measurements and measurement uncertainty analysis. Annex B of the Guideline details the determination of savings uncertainty for energy efficiency projects.

Federal Energy Management Program M&V Guidelines *(Nexant)* - Table 3-1 contains an Energy Savings Performance Contract Risk, Responsibility, and Performance Matrix in the US

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - Appendix B contains methods for quantifying and evaluating uncertainty, as well as methods for reducing uncertainty. Appendix C provides references for applying standard-error-analysis methods for typical savings calculations.

11.0 DOCUMENTATION PACKAGE

This section presents a list of the documentation required of an ICP compliant project. The documents should be stored in a central project repository, with an easy to follow structure. Folder names and / or project documents should be labelled, clearly describing what information they contain or what portion of the project they pertain to. Accessibility and levels of security should be considered, so that each member of the team, the stakeholders, the QA provider(s), and others involved with the project have access to the information they need.

Project development templates are available on the ICP Europe website which will facilitate the efficient creation of key components required as part of the documentation package. The templates include:

- **Operation Performance Verification template** – this provides a framework and outline of the specific language for creating a project specific commissioning plan. The OPV plan can be used directly to describe the commissioning process to support projects that use either in-house or third-party commissioning providers. Some sections will require the user to customise the language to fit owner requirements or project specific requirements.
- **Operations, Maintenance and Monitoring Plan template** - this provides a framework and outline for creating a project specific OM&M plan. The OM&M plan can be used directly to describe the OM&M process. Some sections will require the user to customise the language to fit owner requirements or project specific requirements. The plan can be used as a stand-alone document, or included as an appendix to the commissioning (OPV) plan.
- **M&V Plan: Option C template** - Measurement and Verification, IPMVP Option C (Whole Facility). This M&V plan template provides a framework and outline for creating a project-specific M&V plan adherent to the IPMVP Option C, Whole Facility approach. The M&V plan can be used directly to describe the M&V process. Various sections will require the user to customise the language to fit project-specific details.

Key:
LT = Large Tertiary
ST - Standard Tertiary
TT = Targeted Tertiary
LAB = Large Apartment Blocks
SAB = Standard Apartment Blocks
TAB - Targeted Apartment Blocks

Table 2 Documentation Package

Protocol Section	ICP Section	Protocol	Documentation Required	Comments
2	Baselining	All (TT and TAB where relevant to the baseline)	Weather data	Can be the actual weather file or data, or a reference to the source of the data used (e.g. weather station)
2	Baselining	All (TT and TAB where relevant to the baseline)	Baseline utility data	Raw utility data
2	Baselining	All	Description of baseline period	Minimum 12 months period; include start/end dates
2	Baselining	All	Utility rate structures	
2	Baselining	All (TT and TAB where relevant to the baseline)	Energy end-use consumption	Estimates or metered data
2	Baselining	All	Building asset / operational / performance data	Building drawings, equipment inventories, system and material specifications, field survey results and/or CAD take-offs, observations, short-term monitored data, spot measurements, and functional performance test results as appropriate
2	Baselining	TT,TAB	Assessment of interactive effects	
2	Baselining-optional	All	Interval meter data	
2	Baselining-optional	All	Sub-metering data	
2	Baselining-optional	All	On-site weather data	
2	Baselining-optional	All	Calibration certificates	For meters
2	Baselining-optional	All	Owner's rental information	
Protocol Section	**ICP Section**	**Protocol**	**Documentation Required**	**Comments**
3	Baselining-Demand	All (TT and TAB where relevant to the baseline)	Copies of utility bills	At least one for electricity and each fuel
3	Baselining-Demand	All (TT and TAB where relevant	Monthly consumption load profiles	

