Understanding the Retro-Commissioning Process

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ldings work. *Better.*

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Poor Building Performance

Building commissioning is an important aspect of *new* construction projects as a process of ensuring that new buildings and their systems perform as designed. **Unfortunately, most buildings have never gone through any type of commissioning** or quality assurance process and are therefore performing well below their potential.

"Quick Fix" Solutions

- Maintenance staff try to correct problems
- Severe time constraints
- Poor documentation
- Makeshift solutions
- May lead to other problems
- May cause unintended consequences

Beyond Quick-fix

- Retro-commissioning (Retro-Cx) goes beyond quick fix
- Determines root causes of building problems
- Optimizes building systems
- Optimizes control sequences for efficient and effective HVAC operation
- Often reduces or eliminates need for capital improvements

Why Commission Anything?

- An LBNL study of 60 buildings of different types showed that:
  - Over 50% had control problems
  - 40% had HVAC equipment problems
  - 15% had missing equipment
  - 25% had BAS with economizers, VFDs, and advanced applications that were simply not operating correctly.

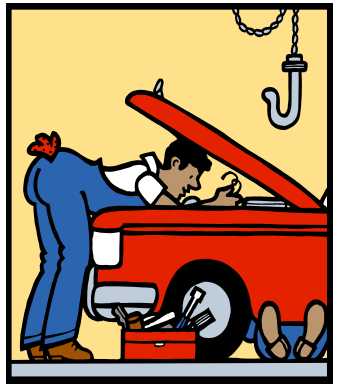
Source: Assoc. of State Energy Research Technology Internships and US Department of Energy

Heard of these??

- Complaints about being too hot or too cold??
- Air quality complaints or concerns??
- Building systems not cooling adequately??
- Constant “call backs” to Service Contractors for issues??
- Systems doing the “opposite” of what you would otherwise expect??
- Lights on at night or lights on when daylighting indicates they should be off??
- High energy bills??

Why Retro-Cx Anything?

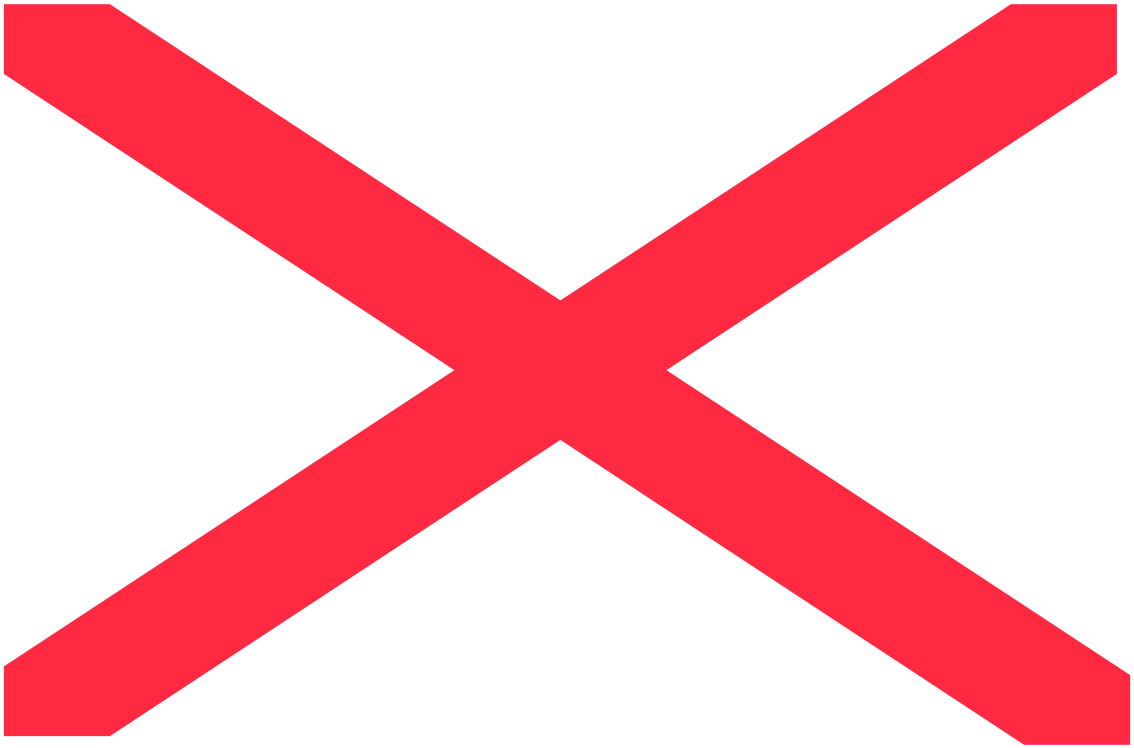
- Energy savings
- Space complaints – temperature, IAQ, etc.
- Bldg. changes from original intent
- Modifications made to system components
- Undocumented changes to controls sequences, set points
- Building not operating efficiently against benchmarks



THINK ABOUT IT AS A BUILDING

"TUNE-UP!!"

Commissioning Definitions



"Flavors" of Commissioning

- Building commissioning (Cx)
- Recommissioning (ReCx)
- Continuous commissioning (CC)
- Retro-commissioning (Retro-Cx)

Commissioning

Total building commissioning (Cx) is the systematic **process** of assuring by test verification and documentation, from the design phase to a minimum of one year after construction, that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs.

Recommissioning

Recommissioning (ReCx) applies only to buildings that have previously been commissioned or retro-commissioned. The original commissioning process documented that the building systems performed as intended at one point in time. The **intent of recommissioning** is to help ensure that the benefits of the initial commissioning process endure.

Continuous Commissioning

Continuous-commissioning (CC) is an “on-going process” to resolve operating problems, improve comfort, and continually optimize energy use for existing buildings.

Retro-Commissioning

Retro-commissioning (Retro-Cx) is a systematic process for improving the current conditions and operations of an existing building, to ensure the functionality of equipment and systems and also to optimize how they operate together to reduce energy waste and improve building operation and comfort – applies to buildings that have never been commissioned.

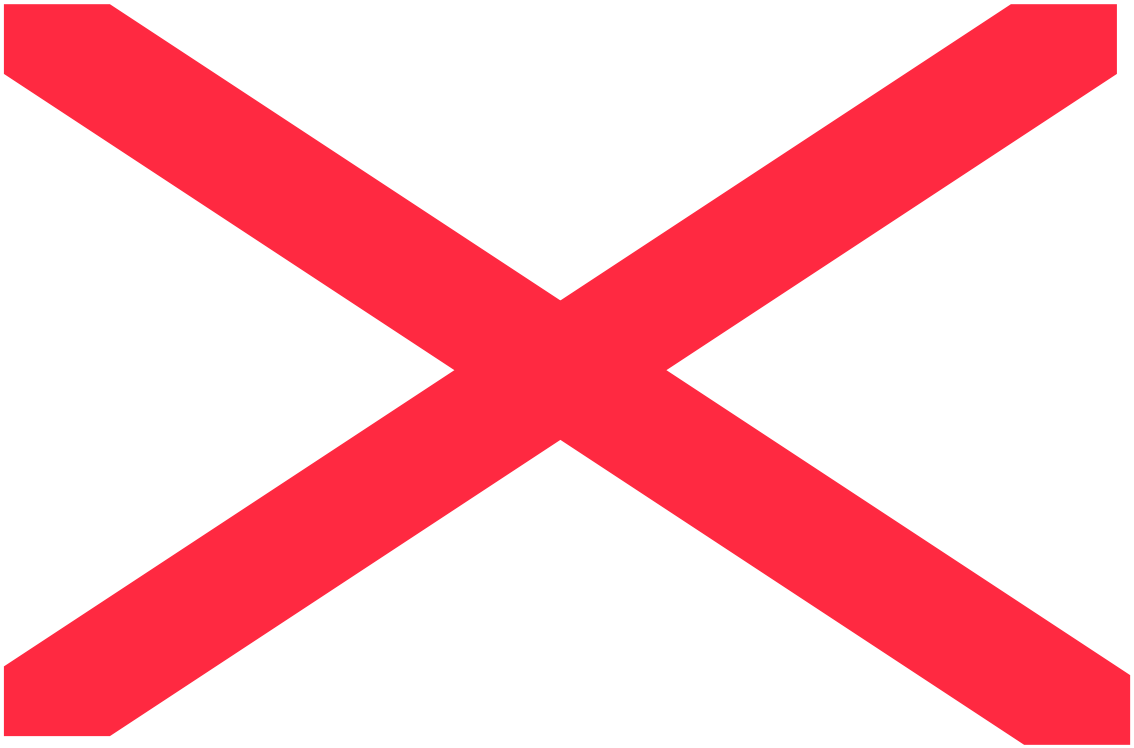
What is Retro-Commissioning?

