Monitoring-Based Commissioning: An Update

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University of California
http://uc-ciee.org/

9 June 2011
California Commissioning Collaborative
Monitoring-Based Commissioning (MBCx)
A Paradigm Shift?

Increased emphasis on energy performance monitoring for:

• Identification of commissioning measures
• Savings accounting
• Ensuring persistence of savings
# Monitoring-Based Commissioning (MBCx): An Information-Driven Model?

| **Project design based on:** | Safe Assumptions | Information
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Savings target based on:</strong></td>
<td>(Pseudo?) certainty from up-front estimates</td>
<td>Benchmarking</td>
</tr>
<tr>
<td><strong>Savings documentation based on:</strong></td>
<td>Verification of assumptions</td>
<td>Monitoring</td>
</tr>
<tr>
<td><strong>Confidence in persistence based on:</strong></td>
<td>Historical measure performance</td>
<td>Monitoring</td>
</tr>
<tr>
<td><strong>Acceptable retro-commissioning project criteria:</strong></td>
<td>Short payback period?</td>
<td>Longer payback period (with persistence)</td>
</tr>
<tr>
<td><strong>Overall efficiency potential:</strong></td>
<td>Limited to measures engineers are comfortable estimating?</td>
<td>Includes measures quantifiable through monitoring</td>
</tr>
</tbody>
</table>

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Brief History of Monitoring-Based Commissioning (MBCx)
Part I – Prior to UC/CSU/IOU Partnership

1985-92  PG&E  Thermal Energy Storage & Load Profile Monitoring

1993  SMUD/PECI  1st National Conference on Building Cx

1994-99  California Utilities/LBNL/CIEE  “Diagnostics for Cx & Ops”
        IMDS 160 Sansome Street
        IMDS 925 L Street
        Texas A&M  $3 million annual savings
        California Cx Collaborative

2000-03  SMUD/LBNL/CIEE  Persistence of Retro-Cx
        UC Santa Barbara  $0.5 million annual savings
        CSU Long Beach
        Central Florida State University  $0.1 million annual savings
        UC Merced  Planning and Design
Information Monitoring & Diagnostic System Prototype (early 1990s)

- Data acquisition system
- High quality sensors (power, flows, temps)
- Data visualization tools
- High frequency data
- Automated diagnostic prototype research

LBNL
Supersymmetry

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State buildings energy intensity decreased slightly despite energy intensive buildings coming online. This is probably the best metric of the performance of our buildings. The Energy Team hopes to continue this downward trend for years to come.
Marginal Benefits of MBCx: Persistent Savings, Deeper Savings

Savings from periodic retro-commissioning
Marginal Benefits of MBCx: Persistent Savings, Deeper Savings

Savings from periodic retro-commissioning

1) Added MBCx savings from persistence

Graph showing energy use over time with shaded areas indicating savings.
Marginal Benefits of MBCx: Persistent Savings, Deeper Savings

Savings from periodic retro-commissioning

1) Added MBCx savings from persistence

2) Added MBCx savings from metering and trending
Marginal Benefits of MBCx: Persistent Savings, Deeper Savings

1) Added MBCx savings from persistence
2) Added MBCx savings from metering and trending
3) Added MBCx savings from continually identified new measures

Savings from periodic retro-commissioning
Marginal Benefits of MBCx: Persistent Savings, Deeper Savings

**Cost Comparison:**
Increased initial cost for permanent monitoring and staff training. Repeated Cx consultant fees replaced by ongoing staff costs?
UC/CSU/IOU Energy Efficiency Partnership
Monitoring-Based Commissioning (MBCx) Program Element
Key Features

Funding for:
• Permanent Monitoring
  – Meters
    • Whole-Building Energy
    • Sub-System
  – Telemetry
  – Trending Software
• Commissioning Consultants
  – Emphasis on Training for Campus Staff
• In-House Staff

2004-05 Pilot Years
• 25 Campuses
  – 37 Building Projects
  – 9 Plant System Projects
  – over 7 million gross square feet
    (~ half laboratory or other energy intensive buildings)
2004-05 UC/CSU/IOU Pilot Partnership
Pilot Program Parameters

• 100% of Project Costs Subsidized

• Very High Incentives:
  ~$0.48+ per (annual) kWh reduction
  “per kW” incentive for average peak period reduction
  ~$3.00+ per (annual) therm reduction
Key Innovative MBCx Program Design Features (Paradigm Shifts?)

