INVESTOR CONFIDENCE PROJECT

PROJECT DEVELOPMENT SPECIFICATION

Version 1.0 – October 2014

EDF ENVIRONMENTAL DEFENSE FUND™
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1.0 INVESTOR CONFIDENCE PROJECT

The Investor Confidence Project (ICP) provides a framework for energy efficiency project development, which standardizes 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 Energy Performance Protocols and credentialing 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.

1.1 ENERGY EFFICIENCY PERFORMANCE – PROJECT DEVELOPMENT SPECIFICATION

This ICP Project Development (PD) Specification 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 Energy Performance 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 Project Development Specification verification process can be applied either through a central authority such as a public program, 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 Project Development Specification are elligible to be credentialed as an ICP Investor Ready Energy Efficiency (IREE) project, which assures investors that a project conforms to ICP Energy Performance Protocols, has standard documentation, and has been verified by a credentialed 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 QM 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. ICP invites 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.

1.2 USING THIS SPECIFICATION

This Project Development Specification is intended to support the elements, procedures and documentation requirements presented in the ICP Energy Performance Protocols. This document's structure mirrors the protocols and utilizes 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 programs, 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 mount when potentially 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 that is willing to engage and adhere to the ICP protocols. Furthermore, in order to protect their own best interests it is highly recommended that project investors hire an independent consultant (or consultants) to provide overview and quality management services, as described in this specification.

The Credentialed Project Development team is responsible for developing a project based on sound engineering principles and best practices as outlined in this document, utilizing industry standard approaches for the development of each component of the project. This PD Specification describes the general best practices and the resources that each team member should utilize in order to adhere to these industry standards and protocols.

The Credentialed Quality Assurance Provider is required to be third party to the transaction, and is responsible for reviewing the outlined components and project documentation to ensure they meet the specifications laid out in this PD Specification. 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 best practices for each section of this Specification, and utilize the QA tasks listed to help guide the process of evaluating and ultimately signing off on project compliance with Energy Performance 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 end-use energy 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 activities that should be performed by the third-party QA provider, and the periods within a project's development that these tasks should be performed..

QUALITY MANAGEMENT TASKS	Develop Baseline	Audit / ECM List	Savings Calculations / Investment Package	Design, Construction & Verification	Operations, Maintenance & Monitoring	Measurement & Verification (Post-Implementation)
	Collect utility data	Collect building asset / performance data	Develop / calibrate energy model	Develop OPV plan	Develop OM&M procedures	Option A/B: Collect post-energy / performance data
	Develop end-use energy usage	Collect weather / occupancy 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
PROJECT TASKS	Load shape development		Develop / inform investment criteria	Perform building operators training	Perform building operators training	Option C: Post-utility data
	Develop energy use 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
				Option A/B: Collect pre-energy / performance data (before construction)		All Options: M&V report
	Review data, energy use equation and baseline model	Review asset / performance data	Review energy model / check calibration	Review OPV plan	Review OM&M procedures	Review data and analysis
	Review end-use energy usage	Review ECM descriptions	Review savings calculations	Review M&V plan	Review FDD, RCx plan, or other monitoring method	Option C: Review regression based model
QA TASKS	Review utility rates		Review costs / constructability	Review systems manual	Review operator's manual	Option A/B: Review verified savings calculations
	Review load shapes		Review ECM bundles / investment package	Review training (interview building operators)	Review training (interview building operators)	Review adjustments and proper application
				Option A/B: Ensure pre-energy / performance data collected		

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
ASTM	American Society of Testing and Materials
BAS	Building automation system
BEDES	Building Energy Data Exchange Specification
BEM	Building energy modeling
BEMP	Building energy-modeling professional
BEPA	Building Energy Performance Assessment
BESA	Building energy simulation analyst
BMS	Building management system
BOC	Building Operator's Certification
BOD	Basis of design
BPA	Bonneville Power Administration
BPI	Building Performance Institute
Btu	British thermal unit
CAD	Computer aided drafting
CBECS	US EIA's Commercial Building Energy Consumption Survey
CDD	Cooling degree days
CEM	Certified Energy Manager
CEUS	California Commercial End Use Survey
cfm	Cubic feet per minute
CFR	Current facility requirements
CMVP	Certified Measurement and Verification Professional
COMNET	Commercial Energy Services Network
CV	Curriculum vitae
CV[RMSE]	Coefficient of variation [root mean square error]
CWEC	California weather for energy calculations
DDC	Direct digital control
DOE	Department of Energy
ECM	Energy conservation measure
EE	Energy efficiency
EEPF	Energy Efficiency Project Framework
EIA	Energy Information Administration
EIS	Energy information system
EMCS	Energy management control system

EMIS	Energy management and information systems
EMS	Energy management system
EPP	Energy Performance Protocols
ESCo	Energy service company
ESPC	Energy savings performance contract
EUI	Energy utilization index
EVO	Efficiency Valuation Organization
FDD	Fault detection and diagnostics
FEMP	Federal Energy Management Program
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
MF	Multifamily
MMBtu	Million British thermal units
NIST	National Institute of Standards and Technology
NMBE	Normalized 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
QA	Quality assurance
QM	Quality management
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 standardized approach to the development of Large, Standard and Targeted energy efficiency projects in commercial and multifamily building types. 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 utilized in the project's development, and the project's overall scale.

The **Large Commercial**/**Multifamily** protocols are intended for:

- Large Buildings - where the cost of improvements and size of savings justifies greater investment energy development analysis. Typically project costs exceed over $1 million;
- Whole-Building Retrofits - projects that typically involve multiple measures with interactive effects;
- High-Performing Projects - projects where the projected energy savings typically cover the project investment cost;
- Calculation Methods - projects that plan to use an energy model to estimate energy savings; and
- Measurement and Verification - projects that will apply an Option C, *Whole Facility* approach.

The **Standard Commercial**/**Multifamily** protocols are intended for:

- Standard Projects - multiple measure projects costing typically under $1 million where engineering requirements must be scaled to fit performance risk;
- High-Performing Projects - projects where the projected energy savings typically cover the project investment cost;
- Calculation Methods - projects that plan to use non-energy modeling methods to estimate energy savings[1]; and
- Measurement and Verification - projects that will apply an Option A and/or B, *Retrofit Isolation* approach[2].

The **Targeted Commercial**/**Multifamily** protocols are intended for:

- Targeted Projects - single or multiple measure projects with limited interactivity, costing typically under $200,000;
- Targeted Scope - limited engineering requirements scaled to fit performance risk;
- Calculation Methods - projects that plan to use non-energy modeling methods to estimate energy savings; and

[1] Note that Standard Commercial/Multifamily projects may also substitute the use of an energy modeling approach to perform savings calculations.
[2] Note that Standard Commercial/Multifamily projects may also substitute the use of an Option C approach to Measurement and Verification.

- Measurement and Verification - projects that will apply an Option A and/or B, *Retrofit Isolation* method.

