National Institute of Building Sciences

Provider Number: G168

Trust, but Measure and Verify:

Standards, Practices and the Use of Data Analytics

Course Number: 2-WE-4B

Robert J. Knoedler, P.E. CxA EMP

President - Energy Management Association

Vice President / Principal
Hanson Professional Services Inc.

January 9, 2019

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

Course Description

A critical aspect of any energy savings program involves accurate measurement and verification of the energy consumption (and demand) associated with the implemented measures / activities. Several standards exist in this field, including the International Performance Measurement and Verification Protocol (IPMVP) and ASHRAE Guideline 14-2014 – Measurement of Energy, Demand, and Water Savings.

The evolution of power monitoring and sub-metering systems, either separate or through upgraded BAS systems, has allowed clients to obtain enhanced, real-time energy information, improving the accuracy of data needed to verify specific system / measure performance.

In addition, the increased incorporation of renewal energy technologies, including local micro-grids, often expands the M&V requirements beyond pure energy consumption and cost savings; to include reduction in atmospheric emissions, reduction in risks associated with fuel extraction and transportation, distribution interruptions, etc.

However, even with the advancements in data collection and analysis, an experienced energy management professional needs to review the M&V data to assess its validity; determining whether any 'normalization' is required to accommodate changes in weather, building usage, system parameters, occupancy, etc.

This presentation will address the current standards and practices of the M&V industry, along with ongoing developments (such as the current updating of ASHRAE Guideline 14-2014) and the presenters' outlook for the industry, incorporating the use of data analytics.

CONTINUING EDUCATION AIA

BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

Learning Objectives

At the end of the this course, participants will be able to:

1. Recognize the industry accepted standards and guidelines for M&V, including the International Performance Measurements and Verification Protocol (IPMVP) and ASHRAE Guideline 14-2014.

2. Understand the multi-step process for M&V, including the various approaches (options) establishing implemented measures' baseline performance and activities to verify projected improvement(s).

3. Utilize M&V procedures beyond energy consumption and cost savings; potentially including reduction in atmospheric emissions, reduction in risks, and increase in resiliency and reliability.

4. See how advancement and expansion in power monitoring, sub-metering, and data analytics has advanced the availability and accuracy of M&V procedures.

CONTINUING EDUCATION AIA

What is Measurement & Verification (M&V)?

M&V is the process of **using measurement to reliably determine actual savings (energy consumption and cost savings)** created within an individual facility by an energy management, energy conservation or energy efficiency project or program. However, it is being expanded to include **reduction in atmospheric emissions, reduction in risks, and increase in resiliency and reliability.**

Benefits of M&V

- Accurately **assess energy savings** for a project
- **Allocate risks** to the appropriate parties
- **Reduce uncertainties** to reasonable levels
- **Monitor equipment performance**
- Find **additional savings**
- **Improve operations and maintenance** (O&M)
- **Verify cost savings guarantee** is met, and
- **Allow for future adjustments**, as needed

Why Employ M&V?

Part of a **Risk Management Strategy for ESPCs** – Helps Verify Performance:

- **Financial Risks**: Interest rates, energy prices, construction costs, M&V costs, delays,
- **Operational Risks**: Operating Hours, Load, Weather, User Participation
- **Performance Risks**: Equipment performance, Operations, Maintenance and Repair, Equipment Replacement

BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

Who Uses M&V?

- **Energy Performance Contractors** and their customers
- **Facility / Energy managers** properly accounting for energy budget variances
- **New building designers** seeking sustainability / efficiency certification (LEED, Green Globe, WELL, etc.)
- Both **private and public energy users** implementing their own retrofits and wanting to verify savings
- **Water efficiency project developers**
- **Emission reduction program designers**

BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

Key M&V Codes, Standards, and Guidelines

- International Performance Measurement and Verification Protocol (IPMVP)
- ASHRAE Guideline 14-2014 – Measurement of Energy, Demand, and Water Savings
- M&V Guidelines: Measurement and Verification for Federal Energy Projects
- Greenhouse Gas Protocol for Project Accounting
- ASHRAE Standard 211 – 2018 Standard for Commercial Building Energy Audits