- **Savings Targets (vs. Estimates)**
  - Potential to exceed goals

- **Targeting Reduction of Peak Electricity Use**
  - Aligned with reducing customer energy costs
  - Lots of waste on-peak

- **Diagnostics through Trend Analysis**
  - Expands potential beyond measures engineers are comfortable estimating

- **Efforts to Achieve Persistence**
  - Permanent Monitoring/Trending
  - Staff training

- **Savings Accounting Based On Measurement**
  - Observed savings (as opposed to assumed savings)

- **Portfolio Approach**
  - Confidence based on track record of program approach
### 2004-05 MBCx Program Results vs. Program Goals (Cx plus Hybrid Projects)

<table>
<thead>
<tr>
<th></th>
<th>Reduction in Energy Use</th>
<th>Nominal Annual Cost Savings</th>
<th>Total Project Funding</th>
<th>Simple Payback on Funding (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Electricity (kWh/year)</td>
<td>Demand (average during peak period) (kW)</td>
<td>Natural Gas (therms/year)</td>
<td></td>
</tr>
<tr>
<td>Program Commitment</td>
<td>7,387,726</td>
<td>919</td>
<td>302,560</td>
<td>$987,308</td>
</tr>
<tr>
<td>Sum of Project (Portfolio) Targets</td>
<td>9,146,082</td>
<td>1017</td>
<td>579,793</td>
<td>$1,438,415</td>
</tr>
<tr>
<td>Sum of Project (Portfolio) Results</td>
<td>12,229,376</td>
<td>1,370</td>
<td>807,550</td>
<td>$2,155,637</td>
</tr>
<tr>
<td>% of Program Commitment</td>
<td>165%</td>
<td>149%</td>
<td>266%</td>
<td></td>
</tr>
<tr>
<td>% of Portfolio Target</td>
<td>135%</td>
<td>135%</td>
<td>139%</td>
<td></td>
</tr>
</tbody>
</table>
Process Case Study
from UC/CSU/IOU MBCx Program
(1 of 3)

1) Install monitoring augmentation
   Upgrade building power and gas meters
   Add energy information system (EIS) front end for trending

2) Verify historical energy use baseline
   with new equipment and existing building chilled water meter
Process Case Study  
from UC/CSU/IOU MBCx Program  
(2 of 3)

3) Monitor for two days in warm weather  
   Identify chilled water loop imbalance

4) Adjust controls to allow proper chilled water flow to coil

5) Observe fan speed reduction of 40%+  
   peak demand reduction & net energy use reduction incl. chiller plant

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6) Document post-measure energy use

7) Continue trend evaluation to ensure persistence of savings with changing building operation and use

Could this measure have been identified by other means? Probably

Was it identified prior to the MBCx project? No
MBCx Typical Findings

• Mis-located temperature sensors
• Control errors
• Unintended nighttime operation of air handlers, chillers, boilers, lighting
• Poorly tuned control loops
• Valve cycling/alternating heating and cooling
• Excessive simultaneous or sequential heating and cooling
• Broken actuators (e.g. Chilled water valves and economizers)
• Mis-calibrated thermostats
• Chilled water flow imbalance
Peak Period Energy and Demand Reduction with MBCx (Partial List)

- Reduction of on-peak simultaneous heating and cooling
- Enabling of variable frequency drives
- Elimination of valve cycling/alternating heating and cooling
- Repair of stuck chilled water valves or broken economizers
- Calibration of thermostats
- Optimization of chiller water temperature/flow
- Adjustment of lab ventilation rates to campus standard levels
# 2004-05 MBCx Program Results: Cx-Only Projects
(comparison with 2004 Cx meta-analysis)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median / Project Average / Aggregate (Range)</td>
<td>Median / Project Avg.</td>
<td>Median / Project Avg.</td>
</tr>
<tr>
<td>Electricity</td>
<td>9% / 8% / 9%</td>
<td>9% / 11% (N=46)</td>
<td></td>
</tr>
<tr>
<td>Peak Electricity</td>
<td>5% / 6% / 6%</td>
<td>2% / 7% (N= 3)</td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>9% / 15% / 13%</td>
<td>6% / 13% (N=19)</td>
<td></td>
</tr>
<tr>
<td>Chilled Water</td>
<td>17% / N/A / 22%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot Water/Steam</td>
<td>12% / 23% / 18%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Thermal</td>
<td>36% / 37% (N=16)</td>
<td>36% / 37% (N=16)</td>
<td></td>
</tr>
<tr>
<td>Total Source Energy</td>
<td>10% / 9% / 10% (0% - 30%)</td>
<td>13% / 16% (N=46)</td>
<td>8% / 9% (N=24)</td>
</tr>
<tr>
<td>Total Site Energy</td>
<td>11% / 11% / 11%</td>
<td>15% / 19% (N=46)</td>
<td>8% / 9% (N=24)</td>
</tr>
<tr>
<td>Simple Payback Period</td>
<td>2.2 / N/A / 2.1 (0.8 - 6.8)</td>
<td>1.0 / 2.1 (N=98)</td>
<td>1.5 / 2.7 (N=36)</td>
</tr>
</tbody>
</table>

