1. What is measurement and verification?
2. Why implement a measurement and verification program?
3. How do you integrate M&V into the Design Process?
What is Measurement and Verification?

According to the Efficiency Valuation Organization (EVO), “M&V is the process of using measurement to reliably determine actual savings created with an ECM and/or Energy Program.”

EVO writes and Updates the International Performance Measurement and Verification Protocol (IPMVP).
IPMVP has 4 M&V Options: A, B, C, D

A. Retrofit Isolation: Key Parameter Measurement

B. Retrofit Isolation: All Parameter Measurement

C. Whole Facility

D. Calibrated Simulation

Choosing Cost Effective M&V Option Depends on Project

A. Retrofit Isolation: Key Parameter Measurement – Utility uses for lighting rebates

B. Retrofit Isolation: All Parameter Measurement - Utility uses for HVAC rebates

C. Whole Facility – Compare utility bills

D. Calibrated Simulation- used for large new buildings and LEED projects
Why do Measurement and Verification?

YOU CAN’T CONTROL WHAT YOU DON’T MEASURE

UI M&V Program and Objectives

- The purpose of M&V is to document the savings from our Energy Program and/or from specific ECMs.
- M&V Plan must balance cost of M&V with project energy savings and required energy information.
UI M&V Program and Objectives

- M&V is cornerstone for Continuous Cx and maintaining Re-Cx savings
  - Actual Energy Usage is compared to Predicted Energy Usage
  - Issues causing higher energy use are identified and resolved
  - Repeat Quarterly

UI M&V Program and Objectives

- LEED EA 5 M&V - 3 Credits for LEED
  - M&V and Metering Plan developed in DDs and refined during construction document phase
  - After Building Occupied:
    - Compare actual energy usage to modeled energy usage monthly & quarterly
    - Model is calibrated and building baseline developed
  - Issues causing higher energy use are identified and resolved early instead of going on for years
How is Measurement and Verification Implemented?

**DESIGN PHASE REQUIREMENTS**

**M&V PLAN Design Dev Phase**

- Identify what IPMVP Option to be used: New Buildings-Calibrated Simulation
- Identify what needs to be measured: Buckets of Energy
  - Lighting
  - HVAC
    - Pumps
    - Fans
    - Cooling
    - Heating
  - Water
- Develop a plan to determine how it will be measured:
  - Gather Base line data
  - Decide on meters, trending, calculations, length of time etc.
  - Screens on the BAS that show the buckets of energy
M&V PLAN - DESIGN Phase

- Identify what IPMVP Option to be used: New LEED Buildings- Option D: Calibrated Simulation
- Identify what needs to be measured
- Develop a plan to determine how it will be measured:
  - Gather Base line data
  - Decide on meters, trending, calculations, length of time etc.

M&V PLAN DD Requirements

- Choose M&V Option A,B,C, or D
- Draft M&V Plan is submitted at DDs for review.
- Include meter schematic for each utility, energy type and BAS interconnections to meters
- Include trending, calculations, and Cx requirements
M&V PLAN Construction Phase

- Cx Agent Verifies that M&V plan is implemented:
  - Electrical sub-metering is installed and measurements are taking place
  - Data is collected for reporting.
  - Reports Reviewed and Acted Upon

M&V PLAN Ongoing

- Data is collected for reporting.
- Heat Maps, 7 day and monthly usage, energy type roll up and other reports reviewed monthly
- Actual usage is compared to modeled usage; model is calibrated and building baseline developed
- Issues causing higher energy use are identified and resolved
- M&V is cornerstone for Continuous Cx and maintaining Re-Cx savings
Design Case Study

University of Iowa
New School of Music Facility

UI School of Music

- 186,000 SF, 6 Levels
- Performance, Rehearsal, Classroom, Studio, Library and Office Spaces
- 63% less energy than 90.1-2007
- Displacement Ventilation, Chilled Beams, Radiant Floor, Standard VAV, Heat Recovery Chillers
- LED Lighting, Daylight Harvesting
Sub-metering System Design Process

1. Define Objectives
2. Define Building Energy Use Categories
3. Analyze Building Energy Flow
4. Determine Meter Placement
5. Design Data Collection Network
Define Objectives