- Typically focuses on:
  - HVAC Systems & Controls (mostly)
  - Lighting Controls
  - Can focus on other systems
- Evaluates the condition of building's systems - optimizes operation and performance to meet current requirements
- Typically focuses on reducing electrical consumption and demand reduction – but gas savings is also an opportunity

Retro-Commissioning Benefits

- Corrections are typically low cost measures to implement
- Savings are realized in reduced energy and O&M costs—typically 5% to 20% in energy costs alone
- Paybacks typically 6 mo to 2 years – 50% to 200% ROI
- Training of O&M staff to sustain ongoing building performance improvement

Retro-Commissioning Process



Retro-Commissioning Phases

Planning Phase

Asses BAS capabilities, potential building opportunities, and Investigation approach.

Investigation

Determine how systems are supposed to operate, measure and monitor how they operate, and prepare a prioritized list of the operating opportunities.

Implementation

Implement opportunities and verify proper operation

Operating Phase

Report operating improvements made and train the building operator how to sustain efficient operation – implement capital improvements

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Planning Phase

Planning Phase

Asses BAS capabilities, potential building opportunities, and investigation approach.

Investigation

Implementation

Operating Phase

Planning Phase

- Kick-off meeting
- Obtain building data
- Benchmark building performance (EUI)
- Review building operational issues
- Quantify range of potential savings
- Develop RCx Plan
- Determine OFRs

RCx Plan - Purpose

Identify the approach to be used in the Investigation Phase

Building Issues:

- Energy Usage
- Comfort
- Indoor Air Quality
- Noise

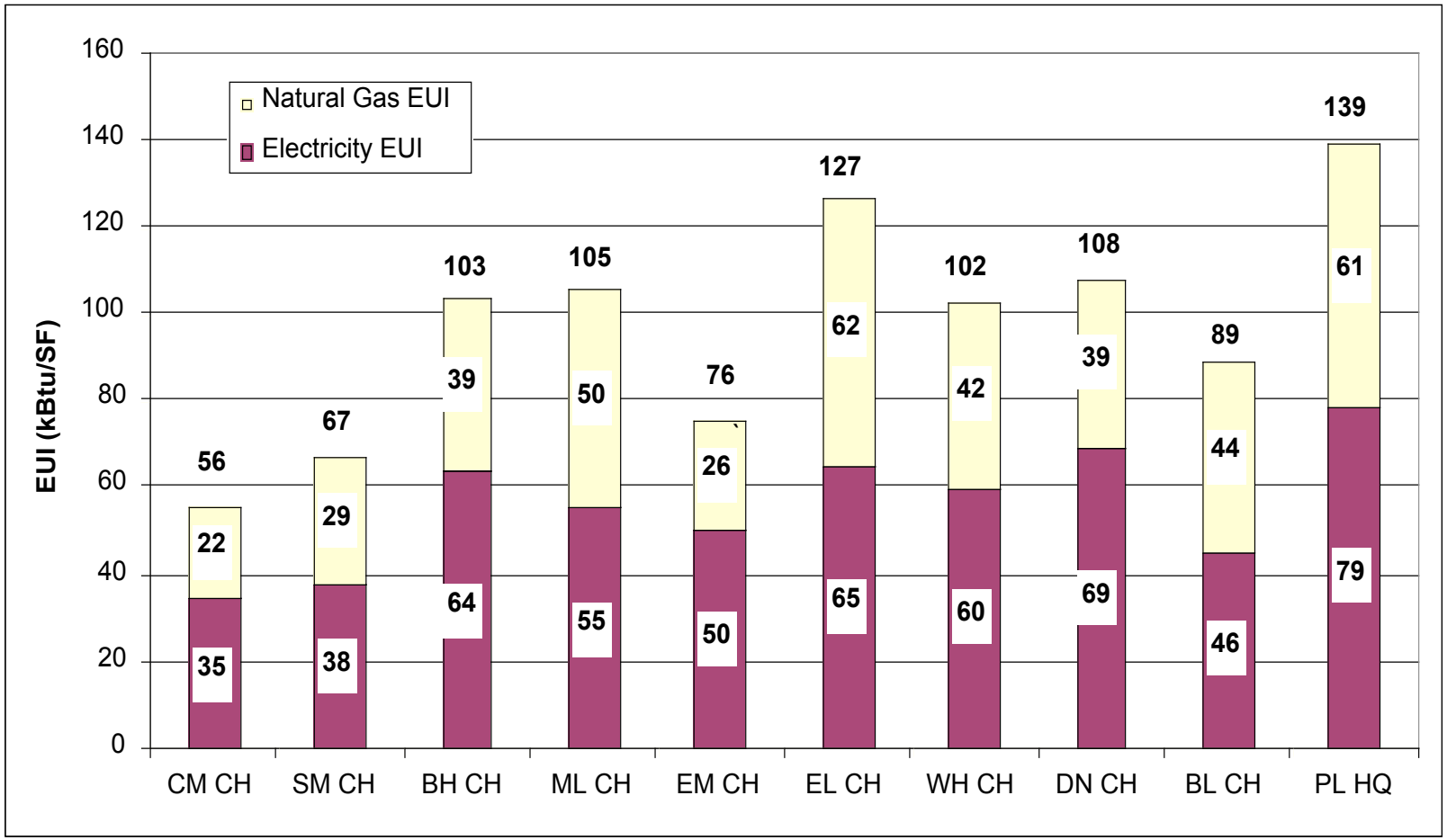
Approach:

- Controls/Trending
- Design
- O&M Participation
- Functional testing
- TAB

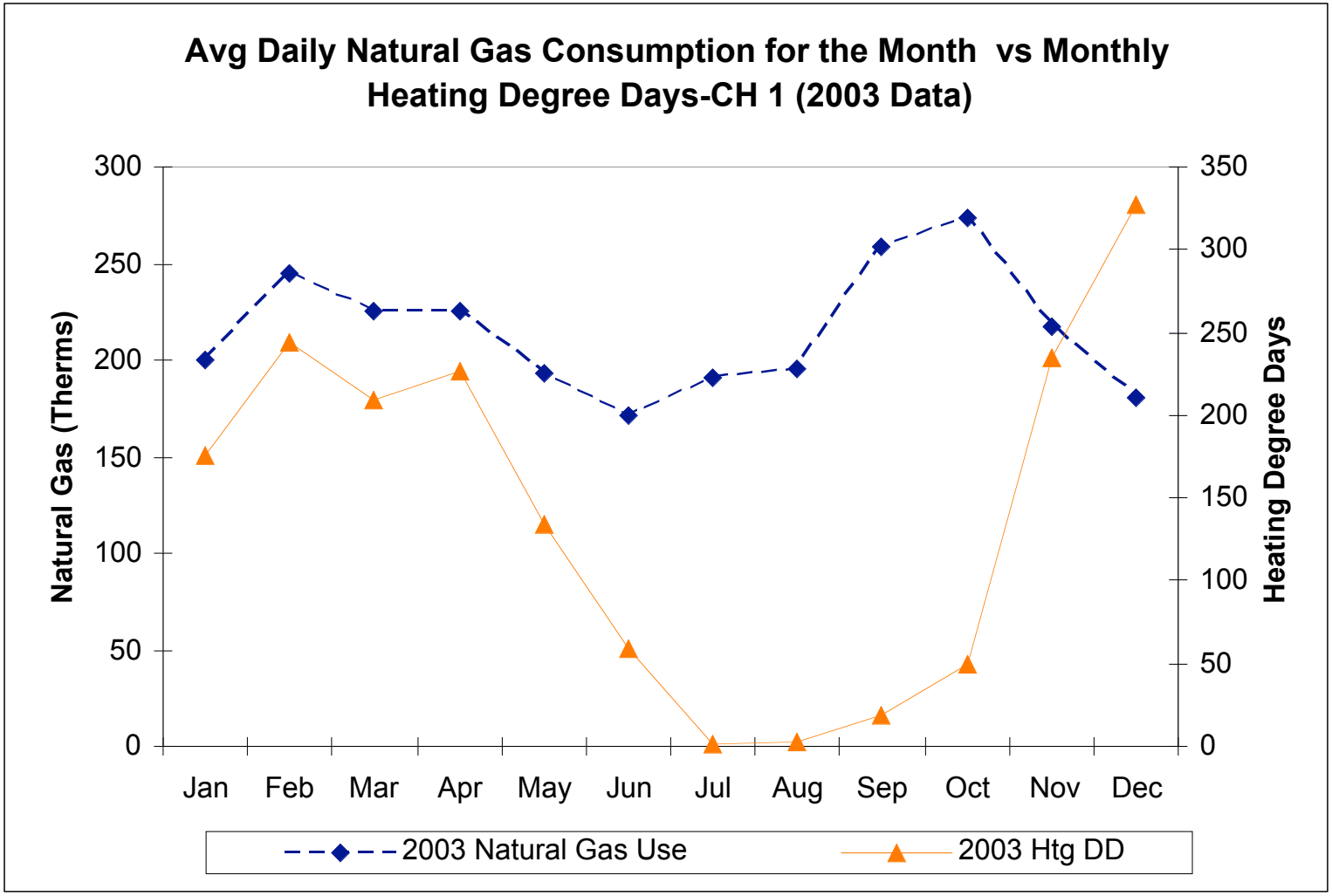
Benchmarking Process

- Building Based:
  - Annual Utility Consumption from Billing
  - Calculate Energy Use Index (EUI) per SF
  - Compare to databases available: SIC, NAICS, CalArch, EIA, others
- Use EUI to identify best candidates for Retro-Cx opportunities
- Note any unique differences in your building systems or equipment as compared to the benchmarks

Example Benchmark – Energy Use Index



Benchmark Example – Normalize Against Weather



Investigation Phase

Planning Phase

Investigation

Determine how systems are supposed to operate, measure and monitor how they operate, and prepare a prioritized list of the operating opportunities.

Implementation

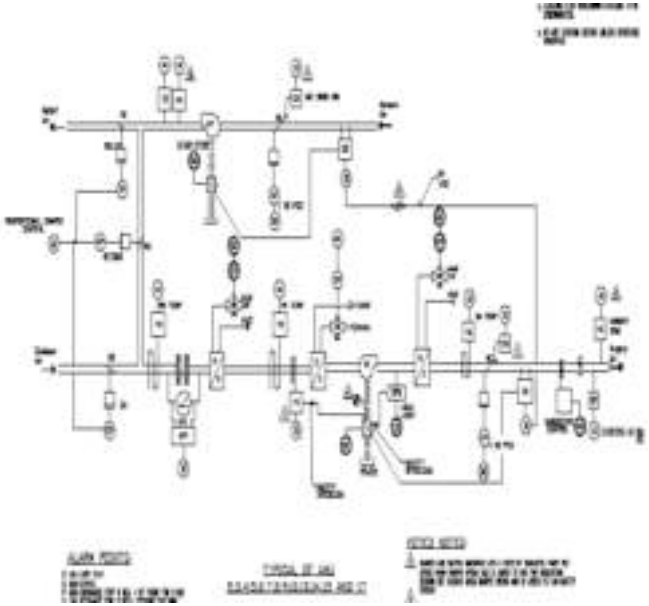
Operating Phase

Investigation Phase

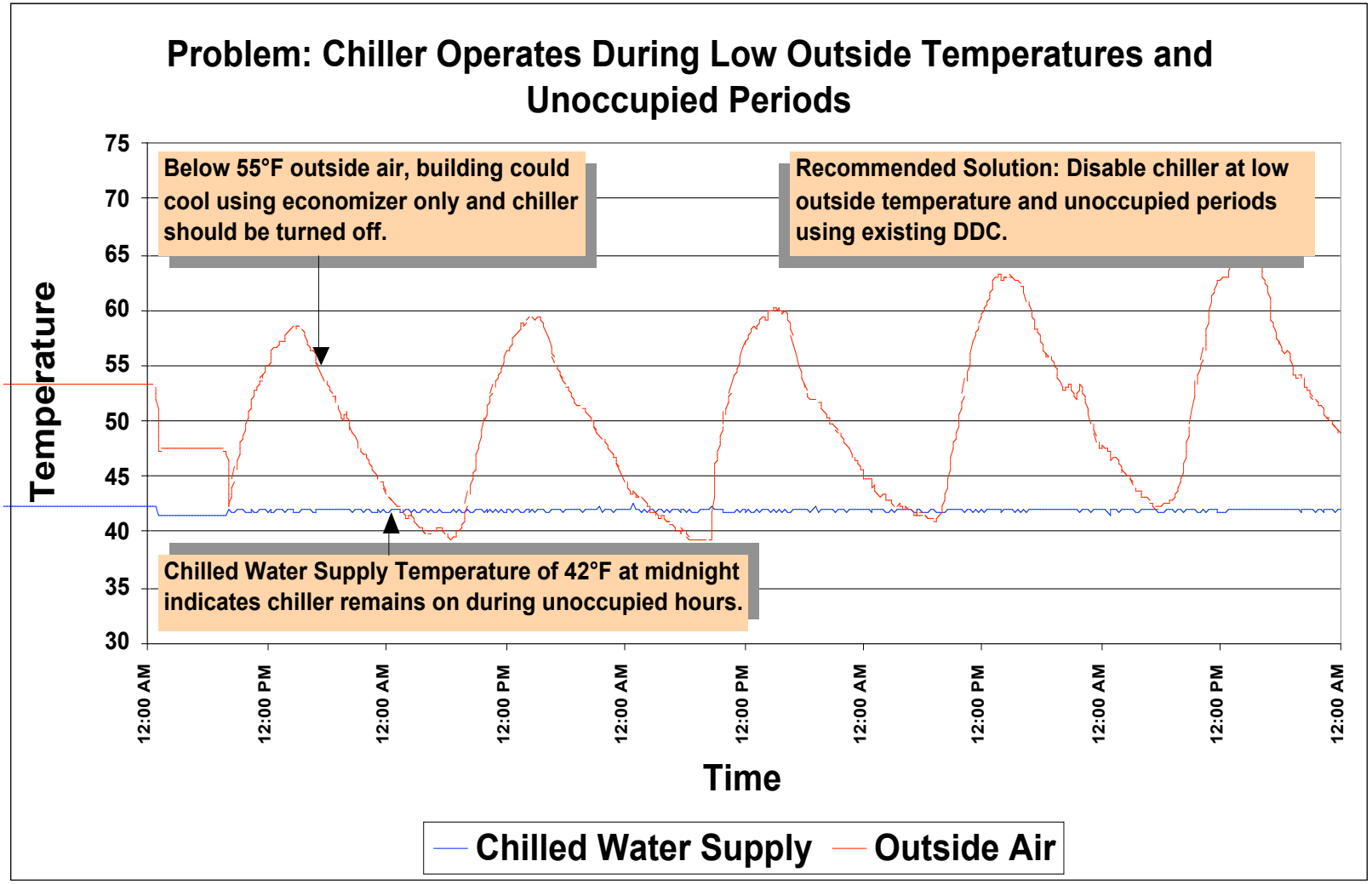
- Inspect, assess, test, measure, document
- Identify inoperable subsystems and equipment – repair if needed for testing
- Perform analysis of energy saving opportunities
- Identify improvements for implementation