Notes: Aggregate savings results exclude failed sites with no savings and no baseline information

One project resulted in a large shift of energy use from the building to the plant, rendering the average of values for chilled water meaningless

Simple payback project average cannot be calculated with a few projects having no savings.
MBCx Lessons Learned

- Procurement can cause significant delays

- Project Management skills are important
  - material procurement, Cx agent management
  - funding program schedule requirements
  - staff time
  - MBCx can be complex

- Have contingency funds for repairs and anticipated efforts

- Check accuracy of installed metering!
MBCx Lessons Learned - continued

• Internalize the process and lessons to be able to continuously commission the building
  – Have campus staff work closely with Cx Agent

• Look for innovative measures
  – Free cooling to cool computer rooms at night
  – Isolation dampers to eliminate conditioning on unused floors at night

• Potential for natural gas savings often underestimated

• Murphy lives and he must be fought!
Key UC/CSU/IOU MBCx Program Design Changes for 2006-08

• Lower Incentive Rates:
  – $0.24 per kWh
  – $1.00 per therm
  (incentives reduced to < 50% of project costs on average)

• Benchmarking to assist project selection (UC)

• Savings accounting requirements have more emphasis on IPMVP Option C—Whole Building Measurement
Measurement Protocol Guidance for the 2006-08 UC/CSU/IOU Partnership Program

• IPMVP Option C – Whole Building
  – Savings determined by measuring energy use at whole facility level
  – Continuous measurement
  – Adjustment for post-implementation conditions
• Compromises for the Partnership Program
  – Typical Savings: minimum 5% expected
  – Independent Variables
  – Measurement Period
# 2009 and 2006-08 MBCx Program Results

(comparison with 2004-05 and 2004 Cx meta-analysis)

<table>
<thead>
<tr>
<th></th>
<th>UC/CSU/IOU Partnership</th>
<th>2004 Cx Meta Analysis (Mills et al)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preliminary 2009 N=8</td>
<td>Preliminary 2006-08 N=44</td>
</tr>
<tr>
<td><strong>Reduction in Energy Use:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12% / 14%</td>
<td>9% / 9%</td>
<td>9% / 8% / 9%</td>
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<tr>
<td>Peak Electricity</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Simple Payback Period</strong></td>
<td>2.9/3.1</td>
<td>2.3 / 2.1</td>
</tr>
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Notes: 2006-08 projects include one small project with no savings, one small project with 62% savings. 2006-08 projects include projects with simple payback periods ranging from 0.5 years to a small project with no savings (no payback).
Key UC/CSU/IOU MBCx Program Design Improvement for 2009-12

• Incentives limited to 80% of project costs

• For UC, a bond-funded loan program established to provide balance of project costs

• Incentives Paid on Actual Savings
  – (as opposed to targeted savings in 2004-05 and 2006-08)
# 2009 and 2006-08 MBCx Program Results
(comparison with 2004-05 and 2004 Cx meta-analysis)

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<td></td>
<td>Preliminary 2009 N=8</td>
<td>Preliminary 2006-08 N=44</td>
<td>2004-05 N=24 (median)</td>
<td>Full Data Set (incl. Texas A&amp;M Sites)</td>
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Monitoring-Based Commissioning (MBCx) Signature Trend: UC Berkeley Tang Hall—Student Health Services Building
Monitoring-Based Commissioning (MBCx) Signature Trend: UC Berkeley Le Conte Hall (Physics Department)

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Long-term MBCx: How to Track?

Current Accounting Paradigm

Savings

Time (~ 15 years)

Energy Use
Marginal Benefits of MBCx:
Proven ("provable") Savings?

1) Savings from periodic retro-commissioning
2) Added MBCx savings from persistence
3) Added MBCx savings from metering and trending
4) Added MBCx savings from ongoing identification of new measures
Monitoring-Based Commissioning: How Successful in Shifting Paradigms?

