Existing Building Commissioning
Current practices and new developments
BEST Center/ LBNL workshop
January 7th, 2015

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www.quest-world.com
Overview

- What is EBCx?
- EBCx Benefits
- Case Studies
- Need for M&V in EBCx projects
- Guidelines and Tools
What is EBCx?

2 Definitions:

1. **Building Commissioning Association**
   - Similar to new construction Cx
   - Goal is efficient operations meeting owners requirements

2. **Utility Program Definition**
   - Similar to audit/retrofit process
   - A means of acquiring low cost energy savings
BCA Definition

“EBCx is a systematic process for investigating, analyzing, and optimizing the performance of building systems through identification and implementation of Facility Improvement Measures and insuring their continued performance.”

www.bcxia.org
BCA - Scope

- Total Building
- HVAC & Lighting
- Domestic Water
- Control Systems
- Indoor Environmental Quality
- Operations & Maintenance
- Equipment Reliability
- Etc.
Utility Definition

“Retrocommissioning (RCx) is a systematic process for identifying less-than-optimal performance in your facility’s equipment, lighting and control systems and making the necessary adjustments. While retrofitting involves replacing outdated equipment, RCx focuses on improving the efficiency of what’s already in place.”

Utility RCx - Scope

Generally:

- HVAC
- Lighting
- Controls

- Less comprehensive than BCA
- Tends to view “improvements” as units of energy savings
Why EBCx? - Benefits

- 15% energy savings per building on average
  - Mills study, LBNL, 2008
- Improved operations
- Improved indoor air quality
- Better informed and trained operations staff
- Obtain LEED-EBOM (Green Building Certification) credits
  - Many Owners seeking LEED EBOM have already done EBCx/RCx
Case Study

- UC Berkeley Soda Hall
- Case study introduces need for M&V
Project funded under the UC/CSU/IOU Partnership’s Monitoring-Based Commissioning (MBCx) Program

- RCx process enhanced by addition of permanent monitoring capability to understand system performance
  - Diagnostics
  - Savings calculations
  - Savings verification
- Soda Hall (2006):
  - Steam meters added
  - Electric and steam meters connected to Web-based tool
  - Meters provide short-time interval (e.g. 15-min) data.
Soda Hall

- UC Berkeley’s Computer Science Department (24/7 operation)
- 109,000 ft²
- Energy Use Intensity: 174 kBtu/ft²-yr
- 2 - 215 ton chillers (lead/lag)
- Constant Speed Primary/Variable Speed Secondary Chilled Water System
- Two 2-speed, forced draft, open loop cooling towers
- 3 Main VAV AHUs,
  - AHU1 serves building core,
  - AHUs 3 and 4 serve the perimeter, with hot water reheat
- 11 computer room DX units, water cooled with variable speed pumps
- Steam to hot water heat exchanger, 2 variable speed HW pumps
Soda Hall Findings

- Minimum VAV Box Damper Positions at 50%
  - Causes excessive reheat in perimeter zones
  - Little modulation of fan VFD
- Several AHU VFDs broken or not modulating
  - Return to designed VAV operation
  - Return to scheduled operation
- Re-establish supply air temperature set point reset control in AHU1
- Other measures

- Approximately 483,000 kWh (10%), 2.7M lbs/yr steam (51%)
  - Estimated using DOE2 analysis
- Cost reduction $84,000 (14%), Payback 0.7 years
# Soda Hall Measures

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<th>Measure No.</th>
<th>Description</th>
<th>Implementation Date</th>
<th>Energy, kWh/yr</th>
<th>Energy, lbs/yr</th>
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Finding Measures

- Economizer problems

- Cause: Stuck damper
Excessive Building Schedule

- Cause: old building warm-up schedule
Lighting on at Night

- Cause: malfunctioning occ sensors and sweep timers
Chiller Staging

- Unnecessary Chiller Operation
  - # chillers operating vs. ambient temperature

- Cause: improper chiller staging control algorithm
Note on EBCx Energy Savings

- Based on data collected before improvements made
  - Called “ex-ante” savings estimates
  - No standard calculation methodologies for ex-ante savings
## Ex-Ante Savings Calculations

### A Baseline Operation w/ IGV

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<th>Air Flow Rate Profile</th>
<th>Speed</th>
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### D Proposed Operation w/o IGV, w/ VFD High Limit & w/ VFD Modulation

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**Savings** = 24,379 – 7,603 = 16,776 kWh annually
Are Savings Real?