These definitions of project types are not hard and fast rules. 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 to determine the most suitable protocol to apply to any given project.

3.1 Determining Project Approaches

A comprehensive project development approach should be established early in the process. A key decision regarding establishing an approach involves determining 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 modeling. However, energy modeling offers a comprehensive assessment of a building's operation, and 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 analyzes 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 use (typically representing greater than 10% of total energy use). 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 (or protocol sections) to utilize in the development of a project.

4.0 BASELINING – CORE REQUIREMENTS

4.1 OVERVIEW

A technically sound energy-use 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. The baseline must establish how much fuel and electricity a building can be expected to use over a representative 12-month period. It 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; or any other resources consumed as fuel and any electricity generated on site from alternative energy systems. It must also factor in the impact of independent variables such as weather, occupancy, and operating hours on the building's energy-use.

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. Commonly known as Energy Management and Information Systems (EMIS), these software tools store, analyze, and display energy use or building systems data, and can be used to automate the processes involved in the baselining component of energy efficiency (EE) project development. EMIS 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 EMIS tools in greater detail.

The following elements are common to all protocols:

- 4.2.1 Utility Data and Baseline Period / Normalized Baseline Development
- 4.2.2 End-Use Energy Use
- 4.2.3 Weather Data
- 4.2.4 Occupancy Data
- 4.2.5 Building Asset / Operational / Performance Data

The following element is specific to the Standard and Targeted Commercial / Multifamily protocols:

- 4.2.6 Retrofit Isolation Baseline

4.2 PROTOCOL ELEMENTS

4.2.1 UTILITY DATA AND BASELINE PERIOD / NORMALIZED BASELINE DEVELOPMENT

Best Practices

Historical energy use 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 are collected for a three year period (or minimum of a 12 month period) for all of the information contained in Section 10.3 of the Building Energy Performance Assessment (BEPA) Standard, summarized here:

- Electricity use

  - utility name
  - electricity use (kWh)
  - peak electricity demand (maximum kW demand for each month of a twelve month period)
  - on-site electricity generation (kWh) and method
- On-site fuel for heating or cooling
  - fuel type(s), including renewable energy
  - utility or provider name
  - fuel usage
- District steam, hot water, or chilled water
  - type
  - district steam provider
  - usage
- Cost data
  - 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 do not correspond to calendar month periods (such as for two partial months) should be converted to calendar months. Determine average daily use during each partial month, and sum the daily average use over the number of days in the calendar month. For raw fuel delivered to the facility (e.g. fuel oil, propane), estimate monthly energy use based on actual use between fuel deliveries, or by pro-rating actual use between deliveries by an appropriate metric such as heating degree days.

Building energy-use metrics should be developed using the baseline historical utility data. This should include kWh/yr, kBtu/yr, kWh/ft^2-yr, and kBtu/ft^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 may be estimated. If the building is located at higher elevations (greater than 2,000 ft above mean sea level), gas heating values should be adjusted for elevation (see section 11.3.2 of the BEPA standard).

Regression-based energy modeling involves the development of an energy-use equation, which relates the dependent variable (total site energy-use, including electricity and on-site fuel or district energy) to independent variables known to significantly impact the building's energy-use. 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-use equation can be determined using a weighted ordinary least squares regression. This multiple-linear regression allows for the analysis of the building's energy-use as a function of the independent variables that change monthly. More complex regression techniques may also be employed. The Inverse Modeling Toolkit provides descriptions of various techniques that may be employed to develop regression-based energy models.

The regression-based energy model and the energy-use 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.

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-use predicted by the developed energy-use 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).

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 visualization 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 gross floor area, or a change that affects estimated total building energy-use by greater than 10%, i.e. "major renovation." Information regarding renovations or changes to the building or its operation needs to be collected during the energy audit. Energy-use 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 conform to the report format presented in the BEPA standard (Appendix X6) or a similar format that satisfies the project's requirements (i.e. client or stakeholder's expectations).

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-use data types have been accounted for.
- Ensure that the collected data do not include any periods involving major renovations.
- Review the regression-based energy model and the energy-use equation form. Ensure that all independent variables that significantly affect energy use have been accounted for and are represented in the energy-use 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-use 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

ASHRAE Standard 105 - Provides a common basis for reporting building energy-use in terms of delivered energy forms and expressions of energy performance.

ASTM E2797-11 Building Energy Performance Assessment (BEPA) Standard - Provides a methodology for the collection, compilation, analysis, and reporting of building energy performance information associated with a commercial building.

Commercial Buildings Energy Consumption Survey (EIA) 2003 - Data gathered from the US Energy Information Administration's CBECS, which is useful for comparison of the building's energy-use intensity (EUI) to its peer group. Updated database forthcoming in 2014.

Inventory of Commercial EMIS for M&V Applications (PECI) - Report that provides descriptions and comparisons of EMIS tools useful for baseline development.

Inverse Modeling Toolkit (ASHRAE) - Guidelines for calculating linear, change-point linear, and multiple-linear inverse building energy models. This toolkit describes the numerical algorithms used to find general least squares regressions, variable-base degree day change-points, and combination change-point multivariable regression models. It also describes the equations used to estimate the uncertainty of predicting energy use for the purpose of measuring savings.

4.2.2 End-Use Energy Use

Best Practices

Estimating or measuring end-use energy use 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 end-use energy use. 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 end-use annual energy consumption. Similar to the methodology described in the total building energy baseline development effort, this regression analysis requires the development of an energy-use equation, which relates the dependent variable to independent variables known to impact the end-use energy use.

A bottom up approach to end-use energy consumption estimates may also be employed. This involves using the information collected during the 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 end-use energy use. Resources such as the ASHRAE Sample End-Use Breakdown workbook can be used to assist with this approach.

A third and simpler approach to end-use energy use estimation involves the use of resources such as the Commercial Buildings Energy Consumption Survey (CBECS). Based on building characteristics and region, the appropriate CBECS estimated end-use 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 end-use energy use estimates can be used to calibrate the baseline (base year) energy model. Along with traditional calibration methods, the end-use energy use can be used to establish boundaries for the energy model outputs, allowing the modeler 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 end-use energy 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.
    - End-use calculation method: check equipment inventories for completeness, and check estimates of AFLHs to ensure that end-use calculations are accurate and reasonable.
    - Resource (CBECS) application: check that the selected building end-use percentages applied to the total building energy consumption are appropriate for the region and building characteristics (building type, system types, building/system vintages, etc.)
- End-use energy use estimates should be applied to energy model development and energy conservation measure (ECM) savings calculation calibration efforts.

Resources

ASHRAE Sample End Use Breakdown - Workbook used to develop end-use energy use from various measurements or estimates.

Commercial Buildings Energy Consumption Survey (EIA) 2003 - Data gathered from the US Energy Information Administration's CBECS, which is useful for comparison of the building's energy-use intensity (EUI) to its peer group. Updated database forthcoming in 2014.

