Steps to Making Existing Commercial Buildings Become High Performance

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Steps to Advanced Existing Building Energy Performance

Presentation's Reference Documents

- ASHRAE's *Energy Efficiency Guides for Existing Commercial Buildings – Business Case & Technical Implementation* publications
- ASHRAE's *Performance Measurement Protocols for Commercial Buildings: Best Practices Guide*
- *ASHRAE's Procedures for Commercial Building Energy Audits, 2nd Edition*
- ASHRAE *Journal's Retro-commissioning Case Studies*
- NEBB's *Procedural Standard for the Technical Retro-commissioning of Existing Building Systems, 2nd Edition*

Energy Efficiency Guides for Existing Commercial Buildings

- New Buildings = 2% of Building Programs
- 86% of U.S. Annual Building Construction Expenditures Relate to Building Renovations
- Even with Commissioned Buildings in the U.S., their Performance Deteriorates after 3 years by 30%
- ASHRAE Research has shown that the "potential" for reduction of a building's energy use is between 10% and 40% simply by changing operational strategies
- 70% - 80% of Buildings in 2030 exist today
- Over next 30 years, 150 billion SF of existing buildings will be renovated (1/2 U.S. bldg. stock)

Energy Efficiency Guides for Existing Commercial Buildings

BOMA's Building Energy Efficiency Program (BEEP) reports the following energy savings potentials:

- **7% - 28% achievable thru no-cost/low-cost energy efficiency measures**
- **3% - 15% savings thru occupant awareness programs, hi-efficiency equip., power management software (EMS) and use of task/ambient lighting**
- **Lighting = 22% of office bldg. consumption →off-the-shelf technologies = < 1 yr simple payback period**

Energy Efficiency Guides for Existing Commercial Buildings

BOMA's Building Energy Efficiency Program (BEEP) reports the following energy savings potentials:

- **7% - 22% savings potential thru calibration & monitoring of "control devices"**
- **3% - 15% whole bldg. energy savings potential thru either performance optimization or equipment changes for HVAC systems and controls**
- **Utility expenditures are largest expense after taxes and on the average = 1/5th of total costs and 1/3rd of total variable costs**
- **IFMA → 25+% Increase in Utility Costs since 2006**

Energy Efficiency Guides for Existing Commercial Buildings

- **Building Selection Criteria for**

  Technical Retro-Commissioning (RCx)
  - **Buildings scoring < 75% ENERGY STAR score**
  - **Buildings needing major upgrades (ESCO)**
  - **Buildings having building systems that don't work properly**
  - **Buildings that have undergone re-configurations**
  - **Buildings with recurring occupant's complaints about thermal comfort**
  - **Buildings receiving Photovoltaic installations**

Energy Efficiency Guides for Existing Commercial Buildings

Improving Building Performance

- **NEBB Technical Retro-Commissioning (RCx) Process**

  Process RCx utilizes a paper-based process conducted by others or is limited to an energy audit

  Technical RCx utilizes a technical testing-based process conducted by an RCx CP and includes system adjustments and optimization

- **The NEBB Technical RCx Process:**

  1. **Planning Phase**
  2. **Investigation Phase**
  3. **Improvement Phase**
  4. **Performance Verification Phase**

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Planning Phase

- Facility Walk Through
  - Check Building Condition, Pressure and Construction details
  - Equipment, systems and components accessibility
  - Physical condition(s) of building systems
  - Security concerns, special work conditions
  - Availability of drawings, energy records, TAB & Cx reports, maintenance work orders, O&M manuals & staff
- Owner Responsibilities
  - Defines systems & quantity of systems for RCx
  - Defines if plumbing, building envelope, electrical and/or lighting systems are in SOW
  - IEQ areas in SOW

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Planning Phase

- **RCx Team Development**
  - Members who have knowledge & experience in HVAC systems, controls, plumbing, electrical & lighting systems and building envelope (defined in SOW requirements)
  - Owner's staff & Operating Personnel involvement in RCx Program
  - NEBB Retro-Commissioning Certified Professional (RCx CP)
- **Proposal Development**
  - Define deliverables, owner's obligations, project schedule and costs
  - Develop scope of services
  - Estimate time requirements per scope of proposed work

