Existing Building Commissioning

Current practices and new developments

BEST Center/ LBNL workshop

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Overview

- What is EBCx?
- EBCx Benefits
- Case Studies
- Need for M&V in EBCx projects
- Guidelines and Tools

What is EBCx?

- 2 Definitions:
  1. Building Commissioning Association
     - Similar to new construction Cx
     - Goal is efficient operations meeting owners requirements
  2. Utility Program Definition
     - Similar to audit/retrofit process
     - A means of acquiring low cost energy savings

BCA Definition

"EBCx is a systematic process for investigating, analyzing, and optimizing the performance of building systems through identification and implementation of Facility Improvement Measures and insuring their continued performance."

www.bcxa.org

BCA - Scope

- Total Building
- HVAC & Lighting
- Domestic Water
- Control Systems
- Indoor Environmental Quality
- Operations & Maintenance
- Equipment Reliability
- Etc.

Utility Definition

"Retrocommissioning (RCx) is a systematic process for identifying less-than-optimal performance in your facility's equipment, lighting and control systems and making the necessary adjustments. While retrofitting involves replacing outdated equipment, RCx focuses on improving the efficiency of what's already in place."

http://www.pge.com/en/mybusiness/save/rebates/retrocommissioning/index.page

Utility RCx - Scope

Generally:

- HVAC
- Lighting
- Controls

- Less comprehensive than BCA
- Tends to view “improvements” as units of energy savings

Why EBCx? - Benefits

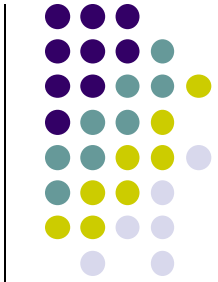
- 15% energy savings per building on average
  - Mills study, LBNL, 2008
- Improved operations
- Improved indoor air quality
- Better informed and trained operations staff
- Obtain LEED-EBOM (Green Building Certification) credits
  - Many Owners seeking LEED EBOM have already done EBCx/RCx

Case Study

- UC Berkeley Soda Hall

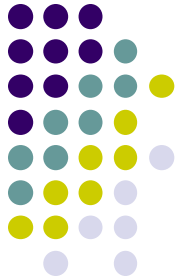
- Case study introduces need for M&V

UC Berkeley – MBCx Program



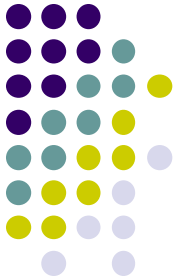
- Project funded under the UC/CSU/IOU Partnership's Monitoring-Based Commissioning (MBCx) Program
  - RCx process enhanced by addition of permanent monitoring capability to understand system performance
    - Diagnostics
    - Savings calculations
    - Savings verification
  - Soda Hall (2006):
    - Steam meters added
  - Electric and steam meters connected to Web-based tool
  - Meters provide short-time interval (e.g. 15-min) data.

Soda Hall



- UC Berkeley's Computer Science Department (24/7 operation)
- 109,000 ft^2
- Energy Use Intensity: 174 $kBtu/ft^2$-yr
- 2 - 215 ton chillers (lead/lag)
- Constant Speed Primary/Variable Speed Secondary Chilled Water System
- Two 2-speed, forced draft, open loop cooling towers
- 3 Main VAV AHUs,
  - AHU1 serves building core,
  - AHUs 3 and 4 serve the perimeter, with hot water reheat
- 11 computer room DX units, water cooled with variable speed pumps
- Steam to hot water heat exchanger, 2 variable speed HW pumps

Soda Hall Findings



- Minimum VAV Box Damper Positions at 50%
  - Causes excessive reheat in perimeter zones
  - Little modulation of fan VFD
- Several AHU VFDs broken or not modulating
  - Return to designed VAV operation
  - Return to scheduled operation
- Re-establish supply air temperature set point reset control in AHU1
- Other measures

- Approximately 483,000 kWh (10%), 2.7M lbs/yr steam (51%)
  - Estimated using DOE2 analysis
- Cost reduction $84,000 (14%), Payback 0.7 years