- Provide on-going monitoring of energy efficiency strategies
- Provide metering to support LEED M&V Plan (Option D - Calibrated Simulation)
- Provide detailed performance data for heat recovery chillers
- Measure energy used for snow melt
- Measure energy used for performance lighting

Design Process

1. Define Objectives
2. Define Building Energy Use Categories
3. Analyze Building Energy Flow
4. Determine Meter Placement
5. Design Data Collection Network
Building Energy Use Categories ("Buckets")

- HVAC
  - Heating
  - Cooling
  - Fans & Pumps
- Interior Lighting
- Domestic Hot Water
- Exterior Lighting
- Plug/Process
  - Performance Lighting
  - Snow Melt
  - Receptacles & Miscellaneous

Design Process

1. Define Objectives
2. Define Building Energy Use Categories
3. Analyze Building Energy Flow
4. Determine Meter Placement
5. Design Data Collection Network
Energy Sub-metering for Measurement and Verification

Energy Flow Schematic

Energy Flow Schematic - Sources
Energy Flow Schematic – Domestic Water

Energy Flow Schematic – Site Lighting
Energy Sub-metering for Measurement and Verification

Systems - Chilled Water

Systems - Steam
Energy Sub-metering for Measurement and Verification

Systems - Electricity

Systems - Natural Gas
Systems - Heating Hot Water

Design Process

1. Define Objectives
2. Identify Building Energy Sources
3. Define Building Energy Use Categories
4. Identify Building Energy Loads
5. Analyze Building Energy Flow
6. Determine Meter Placement
7. Design Data Collection Network
Building Energy Use Categories
(“Buckets”)

- HVAC
  - Heating
  - Cooling
  - Fans & Pumps
- Interior Lighting
- Domestic Hot Water
- Exterior Lighting
- Plug/Process
  - Performance Lighting
  - Snow Melt
  - Emergency Power
  - Receptacles & Miscellaneous

Utility / Revenue Meters
Direct Measurement

[Diagram of energy sub-metering for measurement and verification]

Janet Razbadouski, University of Iowa
Dwight Schumm, Design Engineers
Direct Measurement

[Graph showing energy sub-metering for measurement and verification]

Direct Measurement

[Graph showing energy sub-metering for measurement and verification]
Direct Measurement

Energy Sub-metering for Measurement and Verification

Janet Razbadouski, University of Iowa
Dwight Schumm, Design Engineers
Building Energy Use Categories
(“Buckets”)

- HVAC
  - Heating
  - Cooling
  - Fans & Pumps
- Interior Lighting
- Domestic Hot Water
- Exterior Lighting

- Plug/Process
  - Performance Lighting
  - Snow Melt
  - Emergency Power
  - Receptacles & Miscellaneous

Heating
Energy Sub-metering for Measurement and Verification

Heating

Heat Recovery Chillers

\[ \text{COP} = \frac{\text{[Energy Product]}}{\text{[Energy Input]}} \]

\[ \text{COP} = \frac{\text{[Hot Water]}}{\text{[Electricity]}} \]
Heating

Heating = E2

Heating

Heating = E2 \(-\) [Snow Melt]
Heating

Heating = E2 – [Snow Melt]

Snow Melt = H2/COP

Heating = E2 – [Snow Melt] + [S1 – S2]
Heat Recovery Chiller
Heating Output

HRC Heating = H1 (Equipment Performance Meter)

COP = H1/E2

Building Energy Use Categories
(“Buckets”)

- HVAC
  - Heating
  - Cooling
  - Fans & Pumps
  - Interior Lighting
  - Domestic Hot Water
  - Exterior Lighting

- Plug/Process
  - Performance Lighting
  - Snow Melt
  - Emergency Power
  - Receptacles & Miscellaneous
Energy Sub-metering for Measurement and Verification

Cooling

[Diagram of Cooling System]

Cooling

[Diagram of Cooling System]
Cooling

Cooling
Net Cooling

\[ \text{Cooling} = C_1 - C_2 \]

Heat Recovery Chiller

Cooling Output

\[ \text{HRC Cooling} = C_3 \text{ (Equipment Performance Meter)} \]
Building Energy Use Categories
(“Buckets”)

- HVAC
  - Heating
  - Cooling
  - Fans & Pumps
- Interior Lighting
- Domestic Hot Water
- Exterior Lighting