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Planning Phase

- Draft RCx Plan Development
  - Basic Programming Requirements & RCx Project Process
- Document Procurement & Review
  - Drawings, Specifications & O&M Manuals
  - TAB, Cx/RCx or Engineering Study Reports
  - Utility Bills & contracts
- Contract (Owner & RCx CP)
  - RCx Program Scope of Activities
  - Owner resource commitment to RCx Team
  - Retro-Commissioning schedule expectations

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Planning Phase

- "Draft" Current Facility Requirements (CFR)
  - Building Requirements – Use & occupancy
  - Required Space Conditions temps, H, IEQ, acoustics, etc.
  - Energy efficiency goals
  - Sustainability requirements/goals
  - Operation & Maintenance – Training requirements;
  - Performance Measurement program

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Investigation Phase Overview

- **ACTIVITIES:**
  - ❑ Verify CFR
  - ❑ Energy Audit
  - ❑ Interviews
  - ❑ Evaluation of Operations Performance
  - ❑ Systems' Assessments
  - ❑ Perform Quick Fixes
  - ❑ Perform Systems' Optimizations

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Investigation Phase Overview

- **ACTIVITIES:**
  - Define Issues Affecting Building's Performance
  - Create Issue Descriptions
  - Recommended Solutions
  - Solution Calculations if required
  - Expected Results of Recommended Correction

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Investigation Phase

- Issues looked for:
  - Design deficiencies
  - Installation defects
  - Deferred Maintenance
  - Operational issues
  - Control issues
- Typical order of energy efficiency improvements
  1. Operational changes
  2. Lighting & lighting controls
  3. HVAC controls, maintenance, VSD motors, etc..
  4. Envelope measures
  5. HVAC equipment replacement

Energy Efficiency Guides for Existing Commercial Buildings

Verify CFR

- Field Verification
  - Document change of use
  - Document zoning revisions
  - Document non compliant conditions

Energy Efficiency Guides for Existing Commercial Buildings

Energy Audit

- Compile energy bills and meter readings 24-36 months
- Conduct Walk-Through Survey, Energy Survey and Engineering Analyses (ASHRAE Levels 1 & 2 Analyses)
- Determine Energy EUI
  - Calculate annual BTUs consumed for each fuel source & get total annual BTUs

Energy Efficiency Guides for Existing Commercial Buildings

Energy Audit

- ENERGY STAR Portfolio Manager
  - Comparison to similar buildings
  - Correlates bldg hours of use and occupancy levels
  - Bldg parameters used include:
    - % of bldg air conditioned
    - Amount O/A conditioned
    - # computers in a school
    - # beds in a hospital

Energy Efficiency Guides for Existing Commercial Buildings

Determine the Building's Energy Utilization Index (EUI)

Fuel	Usage	Conversion	kBtus
Electricity	100,000	3412	341,200
Natural Gas	2,000	100,000	200,000
#2 Htg Oil	10,000	139,000	1,390,000
Total Annual	Bldg Energy	Usage (Btus)	1,931,200
Total Bldg.	Gross SF		20,000
Total EUI	(Btu/SF/yr)		96.560

Energy Efficiency Guides for Existing Commercial Buildings

Meaning of Calculated EUI

- Primary tool to normalize & compare like buildings is the DOE Commercial Buildings Energy Consumption Survey (CBECS) data.
- CBECS provides EUI comparisons for building types and climate zones
- CBECS information – Weighted Mean Energy Use Intensities by Subsector & Climate Zone

Table 1-2. 2003 CBECS[1] Weighted Mean Energy Use Intensities[2] by Subsector and Climate Zone[3,4]: IP Units kBtu/ft^2·yr