Investigation Phase

- Validate the direct digital control (DDC) system & calibration
- What is the equipment actually doing?
- Trend system points
- Sub-meter systems
- Document existing controls conditions and sequences

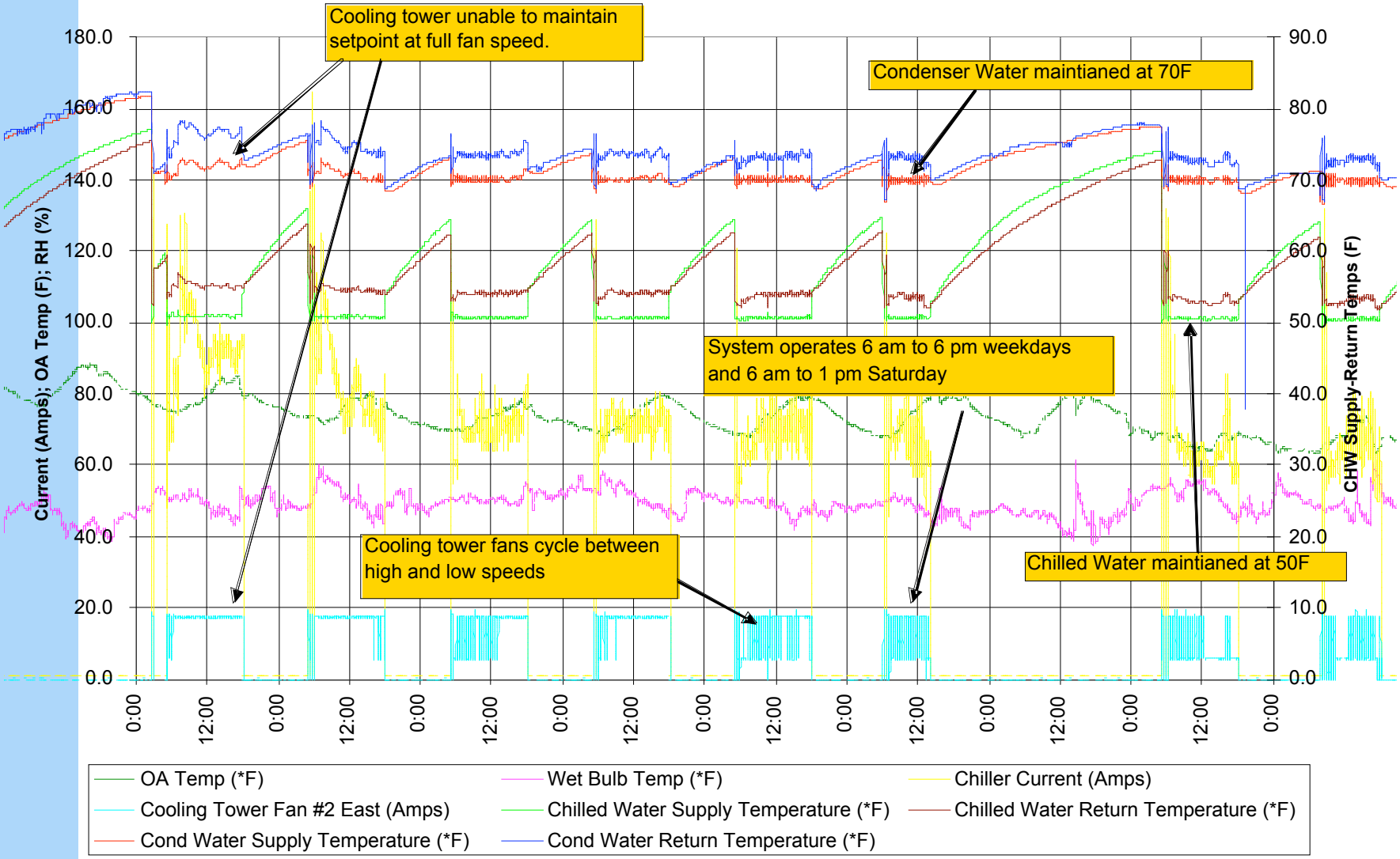


Evaluate Trend Data



Evaluate Trend Data

Mountain America Credit Union

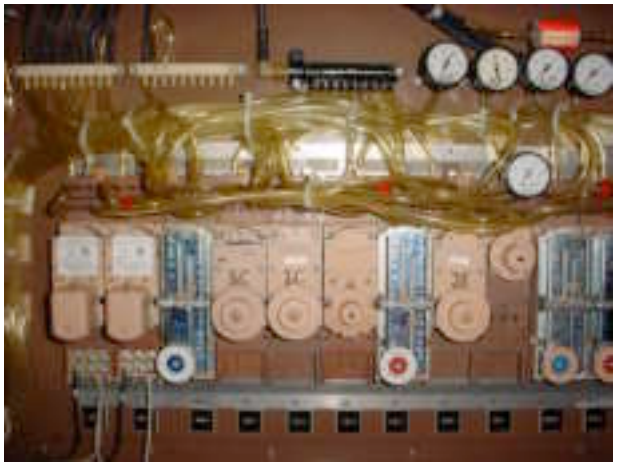


Investigation Phase

- Validate (re-balance?) air and hydronic systems – if needed
- Redistribute air and water to meet loads
- Calibrate & test terminals and sensors
- Test building pressurization
- Verify indoor air quality and ventilation air levels
- System functional testing

Investigation: DDC vs. Pneumatics

- Can you RCx pneumatics?
- YES!!!!!
- Trending analysis - not
- Pneumatics – Pt to pt verification, calibration
- Look for the signs
- Compressed air system improvements
- Understand the theory
- Work with qualified technicians



Energy Analysis Tools

- Simulation Models:
  - Tend to over-predict savings
  - Difficult to reconfigure geometry sometimes
  - Only means to handle multiple measures
  - Difficult to model "poor" buildings
- Spreadsheets
  - Good for individual measure assessments
  - Everything "seen" – no hidden algorithms
  - Easier to modify for specific situations

Investigation Phase

- Investigation report documents the retro-commissioning effort
  - As-found conditions
  - Adjustments or repairs made to systems
  - Results of evaluation and implementation plan
  - Implementation costs and savings estimates
  - Remaining issues that cannot be resolved without upgrade-repair-replacement project
- Identify any capital projects to improve operations or correct problems