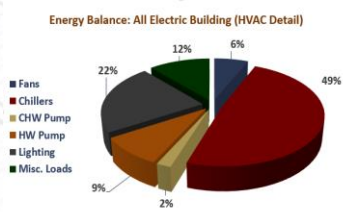
The M&V Process

- Determination of **baseline performance** against which energy consumption can be measured going forward
- **Estimated savings** through an audit, [Level 2 or Level 3 (investment grade audit)]
- Development of an **M&V plan**
- Compilation of a **post-implementation report** (verifying performance), and
- **Ongoing M&V activities** according to a prescribed schedule

The M&V Process

Establish Baseline Performance

Collect and analyze utility bills (minimum 3 years)



Create Energy Balance

1. Identify baseline energy usage by fuel source
2. Define energy balance for each energy source
3. Subdivide the largest energy-consuming systems
4. Establish a baseline against which demand and consumption can be measured going forward

This may be for the whole facility or specific systems, depending upon how data is gathered.

ECM (EEM) vs. FIM

Energy Conservation Measure (ECM) or Energy Efficiency Measure (EEM) – a project conducted, an initiative or technology implemented that reduces the consumption of energy in a facility. The measures are life cycle cost effective and typically involve energy conservation, cogeneration facilities, renewable energy sources, improvements in operations and maintenance, or retrofit activities. The measures can affect a variety of resources mainly water, electricity and gas for commercial and industrial facilities.

Facility Improvement Measure (FIM) – a project or initiative to improve building and system performance, system reliability / resiliency, reduce O&M costs, improve Indoor Environmental Quality (IEQ), etc. The measure may or may not reduce energy consumption and related costs.

Evaluating Energy Opportunities

Evaluating Potential ECMs / EEMs

- Establish financial analysis method(s) to be employed

Simple Payback

$$\text{Payback Period (years)} = \frac{\text{Initial cost of Measure}}{\text{Savings per year}}$$

Return on Investment (ROI)

$$\text{ROI (annual)} = \frac{\text{Return (savings) from investment (annual)}}{\text{Cost of Investment}}$$

Life Cycle Cost Analysis

BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

Evaluating Energy Opportunities

Life Cycle Cost Analysis

- Method of assessing the total cost of facility ownership; taking into account all costs associated with acquiring, owning and disposing of a building or building system
- Useful in comparing alternate systems that may fulfill performance requirements, but differ in first and operating costs
- Typical building-related costs include:
  - Initial Costs
  - Fuel Costs
  - Operation, Maintenance and Repair Costs
  - Replacement Costs
  - Residual Values, Resale or Salvage
  - Disposal Cost
  - Finance Charges
  - Non-monetary Benefits

Evaluating Energy Opportunities

Basic Life Cycle Cost Calculation

LCC = I + Repl – Res +E +W + OM&R +O

Where:

LCC = Total life cycle costs in present-value (PV) dollars
I = PV investment costs
Repl = PV capital replacement costs
Res = PV residual value (resale or salvage) less disposal costs
E = PV of energy costs
W = PV of water costs
OM&R = PV of non-fuel operating, maintenance and repair costs
O = PV of other costs (e.g. contract costs for ESPCs, etc.)

Savings Calculations and Implementation Estimates

Level of accuracy depends upon level of audit (Level 3 – Investment Grade Audit being the most accurate):

- **Savings calculations need to consider**
  - Variables such as occupancy / operating times, weather, control strategies
  - Consumption, demand, and utility charges
  - Interactions between various measures
- **Implementation estimates need to consider all related costs** (design, commissioning, M&V, etc.)
  - Construction cost guides (Means, Dodge, etc.)
  - Contractor and vendor quotes
  - In-house costing for measures performed with in house staff

Establish M&V Budget

The **more rigorous the M&V, the more expensive** it will be to determine energy savings. Factors that affect M&V accuracy and cost include:

- Level of detail and effort associated with verifying baseline and performance period surveys
- Sample sizes (number of data points) used for metering representative equipment
- Duration and accuracy of metering activities
- Number and complexity of dependent and independent variables that are metered or accounted for in analyses

Establish M&V Budget

(cont'd)

- Level of engineering required to conduct analyses
- Availability of existing data collecting systems (e.g. BAS)
- Contract term (in performance-based contracts)
- Level of accuracy needed in energy savings calculations

The M&V effort should be scaled to the value of the project. Rule of thumb estimates place **annual M&V costs between 2% and 5% of the typical annual project cost savings**