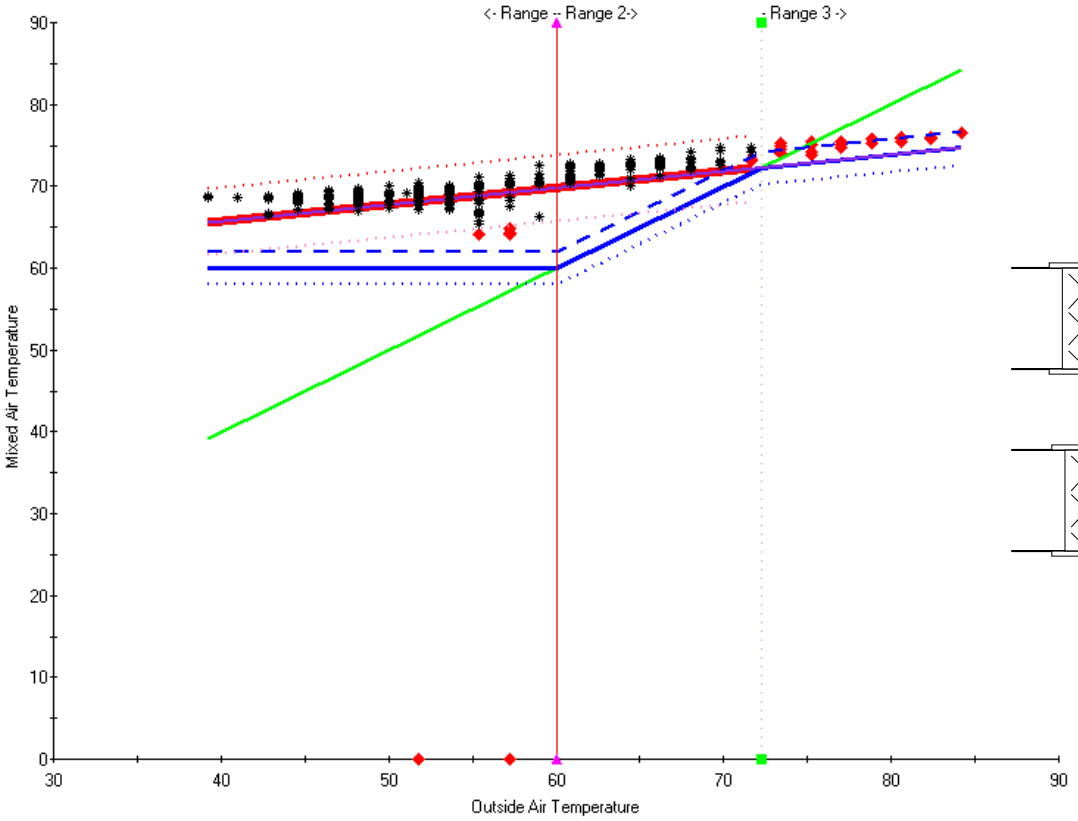
Soda Hall Measures

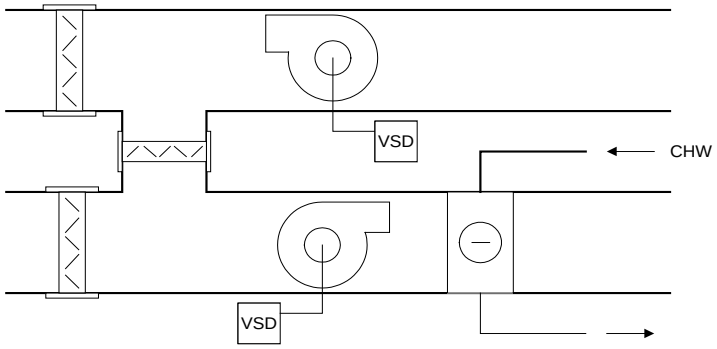
Measure No.	Description	Implementation Date	Estimated Savings: Energy, kWh/yr	Estimated Savings: Energy, lbs/yr	Estimated Savings: Dollars, $/yr	Estimated Measure Cost, $	Payback, yr
AHU1-2	Resume supply air temperature reset control and return economizer to normal operation	10/25/2006	129,800	266,250	$19,004	$1,550	0.1
AHU1-3	Repair/replace VFDs in return fans	10/25/2006	34,308		$4,460	$7,000	1.6
AHU1-4	Reduce high minimum VAV box damper position	3/9/2006	46,300	119,300	$6,973	$15,250	2.2
AHU3-2 & AHU4-2	Option 2: Reduce high minimum VAV box damper position	3/9/2006	30,600	2,328,100	$22,603	$17,250	0.8
AHU3-3 & AHU4-3	Re-establish scheduled fan operation and VAV AHU-3 (includes repair/replace VFD on return fan EF-17), AHU-4 (includes repair/replace VFDs on supply SF-18 and return EF-19 fans, and elimination of low VFD speed setting during the day)	10/25/2006	242,000		$31,460	$14,000	0.4
Total			**483,008**	**2,713,650**	**$84,500**	**$55,050**	0.7
		Percentage Savings	10%	51%	14%		