4.2.3 Weather Data

Best Practices

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) corresponding to the baseline period.

Keep in mind that the relationship between temperature and energy use may vary based on time of year. Similarly, the relationship between energy use and weather may not be linear. These factors may need to be considered when developing an energy-use 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, known as Typical Meteorological Year (TMY) data. These represent a thirty year average of weather data for a specific region. However, weather data used for energy-modeling 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 were 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 are used for energy-modeling calibration purposes or data analysis.

Resources

California Weather Files - California specific weather file repository.

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

DOE2.com - Weather data repository containing TMY weather files.

Elements (RMI, Big Ladder Software) - A format neutral weather application that provides inputs for building energy modeling. This tool allows the user to read/write/convert between all major weather file formats, create custom files from measured data, display statistical data, and visualize or inspect data graphically.

National Climatic Data Center (NOAA) - Resource for historical climate and weather data.

4.2.4 Occupancy Data

Best Practices

Collect monthly occupancy (or vacancy) rates 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.

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 use of the heating or cooling equipment serving these spaces.

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-use.

4.2.5 Building Asset / Operational / Performance Data

Best Practices

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

Information regarding the building, and its operation and system performance are collected from various sources during the energy audit. This information can include: site observations and nameplate data; building as-built drawings; interviews with facility personnel, maintenance personnel, manufacturer's representatives, service providers and occupants; test, adjustment and balance (TAB) reports; sequences of operation; commissioning reports; spot measurements or short-term monitored data; or previous energy audits. A checklist of building information that should be collected is contained in the BEPA standard Appendix X8.

It is important to collect this information in a consistent and standardized way. Therefore the data collection process must utilize standardized 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 auditors with different levels of skill or experience should be able to follow a specific process and utilize standardized 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 these data and their 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. Standardizing the way these data are reported is also critical. The U.S. Department of Energy's (DOE's) Building Energy Data Exchange Specification (BEDES) currently involves an effort to define a common format for the reporting, exchange, and aggregation of building data.

Additional information on energy surveys and data collection methods can be found in the *ASHRAE Procedures for Commercial Building Energy Audits* and the *2011 ASHRAE Handbook - HVAC Applications*, Chapter 36, "Energy Use and Management," and Chapter 41, "Building Energy Monitoring."

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 BEPA 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 were collected accurately, and that the sources of these 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 these data are well documented.

Resources

ASHRAE Handbook, HVAC Applications - *Chapter 36*, "Energy Use and Management," and *Chapter 41*, "Building Energy Monitoring."

ASTM E2797-11 Building Energy Performance Assessment (BEPA) Standard - Provides a methodology for the collection, compilation, analysis, and reporting of building energy performance information associated with commercial buildings.

ASHRAE Procedures for Commercial Building Energy Audits (Second Edition 2011) - Defines best practices for energy surveys and analyses. This is useful for both purchasers and providers of energy audit services.

ASHRAE Standard 100 - Energy survey requirements, operation and maintenance requirements, and building and equipment modification requirements.

Building Energy Data Exchange Specification (LBNL/DOE) - Designed to facilitate the utilization and sharing of empirical building energy performance data among software tools and data collection and analysis activities. Resources should be available in 2014.

4.2.6 Retrofit Isolation Baseline

Best Practices

A retrofit isolation baseline presents a baseline specific to proposed ECMs, and is best applied when applying an Option A or B M&V approach. The development of the retrofit isolation baseline(s) should follow all of the same procedures 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 describe 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.

The developed baseline(s) should be informed by all available information, including equipment inventories and operating performance, and should be consistent with calculated end-use energy use. 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 the procedures 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 use calculations.
- ❖ Ensure that baselines document load and hours-of-use components, and whether these components are constant or variable.
- ❖ Ensure that developed baseline(s) are used to bound savings estimates, and are used for Option A or B M&V efforts.

Resources

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

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 dollar 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. Rates that include Ratchet provisions 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 use.

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-use 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 EE projects.

5.2 PROTOCOL ELEMENTS

5.2.1 ANNUAL / AVERAGE DAILY LOAD PROFILES

Best Practices

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, demand ratchets, fuel price adjustments, early payment discounts and taxes. Average or blended prices should never be used to calculate cost savings.

The price schedule used for the purposes of M&V will need to be determined - whether energy-cost savings are verified using the baseline or reporting-period price schedule. Typically, the price schedule associated with the reporting period is used to calculate verified costs savings.

If interval data are available, they 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.

Load profiles should be developed using available interval data for typical weekday and weekend days in the spring, summer, winter and fall. Time should be charted on the x-axis and appropriate energy units (such as kW or MBtu) on the y-axis.

The developed load profiles can indicate excessive energy use 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 are available), and how they were used to inform identification of ECMs or energy-modeling 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; 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.

6.0 SAVINGS CALCULATIONS

6.1 OVERVIEW

Savings calculations can be performed using detailed energy modeling, spreadsheet calculations, or other methods, depending on the requirements of the project and protocol. Regardless of the method employed, these efforts need to be transparent and well documented. Calculation methods must be based on sound engineering methods, and be consistent with ASHRAE principles. The results must be calibrated to estimated or known end-use energy use. Assumptions must be based on observations, field measurements, monitored data, or documented resources. In all cases, these assumptions should be conservative and transparent.

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. Similarly, sound cost estimates that can be used to form return on investment criteria and to prepare a clear, realistic financial package should be developed.

The following elements are common to all protocols:

- 6.2.1 ECM Descriptions
- 6.2.5 Cost Estimates
- 6.2.6 Investment Criteria

The following elements are specific to the Large Commercial/Multifamily protocols:

- 6.2.2 Energy Modeling
- 6.2.3 ECM Modeling

The following element is specific to the Standard and Targeted Commercial/Multifamily protocols:

- 6.2.4 Non-Energy Modeling ECM Calculations

6.2 PROTOCOL ELEMENTS

6.2.1 ECM DESCRIPTIONS

Best Practices

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. Detailed descriptions of the measures must be developed so that these estimates can in turn be accurately developed.

Documentation for each recommended measure should include the following information:

- The present condition of the system or equipment
- Recommended action or improvement
- Who should accomplish this action or improvement

- Necessary documentation
- Potential interference to successful completion
- Staff effort required
- Risk of failure
- Interaction with other end uses and ECMs
- Maintenance considerations
- Schedule for implementation

Quality Assurance Methods

- ❖ Review the ECM descriptions to ensure that they contain sufficient information, as described in the Best Practices section above.

6.2.2 Energy Modeling

Best Practices

An energy-modeling approach 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 public domain or commercially available software that meets the current ASHRAE Standard 140 specifications for 8760 hour annual simulation of building energy-use.

The modeling 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 input. 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 derived from WYEC (Weather Year for Energy Calculation), TMY (Typical Meteorological Year) or CWEC (Canadian Weather for Energy Calculations) climate data.
- Utility rate information.

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 minimized, 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.