Outline for Project Specific M&V Plan

- Develop details of **'baseline' conditions** and data collected
- Documentation of **all assumptions and sources of data**
- **What will be verified**
- **Who will conduct the M&V activities**
- **Schedule for all M&V activities**
- Details of **engineering analysis** performed

Outline for Project Specific M&V Plan
(Cont'd)

- **How energy savings will be calculated**
- Indicate **locations for all required meters** / monitoring devices and the units of measurement (kW, BTUh, Gallons, Cu. Ft., etc.)
- **Utility rates and how they will be used to calculate energy savings**
- Specific information regarding the **method / frequency for data collection and analysis** against the documented baseline condition.

Outline for Project Specific M&V Plan
(Cont'd)

- Detail any **operations and maintenance (O&M) cost savings** claimed and any O&M reporting responsibilities
- Specific information regarding the **corrective action strategy** if measured data deviates from the expected (projected) performance.
- Establish the **M&V period**; e.g. one year past construction, length of performance contract, etc.
- Define **content and format of all M&V reports** (Post-installation, Commissioning, and periodic M&V)

The M&V Process

Two Approaches:

Retrofit Isolation Approach

- Looks only at the affected systems / equipment for energy savings, independent of the balance of the facility

Whole Facility Approach

- Considers total energy use of the entire facility, ignoring specific system / equipment performance.

The M&V Process

Four M&V Options:

Option A - Retrofit Isolation Approach

- Stipulated and Short Term Measured Factors

Option B - Retrofit Isolation Approach

- Continuously Measured and Stipulated Factors

Option C – Whole Facility Approach

- Utility Billing (Meter / Sub-meter) - Regression Analysis

Option D – Calibrated Computer Simulation

- Based upon computed simulation model calibrated with whole-building or end-use metered data

M&V Option A – Retrofit Isolation

- Actual savings determined from short term data collection, engineering calculations and stipulated factors
- Post-installation energy use, equipment performance, and usage are NOT continuously measured
- **Intent is to verify performance through pre- and post- retrofit measurements**
- Level of accuracy of the calculated savings depends upon the validity of the assumptions and what measurements are taken

Option A Example – Lighting Upgrade

- **Key Parameters:**
  - Number of fixtures
  - Power consumption per existing fixture (baseline)
  - Power consumption per new fixture (retrofit)
  - Operating hours for fixtures
- **Energy savings:** difference between power consumed by existing fixtures and power consumed by new fixtures multiplied by operating hours
- **Implementation cost:** Total cost of fixtures and labor to install same

M&V Option B – Retrofit Isolation

- Similar to Option A, but **uses periodic or continuous metering (monitoring) during the post-implementation period**
- Intended for retrofits with **performance factors or operational factors that can be measured at the component or system level**, and where long term performance needs to be verified
- Continuous monitoring information can be used to improve or optimize system / equipment operation over time
- This approach provides the **greatest accuracy in the calculation of savings**

Option B Example – VFD Installation

- **Key Parameters:**
  - Measured energy consumed by motor during constant speed operation over baseline period using meter (data logger)
  - Measured energy consumed by motor post-retrofit during equal time period (as defined by M&V schedule)
- **Energy savings:** difference between metered (measured) energy consumed; pre-retrofit and post-retrofit
- **Implementation cost:** Total cost of VFD, labor to install same, and any associated meter / data logger (if applicable)

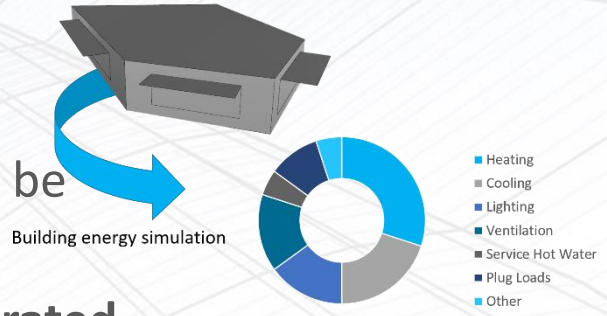
M&V Option C - Whole Facility

- Savings based on **actual energy consumption as measured by the utility meter(s) and/or regression modeling**
- Evaluation based on facility-level metered data using techniques ranging from billing comparison to multivariate regression analysis
- Generally the **overall level of savings must be 10% of total metered usage** for the method to be effective
- Analyses usually consider changes in weather, occupancy, loads and operations and adjusts baseline accordingly
- This option will **verify the total performance of all implemented measures including interactions**