Utility Data		
Steam	5,325,717	lbs
Electricity	4,871,678	kWhr
Cost	$621,575	

Finding Measures

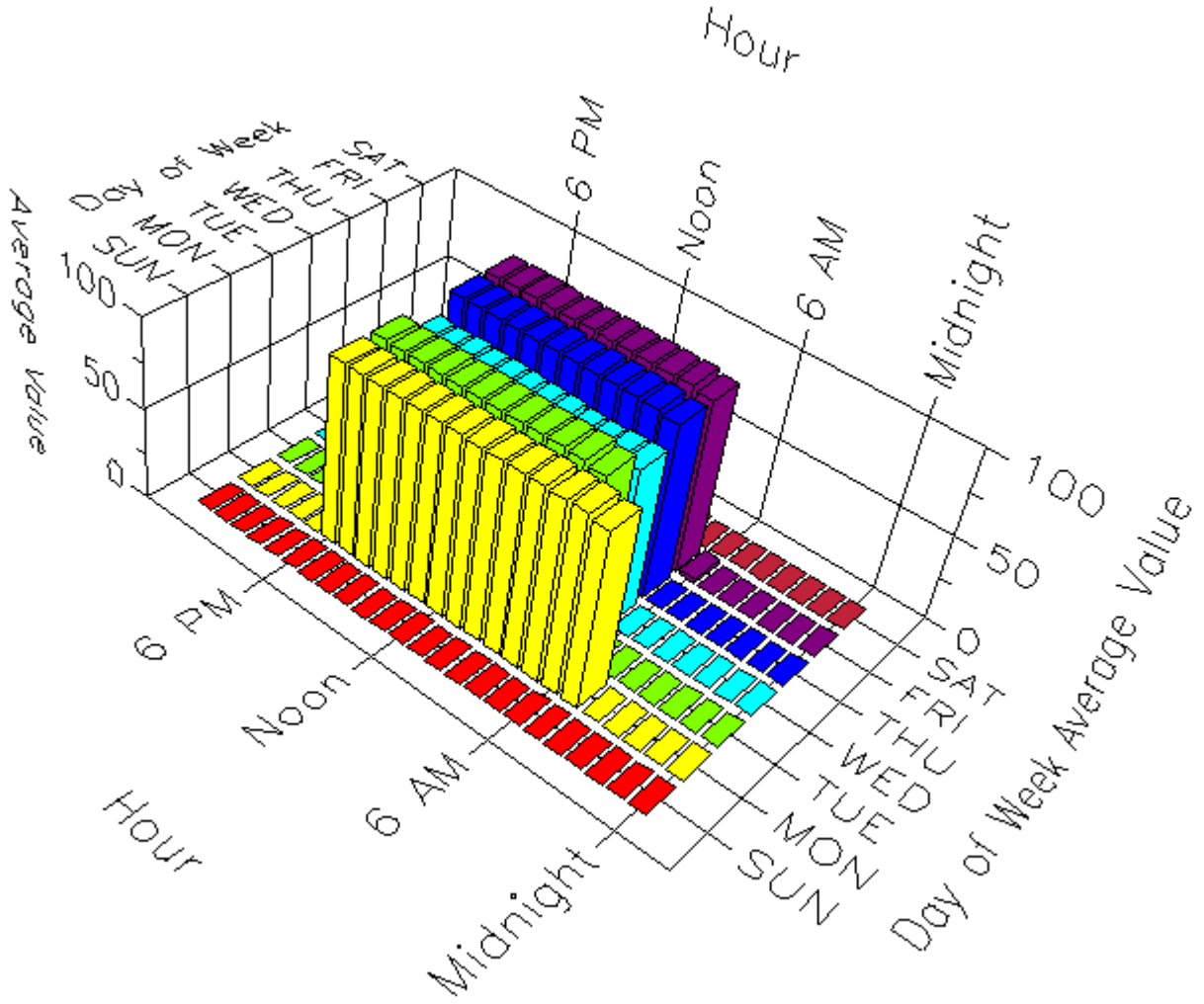
- Economizer problems





- Cause: Stuck damper

Excessive Building Schedule



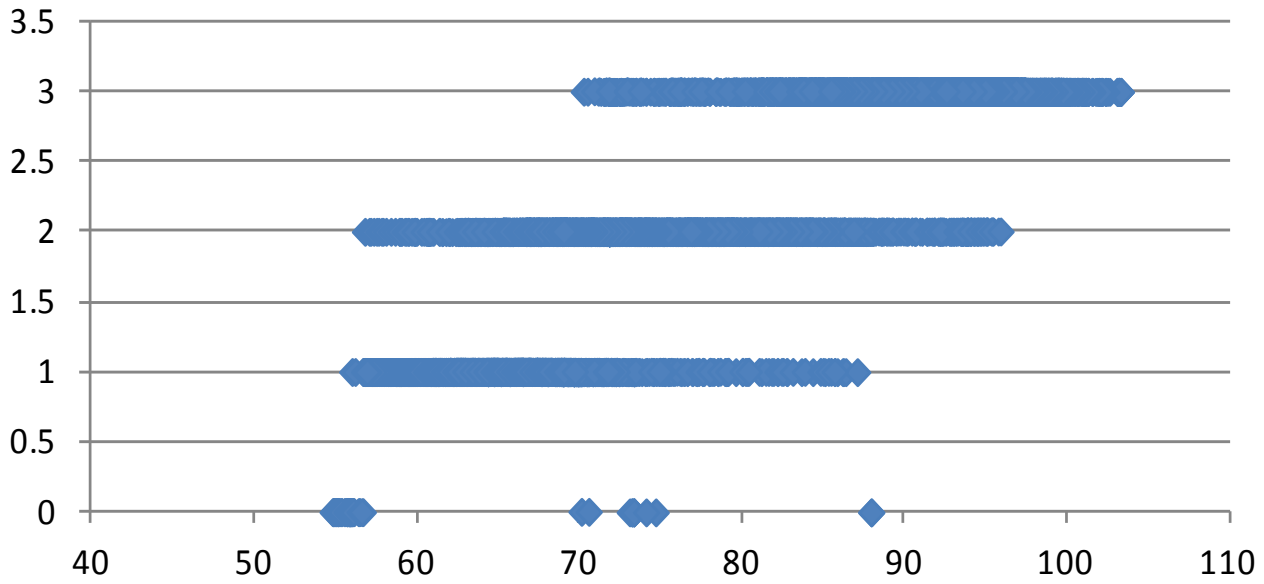
- Cause: old building warm-up schedule

Lighting on at Night

- Cause: malfunctioning occ sensors and sweep timers

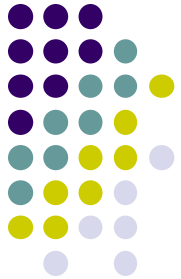
Chiller Staging

- Unnecessary Chiller Operation
  - # chillers operating vs. ambient temperature



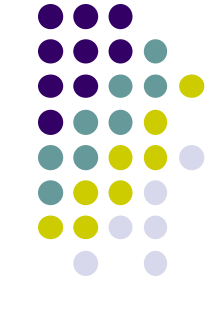
- Cause: improper chiller staging control algorithm

Note on EBCx Energy Savings



- Based on data collected before improvements made
  - Called “ex-ante” savings estimates
  - No standard calculation methodologies for ex-ante savings

Ex-Ante Savings Calculations

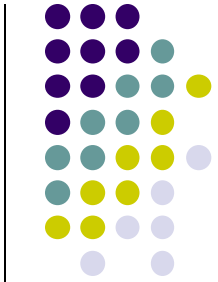


A Baseline Operation w/ IGV				
Air Volume Flow Rate Profile	Speed	IGV Power Ratio [Note 1]	Power	Annual Energy Use
%	%	%	kW	kWh/Yr
100%	100%	109%	12.8	51
98%	100%	105%	12.3	74
96%	100%	102%	12.0	96
94%	100%	99%	11.6	267
92%	100%	96%	11.3	362
91%	100%	93%	10.9	436
89%	100%	90%	10.6	244
87%	100%	87%	10.2	602
85%	100%	85%	10.0	750
83%	100%	84%	9.9	782
81%	100%	83%	9.7	1,358
79%	100%	81%	9.5	1,055
77%	100%	80%	9.4	808
75%	100%	78%	9.2	1,003
74%	100%	77%	9.0	801
72%	100%	76%	8.9	454
70%	100%	74%	8.7	835
68%	100%	73%	8.6	774
66%	100%	73%	8.6	697
64%	100%	71%	8.3	1,212
62%	100%	70%	8.2	869
60%	100%	69%	8.1	1,013
58%	100%	68%	8.0	1,048
57%	100%	67%	7.9	940
55%	100%	66%	7.8	562
53%	100%	65%	7.6	1,284
51%	100%	65%	7.6	958
50%	100%	65%	7.6	1,041
50%	100%	65%	7.6	1,467
50%	100%	65%	7.6	631
50%	100%	65%	7.6	509
50%	100%	65%	7.6	456
50%	100%	65%	7.6	319
50%	100%	65%	7.6	152
50%	100%	65%	7.6	122
50%	100%	65%	7.6	122
50%	100%	65%	7.6	84
50%	100%	65%	7.6	122
50%	100%	65%	7.6	23
			12.8	24,379

D Proposed Operation w/o IGV, w/ VFD High Limit & w/ VFD Modulation				
Air Volume Flow Rate Profile	Speed w/ VFD Modulation	VFD Power Ratio [Note 2]	Power w/ VFD Modulation	Annual Energy Use
%	%	%	kW	kWh/Yr
100%	89.3%	71%	9.1	36
98%	87.6%	68%	8.4	50
96%	85.9%	64%	7.7	62
94%	84.2%	63%	7.3	168
92%	82.6%	60%	6.8	218
91%	80.9%	57%	6.2	248
89%	79.2%	56%	5.9	136
87%	77.5%	53%	5.4	319
85%	75.8%	50%	5.0	375
83%	74.1%	49%	4.9	387
81%	72.5%	46%	4.5	630
79%	70.8%	44%	4.2	466
77%	69.1%	43%	4.0	344
75%	67.4%	40%	3.7	403
74%	65.7%	38%	3.4	303
72%	64.0%	37%	3.3	168
70%	62.3%	34%	3.0	288
68%	60.7%	32%	2.8	252
66%	59.0%	30%	2.6	211
64%	57.3%	28%	2.3	336
62%	55.6%	26%	2.1	223
60%	53.9%	24%	1.9	238
58%	52.2%	23%	1.8	236
57%	50.5%	21%	1.7	202
55%	48.9%	19%	1.5	108
53%	47.2%	19%	1.4	237
51%	45.5%	17%	1.3	164
50%	44.7%	16%	1.2	164
50%	44.7%	16%	1.2	232
50%	44.7%	16%	1.2	100
50%	44.7%	16%	1.2	80
50%	44.7%	16%	1.2	72
50%	44.7%	16%	1.2	50
50%	44.7%	16%	1.2	24
50%	44.7%	16%	1.2	19
50%	44.7%	16%	1.2	19
50%	44.7%	16%	1.2	13
50%	44.7%	16%	1.2	19
50%	44.7%	16%	1.2	4
			9.1	7,603

Savings = 24,379 – 7,603 = 16,776 kWh annually (?)