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. 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 TMY weather data). When creating a custom weather file, the weather data parameters that the building simulation program requires must be determined. This weather data may in some cases need to be collected from different weather stations.

ASHRAE RP-1051 describes an analytical calibration process that includes four distinct processes: sensitivity analysis, parameter identification analysis, optimization, and uncertainty analysis. Whenever possible, this general calibration process should be applied:

- Sensitivity analysis - identification of influential parameters and their possible input value range
- Parameter identification - determination of the strongly influential unknown (default) parameters
- Optimization - responsible (conservative) adjustments to unknown input values to minimize differences between the building's modeled and baseline energy-use
- Uncertainty analysis - use of Monte Carlo (or similar) methods to determine uncertainty of strong parameters

Calibration efforts should not include the adjustment of any known model inputs. Adjustments to unknown or assumed inputs should be conservative, and within reasonable defined parameters. The results of the calibration effort should follow the ASHRAE Guideline 14 recommendations for accuracy, which suggest that calibrated modeling efforts should result in a Normalized Mean Bias Error (NMBE) of

5% and a CV(RMSE) of 15% relative to monthly calibration data. Section 5.2.11.3 of ASHRAE Guildeine 14 contains details regarding calculation of these indices.

If daily load shapes are available from the baseline utility data, these data can be used to assist with the "fine tuning" of the calibrated model. Similarly, monitored data of systems, subsystems or end-uses can also further inform the modeling and calibration process.

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

Quality Assurance Methods

- Review modeling 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 rate schedule(s) have been used in the energy model.
- Review model errors or warnings.
- Review output reports, and compare metrics to typical comparable metrics (such as EUI, ventilation rates, load densities, etc).
- Review calibration methods to ensure that adjustments to the model are reasonable. Calibration efforts should utilize a local weather file for the time period corresponding to the baseline. Calibration results should result in a NMBE of 5% and a CV(RMSE) of 15% relative to monthly calibration data.

Resources

ASHRAE Guideline 14-2002 - Highly technical document strongly focused on calculating energy and demand savings using measurements and measurement uncertainty analysis, applicable to Options B, C and D M&V approaches. Section 6.3.3 contains details specific to energy model development and calibration efforts.

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

ASHRAE RP-1051 - ASHRAE Research Project that describes an analytical calibration process that includes four distinct processes: sensitivity analysis, parameter identification analysis, optimization and uncertainty analysis.

ASHRAE Standard 209 "Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings" - ASHRAE-sponsored effort for a proposed modeling standard currently underway. The scope will apply to new buildings, major renovations and additions, and will define nominal requirements for using modeling to support integrated design efforts.

BEM Library (IBPSA) - Demonstrative site under development. The concept behind the DOE-funded Building Energy Modeling (BEM) Library project is to develop a freely-shared, information repository for building energy modeling. The Library consists of best-practice methods and key resources linked to frameworks used for delivering services. The frameworks draw from the same set of best practices, methods and resources, which promotes consistency across the many uses for building performance simulation.

BEM Stack Exchange Platform (Big Ladder Software) - Forum for energy-modeling discussions.

BEMBook Wiki (IBPSA-USA) - A guide to the BEM Body of Knowledge, which describes what portion of the Body of Knowledge is generally accepted, organizes that portion, and provides topical access to the information.

Building Component Library (NREL) - U.S. Department of Energy's comprehensive online searchable library of energy-modeling building blocks and descriptive metadata.

COMNET (IMT/NBI) - A quality assurance initiative to standardize building energy modeling, 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.

Contrasting the Capabilities of Building Energy Performance Simulation Programs (Crawley et al) - Paper that provides comparisons of twenty major building energy simulation programs.

Elements (RMI, Big Ladder Software) - Currently under development, this tool provides a format neutral weather application to provide input for building energy modeling. The tools allows the user to read/write/convert between all major weather file formats, create custom files from measured data, display statistical data, and visualize or inspect data graphically.

Energy-Modeling Input Translator (RMI) - EMIT comprises a compilation of spreadsheet-based calculators developed in response to the need for tools that help building professionals translate design data and code requirements into typical energy model inputs.

Model Manager (RMI) - An Excel-based tool that accesses eQUEST batch processing capabilities as well as results extraction functions.

Modelica - A non-proprietary, object-oriented, equation based language to conveniently model complex physical systems containing mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents. Utilizes open programming standards that allows reusing technologies (model libraries, numerical solvers, tools for code generation) that are shared across industries, and can be used to consistently model advanced building controls.

Procedures for Commercial Energy Audits (ASHRAE) - Supplemental files useful for conducting energy audit and energy modeling tasks. Materials include ECM summary tables, formulas and unit conversions, hourly simulation checklists, audit forms, end-use breakdowns, and audit checklists.

6.2.3 ECM Modeling

Best Practices

The calibrated baseline model should be updated to include the proposed ECMs and to estimate energy savings. In order to account for interactive effects, the measures can be modeled iteratively, effectively creating a “rolling” baseline that includes all previously modeled 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 modeled 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 modeled to include previous measures, and are modeled 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 modeled 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 modeling 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 modeling or the modeling of packages (bundles) of ECMs.

Resources

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

6.2.4 Non-Energy Modeling ECM Calculations

Best Practices

Calculation methods other than energy modeling, such as temperature bin analysis or 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 Uniform Methods Project (UMP) provide detailed guidelines for calculation methods and best practices. Vetted resources for calculation tools such as those developed by the US Department of Energy (DOE) Federal Energy Management Program (FEMP) 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 efforts 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. These 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. Just with energy modeling, 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 to estimate the energy savings associated with their product.

Estimated energy savings should always be compared to the estimated or measured end-use energy use to ensure that the estimated energy savings are in line with baseline estimates. Similarly, estimated energy savings should be compared to simple estimation efforts or previous energy savings estimates for reasonableness. This provides a "sanity check" and 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 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

Guidelines for Verifying Savings From Commissioning Existing Buildings (CCC) - Provides standardized methods that may be used to calculate and verify energy savings. Chapter 4 contains a description of methods to use to develop engineering calculations coupled with field verification.

Uniform Methods Project (NREL) - 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 Cost Estimates

Best Practices

Accurate cost estimation for the proposed ECMs represents a critical component that is used to financially evaluate a proposed EE project. Ideally, the final investment package should have pricing based upon bids that represent the price for which a contractor has committed to make the improvements. Quotes can sometimes be obtained from independent contractors, and it is recommended that the project use any contractors familiar to the building owner.

If direct quotes are not be available, cost estimates are typically based upon the engineer's experience with previous projects, detailed conceptual estimates, R.S. Means estimation, general contractor quotes or other sources. These estimates can be used to rank order improvements and determine which measures will be included in a final bid package.