Implementation Phase

Planning Phase

Investigation

Implementation

Implement opportunities and verify proper operation

Operating Phase

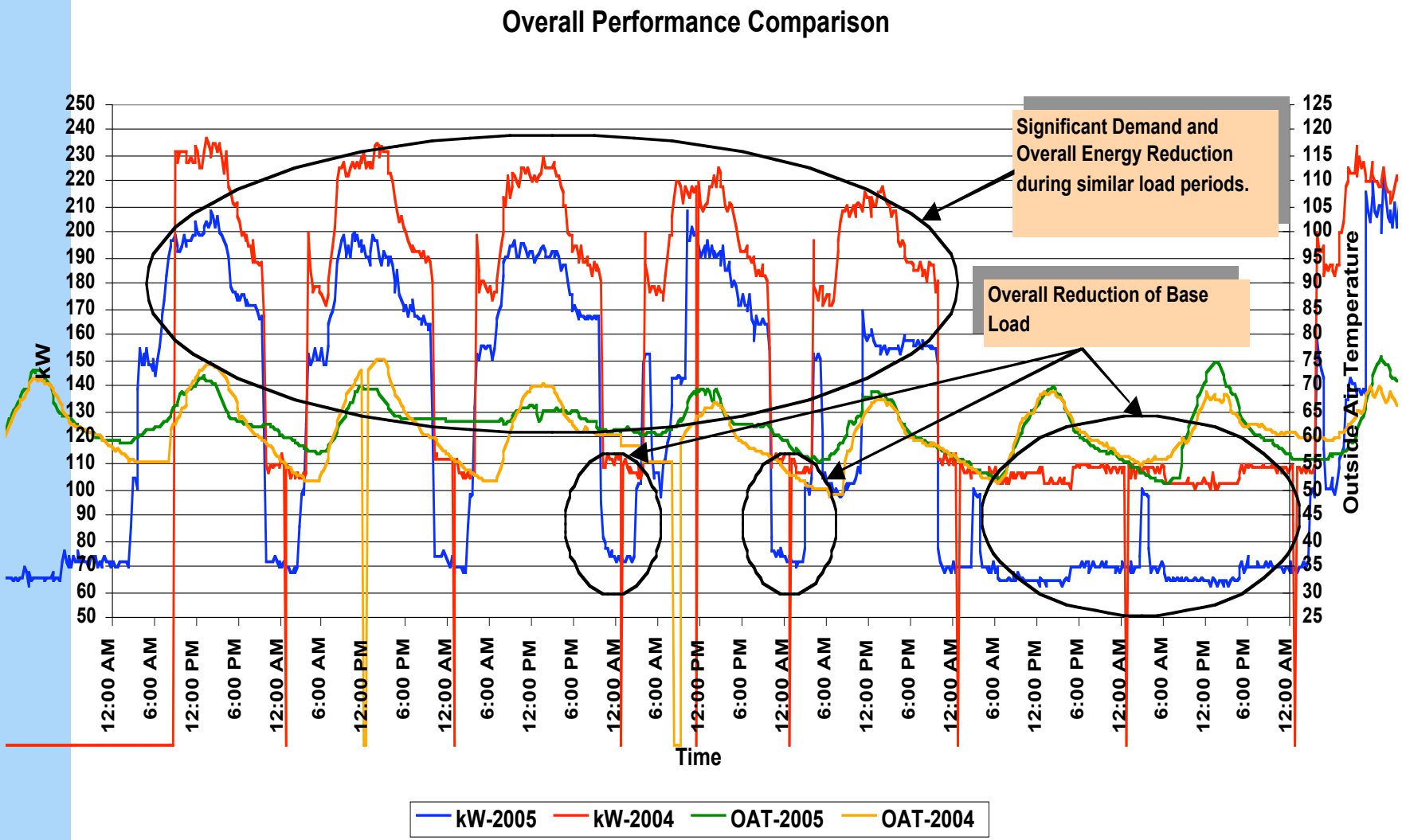
Implementation Phase

- Implement operational improvements to correct deficiencies & improve system operation to achieve improved efficiencies
- Test changes and validate improved performance
- Typically takes less time than investigation

Implementation Phase - Verification

- Verify modifications are in place
- Perform functional tests to assure modifications are operating as designed
- Trend performance to verify energy savings

Implementation Phase - Verification



Operating Phase

Planning Phase

Investigation

Implementation

Operating Phase

Report operating improvements made and train the building operators how to sustain efficient operation – implement capital improvements

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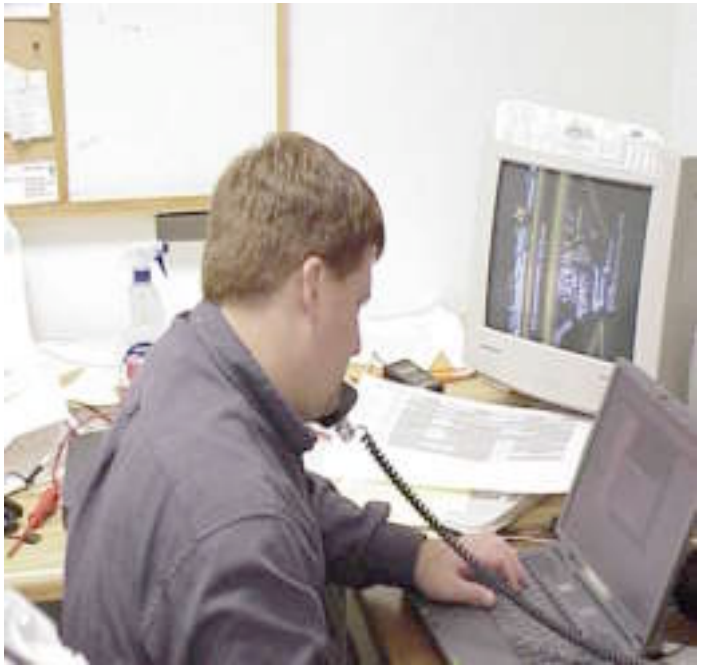
Operational Phase