- Savings *estimates* are based on:
  - Design documentation
  - Equipment specifications
  - Monitored operational data
    - Independent data loggers
    - Control system trends
  - Bin models, engineering models, computer simulations, etc.

- Do savings estimates = “real” savings?
  - Model errors
  - Incomplete or inaccurate data
  - Incorrect assumptions
  - Etc.

- Savings calculation effort takes time, focus, & resources away from commissioning the building!
What are risks?

- Savings not delivered, no return on investment
- No means to demonstrate actual savings
- No ability to track energy performance
- Savings do not last:
  - “Soft” measures that can be and often are defeated
Need for M&V in EBCx

Needs:
- Demonstrate actual, verified energy savings benefits of RCx
- Provide a mechanism to determine measure savings persistence
- Smooth process of third party EM&V in public-goods funded RCx programs

Opportunities:
- Standardization of M&V processes for RCx
- Provide information tools for operators and owners to maintain measure savings, and further improve energy performance
What is M&V?

Savings estimates are based on data collected in baseline period.

Verified savings are based on energy measurements before and after improvements.

What is M&V?

Verified savings are based on energy measurements before and after improvements.

Savings estimates are based on data collected in baseline period.
Measurement & Verification

- Partial definition:
  - Savings estimation based on measurements and analysis of energy use before & after EEM implementation, adjusting for conditions

- Measurement Boundary
  - Whole-building (uses main meters)
  - System (uses sub-meters, EMS, or data logger)
  - Individual EEM
M&V Approach

- Select measurement boundary
- Option C - Whole Building
- Option B: Retrofit Isolation (HVAC Systems)
M&V Methods

- Regression analysis
  - Whole building
  - Systems
- Calibrated Simulation
  - Whole building
  - Systems
  - Individual EEMs
- Load and Schedule Calculations
  - Systems
  - Individual EEMs
Back to Case Study

- Regression method selected
  - Energy use totaled each day
  - Ambient temperatures averaged over the day

- Measurement Boundaries
  - Whole building
  - System (HVAC)

- Data
  - 8 months of trended data collected

- System energy data – how to get?
  - “Spot” measurements of kW for constant load equipment
  - Short term logging of variable load equipment kW
    - Corresponding speed data from EMS
    - Relationship between kW and speed developed
Soda Hall M&V: HVAC Systems

Baseline Model:
\[ \text{kWh} = 79.9 \times \text{OAT} + 1129 \]
RMSE = 136 kWh

Post-Install Model:
\[ \text{kWh} = 44.1 \times \text{OAT} - 336 \]
RMSE = 213 kWh
### Costs

<table>
<thead>
<tr>
<th>Building</th>
<th>Metering Costs</th>
<th>MBCx Agent Costs</th>
<th>In-House Costs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soda Hall</td>
<td>$4,442</td>
<td>$62,160</td>
<td>$51,087</td>
<td>$117,689</td>
</tr>
<tr>
<td>Tan Hall</td>
<td>$22,573</td>
<td>$53,000</td>
<td>$15,300</td>
<td>$90,873</td>
</tr>
</tbody>
</table>

- Including all costs, project remains cost-effective:
  - Soda Hall: 1.7 year payback
  - Tan Hall: 0.7 year payback
- Added costs of metering hardware and software did not overburden project’s costs
- Realization rate (CPUC evaluation): > 95%
- UC Best Practices Awards
- In private sector – metering costs lower
  - Existing electric meters
  - Sophisticated EMS systems
Integrating M&V into EBCx
M&V Process