Are Savings Real?



- Savings *estimates* are based on:
  - Design documentation
  - Equipment specifications
  - Monitored operational data
    - Independent data loggers
    - Control system trends
  - Bin models, engineering models, computer simulations, etc.
- Do savings estimates = “real” savings?
  - Model errors
  - Incomplete or inaccurate data
  - Incorrect assumptions
  - Etc.
- Savings calculation effort takes time, focus, & resources away from commissioning the building!

What are risks?

- Savings not delivered, no return on investment
- No means to demonstrate actual savings
- No ability to track energy performance
- Savings do not last:
  - “Soft” measures that can be and often are defeated

Need for M&V in EBCx

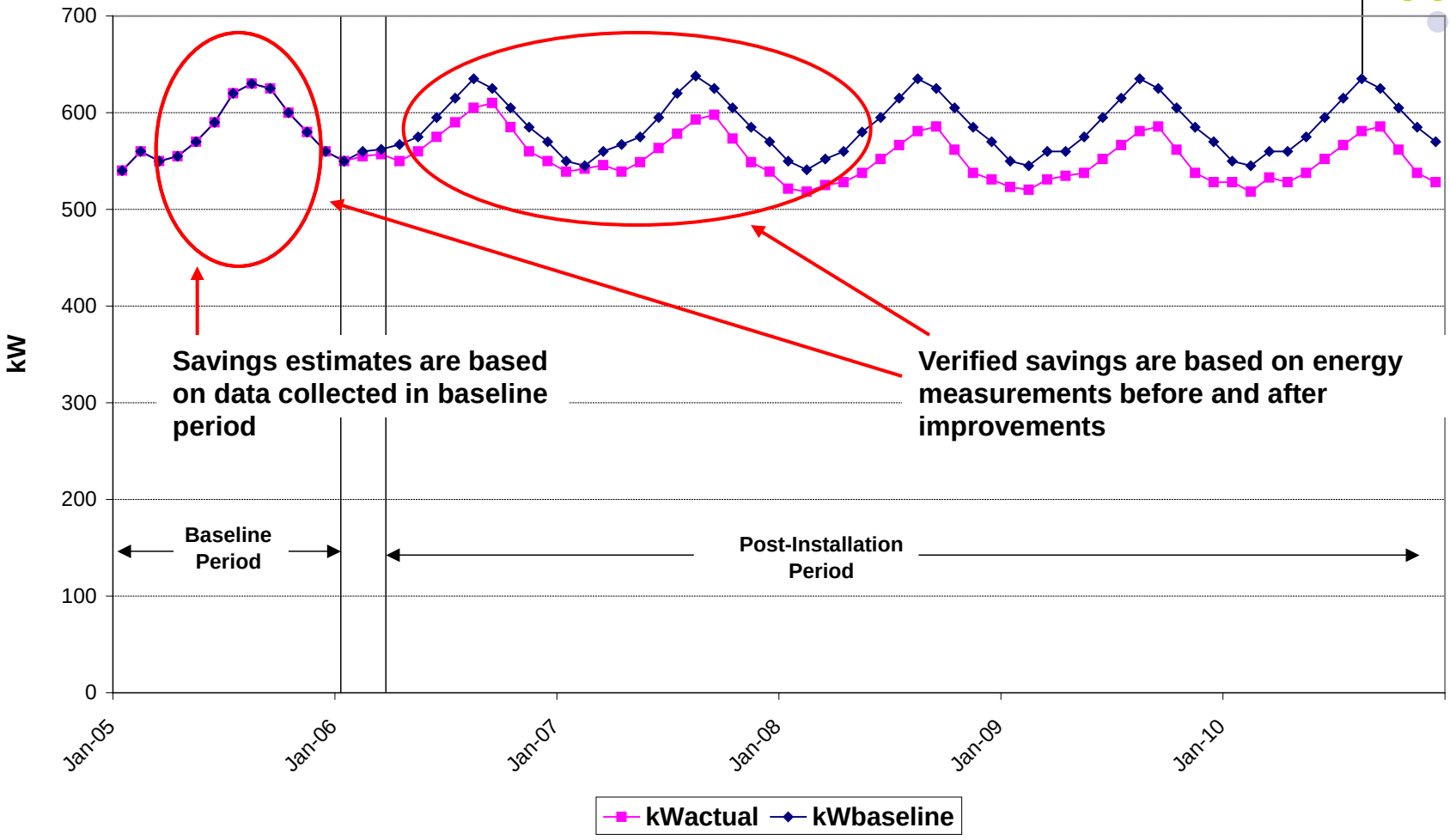
Needs:

- Demonstrate actual, verified energy savings benefits of RCx
- Provide a mechanism to determine measure savings persistence
- Smooth process of third party EM&V in public-goods funded RCx programs

Opportunities:

- Standardization of M&V processes for RCx
- Provide information tools for operators and owners to maintain measure savings, and further improve energy performance

What is M&V?


700
600
500
400
300
200
100
0
kW
Savings estimates are based on data collected in baseline period
Verified savings are based on energy measurements before and after improvements
Baseline Period
Post-Installation Period
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
kWactual
kWbaseline

Measurement & Verification

- Partial definition:
  - Savings estimation based on measurements and analysis of energy use before & after EEM implementation, adjusting for conditions

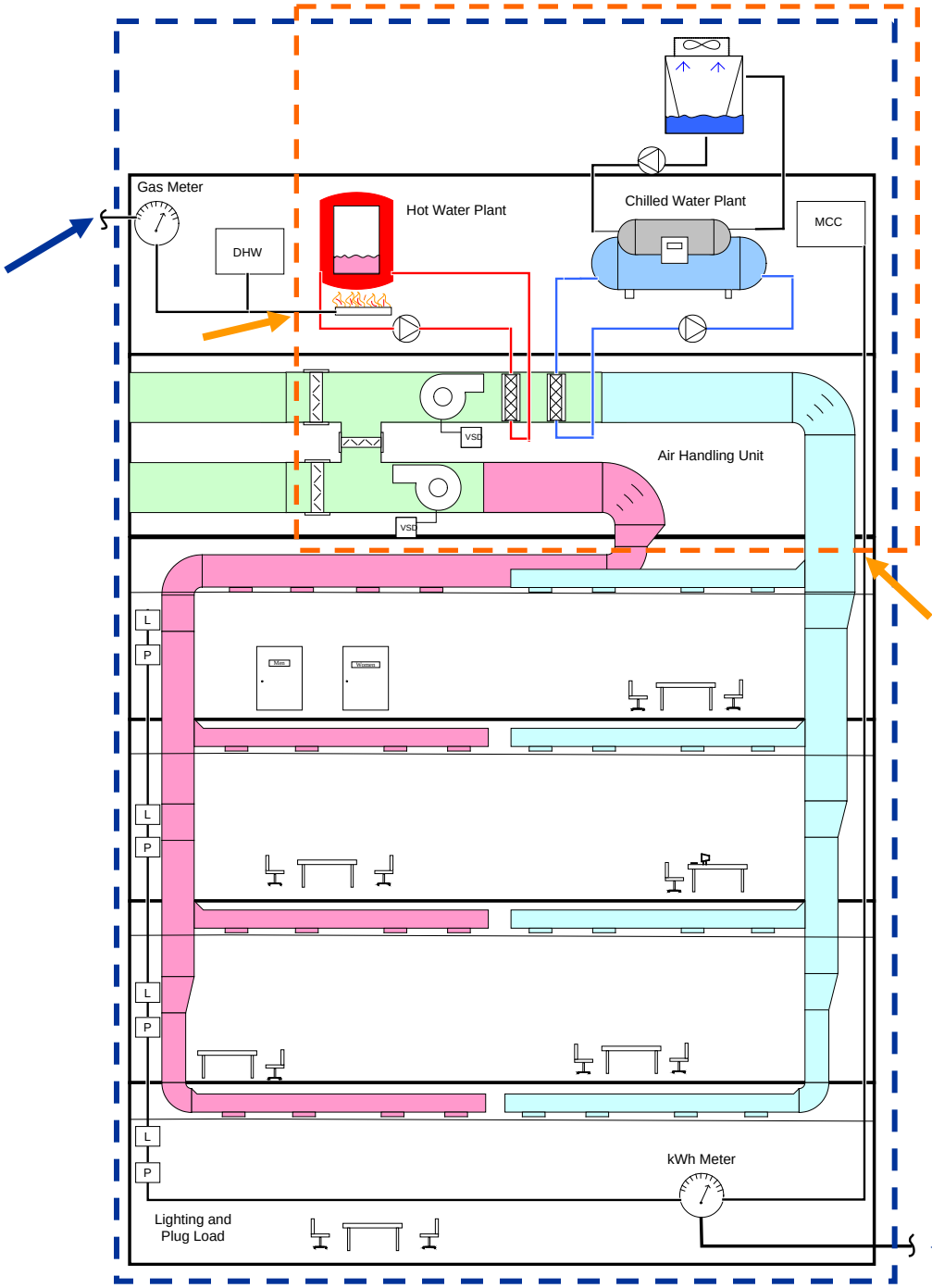
- Measurement Boundary
  - Whole-building (uses main meters)
  - System (uses sub-meters, EMS, or data logger)
  - Individual EEM

M&V Approach

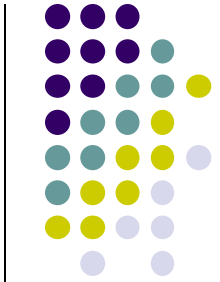
- Select measurement boundary

- Option C - Whole Building

- Option B: Retrofit Isolation (HVAC Systems)



M&V Methods



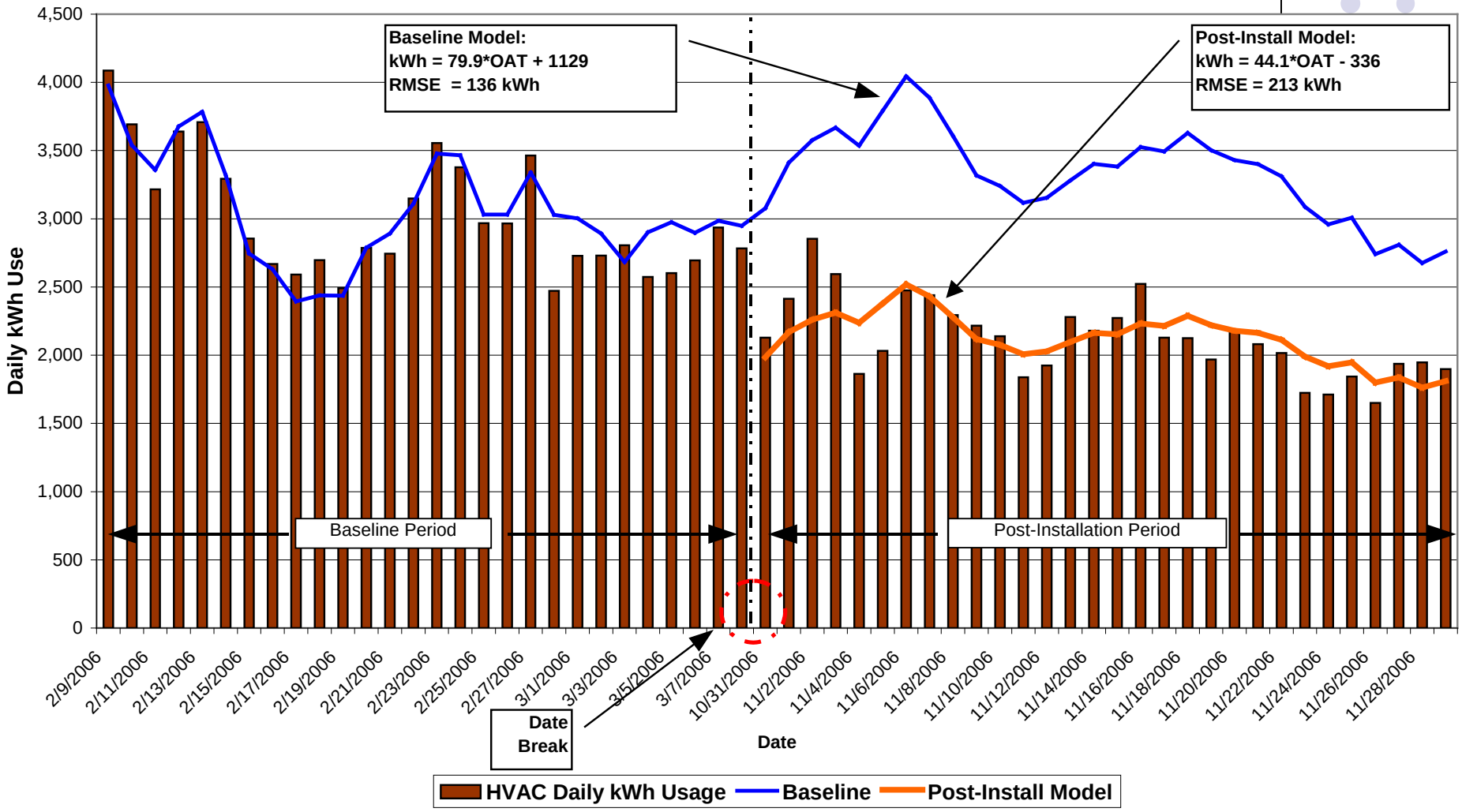
- Regression analysis
  - Whole building
  - Systems
- Calibrated Simulation
  - Whole building
  - Systems
  - Individual EEMs
- Load and Schedule Calculations
  - Systems
  - Individual EEMs

Back to Case Study

- Regression method selected
  - Energy use totaled each day
  - Ambient temperatures averaged over the day
- Measurement Boundaries
  - Whole building
  - System (HVAC)
- Data
  - 8 months of trended data collected

- System energy data – how to get?
  - “Spot” measurements of kW for constant load equipment
  - Short term logging of variable load equipment kW
    - Corresponding speed data from EMS
    - Relationship between kW and speed developed