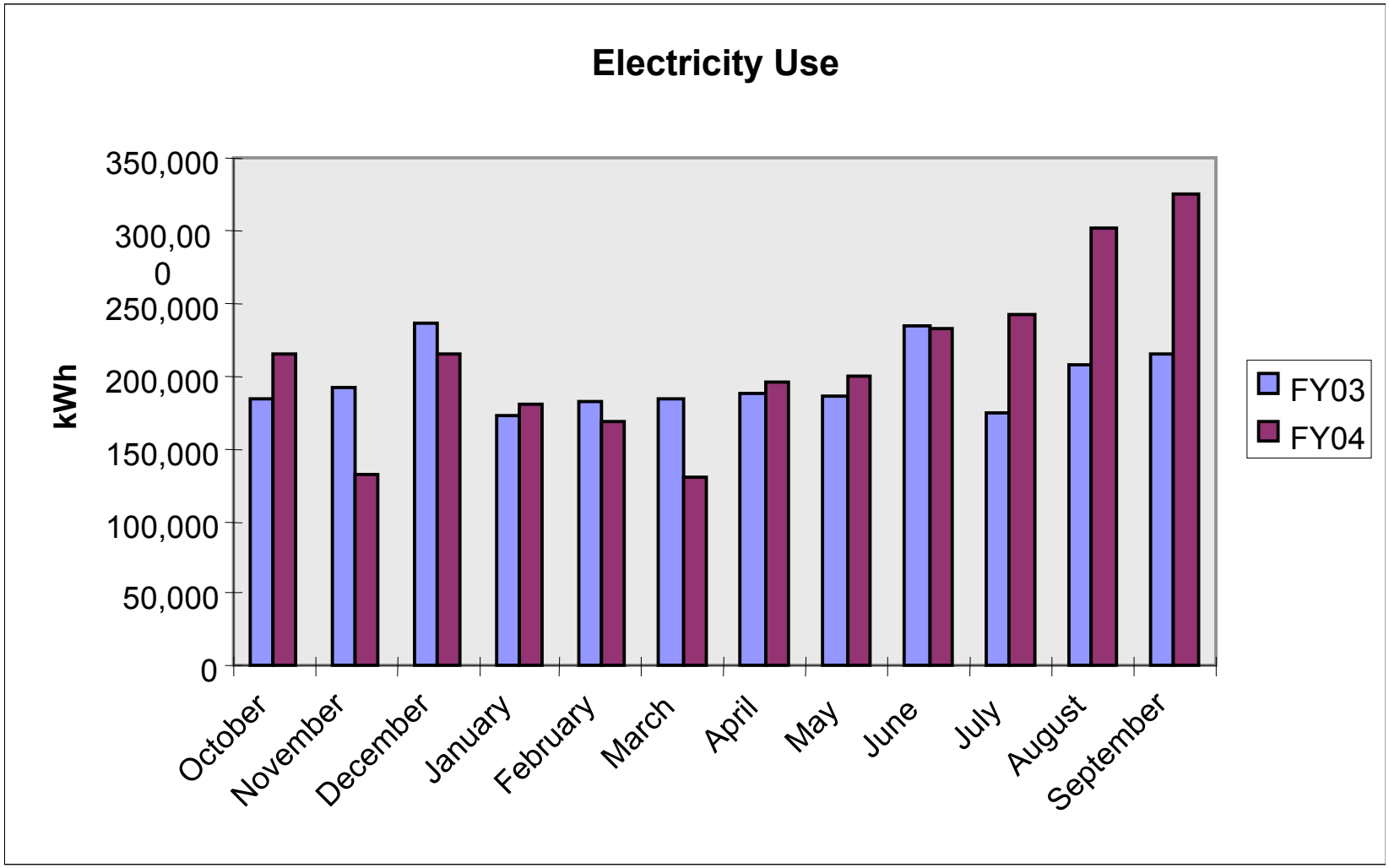
- Provide on-site training – "how the building should operate" – to <u>sustain</u> improvements
- Update O&M data
- Document setpoints and settings for systems – on-going benchmarking



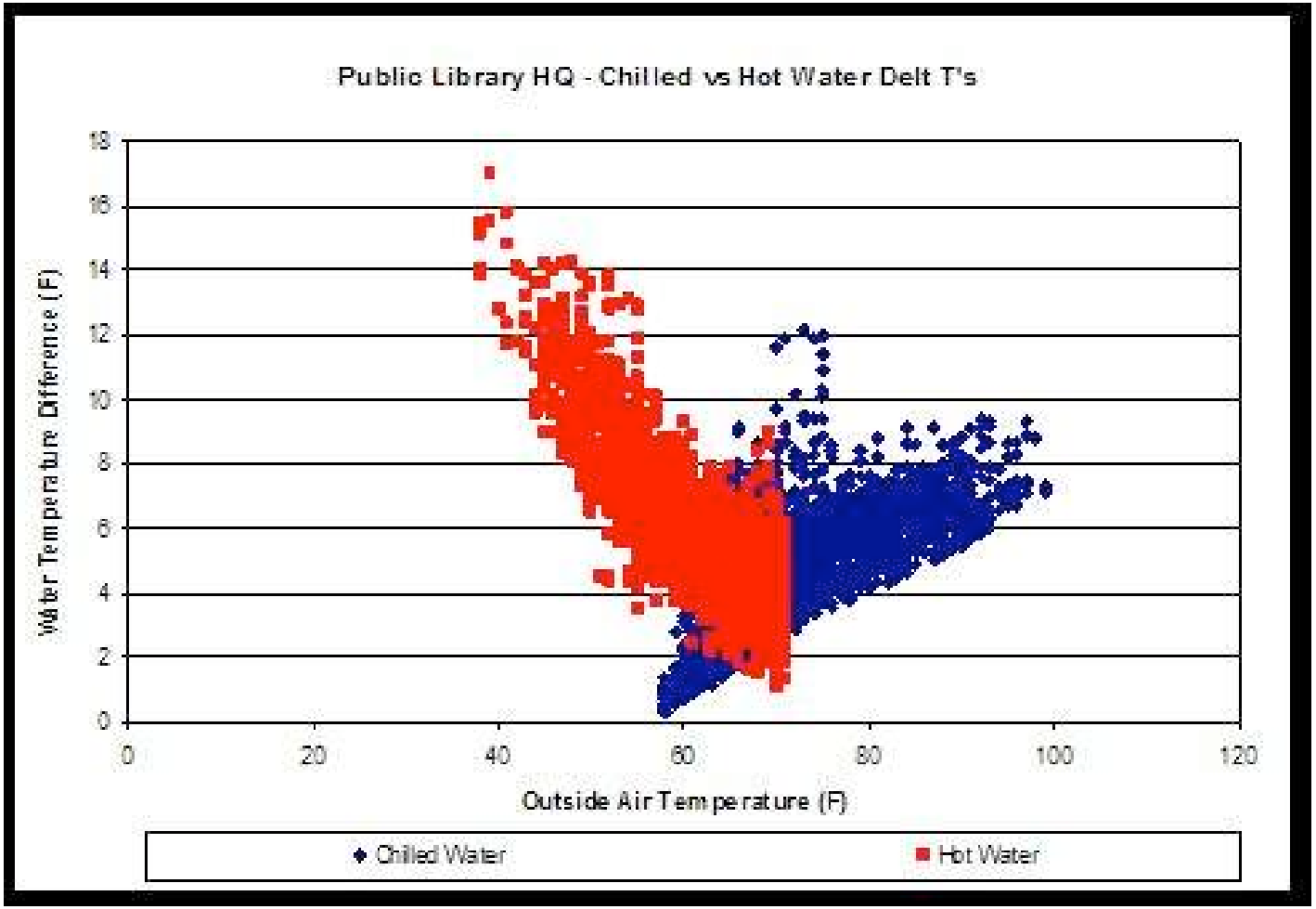
Sustaining Improvements

- Track monthly building energy use
- Track sub-metered electrical use (fans, refrigeration, pumps)
- Verify operation of energy conservation strategies