Baseline Period
- Define Scope of M&V Activity
- Identify purpose/goals of M&V activity
- Identify affected systems
- Design the M&V Process
  - Assess Project & Source of Savings
  - Define Approach
- Add points & collect data
  - Energy and indep. variable (OAT, etc.)
  - Bldg. level: gas pulse, steam meter, etc.
  - Systems: Chiller kW, other var. loads
- Document the baseline
  - Equipment inventory and operations
  - Develop baseline energy model
  - Assess baseline model
- Finalize and Document the M&V Plan

Post-Installation Period
- Verify proper performance
- Collect post-installation data
- Develop post-install model
- Verify savings at conclusion of EBCx

Persiste Phase
- Verify continued equipment performance
- Establish energy tracking system
- Provide periodic savings reports

EBCx Process

Scope of Cx Activity
- Identify purpose/goals of Cx activity
- Describe roles of involved parties
- Identify systems included in Cx process

Planning Phase
- Establish bldg. requirements
- Review available info./visit site/interview operators
- Develop EBCx Plan
- Document operation conditions

Investigation Phase
- Identify current building needs
- Facility performance analysis
- Diagnostic monitoring
- System testing
- Create list of findings

Implementation Phase
- Prioritize recommendations
- Install/Implement recommendations
- Commission Recommendations
- Document improved performance

Turnover Phase
- Update building documentation
- Develop final report
- Update Systems Manual
- Plan ongoing commissioning
- Provide Training

Persistence Phase
- Monitor and track energy use
- Monitor and track non-energy metrics
- Trend key system parameters
- Document changes
- Implement persistence strategies

(Guideline p.2)
M&V Guidelines and Tools
Application Protocols and Guidelines

- Bonneville Power Administration
  - Conduit: [https://conduitnw.org/](https://conduitnw.org/)
    - Engineering Calculations with Verification
    - Sampling Reference Guide & Tool
    - **Regression Reference Guide**
    - Equipment or End-Use Metering
      - Option A or B
    - Energy Modeling (Option B or C)
    - Energy Use Indexing (Option C)
    - Existing Building Commissioning Application Guide
    - End-Use Metering (absent baseline) Application Guide
Application Protocols and Guidelines

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      - Option A or B
    - **Energy Modeling (Option B or C)**
    - Energy Use Indexing (Option C)
    - Existing Building Commissioning Application Guide
    - End-Use Metering (absent baseline) Application Guide
California Commissioning Collaborative

- Guidelines for Verifying Existing Building Commissioning Project Savings
- www.cacx.org
- Engineering Calculations with Field Verification
- System or Equipment Energy Measurement (Option A or B)
- **Energy Models Using Interval Data (Option B or C)**
- Calibrated Simulation (Option D)
M&V Tool: What is it?

- Analysis Module within Universal Translator (v3)
  - UT3 provides:
    - Data merge
    - Time interval re-sampling
    - Charting – data quality checks

- M&V Analysis Module provides:
  - Advanced regression modeling
    - Time of week and temperature (LBNL)
  - Model fit and sufficiency checks
  - Savings quantification
  - Uncertainty analysis (beta)
Tool Benefits

- Streamline arduous data preparation functions
  - Data set merging
  - Re-sampling to common time interval

- Streamline difficult analysis
  - Regressions, statistics, uncertainties

- Standardized & Transparent Savings Calculations

- Leverage commonly available 15-min interval data
  - TOU, Smart Meters, sub meters
  - Data loggers
UT3 M&V Tool
Where to Find It?

- [www.utonline.org](http://www.utonline.org)
  - Create account, obtain access

- M&V Analysis Module User Group
  - FAQ, Discussion Forum

**Universal Translator 3 BETA Release (Build 3.0.1403.1816.beta3)**

UTOnline.org and the PG&E Pacific Energy Center are pleased to announce the launch of the Universal Translator 3 (UT3).

The UT3 is the culmination of over 3 years of work to re-develop the Universal Translator 2 to make it fast, reliable and extensible.
Questions?

Thank you!!

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