- Plug/Process
  - Performance Lighting
  - Snow Melt
  - Emergency Power
  - Receptacles & Miscellaneous

Receptacles and Miscellaneous Plug Loads

RECEPTACLES AND MISC = E1-E2-E3-E4-E6
Design Process

1. Define Objectives
2. Identify Building Energy Sources
3. Define Building Energy Use Categories
4. Identify Building Energy Loads
5. Analyze Building Energy Flow
6. Determine Meter Placement
7. Design Data Collection Network

Meter Schematic
UI Energy Management
“Measurement & Verification-PI Interface”

PBDB ELECTRIC SUB-METER INTERFACE

**EMON - METERS**
- Lighting
- Process
- Plug

- BACnet MSTP
- BACnet Ethernet Interface
- JCI

**DRIVES:**
- Fans
- Pumps
- Process

- BACnet MSTP
- BACnet Ethernet Interface
- JCI

Janet Razbadouski, University of Iowa
Dwight Schumm, Design Engineers
Energy Sub-metering for Measurement and Verification

Lab Building: PBDB

Pappajohn Biomedical Discovery Building M&V Plan

- Utility Revenue Meters
- Fans and Pump energy from VFD Power Data
- Emon sub-meters for Lighting and Plug Loads
- Heat Maps, 7 day usage, monthly energy types roll up
- Compare model to actual and take corrective action as needed

Building Energy Loads

<table>
<thead>
<tr>
<th>Load Description</th>
<th>Category</th>
<th>Campus Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>HVAC</td>
<td>Electricity, Steam</td>
</tr>
<tr>
<td>Cooling</td>
<td>HVAC</td>
<td>Electricity, Chilled Water</td>
</tr>
<tr>
<td>Fans</td>
<td>HVAC</td>
<td>Electricity</td>
</tr>
<tr>
<td>Pumps</td>
<td>HVAC</td>
<td>Electricity</td>
</tr>
<tr>
<td>Snow Melt</td>
<td>Plug/Process</td>
<td>Electricity, Steam</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>Service Hot Water</td>
<td>Steam</td>
</tr>
<tr>
<td>Interior Lighting</td>
<td>Lighting</td>
<td>Electricity</td>
</tr>
<tr>
<td>Performance Lighting</td>
<td>Plug/Process</td>
<td>Electricity</td>
</tr>
<tr>
<td>Exterior Lighting</td>
<td>Site</td>
<td>Electricity</td>
</tr>
<tr>
<td>Emergency Power</td>
<td>Plug/Process</td>
<td>Natural Gas</td>
</tr>
<tr>
<td>Receptacles</td>
<td>Plug/Process</td>
<td>Electricity</td>
</tr>
</tbody>
</table>
Building Energy Use Categories

- HVAC
  - Heating
  - Cooling
  - Fans & Pumps
- Plug/Process
  - Receptacles
  - Snow Melt
  - Lab Process Loads
- Interior Lighting
- Domestic Hot Water
- Exterior Lighting

Energy Cost Dashboard

Pappajohn Biomedical Discovery Building

Electricity: $88.37
Cost per hour: $54.03

Chilled Water: 0.25
Cost per hour: $1.14

Steam: 0.15
Cost per hour: $0.37

Total Utility Cost: $55.54 per hour
PBDB 7 - DAY HISTORY

PBDB ELECTRIC SUBMETERS
Lab Building: MERF

Medical Education Research Facility

- Return Air Systems for Office and Classrooms
- 100% OA with Heat Recovery for Labs
- T-8 Fluorescent Lighting
- Sophisticated BAS System
Energy Sub-metering for Measurement and Verification

**Energy Cost Dashboard**

Medical Education and Research Facility

- **Electricity**: $77.61 per hour
- **Chilled Water**: $4.29 per hour
- **Steam**: $108.83 per hour

**Total Utility Cost**: $190.73 per hour

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**MERF 7 - DAY HISTORY**

7 Day History

- Electric (KWh)
- Steam (MMBTU)
- Chilled Water (MMBTU)
ENERGY SUB-METERING FOR MEASUREMENT AND VERIFICATION

MERF 24 HR HEAT MAP - ELECTRIC USE

Questions

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