Existing Building Commissioning
(or Retro-Commissioning)

SERBCA Annual Meeting
Covington, KY
December 6, 2013
Session Learning Objectives

- Definition of Existing Building Cx / RetroCx
- Challenges to maintain system optimization
- Benefits from EBCx
- EBCx / RetroCx Process
- Facility Management Practices
- Persistence of Savings
- Performance Monitoring and Tracking
- Case Study
Existing building commissioning (or Retro-commissioning) is a systematic, documented process that identifies low-cost operational and maintenance improvements in existing buildings and/or systems, and brings the buildings (or systems) up to the design intentions and optimal performance of their current usage.
Existing Building Commissioning (EBCx) or “Retro-Commissioning”

- For existing buildings and facilities that have been in service, but never commissioned
- Optimize the performance of existing building systems with respect to current usage and occupancy, working with the building’s operating and maintenance staff.
- Applicable to building systems that can continue to provide service without making major capital improvements
- Look for ‘Low Hanging Fruit’ – often start with Level I energy audit
Challenges to Maintain System Optimization (and Savings)

- Deterioration of equipment (system) performance over time
- Lack of resources – capital and time
- Vague or undefined policies and procedures
- Limited communications between operators and management
- Lack of available data – metering, etc.
- Insufficient tools to collect and analyze data
- Lack of training on tools’ applications and strategies
Benefits of Existing Building Commissioning (EBCx)

- Identifying problems in the system(s)
- Energy and related cost savings
- Documenting the existing systems’ function and performance – improved building documentation
- Benchmarking the performance of existing systems for future changes
- Better understanding / training of O&M operators – improved expertise, reduced operating cost
- Improved IEQ and occupant comfort
- Identification of new energy saving opportunities
Existing Building Cx (RetroCx) Process

Planning Phase
- Select the project
- Set project objectives and obtain support
- Select a commissioning lead
- Document the current operating requirements
- Perform an initial site walk-through
- Develop the Retrocommissioning Plan
- Assemble the retrocommissioning team
- Hold a project kick-off meeting

Investigation Phase
- Review facility documentation
- Perform diagnostic monitoring
- Perform functional tests
- Perform simple repairs
- Develop Master List of Findings
- Prioritize and select operational improvements

Implementation Phase
- Develop Implementation Plan
- Implement selected operational improvements
- Verify results

Hand-Off Phase
- Develop Final Report
- Compile a Systems Manual
- Develop Recommissioning Plan
- Provide training
- Hold close-out meeting
- Implement persistence strategies
The EBCx / RetroCx Process

Three Stages – Four Phases

Pre-Implementation Stage

1. Planning Phase
   - Project Selection
   - Develop Goals, Scope and Team
   - Develop Cx Plan and hold Kick-off Meeting

2. Investigative Phase
   - Review documentation, utility bills
   - Perform Site Assessment
   - Implement Diagnostic Monitoring and Testing, as required
   - Analyze data and identify recommended measures
The **EBCx / RetroCxC Process**

**Implementation Stage**

1. Implementation Phase
   - Implement selected recommendations from Investigative Phase

**Post-Implementation Stage**

1. Final Adjustment
   - Re-test and Re-monitor
   - Train Operators

2. Hand-off and Acceptance
   - Develop Persistence Strategies
   - Final Report
Planning Phase Elements

- Select the in-house team
- Define the scope, objectives and deliverables (work products)
- Hire the Cx Provider
- Develop the RetroCx Plan based upon the scope
- Hold a Kick-off Meeting
What should a **RetroCx Plan** include?

- General Building Information – Contact Information
- Project Objectives and Brief Building Description
- Brief Systems Description (involved in RetroCx)
- Roles and Responsibilities
- Lines of Communication and Work Protocols
- Schedule
- Testing and Diagnostic Plan Outlines
- Discussion of analytical tools to be employed
- Implementation of Recommendations
- List of Project Deliverables
Kick-Off Meeting

Purpose:

• To impart the Owner’s objective for the project
• To discuss and agree to the RetroCx Plan
• To clarify the key roles and responsibilities of commissioning team members
• To identify and agree to schedules
• To define the work protocols and policies
• Document the meeting
Investigation Phase Elements

- Gather building documentation and utility bills
- Perform Site Assessment
- Obtain trend logs and/or perform functional testing
- Develop a Master List of Findings, performing analysis to determine which improvements provide the greatest benefit
- Develop Recommendations
  - Focus on long lasting operating improvements with short paybacks
  - May include capital improvement opportunities
  - May include training recommendations
Site Assessment Form