Option C Example – Boiler Replacement

- **Key Parameters:**
  - Gas consumption by existing boiler during baseline period, as determined by monthly utility bill
  - Gas consumption by new high efficiency boiler during equal retrofit period, as determined by monthly utility bill
- **Energy savings:** use a regression model with monthly heating degree days to establish baseline model and to normalize post-retrofit period
- **Implementation cost:** Cost of new boiler with associated piping, electrical and flue work; along with all installation labor (and any sub-metering, if applicable)

M&V Option D - Whole Facility



- Primarily a whole facility method, but can be used at the component (isolation) level
- Savings are based on the results of a **calibrated computer simulation model**
- Estimated savings may vary over the contract if real weather data is used
- Linking simulation inputs to baseline and post-installation conditions completes the calibration
- Long term whole building energy use data, as well as system level performance measurements may be used to calibrate the simulations

Option D Example – Multiple Interactive Measures

- **Key Parameters:**
  - Measures include: glazing replacement, new roof with increased insulation and major upgrade of HVAC system
  - Create computer simulation model with baseline building envelope and existing HVAC system; calibrate with utility data
- **Energy savings:** edit simulation model with implemented retrofit measures (envelope and HVAC) and run with annual weather data used for baseline
- **Implementation cost:** Cost of all associated general work (glazing replacement, roofing, and associated demolition), cost of all HVAC and associated electrical and controls' work, along with associated design costs

The M&V Process

Post Implementation Report

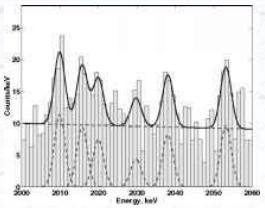
- Project Description
- Installation verification – implemented measures
- Details of any changes in as-built conditions with energy impacts
- Documentation of post-installation verification activities and performance measurements
- Commissioning results and documentation
- Performance Verification – how criteria were met
- Validation of construction period savings (if any) and expected savings for the first year

The M&V Process

Ongoing M&V Activities

- Monitoring-based Commissioning (MBCx)
- Maintenance Management Plan
- Periodic Training of O&M staff, as required
- Annual Performance Reports, as required
- Benchmark Building Performance – Portfolio Manager
- Recommissioning
- Retro-commissioning

BAS, Data Analytics and M&V



BAS systems are being augmented with various **energy information and FDD packages** enhancing the opportunities for M&V

- **New construction** – identify critical parameters to be measured during design for incorporation in energy management system
- **Existing building** – assess existing points / capabilities of building automation system
  - Ensure required meters / sensors are in place
  - Ensure proper trends are established with appropriate schedules
  - Use of FDD algorithms for normalization and sensitivity analysis
  - Establish “isolated benchmarking” using historical trend data

M&V of other Target Goals

Besides energy and cost savings, a number of clients have other **sustainability and operational goals** that could be tracked and verified:

- **Reduction in atmospheric (carbon) emissions**
- **Decrease dependency on fossil fuels, increase percentage of renewable energy use**
- **Reduction in domestic water consumption**
- **Reduction in waste, increase in recycled materials (tons)**

M&V of other Target Goals

(Cont'd)

Other **sustainability and operational goals** that could be tracked and verified:

- **Increase in resiliency / reliability**
  - **Track number of business interruptions during the year (all causes)**
  - **Track number of power outages and their duration during the year**
  - **Reduction in hours loss due to the above**
- **Reduction in maintenance hours / $$$ on an annual basis**
- **Reduction in employee sick hours / comfort complaints**

BUILDING INNOVATION 2019
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

Questions

BUILDING INNOVATION 2019

National Institute of BUILDING SCIENCES

CONFERENCE & EXPO

Thank You!

This concludes The American Institute of Architects
Continuing Education Systems Course

EMA

Energy Management Association

HANSON

Engineering | Planning | Allied Services

Robert Knoedler, P.E., CxA, EMP

Principal – Energy / Cx Services

RKnoedler@hanson-inc.com

CONTINUING EDUCATION AIA