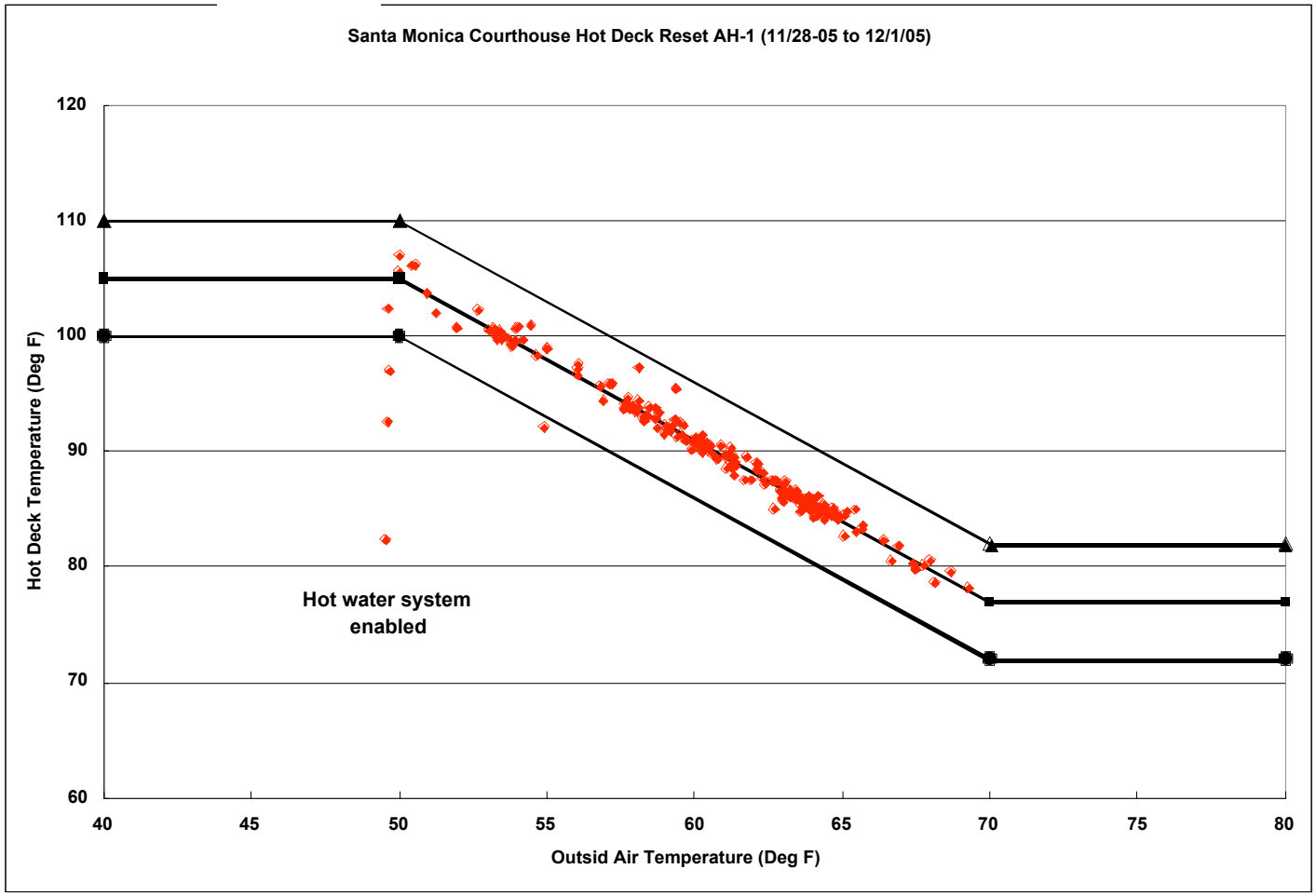
Track Monthly Energy Use



Track System Level Metrics – Simultaneous Htg and Clg



Track System Level Metrics – Hot Deck Reset Control



Retro-Cx and LEED EB

- Pre-Requisite Requirement
- Follows similar process
- Typically a major activity for LEED EB certification
- Requires Energy Star Score of 60 <u>or</u> implement improvements and wait 1 year for new data
- Don't just confirm design but "optimize" operation for maximum points under LEED EB

LEED EB RCx Focus

- Optimize HVAC system controls not just "return to original design" – 10 credits available
- Continuous Cx – up to 3 credits
- M&V – up to 4 more credits
- Cost is a function of complexity and quantity of equipment and systems

LEED EB RCx Requirements

- Comprehensive building operations plan – heating, cooling, lighting, BAS
- Retro-Cx plan for testing and verification
- Implement corrections and repairs
- Re-test repairs or corrections
- Document findings and summarize results
- Repeat process for building occupancy changes or building mods

Retro-Commissioning Case Studies

"Top 10" HVAC Opportunities Found

- 10. Improve boiler efficiency/controls
- 9. Reset supply air static pressure set-points
- 8. Terminal unit tune-ups – dampers, valves, sensors
- 7. Return VFDs to variable speed operation
- 6. Lower condenser water temps
- 5. Improve chiller sequencing
- 4. System level test & balance (over air, over pumping)
- 3. Optimize/restore economizer operation
- 2. Eliminate simultaneous heating and cooling
- 1. Turn off equipment when not needed (Scheduled S/S)

Case Study – Operational Problems

Problem:

- **Photo A:** Static pressure actually measured at 2” W.C. with relief dampers open.
- **Photo B**: Insulation is blown against SF-2 backdraft dampers.
- Not shown: Insulation is torn at SF-2 discharge.

Suspect:

- Both fans have been run at one time in order to generate enough static pressure to tear insulation.

Case Study – Operational Problems

Problem:

- **Photo A: Turning vanes at duct chase (main air shaft) are missing. Some turning vane mounts are broken.**

Question:

- **Where are the turning vanes?**

Case Study – Operational Problems

Answer:

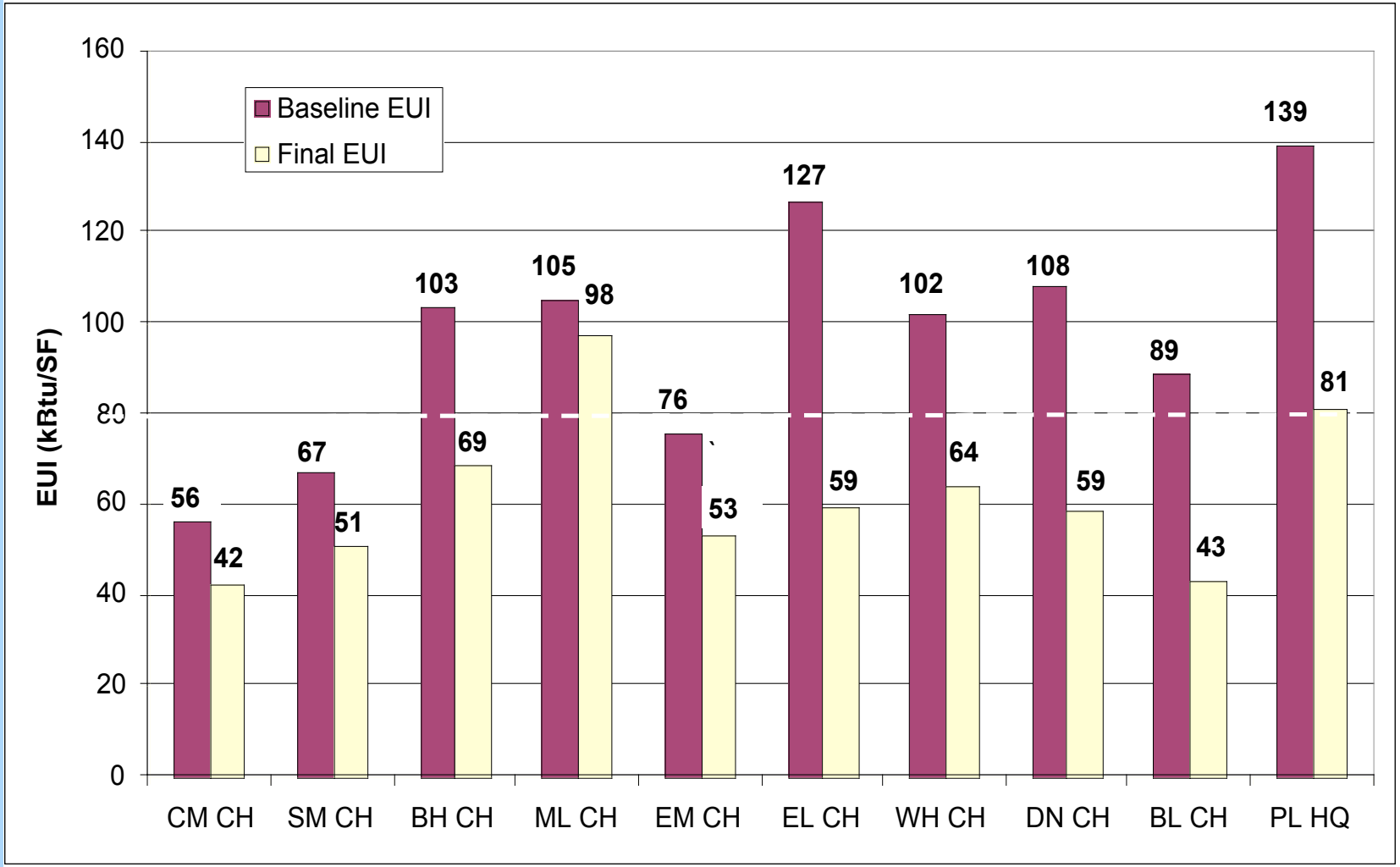
- Bottom of the supply air duct chase, obstructing the basement floor ductwork.
- Static pressure past basement floor turning vanes = 1.65”. Pressure drop from fan to basement duct is 0.6” W.C.