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 standard 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 with major pieces of equipment must back up trade categories.
- All lines by trade must include labor and materials. "Labor" can be specified by budgetary allowance rather than by hours and hourly rates, but must state expressly whether or not the job must be union or requires prevailing wage.
- 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 bifurcated into total cost and incremental cost, depending on the audience and the investment contemplated. 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. See: National Institute of Standards and Technology (NIST) Life Cycle Costing Handbook 135.
- 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 (ASHRAE standards).

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 bifurcated if necessary (total cost and incremental cost).
❖ If LCCA is performed, ensure that the proper assumptions were used in the analysis.

Resources

Life Cycle Costing Handbook 135 (NIST) - Guide to understanding the LCC methodology and criteria established by FEMP for the economic evaluation of energy and water conservation projects.

LCCAid (RMI) - An Excel-based tool designed to make LCCA easier for architects, engineers and other building design and construction professionals who do not have extensive financial backgrounds. This analysis tool is intended to comply with all government standards for LCCA, including NIST Handbook 135 and its 2009 supplement; Current Facility Requirements (CFR) Title 10 Part 436; and Office of Management and Budget (OMB) Circular No. 11-A Part 7.

6.2.6 Investment Criteria

Best Practices

Different programs 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. 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.
>
> **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.

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.

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.

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 (NIST) - Program 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, standardized tools and guidelines to support economic and financial evaluation of EE projects.

Life Cycle Costing Handbook 135 (NIST) - Guide to understanding the LCC methodology and criteria established by FEMP for the economic evaluation of energy and water conservation projects.

LCCAid (RMI) - An Excel-based tool designed to make LCCA easier for architects, engineers and other building design and construction professionals who do not have extensive financial backgrounds.

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

7.0 DESIGN, CONSTRUCTION AND VERIFICATION

7.1 OVERVIEW

These tasks focus on the QA activities provided during the engineering, implementation and operational performance verification phase of the project. The QA activities performed during this phase include providing oversight to the design as well as general oversight during construction to ensure that the project is designed and implemented as intended. The submittal 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” is used regarding retrofit or energy efficiency upgrade projects to distinguish these associated tasks from a “comprehensive” commissioning effort. These tasks focus on the commissioning activities specific to the EE upgrades and ECMs, rather than involving the commissioning of all building systems and components.

The QA process should ensure that roles, responsibilities, expectations, timelines, communication and site access requirements have been established. Furthermore, the process should ensure 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.

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 stakeholders and project development/construction teams to ensure that the project is completed on time and within budget.

The following elements common to all protocols include:

- 7.2.1 Operational Performance Verification
- 7.2.2 Training
- 7.2.3 Systems Manual

7.2 PROTOCOL ELEMENTS

7.2.1 OPERATIONAL PERFORMANCE VERIFICATION

Best Practices

The operational performance verification (OPV) effort begins with the development of an OPV plan. This plan should be developed preconstruction, and should describe the verification activities, target energy budgets and key performance indicators associated with the project and the individual ECMs. The plan needs to also describe the data logging, control system trending, 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 effort itself should include consultation with the energy audit team, monitoring of designs, submittals and project changes, and inspections of the implemented changes. It also involves the responsibility 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 agent 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.

The OPV effort is accomplished 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. Measures with greater savings at risk or greater uncertainty will require a greater depth of OPV, such as the collection and analysis of post-installation performance data.

The M&V method being employed may also factor into the OPV approach taken. That is to say, if an Option B M&V approach is being employed, 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 utilized 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-use 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 - setup trends or install data logging equipment and analyze data, and/or review control logic; applied when ECM performance may vary depending on controls or loads, and savings or uncertainty are high.

As a result of these efforts, concise documentation should be provided that details activities completed as part of the OPV process and significant findings from those activities. This documentation should be continuously updated during the course of a project.

Quality Assurance Methods

- Review OPV plan 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 effort results and 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, Chapter 4.4 contains information regarding the operational performance verification general process.

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. Provides descriptions of the operational performance verification general process.

7.2.2 TRAINING

Best Practices

Training of the facility staff and building operators may be one of the most important factors determining the operational performance and persistence of energy savings. Without proper understanding of the new systems, the skills to operate the systems properly, 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 implementation. Assisting with the OPV efforts provides critical on-the-job training, and familiarity with the new systems and installed ECMs.

A well-developed training plan should be created, supported by comprehensive and useful building documentation and video recorded training sessions. The training sessions regarding changes stemming from the energy efficiency project and implemented ECMs should be developed/contributed to and performed by the consultants, vendors, and contractors.

The training involved with the OPV activities should be combined with the training performed as a 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

- 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
- O&M requirements needed to ensure persistence of performance and savings (service, maintenance and preventative maintenance 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 previously described in the Best Practices subsection 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.

References

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

7.2.3 Systems Manual

Best Practices

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 optimize the facility systems over their useful lives.

The Systems Manual should document the modified systems and equipment involved with the EE 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 the ASHRAE Guideline 1.4P, *Procedures for Preparing Facility Systems Manuals*):

- *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; manufacturer's operation and maintenance data; warranties; as well as contractor / supplier listing and contact information

- *Facility operations*: operating plan; building and equipment operating schedules; set points and ranges; sequences of operation; limitations and emergency procedures actions; maintenance procedures, checklists and records; maintenance schedules; 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; 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 optimization 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 ASHRAE Guideline 1.4P, *Procedures for Preparing Facility Systems Manuals*.
- ❖ 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 optimization of the systems, and a clear process and responsibility matrix for addressing issues.

Resources

ASHRAE Guideline 0-2005, The Commissioning Process - Section 6.2.6 and Annex O, contain information about Systems Manuals and contents.

ASHRAE Guideline 1.4P, Procedures for Preparing Facility Systems Manuals - Detailed guideline specifying development of a Systems Manual, content materials, and instructions for updating the manual, for new and existing buildings.

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 following elements common to all protocols include:

- 8.2.2 Operator's Manual
- 8.2.3 Training on OM&M Procedures

The following element is common to the Large and Standard Commercial / Multifamily protocols:

- 8.2.1 Operations, Maintenance and Monitoring Procedures

8.2 Protocol Elements

8.2.1 Operations, Maintenance & Monitoring Procedures

Best Practices

OM&M and building performance tracking is a process of continuous improvement, and involves tracking, analyzing, diagnosing and resolving issues involving building HVAC, lighting or other energy-consuming systems. While the focus from an EE 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 optimizing energy performance. A common problem that often arises involves the fact that building operators first responsibility is to provide occupant comfort, essentially responding to and resolving "hot and cold" calls. This directive is often counter-productive to a building's EE 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, analyzing, 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 are tracked along with energy consumption data. Various tools are available to support these tracking efforts and typically multiple tools can be 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 optimizes energy performance.

A strong OM&M management framework needs to illustrate 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.

Automated energy information systems (EIS) or EMIS can be incorporated into the OM&M management regime, and provide a method for tracking, analyzing, and assessing energy performance against savings projections and benchmarks. These tools can be used in conjunction with the Baselining and M&V efforts involved with the EE project development.

Data acquisition systems are used to collect energy data and transmit these data to the EIS. These data are typically collected in intervals between one minute and one hour, and can track either whole-building energy consumption, or the energy use of specific systems or end-uses. The EIS aggregates these data, looks for errors, analyzes the data, and provides graphical representations of the data or reports used to assess the energy performance of the building in real time.

While EIS 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 automation system (BAS), 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 BAS 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. Metrics typically include zone temperatures, equipment efficiencies, system efficiencies, and ventilation rates.

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

FDD tools utilize existing BAS points, and in some cases additional dedicated sensors external to the BAS, and analyze the data using fault detection algorithms. These algorithms are typically proprietary, but some tools allow for customization 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.

Retrocommissioning 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 use and peak demand use, 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 EE project, complexity of systems, and the skill level of the facility staff.
- Ensure that key performance indicators have been selected 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

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

Best Practices

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 Best Practices 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

Best Practices

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 diminish system energy performance over time, and jeopardize the financial performance of an EE 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:

- *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.
- *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 computerized 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 program, 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 best practices, 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 regarding how to utilize 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 defense" against performance degradation, and their proper understanding of the monitoring systems and analysis tools represent key components to a project's success.

Nationally recognized competency-based training and certification programs are available that can 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, such as the Building Operator's Certification (BOC), 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 the Best Practices subsection 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

ASHRAE Handbook-2011, Chapter 39 - Description of proper maintenance best practices.

ASHRAE/ACCA Standard 180, Standard Practice for Inspection and Maintenance of Commercial HVAC Systems - Establishes minimum HVAC inspection and maintenance requirements that preserve a system's ability to achieve acceptable thermal comfort, energy performance, and indoor air quality.

Building Operator's Certification (BOC) - Nationally recognized, competency-based training and certification program that offers facilities personnel the improved job skills and knowledge to transform workplaces to be more comfortable, energy-efficient and environmentally friendly.

Operations and Maintenance Best Practices (FEMP) - Provides information regarding O&M management, technologies, energy and water efficiency, and cost-reduction approaches.

9.0 MEASUREMENT AND VERIFICATION

9.1 OVERVIEW

All 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, normalized 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.

Table 1. Overview of M&V Options[3]

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 behavior.

[3] 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 use of the ECM-affected system. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the savings and the length of the reporting period.	Short-term or continuous measurements of baseline and reporting-period energy, and/or engineering computations using measurements of proxies of energy use. 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 use.
C. Whole Facility Savings are determined by measuring energy use at the whole facility or sub-facility level. Continuous measurements of the entire facility's energy-use 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 program affecting many systems in a facility. Measure energy use 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 following elements common to all protocols include:

- 9.2.1 M&V Plan and Implementation
- 9.2.2 Energy Data

The following element is common to the Large Commercial / Multifamily protocols (Option C approach):

- 9.2.3 Regression-Based Model

The following elements are common to the Standard and Targeted Commercial / Multifamily protocols (Option A and B approaches):

9.2 Protocol Elements

9.2.1 M&V Plan and Implementation

Best Practices

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
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-use equation and actual weather data (not TMY data) to determine the monthly baseline energy-use, 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-use 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 EE project has been defined. Early development of the plan will ensure that all data needed for savings determination will be collected and available. This is particularly important in an Option A or B approach, in which pre-retrofit data are 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
- Definition of the reporting period (typically the length of time required to recover the investment costs associated with the EE project)
- Descriptions of the basis for adjustments
- Description of the analysis procedures, including algorithms and assumptions to be used for the verification effort
- 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 effort (initial and ongoing)
- Description of the M&V reporting format and schedule
- Description of quality assurance procedures applicable to the M&V efforts

The third step in the M&V process involves operational performance verification, which provides a means for realizing 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

For Option C approaches, the measurement boundary will include the entire building. The measurement periods should adhere to the ASHRAE BEPA guidelines, 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-use 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 use 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 use. This can be accomplished through interviews with the building owner and facility personnel, periodic site visits, observation of unexpected energy-use patterns, or other methods.

Accurate and conservative calculation of the effects these non-routine adjustments have on energy use is critical. Sometimes these effects can be estimated within the energy-modeling 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 rigor 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 use should be considered. And assumptions used within the adjustments need to be conservative and based on actual measurements, field observations, or well vetted and documentable sources.

Verified Energy Savings - Options A and B

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 use that provide an indication of energy use.

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

Both the baseline period and the post-retrofit (reporting) period need to be determined early on in the project development so that appropriate and adequate baseline data can be captured. The measurement periods need to collect data that reflect equipment operation through its full operating cycle (maximum energy use to minimum). The data should represent all operating conditions, and the baseline period should 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 6) 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

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.

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.

9.2.2 Energy Data

Best Practices

Data collection can be performed through the use of metering equipment, remote data logging equipment, trending through the BAS, 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 for measurements such as temperature or airflow.

Issues such as slowing computer processing, 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 they will almost always produce some erroneous or missing data. Methods and procedures for dealing with erroneous or missing data, 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 project development. Tools such as the Universal Translator 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

ASHRAE Guideline 14-2002 - Highly technical document strongly focused on calculating energy and demand savings using measurements and measurement uncertainty analysis, applicable to Option B approaches. Details regarding data collection and instrumentation can be found in Section 7 of the Guideline.

ASTM E2797-11 Building Energy Performance Assessment (BEPA) standard - Prescriptively addresses the baseline data collection and analysis process for Option C approaches.

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

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.

Universal Translator v3 (PG&E) - The UT3 is software designed for the management and analysis of data from loggers and trend data from building management systems. The software features import routines, time and interval correction, calibration error correction, data filters, charting tools, and export capabilities. It also features analysis modules to analyze economizers, lighting loads, plug loads, psychometrics, setpoints, statistics, control loop diagnostics, fans, AHUs, terminal units, fan coils, and an M&V analysis module (regression modeling).

9.2.3 Regression-Based Model

Best Practices

Development of the regression-based energy model involves development of an energy-use equation, which relates the dependent variable (total site energy-use, including electricity and on-site fuel or district energy) to independent variables known to significantly impact the building's energy-use. 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 use equation can be determined using a weighted ordinary least squares regression. This multiple-linear regression allows for the comparison and analysis of the building's energy-use as a function of the independent variables that vary monthly. More complex regression techniques may also be employed. The Inverse Modeling Toolkit, as well as the IPMVP and ASHRAE Guideline-14, provide descriptions of various techniques that may be employed to develop these regression-based energy models. 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. As previously described in the Baselining section, a description and comparison of some of these applications is summarized in the *Inventory of Commercial EMIS for M&V Applications* developed by Portland Energy Conservation, Inc.

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-use equation (model) to ensure that the appropriate independent variables that affect energy use have been considered and incorporated into the equation, and that the independent variables 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

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

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.

Inventory of Commercial EMIS for M&V Applications (PECI) - Report that provides descriptions and comparisons of EMIS tools (IPMVP Option C approach).