		to the baseline)		
3	Baselining-Demand	All (TT and TAB where relevant to the baseline)	Monthly peak demand	
3	Baselining-Demand	All (TT and TAB where relevant to the baseline)	Interval meter data	
4	Savings Calculations	LT,LAB	Modeller qualifications	
4	Savings Calculations	ST,TT,SAB,TAB	Savings calculator qualifications	
4	Savings Calculations	LT,LAB	Model calibration	Demonstrate that the calibration criteria are met
4	Savings Calculations	LT, LAB	Model input files	Including information about modelling software used and version number
4	Savings Calculations	All	Descriptions of ECMs	Including information about any interactive effects
4	Savings Calculations	ST,TT,SAB,TAB	Calculations	Workbooks, spreadsheets and other calculation tools
4	Savings Calculations	All (TT and TAB where relevant to the ECMs)	Weather file	Used for simulation or savings calculations
4	Savings Calculations	All	Calculation results	
4	Savings Calculations	All	Cost estimate details	For each ECM
4	Savings Calculations	All	Bids by trade	If applicable
4	Savings Calculations	All	Quality control statement	Review of model / calculation results against data from comparable projects
Protocol Section	**ICP Section**	**Protocol**	**Documentation Required**	**Comments**
5	Design, Const & Verification	All	OPV authority qualifications	
5	Design, Const & Verification	LT,ST,LAB,SAB	OPV Plan	
5	Design, Const & Verification	All	OPV statement of project conformity	Project conforms with audit intent and scope

5	Design, Const & Verification	All	OPV report	
5	Design, Const & Verification	All	Training materials	And record of training
5	Design, Const & Verification	LT,ST,LAB,SAB	System manual(s)	For all new and modified systems and equipment
6	OM&M	LT,LAB,ST,SAB	Points list/trending plan	Key variables trended in BMS
6	OM&M	LT,LAB,ST,SAB	Plan for fault detection and remediation	
6	OM&M	All	Operator's Manual and Organisational chart	Persons involved with OM&M, and responsibilities for monitoring and response
6	OM&M	All	Maintenance plans / service response logs	Including warranties for new equipment
6	OM&M	All	Training curriculum	

Protocol Section	ICP Section	Protocol	Documentation Required	Comments
7	M&V	All	M&V Plan	
7	M&V	All	Routine adjustments	
7	M&V	All	Non-routine adjustments	
7	M&V	LT,LAB	Reporting-period utility data	Used in the Option C analysis
7	M&V	LT,LAB	Reporting-period independent variable data	Used in the Option C analysis
7	M&V	LT,LAB	Reporting-period dependent variable data	Used in the Option C analysis
7	M&V	LT,LAB	Regression-based energy model	Used in the Option C analysis
7	M&V	ST,TT,SAB,TAB	Data collected	Used in the Options A/B analysis
7	M&V	ST,TT,SAB,TAB	Verified savings calculations	Used in the Options A/B analysis, including assumptions

12.0 GLOSSARY

Building simulation model – computer-based modelling used to assess the energy performance of a building dynamically i.e. over the course of a whole year.

Energy audit - systematic inspection, survey and analysis of a building or system's energy uses and consumption in order to identify, quantify and report on the potential for energy efficiency improvements. The energy audit process typically consists of the following stages: data/information collection, site visit, data analysis, and reporting.

Energy conservation measure (ECM) – measure implemented in order to reduce energy consumption. This can include energy efficiency measures, such as variable speed drives and lighting controls, and also low and zero carbon measures, such as Combined Heat and Power, and solar photovoltaic panels.

Energy end-use – energy consumed by system or equipment, classified according to type of load e.g. internal lighting, cooling, process, pumps.

Energy sources – a type of energy or fuel consumed in a building. This should include: total electricity purchased; purchased or delivered steam, hot water, or chilled water; natural gas; fuel oil; coal; propane; biomass; any other resources consumed as fuel and any electricity generated on site from alternative energy systems; and any renewable energy generated and used on site.

Energy consumption baseline – energy consumption over a specified period providing a basis for comparison of energy performance, before and after implementation of ECMs. The baseline is usually normalised against variables affecting energy consumption.

Green leasing – a standard lease which includes additional specific obligations and targets to ensure the building is operated sustainably and efficiently.

International Performance Measurement and Verification Protocol (IPMVP) - standardised approach to energy efficiency M&V, developed by Efficiency Valuation Organization.

Measurement and verification – process used to quantify the actual savings achieved, following the implementation of ECMs, and to determine whether they meet the predicted savings targets.

Non-routine adjustments – adjustments made to the baseline to account for unexpected changes in energy consumption not due to installed ECMs, such as changes in occupancy, type of space use, equipment, operating hours, service levels, and utility rates.