Case Study

HVAC Tune – Up Recommendations:

- Optimize equipment schedules
- Repair/upgrade outside air economizers
- Restore VFDs & automatic speed control
- Repair terminal units (mixing boxes, reheats)
- Revise control sequences – AHUs
- Tower fan, condenser water temp. control

Economic Benefit of RCx



Economic Benefit of RCx – Summary of All Buildings

Facility	Peak Monthly Demand Savings kW	Electricity Savings kWh	Natural Gas Savings Therms	Total Electrical Savings $	Total Natural Gas Savings $	Total Annual Savings $/year	Implemen-tation Costs $	SPB years
PL HQ	26	272,300	33,109	$ 46,673	$ 31,834	$ 78,507	$ 41,492	0.5
BL CH	(1)	364,600	32,617	$ 59,778	$ 31,778	$ 91,165	$ 58,800	0.6
DN CH	17	698,909	28,336	$ 113,898	$ 27,352	$ 141,250	$ 99,663	0.7
CM CH	(40)	509,100	54,164	$ 87,687	$ 45,385	$ 133,072	$ 79,042	0.6
SM CH	(12)	224,300	25,495	$ 34,409	$ 23,741	$ 58,150	$ 28,248	0.5
BH CH	(15)	350,700	16,020	$ 52,431	$ 15,468	$ 67,899	$ 37,784	0.6
MA CH	11	65,581	5,598	$ 12,187	$ 5,405	$ 17,592	$ 41,626	2.4
EL CH	18	584,670	14,878	$ 99,841	$ 13,978	$ 113,819	$ 21,435	0.2
ELA CH	48	653,792	37,128	$ 102,964	$ 34,549	$ 137,513	$ 80,420	0.6
WH CH	39	523,332	14,030	$ 90,550	$ 13,280	$ 103,830	$ 35,420	0.3
Total	91	4,247,284	261,375	$ 700,418	$ 242,770	$ 942,797	$ 523,930	0.6

Economic Benefit of RCx – Program Summary

Annual Electric Energy Savings	4,765,284 kWh (176% of goal)
Annual Natural Gas Savings	287,830 therms (72% of goal)
Annual Energy Cost Savings	$689,000
Simple Economic Payback	Approx. 1 year

Case Study Office Building

- 11-story (386,000 sq ft) Medical Administration building constructed in 1973
- Radiant heating and cooling system
  - High energy use
  - High electrical demand
  - Inadequate cooling capacity

Case Study Office Building

- Flow imbalance in chilled water system limited available cooling
- Reduce ventilation fan speed to save electrical demand
- Provide economizer control on ventilation fans
- Optimize chiller/flat plate free cooling control
- Reset heating and chilled water temperatures supplied to radiant panels

Case Study Office Building

Savings & Payback

Electric Peak Demand Savings	289.2 kW
Annual Electric Energy Savings	1,698,781 kWh
Annual Energy Cost Savings	$133,830
Simple Economic Payback	0.9 years

Case Study Electric Demand Savings – Mall

Cherry Creek Mall Background

- Constructed in 1990
- 1,000,000 SF
- Very upscale
- #1 tourist destination in Colorado
- EMC performed Retro-Cx under Xcel Energy Recommissioning Program

Cherry Creek Mall HVAC

- 48 packaged rooftop units
- CSI/INET 2000 BAS
- VAV reheat for stores
- Constant volume for common areas
- Water source heat pumps for restaurants
- Cooling tower for heat pump loop

Cherry Creek Mall – Planning Phase

- Xcel Retro-Cx program targets electric demand savings on summer weekdays from 3 pm to 7 pm
  - Demand savings must occur when mall is open during the hottest part of the year
- Initial site visit indicated questionable performance of BAS
  - Point to point BAS sensor verification
  - Functional testing
  - Trending with BAS supplemented with temporary monitoring equipment

Cherry Creek Mall

Cherry Creek Mall Deferred Maintenance?

Cherry Creek Mall

- Two 75 hp tower pumps
- Flat Plate Heat Exchanger
- Two 125 hp heat pump loop pumps
- Pumps seemed too large for the cooling tower and heat pumps served

Cherry Creek Mall Maintenance Items

- 12 Outside air dampers stuck open
- 8 Outside air dampers stuck at minimum position
- 13 Mixed air temperature sensors significantly out of calibration
- All outside air temperature sensors significantly out of calibration – HAPPENS ALL THE TIME!!!!
- OSA sensors govern most control sequences – need to be accurate!

CC Mall - Add'l Energy Opportunities

- Raise economizer high limit from 63°F to 75°F
- Reduce outside air setting from 20% to 10% (Reduced air flow rate is double ASHRAE Standard 62.1 requirement assuming parking lot is full with 2 people per car)

Cherry Creek Mall – Savings & Payback

Electric Peak Demand Savings	398 kW***
Annual Electric Energy Savings	659,600 kWh***
Annual Energy Cost Savings	$84,053*
Simple Economic Payback	No cost to owner**

*Colorado has cheap energy

**All measure covered under existing maintenance contract or were simple setpoint changes

"Indicators" of RCx Opportunities

- Changes to operating sequences
- Deferred basic maintenance
- Control sequences modified
- Comfort complaints (hot or cold calls)
- Interim "fixes" to respond to localized requests
- Rising energy consumption – kW, kWh, therms - check EUI!!
- Check your Utility offered DSM Programs

Benefits of Cx/R-Cx

- Cost based on systems, bldg size & type
- Budgetary estimates:
  - RCx from $0.30 to $0.90 per SF depending on scope and size of bldg
- ROI & Payback – Excellent (<1 yr typ.)
- Energy savings typically 5 to 15%
- Existing buildings account for over 95% of building SF – most do not operate efficiently nor very comfortably
- What is the cost of loss of comfort resulting in loss of productivity in a poor building environment? A LOT!!!!!!

Cx & RCx Economic Benefits

- New Construction - $0.05/sf-yr median normalized energy cost savings, 4.8 years median payback (35 Buildings)*
- Existing Buildings - $0.26/sf-yr median normalized energy cost savings, 0.7 years median payback (59 Buildings)*

* 'The Cost-Effectiveness of Commercial Buildings Commissioning – A Meta-Analysis of Existing Buildings and New Construction in the United States', Nov 23, 2004 – Lawrence Berkeley National Laboratory, Portland Energy Conservation Inc., Energy Systems Laboratory-Texas A&M University

Example Resources

- **Portland Energy Conservation Inc – www.peci.org**
- **Building Commissioning Association, www.bcxa.org**
- **"Practical Guide to Commissioning Existing Buildings," Haasl & Sharp, 1999,**

  ateam.lbl.gov/mv/docs/RetroCommissioningGuide.pdf
- **ASHRAE, Guideline 1-1996, "The HVAC Commissioning Process," www.ashrae.org**
- **"Continuous Commissioning Guidebook for Federal Energy Managers" http://www.eere.energy.gov/femp/pdfs/ccg01_covers.pdf**
- **U.S. DOE / FEMP,www.eere.energy.gov/femp**
- **GSA Commissioning Handbook, www.gsa.gov**

Thank You!