- Use standard form for review of documentation, site walk-thru and discussions with On-site personnel
- Review existing installation and condition of equipment
- Observe current system operation and controls
- Discuss current schedule and any planned changes to building use or schedule
Investigation Assessment

Verify building documentation

- Original design intent / current operating requirements
- Drawings / Control sequences of operation
- Utility bills

Verify actual operation (and procedures)

- Interview Owner’s staff and contractors
- Implement diagnostic monitoring (trend logs) and testing
- Develop Master List of Findings
- Analysis to identify recommended measures
## Utility Bill Review

**METER #:** 105548  
**ELECTRIC RATE:** E46 - General Service Medium Electric  
**TURN ON DATE:** 2/4/1999  
**MULTIPLIER:** 900  
**latest 12 month**  
**monthly average**  
**$35,432.43**

<table>
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<tr>
<th>Service</th>
<th>Read Date</th>
<th>Reading</th>
<th>kWh Usage</th>
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<th>Customer Charge</th>
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<th>Fuel Adj. Factor</th>
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<td>$1,468.42</td>
<td>$53,813.91</td>
<td>64.2%</td>
</tr>
</tbody>
</table>

**Total**

- **$35,432.43**
Utility Bill Analysis

Analysis:

- Calculate benchmark numbers, kWh / SF, MBtu/SF, $ / SF, etc.
- Look for trends and/or unusual consumption
- Compare to national averages (Energy Star, etc.)
- Establish weighted unit costs for utilities
Utility Bill Analysis - Graphics

Graphical Representation compares annual or monthly trends

Can be used to compare facility under study to database benchmarks
Diagnostic Monitoring and Testing

Types:

- BAS Trend Logging
- Portable Data Loggers
- Functional testing in conjunction with data and trend logging
- Manual testing
## What Data is Needed?

<table>
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<tr>
<th>To Assess / Diagnose</th>
<th>You Have to Know / Measure</th>
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<tr>
<td>Temperature Control</td>
<td>- Temperature</td>
</tr>
<tr>
<td>Ventilation Control</td>
<td>- Carbon Dioxide</td>
</tr>
<tr>
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<td>- Humidity</td>
</tr>
<tr>
<td>Lighting Control</td>
<td>- Lighting Levels (foot-candles)</td>
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<tr>
<td></td>
<td>- Lighting zones / schedules</td>
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<tr>
<td>Equipment Runtime / Percent Load</td>
<td>- Operating schedule(s)</td>
</tr>
<tr>
<td></td>
<td>- Current</td>
</tr>
<tr>
<td>Mechanical System Efficiency</td>
<td>- Flow (air or water)</td>
</tr>
<tr>
<td></td>
<td>- Temperature</td>
</tr>
<tr>
<td></td>
<td>- Power Consumption</td>
</tr>
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</table>
Trend Log Analysis

- Review equipment status (On / Off) to see if it aligns with schedules.
- Identify analog readings that are outside of anticipated range (improper setpoints, bad sensors?)
- Review readings to see if they align with sequence of operation (temp. setback of decks, dampers closed during warm-up, coils inactive during economizer operation, etc.)
- Identify suspicious trends to be examined further during functional performance testing.
Functional Performance Tests

- Specific functional tests are developed for each project, using standard templates.
- Tests based upon sequence of operation included in documents, control drawings and BAS programs.
- Tests include ‘integrated system’ testing with inter-related equipment.
- Tests address normal operation, site observation of components and review of BAS status and measurements.
Master List of Findings

List should include:

- Item Number
- Equipment or System ID No. or Name
- Description of Finding
- Recommended Improvement
- Estimated Savings ($/Yr.) or Benefit
- Estimated Cost to Implement
- Payback (Years)
- Recommended Implementation Strategy (optional)
Master List of Findings Form

- Identify various findings, which could include: deficiencies, O&M measures and capital expense measures

- Identifies items as:
  C = Completed during investigation
  I = To be addressed during Implementation phase
  D = Deferred Capital Improvement

- Allows room to address action(s) ‘taken’ or ‘recommended’ and associated date(s)
Analysis of Findings / Recommendations

- Determine level of analysis required, i.e. worksheet, spreadsheet, computer modeling
- Consider all costs for implementation; capital, O&M, replacement.
- Include projected escalation in utility rates
- May need to consider other items: reliability, cost of downtime.
- Calculate payback / ROI
Energy Modeling – Recommended Measures

- System optimization; comparing alternate bldg. / system measures
- Life cycle costing of alternatives
- Determine interactivity of proposed alternatives
- Predict operating costs
- Required for Code compliance, LEED EA Credit 1, Utility incentives
Energy Modeling – Program Tools