- **Savings Targets (vs. Estimates)**
  - Progress: protocols established for 2006-08
  - Progress: Incentives paid on actual savings starting in 2009

- **Targeting Reduction of Peak**
  - Disappointing: incentive eliminated in 2006, fewer sites targeting peak, program credit/accounting not aligned with price signals

- **Diagnostics through Trend Analysis**
  - Progress: trends often used, sometimes embraced by consultants

- **Savings Accounting Based On Measurement**
  - Slow progress: calibrated modeling still used (“assumed” savings)

- **Efforts to Achieve Persistence**
  - Do necessary steps fit current program models?

- **Portfolio Approach**
  - Progress: confidence based on successful 2004-05 program
## Brief History of Monitoring-Based Commissioning (MBCx)
### Part II – UC/CSU/IOU and Beyond

<table>
<thead>
<tr>
<th>Year</th>
<th>Partnership</th>
<th>Campaigns</th>
<th>Savings/Target</th>
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</thead>
<tbody>
<tr>
<td>2004-05</td>
<td>UC/CSU/IOU Partnership</td>
<td>CSU/UC Campuses</td>
<td>$2.4 million savings*</td>
</tr>
<tr>
<td></td>
<td>CEC PIER/CIEE</td>
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<tr>
<td>2006-08</td>
<td>UC/CSU/IOU Partnership</td>
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<td>$3.8 million annual savings*</td>
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<tr>
<td></td>
<td>CCC/IOU Partnership</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>CAHES Conference</td>
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<td>$2.4 million annual savings*</td>
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<td></td>
<td>Best Practice Awards</td>
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<tr>
<td>2009-10</td>
<td>UC/CSU/IOU Partnership</td>
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<td>$1.7 million annual savings*</td>
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<tr>
<td>2009-12</td>
<td>EnerNoc 3rd-Party Programs</td>
<td>PG&amp;E Service Territory</td>
<td>$3 million annual savings target*</td>
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<tr>
<td></td>
<td></td>
<td>SCE Service Territory</td>
<td>$3 million annual savings target*</td>
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<tr>
<td>2011-</td>
<td>UC/CSU/IOU Partnership</td>
<td>Public Energy Dashboards</td>
<td>$6 million annual savings target*</td>
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<tr>
<td></td>
<td></td>
<td>UCSD, UCB, UCSB,…</td>
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</tr>
</tbody>
</table>

* $0.13 per kWh
* $1.00 per therm
* includes hybrid MBCx/retrofit projects for UC/CSU/IOU Partnership
Monitoring-Based Commissioning
Future Trend

Campus Energy Dashboards (Public):

UC San Diego  http://energy.ucsd.edu/index.html
UC Berkeley    http://dashboard.berkeley.edu/building/
UC Santa Barbara http://energy.ucsb.edu/ASP-HTM.asp
UC/CSU/IOU Energy Efficiency Partnership Program
2004-05 Pilot Years

Monitoring-Based Commissioning (MBCx) Partner Team
Mark Bramfitt, Pacific Gas and Electric (PG&E, Co-chair)
Karl Brown, UCOP (Co-chair)
Maric Munn, UCOP
Ryan Stroup, PG&E (Lead for MBCx Training and Education)
Len Pettis & Aaron Klemm, CSU
Paul Kyllo & Tony Pierce, Southern California Edison
Randall Higa, Southern California Gas
Guy Hansen, San Diego Gas and Electric
Keith Marchando, Sonoma State University
Jim Dewey, UC Santa Barbara

MBCx Team Consultants
Richard Sterrett, Alternative Energy Systems Consulting
Mike Anderson, Matt Sullivan & Andrew Meiman, Newcomb Anderson McCormick
Ziyad Awad, Awad & Company
UC/CSU/IOU Energy Efficiency Partnership Program
2004-05 Pilot Program Years

Monitoring-Based Commissioning Support Organizations

Portland Energy Conservation, Inc (PECI)
Project Scoping Consultant to Campuses
MBCx Curriculum Development & Lead Instructor(s)

California Energy Commission
Public Interest Energy Research (PIER) Program
Technical Support (LBNL)
MBCx Case Studies and Needs Assessment
Monitoring (EIS) System Architecture
Benchmarking
MBCx Curriculum Development (PECI thru New Buildings Institute)

Commissioning Providers
Monitoring-Based Commissioning
Contacts and References

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Background/ Documents: