BCxA™ Building Commissioning Association

SOUTHEAST REGION

Existing Building Commissioning (or Retro-Commissioning)

SERBCA Annual Meeting

Covington, KY

December 6, 2013

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Engineering | Architecture | Planning | Allied Services

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 (EBCx) or "Retro-Commissioning"

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 / RetroCx Process

Implementation Stage

1. Implementation Phase
    - Implement selected recommendations from Investigative Phase

Post-Implementation Stage

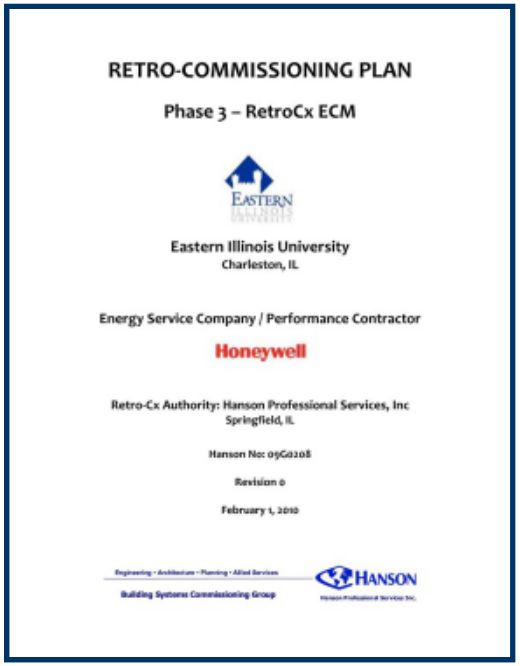
1. Final Adjustment
    - Re-test and Re-monitor
    - Train Operators
2. Hand-off and Acceptance
    - Develop Persistence Strategies
    - Final Report

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


RETRO-COMMISSIONING PLAN

Phase 3 – RetroCx ECM

Eastern Illinois University
Charleston, IL

Energy Service Company / Performance Contractor

Honeywell

Retro-Cx Authority: Hanson Professional Services, Inc
Springfield, IL

Hanson No: 05G0208

Revision 0

February 1, 2010

Building Systems Commissioning Group

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Kick-Off Meeting

Purpose:

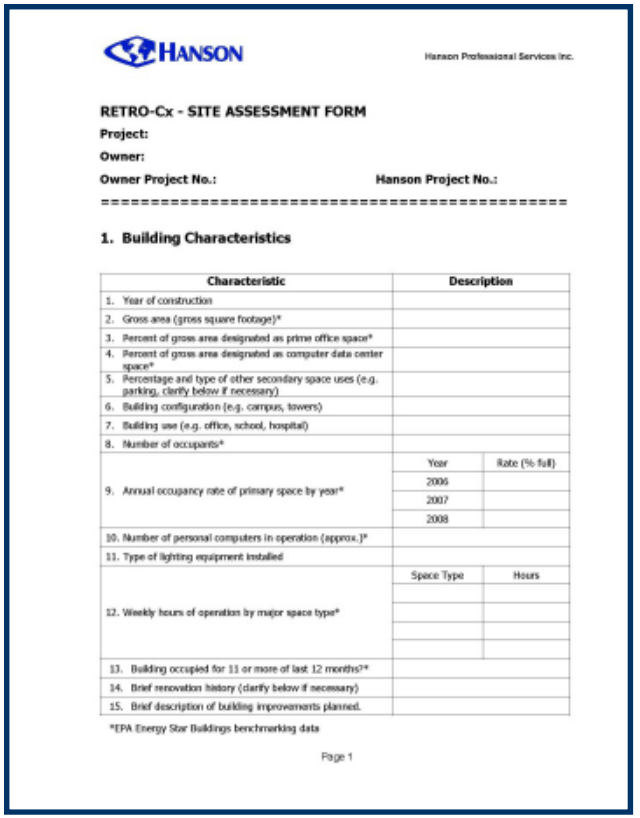
- To impart the Owner's objective for the project
- To discuss and agree to the RetroCx Plan
- To clarify the key roles and responsibilities of commissioning team members
- To identify and agree to schedules
- To define the work protocols and policies
- Document the meeting

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



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Hanson Professional Services Inc.

RETRO-Cx - SITE ASSESSMENT FORM

Project:

Owner:

Owner Project No.: **Hanson Project No.:**

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1. Building Characteristics

Characteristic	Description	
1. Year of construction		
2. Gross area (gross square footage)*		
3. Percent of gross area designated as prime office space*		
4. Percent of gross area designated as computer data center space*		
5. Percentage and type of other secondary space uses (e.g. parking, clarify below if necessary)		
6. Building configuration (e.g. campus, towers)		
7. Building use (e.g. office, school, hospital)		
8. Number of occupants*		
9. Annual occupancy rate of primary space by year*	Year	Rate (% full)
	2006	
	2007	
	2008	
10. Number of personal computers in operation (approx.)*		
11. Type of lighting equipment installed		
12. Weekly hours of operation by major space type*	Space Type	Hours
13. Building occupied for 11 or more of last 12 months?*		
14. Brief renovation history (clarify below if necessary)		
15. Brief description of building improvements planned.		

*EPA Energy Star Buildings benchmarking data

Page 1

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 #: 105546
ELECTRIC RATE: E46 - General Service Medium Electric
TURN ON DATE: 2/4/1999
MULTIPLIER: 960

latest 12 month
monthly average
$35,432.43

Service	Read Date	Read Type	Meter Reading	Days	kWh Usage	Actual kW Demand	Customer Charge	kWh Charge	kW Demand Charge	Fuel Adj. Factor	Utility Tax	Total Electric Bill	Load Factor
Electric	01/14/10	Actual	37321	34	269,760	480.00	$120.00	$15,349.34	$4,944.00	$4,482.33	$863.23	$25,758.91	68.9%
Electric	12/11/09	Actual	37040	28	216,960	460.80	$120.00	$12,345.02	$4,746.24	$4,562.02	$694.27	$22,467.55	70.1%
Electric	11/13/09	Actual	36814	30	264,000	710.40	$120.00	$15,021.60	$7,317.12	$4,634.26	$844.80	$27,937.78	51.6%
Electric	10/14/09	Actual	36539	33	335,040	768.00	$120.00	$19,380.54	$8,081.69	$7,458.66	$1,072.13	$36,113.02	55.1%
Electric	09/11/09	Actual	36190	32	458,880	931.20	$120.00	$29,689.54	$11,304.77	$11,231.09	$1,468.42	$53,813.81	64.2%
Electric	08/10/09	Actual	35712	31	435,840	854.40	$120.00	$28,198.85	$10,372.42	$8,170.26	$1,394.69	$48,256.21	68.6%
Electric	07/10/09	Actual	35258	29	433,920	940.80	$120.00	$28,074.62	$11,421.31	$10,322.52	$1,388.54	$51,327.00	66.3%
Electric	06/11/09	Actual	34806	29	380,160	864.00	$120.00	$24,391.85	$10,379.32	$10,842.16	$1,216.51	$46,949.85	63.2%
Electric	05/13/09	Actual	34410	28	333,120	816.00	$120.00	$18,954.53	$8,404.80	$6,328.28	$1,065.98	$34,873.59	60.8%
Electric	04/15/09	Actual	34063	34	295,680	624.00	$120.00	$16,824.19	$6,427.20	$5,857.72	$946.18	$30,175.28	58.1%
Electric	03/12/09	Actual	33755	31	265,920	585.60	$120.00	$15,130.85	$6,031.68	$4,815.28	$850.94	$26,948.75	61.0%
Electric	02/09/09	Actual	33478	27	221,760	508.80	$120.00	$12,618.14	$5,240.64	$3,277.61	$709.63	$21,966.03	67.3%
Electric	01/13/09	Actual	33247	33	258,240	460.80	$120.00	$14,693.86	$4,746.24	$2,155.27	$826.37	$22,541.74	70.8%
Electric	12/11/08	Actual	32978	28	225,600	499.20	$120.00	$12,836.64	$5,141.76	$2,505.29	$721.92	$21,325.61	67.3%
Electric	11/13/08	Actual	32743	30	276,480	720.00	$120.00	$15,731.71	$7,416.00	$4,089.42	$884.74	$28,241.86	53.3%
Electric	10/14/08	Actual	32455	29	341,760	700.80	$120.00	$19,446.14	$7,218.24	$4,316.09	$1,093.63	$32,194.10	70.1%
Electric	09/15/08	Actual	32099	39	505,920	844.80	$156.00	$32,733.02	$13,332.63	$8,526.78	$1,618.94	$56,367.38	64.0%
Electric	08/07/08	Actual	31572	29	418,560	921.60	$120.00	$27,080.83	$11,188.22	$9,258.13	$1,339.39	$48,986.58	65.3%
Electric	07/09/08	Actual	31136	33	450,240	873.60	$120.00	$29,130.53	$10,605.50	$9,756.25	$1,440.77	$51,053.05	65.1%
Electric	06/06/08	Actual	30667	29	336,000	854.40	$120.00	$21,106.60	$9,992.94	$11,276.83	$1,075.20	$43,571.57	56.5%
Electric	05/08/08	Actual	30317	27	278,400	691.20	$120.00	$15,840.96	$7,119.36	$1,606.37	$890.88	$25,577.57	62.2%
Electric	04/11/08	Actual	30027	29	246,720	652.80	$120.00	$14,038.37	$6,723.84	$2,423.53	$789.50	$24,095.24	54.3%
Electric	03/13/08	Actual	29770	29	230,400	480.00	$120.00	$12,810.24	$4,828.80	$1,968.77	$737.28	$20,465.09	69.0%
Electric	02/13/08	Actual	29530	32	253,440	499.20	$120.00	$14,091.26	$5,021.95	$2,533.39	$811.01	$22,577.61	66.1%
Electric	01/12/08	Actual	29266	32	249,600	595.20	$120.00	$13,877.76	$5,987.71	$5,023.45	$798.72	$25,807.64	54.6%
Electric	12/11/07	Actual	29006	34	279,360	604.80	$120.00	$15,532.42	$6,084.29	$4,233.70	$893.95	$26,864.36	56.6%
Electric	11/07/07	Actual	28715	28	261,120	643.20	$120.00	$14,518.27	$6,470.59	$4,164.08	$835.58	$26,108.53	60.4%
Electric	10/10/07	Actual	28443	29	345,600	816.00	$120.00	$19,577.64	$8,411.55	$6,271.26	$1,105.92	$35,486.38	60.9%
Electric	09/11/07	Actual	28083	33	456,000	921.60	$120.00	$27,952.80	$10,607.62	$5,861.42	$1,459.20	$46,001.04	62.5%
Electric	08/09/07	Actual	27608	30	411,840	940.80	$120.00	$25,245.79	$10,828.61	$4,289.31	$1,317.89	$41,801.60	60.8%
Electric	07/10/07	Actual	27179	32	425,280	912.00	$120.00	$26,069.66	$10,497.12	$2,112.37	$1,360.90	$40,160.05	60.7%
Electric	06/08/07	Actual	26736	30	366,720	787.20	$120.00	$21,937.19	$8,786.73	$5,295.07	$1,173.50	$37,312.49	64.7%
Electric	05/09/07	Actual	26354	28	293,760	720.00	$120.00	$15,833.66	$7,034.40	$1,883.30	$940.03	$25,811.39	60.7%
Electric	04/11/07	Actual	26048	30	283,200	624.00	$120.00	$15,264.48	$6,096.48	$748.50	$906.24	$23,135.70	63.0%

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

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Appendix D – Utility History Analysis

Enclosed are tables noting the electric demand, consumption, and costs on a monthly basis for the past six (6) years. Exhibit D-1 is taken directly from the utility company's billings. Using the building's area (97,800 SF), along with the conversion from kWh to BTU (3,412 BTU / kWh), we can summarize the facility's electrical energy consumption in the following table:

Electric Summary – Koke Mill Medical Center

Year	Total kWh	kWh / SF	Total MBtu	MBtu / SF	Electric Costs *	$ / SF
2009	3,911,040	39.99	13,344,408	136.45	$426,587.78	$4.362
2008	3,821,760	39.08	13,038,845	133.33	$396,997.40	$4.059
2007	3,843,840	39.30	13,115,182	134.10	$366,284.74	$3.745
2006	3,493,440	35.72	11,919,617	121.88	$295,716.93	$3.024
2005	3,394,560	34.71	11,582,239	118.43	$245,999.11	$2.515
2004	2,952,960	30.19	10,075,506	103.02	$204,210.59	$2.088

* - Electric costs include consumption, demand charges, fuel adjustment factor and utility tax

The summary above reflects several trends:

- Electric costs increase consistently each year and have more than doubled over the past six years.
- While the building's electric consumption has remained relatively constant over the past three (3) years, these recent annual totals are approximately 32% above the consumption seen in 2004.
- Recent data notes that average electric consumption for healthcare facilities (hospitals and medical centers) is approximately 28 kWh / SF. This facility has been consistently above this average since 2004. Most recently, in 2009, consumption was approximately 42.8% above this average.

Using total electric costs and total consumption kWh to develop average (weighted) unit electric rates (accommodating consumption, demand, fuel adjustment and taxes), results in the following rates for the past six years:

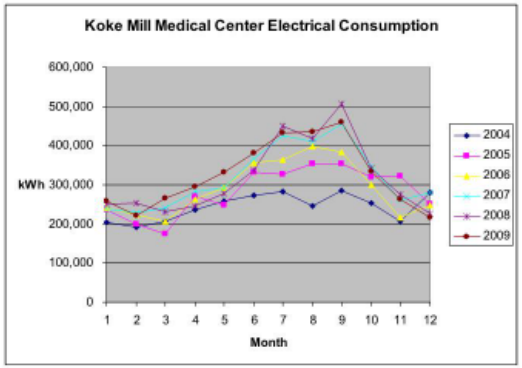
2009 - $0.1091 / kWh 2008 - $0.1039 / kWh 2007 - $0.0953 / kWh
2006 - $0.0846 / kWh 2005 - $0.0725 / kWh 2004 - $0.0692 / kWh

Page 28

Utility Bill Analysis - Graphics

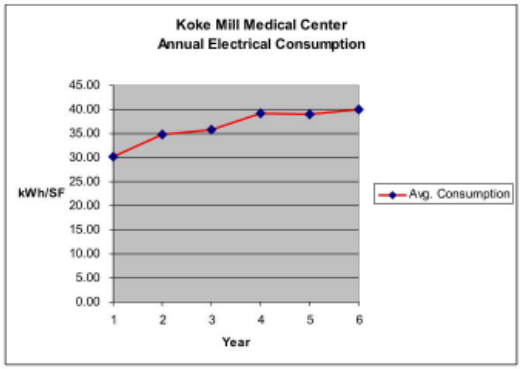
Graphical Representation compares annual or monthly trends

Can be used to compare facility under study to database benchmarks



Annual Energy Consumption for the Past Six (6) years

Exhibit D-2



Average Annual Energy Consumption over past Six (6) Years

Exhibit D-3

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?

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

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

MHS Data Center
2401 West Jefferson

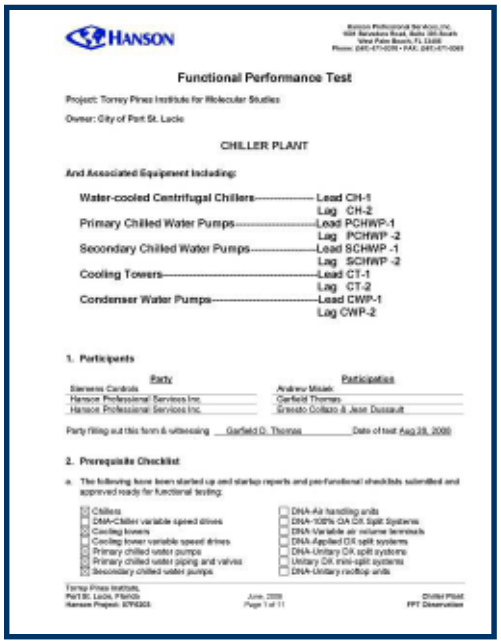
TREND DATA REPORT

Sept. 2nd thru 7th, 2010

DATE	TIME	BLRHWR-T (deg F)	BLRHWS-T (deg F)	BLRR1-C	CD-TEMP (deg F)	CD-DASP	Cooling Load Command	HD-TEMP (deg F)	SF2-STAT
9/2/10	1:30:00 PM	147.875	158.875	On	59.34375	60.0	91.125	128	On
9/2/10	2:00:00 PM	145.375	157.125	On	59.6875	60.0	91.375	126.9375	On
9/2/10	2:30:00 PM	144.75	159.625	On	59.5	60.0	91.25	126.4375	On
9/2/10	3:00:00 PM	142.875	157.25	On	60.09375	60.0	91.4375	125.625	On
9/2/10	3:30:00 PM	144.125	158.625	On	59.8125	60.0	91.375	126.25	On
9/2/10	4:00:00 PM	141.125	164	On	59.5625	60.0	91.25	125.4375	On
9/2/10	4:30:00 PM	141.75	157.375	On	59.21875	60.0	91.5	122.5625	On
9/2/10	5:00:00 PM	144.125	159.5	On	60.15625	60.0	91.4375	124.1875	On
9/2/10	5:30:00 PM	143.625	159.25	On	61.1875	60.0	92.375	124.5	On
9/2/10	6:00:00 PM	146	153.375	On	60.625	60.0	95.1875	127.3125	On
9/2/10	6:30:00 PM	143.625	158.5	On	60.84375	60.0	95.5	123.875	On
9/2/10	7:00:00 PM	141.125	167.75	On	60.375	60.0	95.0625	123.4375	On
9/2/10	7:30:00 PM	144.125	160.5	On	60.90625	60.0	95.5	124.75	On
9/2/10	8:00:00 PM	143.625	159.25	On	60.71875	60.0	95.5	123.9375	On
9/2/10	8:30:00 PM	144.75	162.125	On	60.5625	60.0	95.3125	123.0625	On
9/2/10	9:00:00 PM	142.375	158.75	On	60.4375	60.0	95.0625	123	On
9/2/10	9:30:00 PM	143.625	159.5	On	60.71875	60.0	95.3125	123.4375	On
9/2/10	10:00:00 PM	144.125	159.625	On	60.5625	60.0	95.4375	123.875	On
9/2/10	10:30:00 PM	140.625	149.75	On	59.03125	60.0	94.375	122.8125	On
9/2/10	11:00:00 PM	141.125	152.875	On	58.5	60.0	94.0625	120	On
9/2/10	11:30:00 PM	140.375	152.5	On	56.75	60.0	93.5625	118.875	On
9/3/10	12:00:00 AM	140.125	153.125	On	55.46875	60.0	91.625	118.25	On
9/3/10	12:30:00 AM	135.375	148.75	On	55.34375	60.0	91.8125	115.8125	On
9/3/10	1:00:00 AM	139.875	154.125	On	54.40625	60.0	91.5	116.8125	On
9/3/10	1:30:00 AM	133.625	147.75	On	53.9375	60.0	90.8125	114.125	On
9/3/10	2:00:00 AM	138	153	On	53.0625	60.0	90.4375	115.375	On
9/3/10	2:30:00 AM	135.25	149.5	On	56.65625	60.0	84.625	114.4375	On
9/3/10	3:00:00 AM	133.875	148.125	On	57.6875	60.0	85.625	113.5	On
9/3/10	3:30:00 AM	133	148.875	On	58.5	60.0	85.9375	112.875	On
9/3/10	4:00:00 AM	136.125	150.75	On	59.21875	60.0	86.5	114.4375	On
9/3/10	4:30:00 AM	134.875	149.125	On	58.34375	60.0	85.9375	113.5	On
9/3/10	5:00:00 AM	136.875	155.5	On	57.625	60.0	85.4375	112.875	On
9/3/10	5:30:00 AM	136.75	153.5	On	56.59375	60.0	84.5	112.625	On
9/3/10	6:00:00 AM	132.375	147.625	On	55.8125	60.0	84.3125	111.9375	On
9/3/10	6:30:00 AM	131.25	146	On	55.71875	60.0	84.3125	110	On
9/3/10	7:00:00 AM	131.5	146.625	On	55.9375	60.0	84.3125	111.5	On
9/3/10	7:30:00 AM	143.625	168.5	Off	62.25	60.0	0	108.5625	OFF
9/3/10	8:00:00 AM	109.25	155.25	On	62.46875	60.0	42.34375	94.75	On
9/3/10	8:30:00 AM	107.4375	166.25	On	63	60.0	42.71875	94.9375	On
9/3/10	9:00:00 AM	108.0625	174.625	On	63.34375	60.0	42.9375	95.5625	On
9/3/10	9:30:00 AM	110.5625	154.125	On	65.125	60.0	44.125	98.25	On
9/3/10	10:00:00 AM	113.3125	173.125	On	65.4375	60.0	44.34375	101.875	On
9/3/10	10:30:00 AM	115.9375	166.625	On	66.0625	60.0	44.71875	105.5625	On
9/3/10	11:00:00 AM	118.25	169.125	On	67.125	60.0	45.40625	106.75	On
9/3/10	11:30:00 AM	119.375	156	On	66.375	60.0	50.0625	107.4375	On
9/3/10	12:00:00 PM	120	158.5	On	67.125	60.0	69.0625	106.9375	On
9/3/10	12:30:00 PM	116.875	169.125	On	62.875	60.0	82.375	104.8125	On
9/3/10	1:00:00 PM	115.625	156	On	65.625	60.0	84.25	104	On
9/3/10	1:30:00 PM	115.625	156.375	On	65.4375	60.0	84.125	103.1875	On

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.



HANSON

Functional Performance Test

Project: Torrey Pines Institute for Molecular Studies

Owner: City of Port St. Lucie

CHILLER PLANT

And Associated Equipment Including:

Water-cooled Centrifugal Chillers ---------- Lead CH-1
Lag CH-2
Primary Chilled Water Pumps ---------- Lead PCHWP-1
Lag PCHWP -2
Secondary Chilled Water Pumps ---------- Lead SCHWP -1
Lag SCHWP -2
Cooling Towers ---------- Lead CT-1
Lag CT-2
Condenser Water Pumps ---------- Lead CWP-1
Lag CWP-2

1. Participants

Party	Participation
Siemens Controls	Andrew Misek
Hanson Professional Services Inc.	Garfield Thomas
Hanson Professional Services Inc.	Ernesto Collazo & Jose Dussault

Party filling out this form & witnessing: Garfield D. Thomas Date of test: Aug 29, 2008

2. Prerequisite Checklist

a. The following have been started up and startup reports and pre-functional checklists submitted and approved ready for functional testing.

- [x] Chillers
- [ ] DNA-Chiller variable speed drives
- [x] Cooling towers
- [ ] Cooling tower variable speed drives
- [x] Primary chilled water pumps
- [x] Primary chilled water piping and valves
- [x] Secondary chilled water pumps
- [ ] DNA-Air handling units
- [ ] DNA-100% OA DX Split Systems
- [ ] DNA-Variable air volume terminals
- [ ] DNA-Applied DX split systems
- [ ] DNA-Unitary DX split systems
- [ ] Unitary DX mini-split systems
- [ ] DNA-Unitary rooftop units

Torrey Pines Institute,
Port St. Lucie, Florida
Hanson Project: 07P020.

June, 2008
Page 1 of 11

Chiller Plant
PFT Observation

Master List of Findings

List should include:

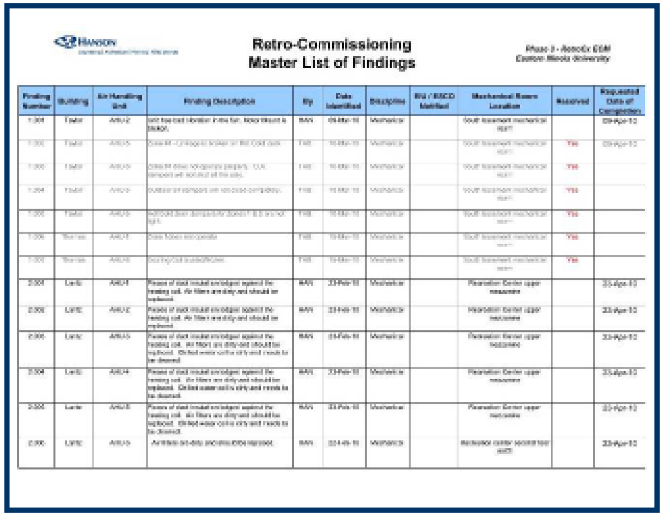
- Item Number
- Equipment or System ID No. or Name
- Description of Finding
- Recommended Improvement
- Estimated Savings ($/Yr.) or Benefit
- Estimated Cost to Implement
- Payback (Years)
- Recommended Implementation Strategy (optional)

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

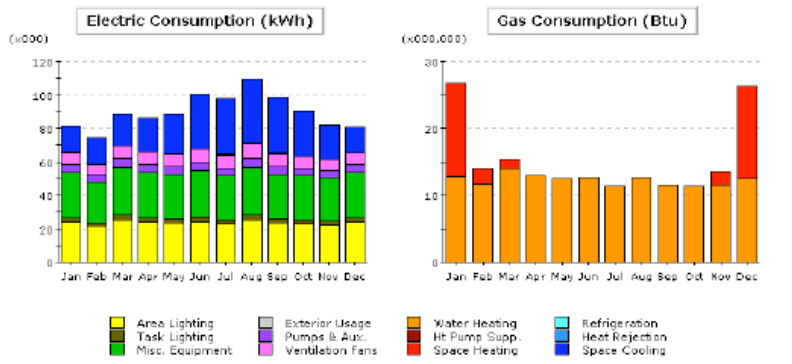
- Allows room to address action(s) ‘taken’ or ‘recommended’ and associated date(s)


Retro-Commissioning
Master List of Findings

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

$$\frac{(hp) \times (0.746\ kW/\ hp) \times (hr/yr) \times (\$/kWh) \times (Load\ Factor)}{\text{Motor efficiency}}$$

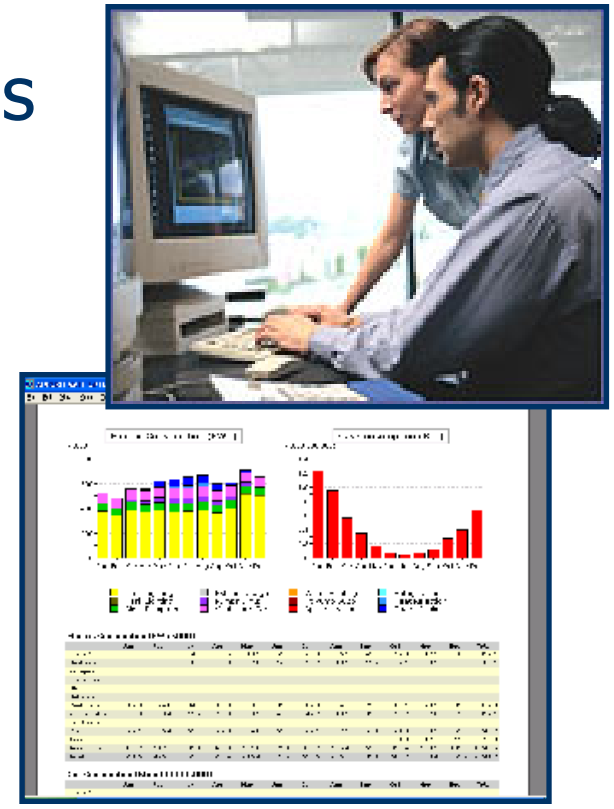


Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	15.7	16.0	19.2	20.0	23.9	32.7	33.5	36.5	33.4	27.0	20.4	14.9	295.2
Heat Reject.	0.0	0.0	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.2	0.1	0.0	2.2
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	6.8	6.1	7.3	7.1	7.1	7.9	7.7	8.6	7.6	7.1	6.5	6.7	86.5
Pumps & Aux.	5.0	4.4	5.2	5.0	4.8	5.0	4.8	5.2	4.8	4.8	4.6	5.0	58.6
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	27.3	24.3	28.9	27.3	26.6	27.7	26.1	28.9	26.6	26.1	25.5	27.3	322.6
Task Lights	2.6	2.3	2.8	2.6	2.6	2.7	2.5	2.8	2.6	2.5	2.5	2.6	31.0
Area Lights	23.9	21.3	25.2	23.9	23.2	24.2	22.9	25.2	23.2	22.9	22.3	23.9	282.1
Total	81.3	74.6	88.7	85.9	88.3	100.6	97.9	109.6	98.6	90.6	81.7	80.4	1,078.1

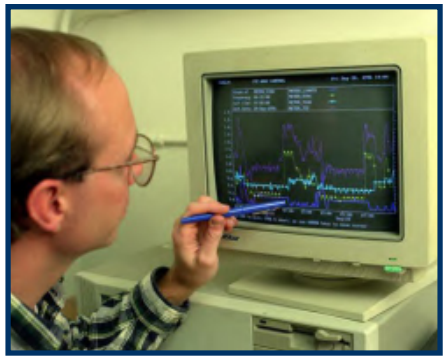
Energy Modeling – Recommended Measures

- 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

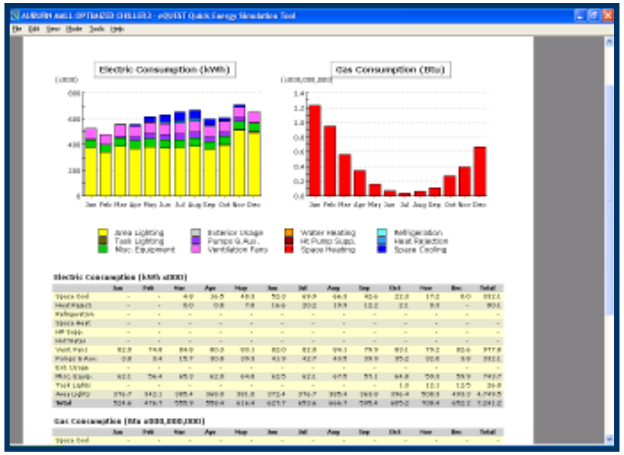


Energy Modeling – Program Tools

- 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

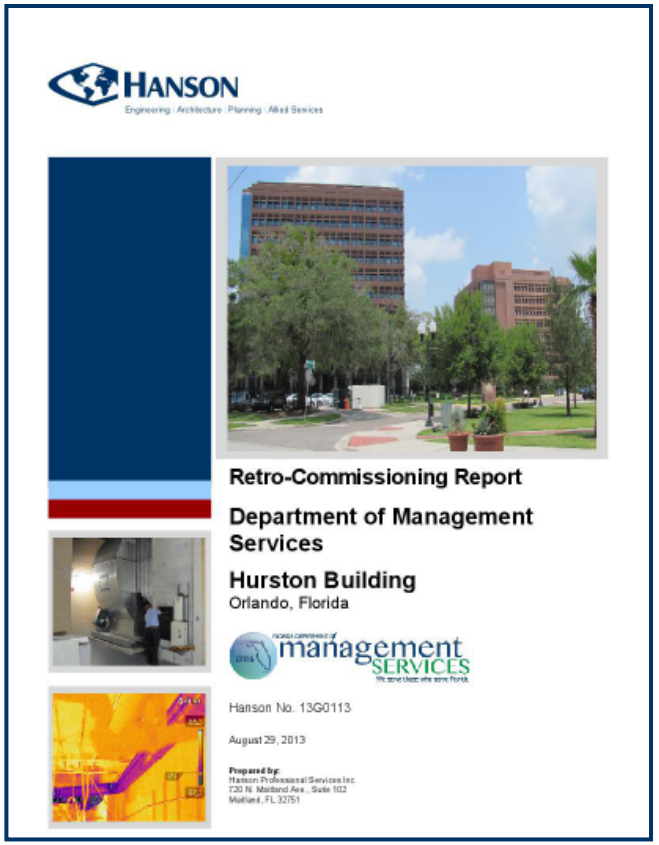
Hand-off Phase Elements

- **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.

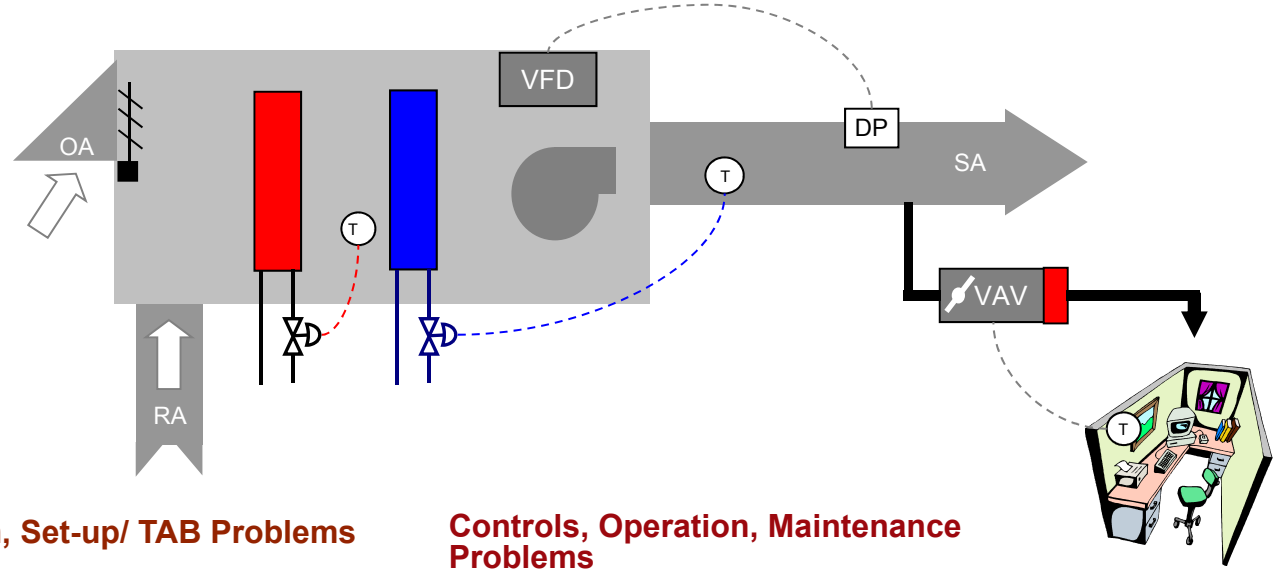


Top 10 Findings - Retro-Commissioning

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

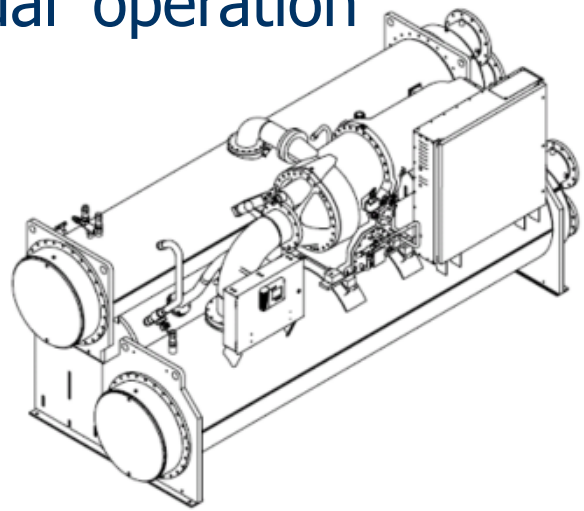
Disable supply air temp reset logic

Actual OA damper position

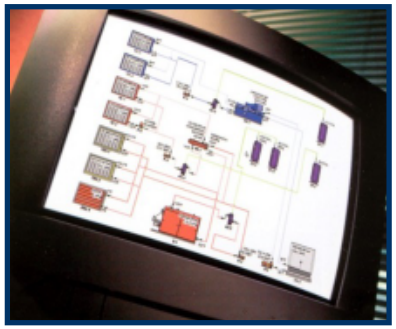
Dirty filters

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

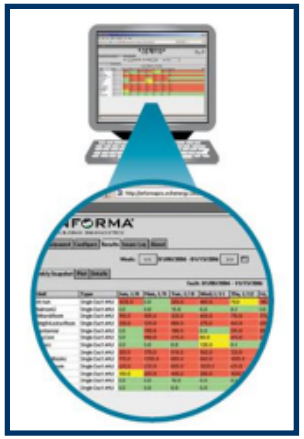
Ensuring 'Persistence of Savings'

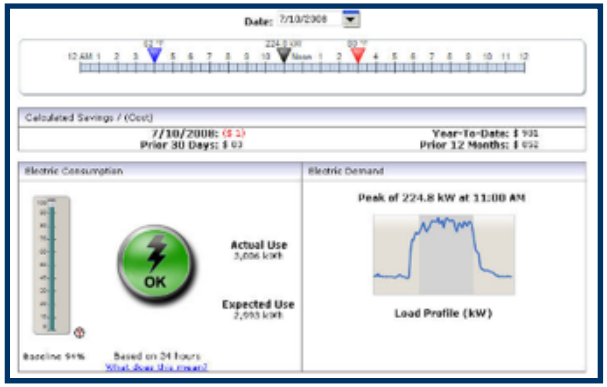
Employee Engagement / Social Marketing

- 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

Bldg. Type	No. of Bldgs.	Energy Savings $/Sq Ft/Yr *	Payback Yrs
Hospitals	6	$0.43	1.1
Lab/Offices	7	$1.26	0.3
Class/Offices	5	$0.43	0.5
Offices	8	$0.22	1.5
Schools	2	$0.17	2.0
Avg./Total	28	$0.54	0.7

Source: Texas A&M ESL

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

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

ECM	Description	Cost	Savings	Payback
ECM-1	Reduce HVAC Equipment Operating Hours	$17,000	$54,156	0.314
ECM-2	Provide Demand Control Ventilation for Air Handling Units A through D	$8,000	$17,269	0.463
ECM-3	Install building pressurization sensors and variable frequency drives on select exhaust fans	$10,500	$2,299	4.57
ECM-4	Shutdown supplemental air handling units AH-1, AH-2 and AH-3 when areas are not occupied	$1,900	$535	3.55
ECM-5	Update remaining variable air volume (VAV) terminal unit controls and reheat coils and integrate into DDC system	$104,000	$13,292	7.82
ECM-6	Replace incandescent lamps with compact fluorescent lamps	$680	$3,030	0.224
ECM-7	Install lighting control system(s)	$29,450	$12,317	2.39
ECM-8	Integrate Power Logics meter into Automated Logic BAS	$2,600	$2,124	1.22
ECM-9	Building Air Balance	$22,000	$3,270	6.72
	Project Totals	**$196,130**	**$108,292 ***	**1.811 ***

* - 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 ???

BCxA™ Building Commissioning Association

SOUTHEAST REGION

Thank You!

Robert J. Knoedler, P.E., EMP, CxA

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