[1] Data source is 2003 CBECS public use microdata

Subsectors	Climate Zones														
	All	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7
All	90	74	72	114	89	70	62	95	108	99	104	87	89	97	71
Office/professional	93	42	82	72	88	70	58	97	143	95	107	66	110	114	68
Nonrefrigerated warehouse	42	22	16		22	21	20	39	29	37	79	60	37	58	33
Education	83	52	73	160	62	74	105	102	38	58	87	79	90	90	84
Retail (except malls)	74	61	93	129	60	50	31	65	100		88	80	93	97	102
Public assembly	94	75	60		112	48	45	110	44	249	103	97	88	102	97
Service	77	60	53		49	61	27	82	83		80	101	88	99	65
Religious worship	44		31		28	31		47	56		52	39	83	34	
Lodging	94	81	91		98	57		92	264	545	89	65	108	93	68
Food services	258	396	208		423	393	82	234		260	258	228	203	236	192
Inpatient healtchcare	249	200	246	360	205	257	204	248	163		294	245	240	235	256
Public order and safety	116		91		160	79		129			108	94	126	148	
Food sales	200		166		212	183	120	242			203	147	242		199
Outpatient health care	95	19	77		55	106		70	190		111	120	112	91	166
Vacant	21		4	47	4	6	0	40	3	60	21	93	22		55
Other	79		48		100	175		71	26		94	92	69	85	57
Skilled nursing	125		71		84	85		148			148	153	118	134	
Laboratory	305				242	170		600			370		268	115	
Refrigerated Warehouse	99							120			68	51	62		

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Interviews

- Interview Management, Operators and Occupants
- Management → Process review & known issues
- Operators → Known issues & operating techniques
- Occupants → Known and perceived issues

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

System Assessment

- Evaluate condition, operability and functionality of each piece of equipment and system
  - Envelope
  - HVAC
  - Controls
  - Plumbing
  - Landscape irrigation
  - Lighting
  - Power & Emergency Power if in SOW

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Data Loggers

- Data loggers are placed in zones to discover actual operating conditions
  - Temperature
  - Humidity
  - Light Level (Used for verification of light control)
- Other specific locations for special issues
  - AHU SA
  - Electrical load
  - Etc…
- Calibrated EMS systems

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

System Investigation

- Begin to observe and test systems for areas that have either comfort, water or energy high usage
  - Inspect
  - Test
- Perform quick fixes where appropriate
  - Control setpoint adjustment
  - Damper adjustment
  - TAB
  - Change operations procedure
  - Quick repair

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

System Investigation

- Systems Optimization during RCx
  - Revise or adjust reset sequences
  - Revise system operating parameters and setpoints
- Perform quick fixes where appropriate
  - Control setpoint and sequence adjustment
  - TAB
  - Change operator procedures
  - Quick repair

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

System Investigation

- Create solutions
  - Solutions that correct one or several found issues
  - Place in order of importance
  - Be aware that some solutions affect other solutions
  - Create SOW for capital upgrades
- Create RCx report
  - Recommend solutions
  - Cost justification and savings for each solutions
  - Recommendation calculation and sketches if required

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Making the Business Case

- **Financial Analysis Methodologies**
  - Simple Payback Period (SPP)
  - Net Present Value (NPV)
  - Internal Rate of Return (IRR)
  - Life-Cycle Cost Analysis (LCC)

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Simple Payback Period (SPP)

$$SPP = \frac{Total\ Project\ Cost}{Annual\ EEM\ Savings}$$

Example – Total Project Cost = $900,000 and estimated annual EEM savings = $103,680/year

SPP = $900,000/$103,680/yr = 8.7 years

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Net Present Value (NPV)

$$\mathrm{NPV}(i,N) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

- Use NPV excel spreadsheet function, enter rate, and annual savings 20 times. The results is total return – investment = NPV

Example – Total Project Cost = $900,000, Annual Change = $103,680/yr, Discount Rate = 7% and time period (N) = 20 years; NPV = $198,387

  - If NPV > 0, Accept
  - If NPV < 0, Reject
  - If NPV = 0, Accept or Reject

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Internal Rate of Return (IRR)

$$\text{IRR} = \text{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0$$

- IRR = Rate of return on the investment that yields a NPV of "zero"
- Not useful to rank mutually exclusive projects such as done when evaluating/choosing EEMs
- Cost-effectiveness of an EEM

$$\frac{\text{Effective Annual Project Cost (\$ per year)}}{\text{Annual Energy Saved}}$$

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Life Cycle Cost Analysis (LCC)

LCC = I + Repl. – Res + L(OM&R)

I = Initial Cost

Repl. = Replacement cost if life is less than L

Res = Residual value at end of L

L = Life time of the system

OM&R = Annual average operating, maintenance, repair and utility costs

- Best suited for comparing alternative choices for a single EEM (lowest LCC is best investment)
- Ideal for evaluating mutually exclusive alternatives for a single EEM such as standard efficiency vs high efficiency
- Can be used to rank or prioritize EEMs based upon budget constaints
- NIST BLCC Program – a free download

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

What is investigated

1. Building Pressure & TAB
2. Outside Air & Economizers
3. Controls – investigation, evaluation & testing
   - Schedule control
   - Setback / Setup setpoints
   - Reset Control
4. Air Balance
5. Water Balance
6. Zoning
7. Humidity
8. Design Issues
9. Operation/Equipment Usage

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

What is Investigated

10. IEQ Airborne contaminant investigation and tests
11. Energy Usage
12. Water Usage
13. Domestic potable water quality test
12. Plumbing system performance tests
13. Landscape water system performance tests
14. Rain water harvesting system tests
15. Grey water system tests
16. Building envelope inspection & testing
17. Lighting level and control tests
18. Electrical system performance tests

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Improvement Phase

- Complete Repairs
  - Repair equipment or systems
  - Replace equipment
- Design & Construct Capital projects
  - New equipment or systems
  - System upgrades
- Commission Capital Projects
- Operator training

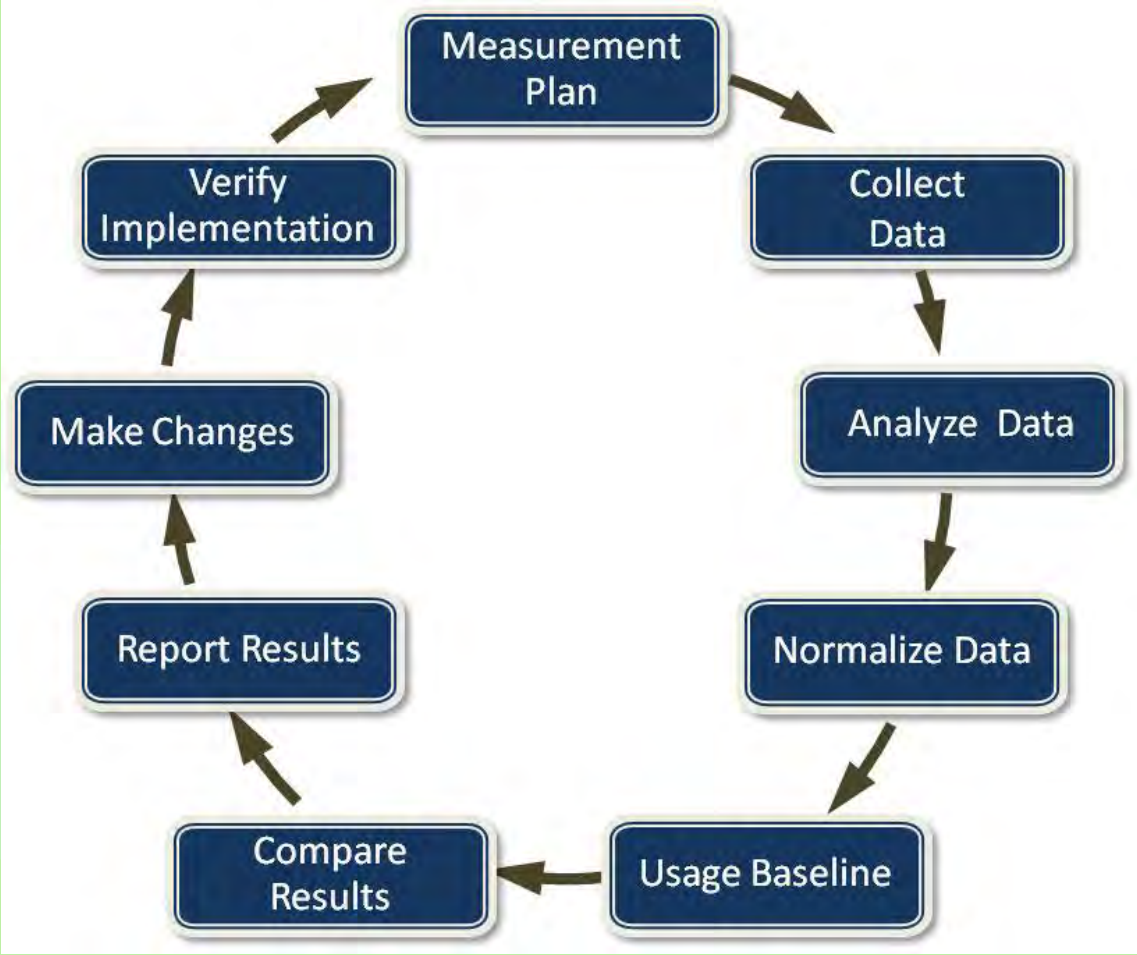
Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Performance Verification Phase

- Establish performance verification system
  - Energy & Water usage data recording
  - IEQ data recording
  - Analysis system / dashboard
  - Results publication
- Measure / Make Adjustments / Repeat
  - Gather Data
  - Compare results to past results
  - Compare results to peer buildings
  - Publish Results
- Holding Operations Accountable

Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Performance Verification Phase



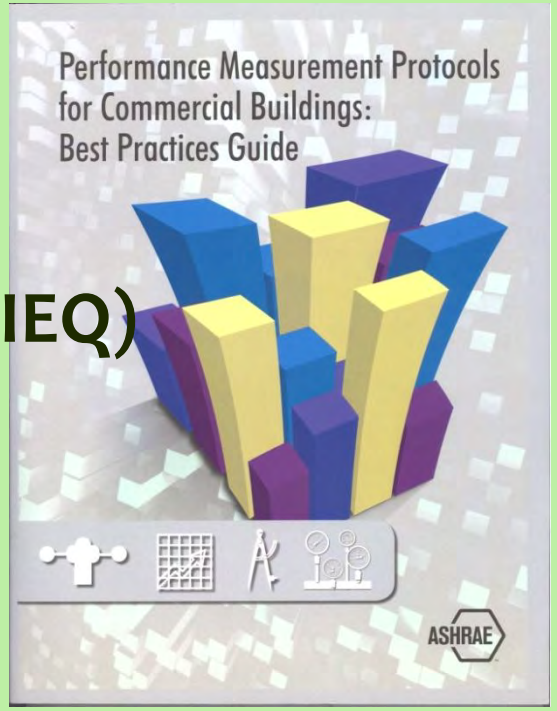
Technical Retro-commissioning (RCx) of Existing Commercial Buildings

Performance Verification Phase

- **Using ASHRAE SP 132**

  "Performance Measurement Protocols for Commercial Buildings: Best Practice Guide"

- **Measurement Categories:**
  - Energy Usage
  - Water Usage
  - Indoor Environmental Quality (IEQ)
    - Thermal Comfort
    - IAQ
    - Lighting / Daylighting
    - Acoustics



PMP Best Practice Guide

Three Levels of Performance

- **Basic Evaluation Level** – Basic, indicative level that uses observations of building characteristics, perceptions of occupants, and data from utility bills.
- **Diagnostic Measurement Level** – Intermediate level that uses physical measurements to conduct diagnostic analysis of problems from Basic Level & to characterize performance in relation to physical standards so as to identify how performance can be improved.
- **Advanced Analysis Level** – Uses results of first two levels + results of professional investigative processes to characterize performance and identify specific actions for performance improvements.

PMP Best Practice Guide

Level 1: Basic Evaluation – ENERGY USE

- Basic measurement of use - Monthly
- Facility Information (Standard 105), Whole-building (WB) Annual Energy Use Index
- Benchmark: National Databases such as Energy Star Portfolio Manager for Similar Buildings in Similar Climates

Level 2: Diagnostic Measurement – ENERGY USE

- Level 1 + Actual use measurement at source
- Level 1 + Weather Normalized WB Monthly Use Index
- Benchmark: Normalized Monthly Use Index for Similar Buildings

Level 3: Advanced Analysis – ENERGY USE

- Level 1 + WB Hourly, Daily Use Data
- Level 1 + Component or Sub-system Performance Models
- Level 1 + WB Hourly Calibrated Simulation
- Benchmark: Normalized Hourly/Daily Use Index for Similar Buildings; Mfr. Performance Models; Code-Compliant Simulation

PMP Best Practice Guide

Level 1: Basic Evaluation – WATER USE

- Basic measurement of use - Monthly
- Benchmark: National Databases such as Energy Star Portfolio Manager for Similar Buildings in Similar Climates

Level 2: Diagnostic Measurement – WATER USE

- Level 1 + Actual use measurement at source
- Level 1 + Normalized for occupancy Monthly Use
- Benchmark: Normalized Monthly Use Index for Similar Buildings

Level 3: Advanced Analysis – WATER USE

- Level 1 + Daily Use Data
- Level 1 + Component or Sub-system Performance Models
- Benchmark: Normalized Hourly/Daily Use Index for Similar Buildings;

PMP Best Practice Guide

Level 1: Basic Evaluation – IEQ (Comfort, IAQ, Lighting, Acoustics)

- Operator Survey, Occupant Survey
- Benchmark: CBE Database of Surveys

Level 2: Diagnostic Measurement – IEQ

- Level 1 + Right Now Surveys, Continuous Feedback, Physical Data Near Occupant
- Spot Measurements

Level 3: Advanced Analysis – IEQ

- Level 1 + 1-min or 5-min Data Logger Measurements
- Datalogger measurements.
- Advanced studies and analysis

PV Phase Optimization

- Find & repair all air, steam and water leaks
- Review schedules to maximize unoccupied periods by zone
- Review set-points for unoccupied periods
- Calibrate control sensors on a periodic basis
- Review all control set-points for space temperatures, hot & chilled water, and economizers
- Adjust any morning warm-up or cool-down and associated optimum start times (Use optimal start stop)
- Adjust ventilation schedules to track occupancy
- Tour facility at midnight to see what equipment is left on/operates unnecessarily
- Review plug loads, minimize parasitic loads

PV Phase Optimization

- Review maintenance routines for filter change and coil cleaning
- Review chiller delta T control > 10°
- Review cooling tower cycles of concentration management
- Monitor and adjust reset sequences for maximum benefit
- Review and adjust lighting control schedule
- Review lighting levels to required levels
- Review lighting fixture maintenance schedules
- Data Trend and review daily/weekly
  - Room Temperature / Humidity
  - Supply air temperatures
  - CW / HW differential temperatures

PV Phase Optimization

- Create and review zone damper % open time per month
- Create and review CW / HW valve % open time per month
- Create and review Economizer hours of use by AHU
- Use these reports as a repair and adjustment diagnostic tool
- Repair pipe and duct insulation
- Color of roofs and exterior walls
- Window shading
- Seal envelope air leaks
- Repair or improve envelope thermal intrusion
- Install premium efficient motor for all replacement motors
- Use Low-flow toilets, urinals, faucets & showerheads, waterless urinals, gray water systems & rain-water harvesting

Improving Energy Performance

- Lighting Systems (30-60% savings)
  - Lighting Level
  - Light type (T-8/T-5 Fluorescent, CFL, LED)
  - Lighting Control
  - Sky lights
- Plug Loads
  - Turn off unused loads, reduce phantom loads (Off verses Sleep mode)
  - Use power strips with occupancy sensors
  - Eliminate unnecessary loads (Heaters, Refrigerators, Fish Tanks, Etc..)

Improving Energy Performance

- **HVAC Systems**
  - Upgrade to high efficiency equipment
  - Energy recovery for ventilation air
  - VFD's for all variable load motors
  - Changing CV system to VAV
  - Demand ventilation CO_2 control
  - Air side and water side economizers
  - Night pre-cooling if low enough OSA temperatures
  - Trim impellers for oversized pumps
  - Install high efficient boiler burner systems

Improving Energy Performance

- Power Systems
  - Photovoltaic power systems
  - Wind energy systems
  - Combined power & energy systems (COGEN)
- Envelope
  - High efficient glazing
  - Window shading, coatings, awnings, louvers, trees
  - Increased insulation

Case Study – RCx of an Existing Office Bldg

- **6 – Story, 140,000 SF occupied in 2000**
- **Existing operational cost = $1.40/SF as compared to original projection of $0.90/SF**
- **Investigation Phase results –**
  - VFDs ran at 100% output
  - 2-way valves of re-heat boxes leaked
  - Duct static pressure set very high
  - Fresh air dampers “opened” when AHUs went into night set-back mode
  - Bldg ran “occupied mode” for 16 hours while occupancy was only 10 hours

Case Study – RCx of an Existing Office Bldg

- **Investigation Phase results –**
  - High air flows when offices/rooms were empty
  - AHU discharge air controllers gave constant temp of 55°F
  - Building exhaust system ran 24/7
  - Space temps varied > 7°F; T’stats required 5°F differential before full output occurred
  - Occupants able to adjust T’stats between 55°F and 85°F
  - Unoccupied VAV boxes setpoints = occupied setpoints

Case Study – RCx of an Existing Office Bldg

- **Investigation Phase results –**
  - Electric baseboard radiation energized when outdoor temperature < 50°F
  - Boiler reset temp = 120°F during summer & caused reheat in spaces
  - Most VAV boxes required constant reheat year around
  - Excessive outside air was introduced per CO_2 measurements
  - AHUs had full economizers + chiller energized at 50°F outdoor air temperature

Case Study – RCx of an Existing Office Bldg

- **Improvement Phase –**
  - VAV minimums were lowered from 8 ACH to 4 ACH
  - CO_2 levels controlled at 800 ppm
  - Lowering of duct static pressure & one duct replacement allowed better overall operation
  - Fresh air dampers kept closed on night setback
  - Occupancy times correspond to actual occupant requirements
  - Interior zone VAV boxes set to low-flow/no flow on night setback

Case Study – RCx of an Existing Office Bldg

- **Improvement Phase –**
  - Occupancy sensors and lighting interlocks put on all conference and meeting room VAV boxes
  - Unoccupied VAV minimum setpoint were set below occupied setpoints
  - Building exhaust system shut off in unoccupied mode
  - Mixed air and discharge air temps reset per cooling and humidity control requirements based on outside air temperatures
  - Chiller activated at 58°F outdoor temperature

Case Study – RCx of an Existing Office Bldg

- **Improvement Phase –**
  - Boiler operating temperatures reset for heating and re-heating requirements
  - Baseboard electric radiation deactivated until outside air temperature was 30°F; Heaters cycled every 5 minutes to reduce electric demand
  - DDC modified to control all thermostats; occupants could still adjust full range but DDC only allowed ± 2°F change from predetermined setpoints
  - Control parameters adjusted to maintain control within ± 0.5°F

Case Study – RCx of an Existing Office Bldg

EEM	Cost	Savings	SPP
• Reduce airflows	$25,000	$7,540	3.31
• Reset DA Temps	$800	$4,708	0.17
• Red. Occ. Run Times	$700	$7,976	0.09
• Red. O/A	$7,500	$27,432	0.27
• Red. AHU S.P.	$2,000	$2,068	0.96
• Red. Pump Press.	$500	$2,072	0.24
• Elim. RH Leaks	$2,500	$8,368	0.30
• Improve Control Seq.	$5,000	$5,000	1.00
• Investigative Costs	$56,000	$2,836	19.7
Totals (2002 $)	$100,000	$68,000	SPP = 1.47

Questions?

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