Operators manual – document targeted at operations and maintenance personnel, and containing all the information required for the correct use and operation of ECMs or systems, such as as-built drawings, equipment location and training materials. In many cases, this is a section within the Systems Manual.

Operational performance verification – process used to ensure that the implemented ECMs have been implemented properly and will have the ability to achieve the predicted energy savings during the M&V phase.

Project Development Specification - document which compiles all relevant and supporting information and best-practices for system application

Routine adjustments – adjustments made to the baseline to account for expected changes in energy consumption, typically include those for weather.

Submittals – these are submissions from contractors for approval (e.g. drawings or equipment details).

Systems manual - document describing the modified systems and equipment, intended to support building operations and maintenance, and to optimize the facility systems over their useful lives. It contains information and documentation regarding building design and construction, commissioning, operational requirements, maintenance requirements and procedures, training, and testing.

Tertiary building – ICP Europe defines tertiary buildings as offices, educational buildings, hospitals, hotels, restaurants, sports facilities, wholesale and retail trade services buildings and institutional buildings.

13.0 COMPREHENSIVE LIST OF RESOURCES

ASHRAE Guideline 0-2005, The Commissioning Process

ASHRAE Guideline 14-2002 - Technical document focused on calculating energy and demand savings using measurements and measurement uncertainty analysis, applicable to Option B approaches.

ASHRAE Hourly Simulation Checklist - Checklist useful for verifying that all appropriate energy-modelling inputs have been satisfied.

Building Life Cycle Costs (NIST) - Programme to provide computational support for the analysis of capital investments in buildings.

Building Performance Tracking Handbook (CCC) - Outlines the steps needed to continually manage building performance, describes the complex array of building performance tracking tools available, and provides guidance on selecting the most appropriate tracking strategy.

Degree Days.net (BizEE) - Degree day data resource aimed at energy efficiency professionals.

Energy Charting and Metrics Tool (PNNL/DOE) - ECAM+ is an add-on for Microsoft Excel® which facilitates analysis of data from the building (energy and other data). Key features of ECAM+ include: creation of charts to help re-tuning, creation of schedules and day-type information to time series data; filtering data from months, years, days, day-type, day of week, day of month, occupancy, temperature binned weather data, pre/post comparisons after retrofits or retro-commissioning; normalizing data and creating metrics based on consumption or equipment; creation of various load profiles or scatter charts for data selected by the user; new additions to the PNNL re-tuning charts; and new M&V for meter data.

Federal Energy Management Program M&V Guidelines (Nexant) - Guidelines and methods for measuring and verifying energy, water, and cost savings associated with federal energy savings performance contracts in the US.

International Energy Efficiency Financing Protocol, 2009 (EVO) - The global “blueprint” for educating and training on the special intricacies, benefits and risks associated with financing EE projects. Intended to serve as a growing set of best practices, resource materials, case studies, standardised tools and guidelines to support economic and financial evaluation of EE projects.

International Performance Measurement and Verification Protocols (EVO), Volume I, 2012 - defines basic terminology used in the M&V field. It defines general procedures to achieve reliable and cost-effective determination of savings. Verification of actual savings is performed relative to an M&V Plan for each project. Volume III provides guidance on application and specific M&V issues.

Measurement and Verification Operational Guides (Nexant) - A collection of M&V operational guides to translate M&V theory into successful M&V projects. Materials include guides for practitioners new to the M&V process as well as experienced practitioners, application-specific guidebooks, and project planning templates.

O&M Best Practices Guide to Achieving Operational Efficiency (PNNL) - Guide with information regarding O&M management, technologies, energy efficiency, and cost-reduction strategies.

RETScreen Financial Analysis Workbook - Workbook used to analyse financial performance and viability of an EE project.

Uniform Methods Project (National Renewable Energy Laboratory) – US resource which provides detailed guidelines for calculation methods and best practices.

US Department of Energy (DOE) Federal Energy Management Program (FEMP) - Calculators and tools that can be used or referred to as models for calculation methods.

Verification by Equipment or End-Use Metering Protocol (BPA) - Presents methods for isolating equipment or end-uses, and monitoring / metering methods and M&V practices specific to retrofit isolation. Intended for measures that change load or operating hours, or both.