- DOE-2 based tools
  - eQuest
  - Visual DOE (front-end to DOE 2.1E)
  - Energy-10™ (NREL)

- Other Programs
  - BLAST
  - Carrier HAP
  - Trane Trace / System Analyzer
  - TRNSYS
  - IES
Implementation Phase Elements

• Meet with Client to select Measures arising from Investigative Phase
• Develop a detailed implementation plan, scopes of work, and budget
• Implement the selected cost-effective improvements (and capital measures)
• Verify and document results
Hand-off Phase Elements

- Develop Persistence Strategies
  - Re-commissioning Plan
  - Energy tracking and re-benchmarking
    - Continuous re-commissioning activities (M&V)
  - Update PM program
  - Redefine responsibilities
  - Training

- Develop the Final RetroCx Report

- Hold a Project Close-out Meeting
  - Present Final RetroCx Report and Persistence Plan
Final Report Elements

- Executive Summary
- Introduction – Project Objectives
- Methodology – data collection / analysis
- Baseline and Facility Description – Current Requirements
- Findings and Recommendations
- Implementation Results
- Persistence strategies
- Appendix – Photos, trend logging figures, utility history analysis, results of functional testing, ReCx plan, summary of measures and savings, etc.
Top 10 Findings - Retro-Commissioning

1. Schedule HVAC Systems
2. Adjust Outdoor (Ventilation) Air to Proper Demand
3. Mitigate Simultaneous Heating and Cooling
4. Reduce Flow from Oversized Pumps
5. Reset Supply Air Temperatures
6. Enable Economizer Controls
7. Reset Static Pressures/Optimize VFD Operation
8. Stage Chillers Properly
9. Lower Condenser Water Setpoints
10. Correct Lighting Control Operation

Source: SERVIDYNE and PECI
Potential Problems – Air Distribution Systems

Design, Installation, Set-up / TAB Problems
- Improper programming sequence
- Coils piped backwards
- OA damper occupied / unoccupied set points
- VAV damper actuator / calibration
- Service access restricted
- Space thermostat calibration
- Sensors in wrong location
- VFD / fan sheave sized for ‘max concurrent’ operation

Controls, Operation, Maintenance Problems
- Overridden BAS temp space set points
- Increased VAV airflow set points
- High duct static DP set point
- Disabled duct static DP reset logic
- Decreased cooling coil setpoint
- Preheat and Cooling coil fighting
- Disable supply air temp reset logic
- Actual OA damper position
- Dirty filters
Potential Problems – Central Plants

- Sequencing (Add / Subtract) Logic
- Incorrect Setpoints – Chilled and/or condenser water
- Poor water treatment – excessive fouling
- Chillers, pumps, tower fans in ‘manual’ operation
- Controlling sensor calibration
- Isolation valves – chillers / towers
Case Studies

#1 HVAC System Operators and Controls Vendor not familiar with Basis of Design – Engineer’s Intent

#2 HVAC Operators not trained on where ‘optimized’ operating points are in system

#3 Finding ‘hidden capacity’ as a result of improper system operation

#4 Improper sequencing of equipment – multiple chillers, pumps, tower fans running, when not needed

Most Common – CONTROLS not Optimized
Facility Management Practices

Establish practices – communicate and enforce

• Energy goals / targets need to be clearly defined
• Identify team – include management, facility operators and User representatives.
• Define collection, analysis and reporting process and responsibilities
• Change operational / management policies
• Ensure adequate training at all levels – O&M equipment, data collection, performance tracking tools, etc.
• Develop design standards and review process

Allocate sufficient time and resources to complete efforts
Ensuring ‘Persistence of Savings’

Engage Facility O&M Staff

• Conduct periodic training in modules
• Explain roles and responsibilities related to energy use
• Not only O&M procedures, but also energy basics and ‘spotting energy saving opportunities’
• Develop method of evaluating staff knowledge – incentive program tied to expertise / suggestions
• Train Senior operators and managers to be ‘future trainers’
Ensuring ‘Persistence of Savings’

Good Documentation

- Implemented measures, RetroCx findings, energy and demand savings estimates, and operations & maintenance procedures

Measurement & Verification

- Verify implemented modifications to systems perform as expected
  - Compare energy consumption and costs against models and historical database benchmarks
Ensuring ‘Persistence of Savings’

Employee Engagement / Social Marketing

- Solicitation of energy saving ideas from staff
- Pre- and Post-implementation surveys
- Identifies barriers to change
- Monitors changes in behavior
Importance of Measurement and Verification (Monitoring)