Inverse Modeling Toolkit (ASHRAE) - Toolkit for calculating linear, change-point linear, and multiple-linear inverse building energy models. Describes the numerical algorithms used to find general least squares regression, variable-base degree- day change-point, and combination change-point multivariable regression models, as well as the equations used to estimate the uncertainty of predicting energy use for the purpose of measuring savings.

9.2.4 STIPULATED PARAMETERS (OPTION A)

Best Practices

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 cooling ton-hours can be spot-measured or short-term-measured during the baseline and post-retrofit periods. Under Option A, any factor not measured is estimated based on assumptions, analysis of historical data, or manufacturer's data.

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

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 stipulated), 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.

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 stipulated parameters do not include variables that are typically not consistent.
- ❖ Check source and reasonableness of estimated (stipulated) parameters.

9.2.5 REVISED CALCULATIONS (OPTIONS A AND B)

Best Practices

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, BAS 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 Quality Assurance Topics

10.1 Owner's Representative / 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.

Operational performance verification and M&V services provide the opportunity to stabilize and enhance an energy efficiency project, as well as the opportunity for unbiased and specialized evaluation of system and energy performance of an energy efficiency project by third-party providers or reviewers. The benefits of operational performance verification and M&V services, and the specialized 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, 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.

Furthermore, engagement of an "overall" owner's representative is recommended. The owner's representative, using this PD Specification, can support the energy efficiency project development by providing the technical expertise required for the development of the project. This representative can also provide focused attention on project element details, components of the project that the owner's staff may have little experience with or insufficient resources to devote to.

It is important that in all cases the third parties engaged for these efforts are hired at the very beginning of the process to work on behalf of the stakeholders. This will allow the third party to review and provide input to development of plans, development of the baseline, savings calculation estimates, identification of potential adjustments, and other activities performed early on in the development of the project. 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.

The third-party owner's representative should have responsibilities for all phases of project development, including: project development team selection, quality control of the investment grade audit (IGA), project implementation assistance, and M&V. These responsibilities can be attributed to one individual, or assigned to specialists for one or multiple tasks. Overall, the typical services provided by a third-party owner's representative include:

1. Assistance with the preparation of a Request for Proposal (RFP) for energy efficiency project development services.
2. Assistance with the review and evaluation of RFP responses, preparation of the selection committee, and interviews of potential project development teams.
3. Review of project development components, including baseline development, energy modeling or savings calculations, price reasonableness, and financial performance metrics.
4. Acting in an advisory role in contract negotiations, including draft review and recommendations.
5. Review of the operational performance verification plan and activities.
6. Review of the M&V plan, adherence to the IPMVP, and assistance in quality control of M&V services provided.

Minimum qualifications for a third-party owner's representative include:

1. Demonstrated working knowledge of energy efficiency project development.
2. Having a PE license, an Association of Energy Engineers (AEE) Certified Energy Manager (CEM) certification, an AEE Certified Measurement and Verification Professional (CMVP) certification, or a minimum of five years professional consulting experience in the development of energy efficiency projects.
3. Willingness to work closely and cooperatively with the project development team, and to act in the best interests of the stakeholders.

10.2 Uncertainty and Risk

Best Practices

The estimated energy-cost savings and implementation cost 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
- Modeling errors
- Statistical sampling
- Interactive effects
- Inaccuracy of assumptions (estimations)

Each of these sources of error can be minimized by using more sophisticated analysis methods, measurement equipment, sample sizes, and accurate assumptions. However, it must also be recognized 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[4] 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 utilizing 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 stabilize a Monte Carlo simulation.

For projects utilizing 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 standardized approaches to this uncertainty analysis have yet to penetrate the energy-modeling field, work is currently underway to develop options for completing uncertainty analysis. In particular, the next release of OpenStudio, an open-source application suite and software development kit which supports whole-building modeling 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 modeling library developed by Sandia National Laboratories. This functionality will allow the assessment of sensitivity of the output to the input parameters, those

[4] This requirement reflects an extension of the Public Utilities Regulatory Act requirements for a class load research sample.

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.
- Utilizing 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 EE 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 EE project development, avoiding bias at all costs.

Recognizing 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 - Highly technical document strongly 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

International Performance Measurement and Verification Protocols (EVO) - Volume I, 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 labeled, 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.

Key:
LC = Large Commercial
SC - Standard Commercial
TC = Targeted Commercial
LMF = Large Multifamily
SMF = Standard Multifamily
TMF - Targeted Multifamily

Table 2. Documentation Package

ICP Sec #	ICP Section	Protocol	Documentation Required		Comments
2	Baselining	All	Weather data		Can be the actual weather file or data, or a reference to the source of the data used (e.g. NOAA, weather station)
2	Baselining	All	Baseline utility data		Raw utility data
2	Baselining	All	Description of baseline period		12 mos period, include start/end dates
2	Baselining	All	Utility rate structures		
2	Baselining	All	End-use energy use		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 takeoffs, observations, short-term monitored data, spot measurements, and functional performance test results as appropriate
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 rent roll		
ICP Sec #	**ICP Section**	**Protocol**	**Documentation Required**		**Comments**
3	Baselining-Demand	All	Copies of utility bills		At least one for electricity and each fuel
3	Baselining-Demand	All	Monthly consumption load profiles		

3	Baselining-Demand	All	Monthly peak demand		
3	Baselining-Demand	All	Interval meter data		
4	Savings Calculations	LC,LMF	Modeler qualifications		
4	Savings Calculations	SC,TC,SMF,TMF	Savings calculator qualifications		
4	Savings Calculations	LC,LMF	Model calibration		Demonstrate that the calibration criteria are met
4	Savings Calculations	LC,LMF	Model input files		Including information about modeling software used and version number
4	Savings Calculations	All	Descriptions of ECMs		
4	Savings Calculations	SC,TC,SMF,TMF	Calculations		Workbooks, spreadsheets and other calculation tools
4	Savings Calculations	All	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		Regarding model / calculation results
5	Design, Const & Verification	All	OPV authority qualifications		
5	Design, Const & Verification	All	OPV Plan		
5	Design, Const & Verification	All	OPV statement of project conformity		
5	Design, Const & Verification	All	OPV report		
5	Design, Const & Verification	All	Training materials		And record of training
5	Design, Const & Verification	All	System manual(s)		For all new and modified systems and equipment
ICP Sec #	**ICP Section**	**Protocol**	**Documentation Required**		**Comments**
6	OM&M	LC,LMF,SC,SMF	Trending plan		Key variables trended in BAS

6	OM&M	LC,LMF,SC,SMF	Plan for fault detection and remediation		
6	OM&M	All	Operator's Manual and Organizational 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		
7	M&V	All	M&V Plan		
7	M&V	All	Routine adjustments		
7	M&V	All	Non-routine adjustments		
7	M&V	LC,LMF	Reporting-period utility data		Used in the Option C analysis
7	M&V	LC,LMF	Reporting-period independent variable data		Used in the Option C analysis
7	M&V	LC,LMF	Reporting-period dependent variable data		Used in the Option C analysis
7	M&V	LC,LMF	Regression-based energy model		Used in the Option C analysis
7	M&V	SC,TC,SMF,TMF	Data collected		Used in the Options A/B analysis
7	M&V	SC,TC,SMF,TMF	Verified savings calculations		Used in the Options A/B analysis, including assumptions

12.0 COMPREHENSIVE LIST OF RESOURCES

ASHRAE/ACCA Standard 180, Standard Practice for Inspection and Maintenance of Commercial HVAC Systems - Establishes minimum HVAC inspection and maintenance requirements that preserve a system's ability to achieve acceptable thermal comfort, energy performance, and indoor air quality.

ASHRAE Guideline 0-2005, The Commissioning Process

ASHRAE Guideline 1.4P, Procedures for Preparing Facility Systems Manuals - Detailed guideline specifying development of a systems manual, content materials, and instructions for updating the manual, for new and existing buildings.

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

ASHRAE Handbook, HVAC Applications

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

ASHRAE Procedures for Commercial Building Energy Audits (Second Edition 2011) - Defines best practices for energy survey and analysis for purchasers and providers of energy audit services.

ASHRAE RP-1051 - ASHRAE Research Project that describes an analytical calibration process that includes four distinct processes: sensitivity analysis, parameter identification analysis, optimization and uncertainty analysis.

ASHRAE Sample End Use Breakdown - Workbook used to develop end-use energy use from various measurements or estimates.

ASHRAE Standard 100 - Energy survey requirements, operation and maintenance requirements, and building and equipment modification requirements.

ASHRAE Standard 105 - Provides a common basis for reporting building energy-use in terms of delivered energy forms and expressions of energy performance.

ASHRAE Standard 209 "Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings" - ASHRAE-sponsored effort for a proposed modeling standard currently underway. The scope will apply to new buildings, major renovations and additions, and will define nominal requirements for using modeling to support integrated design efforts.

ASTM E2797-11 Building Energy Performance Assessment (BEPA) Standard - Provides a methodology for the collection, compilation, analysis, and reporting of building energy performance information associated with a commercial building.

BEM Library (IBPSA) - Demonstrative site under development. The concept behind the DOE-funded BEM Library project is to develop a freely-shared, information repository for building energy modeling. The Library consists of best-practice methods and key resources linked to frameworks for delivering services. The frameworks draw from the same set of best practices, methods and resources, which promote consistency across the many uses for building performance simulation.

BEM Stack Exchange Platform (Big Ladder Software) - Forum for energy-modeling discussions.

BEMBook Wiki (IBPSA-USA) - A guide to the BEM Body of Knowledge, which describes what portion of the Body of Knowledge is generally accepted, organizes that portion, and provides topical access to the information.

Building Component Library (NREL) - U.S. Department of Energy's comprehensive online searchable library of energy-modeling building blocks and descriptive metadata.

Building Energy Data Exchange Specification (LBNL/DOE) - Designed to facilitate the utilization and sharing of empirical building energy performance data among software tools and data collection and analysis activities. Resources should be available in 2014.

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

Building Operator's Certification (BOC) - Nationally recognized, competency-based training and certification program that offers facilities personnel the improved job skills and knowledge to transform workplaces to be more comfortable, energy-efficient and environmentally friendly.

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.

Commercial Buildings Energy Consumption Survey (EIA) 2003 - Data gathered from the US Energy Information Administration's CBECS, useful for comparison of the building's energy-use intensity (EUI) to its peer group. Updated database forthcoming in 2014.

COMNET (IMT/NBI) - A quality assurance initiative to standardize building energy modeling, 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.

Contrasting the Capabilities of Building Energy Performance Simulation Programs (Crawley et al) - Paper that provides comparisons of twenty major building energy simulation programs.

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

DOE2.com - Weather data repository, containing TMY weather files.

Elements (RMI, Big Ladder Software) - Tool that provides a format neutral weather application to provide input for building energy modeling. The tool allows the user to read/write/convert between all major weather file formats, create custom files from measured data, display statistical data, and visualize or inspect data graphically.

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.

Energy-Modeling Input Translator (RMI) - EMIT comprises a compilation of spreadsheet-based calculators developed in response to the need for tools that help building professionals translate design data and code requirements into typical energy model inputs.

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.

Guidelines for Verifying Savings From Commissioning Existing Buildings (CCC) - Provides standardized methods that may be used to calculate and verify energy savings. Chapter 4 contains a description of methods to use to develop engineering calculations coupled with field verification.

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, standardized tools and guidelines to support economic and financial evaluation of EE projects.

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.

Inventory of Commercial EMIS for M&V Applications (PECI) - Report that provides descriptions and comparisons of EMIS tools useful for baseline development.

Inverse Modeling Toolkit (ASHRAE) - Guidelines for calculating linear, change-point linear, and multiple-linear inverse building energy models. Describes the numerical algorithms used to find general least squares regression, variable-base degree day change-point, and combination change-point multivariable regression models, as well as the equations used to estimate the uncertainty of predicting energy use for the purpose of measuring savings.

Life Cycle Costing Handbook 135 (NIST) - Guide to understanding the LCC methodology and criteria established by FEMP for the economic evaluation of energy and water conservation projects.

LCCAid (RMI) - An Excel-based tool designed to make LCCA easier for architects, engineers and other building design and construction professionals who do not have extensive financial backgrounds.

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.

Model Manager (RMI) - An Excel-based tool that accesses eQUEST batch processing capabilities as well as results extraction functions.

Modelica - A non-proprietary, object-oriented, equation based language to conveniently model complex physical systems containing mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents. Utilizes open programming standards that allows reusing technologies (model libraries, numerical solvers, tools for code generation) that are shared across industries, and can be used to consistently model advanced building controls.

National Climatic Data Center (NOAA) - Resource for historical weather and climate data.

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

Operations and Maintenance Best Practices (FEMP) - Provides information regarding O&M management, technologies, energy and water efficiency, and cost-reduction approaches.

Procedures for Commercial Energy Audits (ASHRAE) - Supplemental files useful for conducting energy audit and energy-modeling tasks. Materials include ECM summary tables, formulas and unit conversions, hourly simulation checklists, audit forms, end-use breakdowns, and auditor checklists.

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

Uniform Methods Project (NREL) - Provides detailed guidelines for calculation methods and best practices.

Universal Translator v3 (PG&E) - The UT3 is software designed for the management and analysis of from loggers and trend data from building management systems. The software features import routines, time and interval correction, calibration error correction, data filters, charting tools, and export capabilities. It also features analysis modules to analyze economizers, lighting loads, plug loads, psychometrics, setpoints, statistics, control loop diagnostics, fans, AHUs, terminal units, fan coils, and an M&V analysis module (regression modeling).

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.