• Verify implemented modifications to systems perform as expected
• Compare energy consumption and costs against models and historical database benchmarks
• Needed to document compliance for various legislative requirements and for programs
• Critical in evaluating ESCO performance contracts
Performance Monitoring and Tuning

Energy Performance Tracking Tools
- Benchmarking
- Building automation systems (BAS)
- Energy information systems (EIS)
- Energy anomaly detection (EAD)
- Fault detection and diagnostic tools (FDD)

Predictive / preventative maintenance systems

IT Convergence with Building Operations
Evaluating Results

- Evaluate returns: energy and cost savings, improved performance, increased reliability, reduced maintenance, extended life, etc.
- Typical Owners expect payback within 2 years
- Comprehensive study of 100 buildings by LBNL
  - Electrical savings between 5% and 15%
  - Gas savings between 1% and 23%
  - Payback ranges between 0.2 years and 2.1 years
## Cost Benefits of Retro-Commissioning

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<tr>
<th>Bldg. Type</th>
<th>No. of Bldgs.</th>
<th>Energy Savings $/Sq Ft/Yr *</th>
<th>Payback Yrs</th>
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<td>Hospitals</td>
<td>6</td>
<td>$0.43</td>
<td>1.1</td>
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<tr>
<td>Lab/Offices</td>
<td>7</td>
<td>$1.26</td>
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<td>Offices</td>
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<td>Schools</td>
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<td>$0.17</td>
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<td><strong>Avg./Total</strong></td>
<td><strong>28</strong></td>
<td><strong>$0.54</strong></td>
<td><strong>0.7</strong></td>
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</table>

* - In addition, Non-energy savings of $0.11 - $0.45 /Sq Ft/Yr, including: equipment life, thermal comfort, IAQ, productivity, decreased liability

Source: Texas A&M ESL
Medical Center EBCx Project

- 97,800 SF – 12 years old
- Automated Logic DDC System
- Initial Energy Star Score – 2
- Qualified for utility company RetroCx program
## Cost Benefits - Medical Center Project

<table>
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<th>Description</th>
<th>Cost</th>
<th>Savings</th>
<th>Payback</th>
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<td>ECM-1</td>
<td>Reduce HVAC Equipment Operating Hours</td>
<td>$17,000</td>
<td>$54,156</td>
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<td>ECM-2</td>
<td>Provide Demand Control Ventilation for Air Handling Units A through D</td>
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<td>ECM-3</td>
<td>Install building pressurization sensors and variable frequency drives on select exhaust fans</td>
<td>$10,500</td>
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<td>ECM-4</td>
<td>Shutdown supplemental air handling units AH-1, AH-2 and AH-3 when areas are not occupied</td>
<td>$1,900</td>
<td>$535</td>
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<td>ECM-5</td>
<td>Update remaining variable air volume (VAV) terminal unit controls and reheat coils and integrate into DDC system</td>
<td>$104,000</td>
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<td>ECM-6</td>
<td>Replace incandescent lamps with compact fluorescent lamps</td>
<td>$680</td>
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<td>ECM-7</td>
<td>Install lighting control system(s)</td>
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<td>Integrate Power Logics meter into Automated Logic BAS</td>
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<td>Building Air Balance</td>
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<td><strong>Project Totals</strong></td>
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<td><strong>$108,292</strong></td>
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* - Reduce savings total by 5%, to $102,877, if all ECMs are implemented to accommodate interactive effects. Payback at reduced savings total is 1.906 years.
Energy Reporting - Local Mandates

- New York City – Greener, Greater Building Plan – 2009
  Building Performance, Energy Conserv., Audit, RetroCx, Submetering

- San Francisco – Feb. 2011
  Audit, Benchmark, Report (RetroCx)

- Minneapolis – Feb. 2013
  Audit, Benchmark, Report (RetroCx)

- Boston – June 2013
  Benchmark, Report (RetroCx)

- Chicago – July 2013
  Benchmark, Report (RetroCx)

- Columbus, Cleveland, 8 other major cities .....
Market Potential for RetroCX

- Existing building commissioning (RetroCX) industry has reached about $200 million / year in the U.S. (still in its infancy)

- If one establishes a goal to commission each building every five (5) years, the potential size is approximately $4 billion per year

- To achieve the goal of keeping existing buildings in the U.S. commissioned, it will require an increase in the workforce from approx. 1,500 to 25,000 F.T.E. workers

- While a challenge, it appears realistic given the number of workers in related trades
Questions ???
Thank You!

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