Soda Hall M&V: HVAC Systems

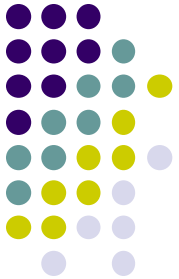


Costs

Building	Metering Costs	MBCx Agent Costs	In-House Costs	Total
Soda Hall	$ 4,442	$ 62,160	$ 51,087	$ 117,689
Tan Hall	$ 22,573	$ 53,000	$ 15,300	$ 90,873

- **Including all costs, project remains cost-effective:**
  - **Soda Hall: 1.7 year payback**
  - **Tan Hall: 0.7 year payback**
- **Added costs of metering hardware and software did not overburden project's costs**
- **Realization rate (CPUC evaluation): > 95%**
- **UC Best Practices Awards**
- **In private sector – metering costs lower**
  - **Existing electric meters**
  - **Sophisticated EMS systems**

Integrating M&V into EBCx



M&V Process

Baseline Period

- Define Scope of M&V Activity
- Identify purpose/goals of M&V activity
- Identify affected systems
- Design the M&V Process
  - Assess Project & Source of Savings
  - Define Approach
- Add points & collect data
  - Energy and indep. variable (OAT, etc.)
  - Bldg. level: gas pulse, steam meter, etc.
  - Systems: Chiller kW, other var. loads
- Document the baseline
  - Equipment inventory and operations
  - Develop baseline energy model
  - Assess baseline model
- Finalize and Document the M&V Plan

Post-Installation Period

- Verify proper performance
- Collect post-installation data
- Develop post-install model
- Verify savings at conclusion of EBCx
- Develop Savings Report

Persistence Phase

- Verify continued equipment performance
- Establish energy tracking system
- Provide periodic savings reports

EBCx Process (Guideline p.2)

Scope of Cx Activity

- Identify purpose/goals of Cx activity
- Describe roles of involved parties
- Identify systems included in Cx process

Planning Phase

- Establish bldg. requirements
- Review available info./ visit site / interview operators
- Develop EBCx Plan
- Document operation conditions

Investigation Phase

- Identify current building needs
- Facility performance analysis
- Diagnostic monitoring
- System testing
- Create list of findings

Implementation Phase

- Prioritize recommendations
- Install/Implement recommendations
- Commission Recommendations
- Document improved performance

Turnover Phase

- Update building documentation
- Develop final report
- Update Systems Manual
- Plan ongoing commissioning
- Provide Training

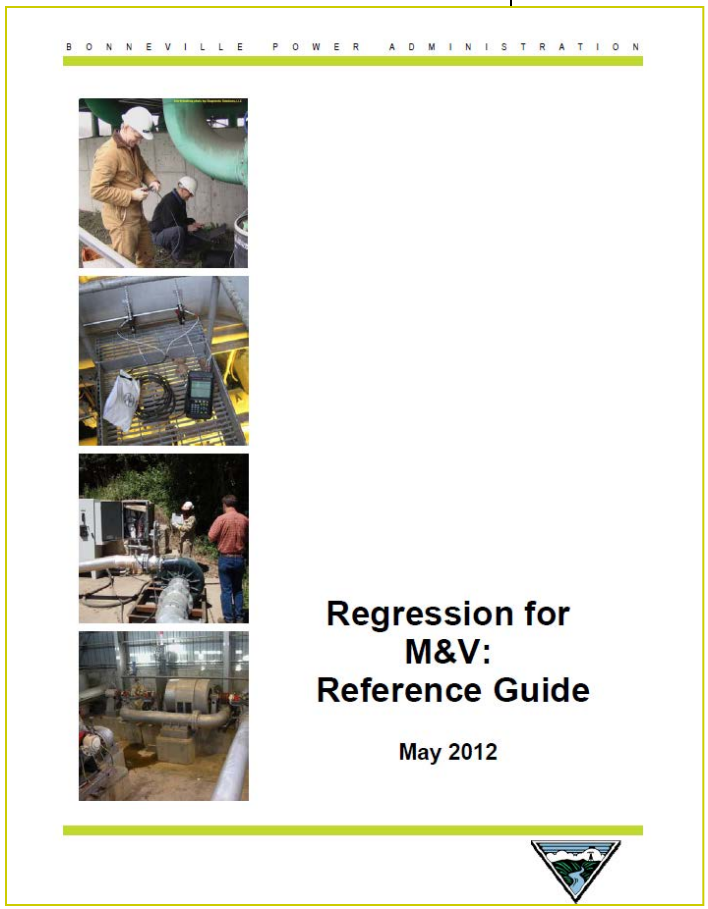
Persistence Phase

- Monitor and track energy use
- Monitor and track non-energy metrics
- Trend key system parameters
- Document changes
- Implement persistence strategies

M&V Guidelines and Tools

Application Protocols and Guidelines

- Bonneville Power Administration
  - Conduit: https://conduitnw.org/
    - Engineering Calculations with Verification
    - Sampling Reference Guide & Tool
    - **Regression Reference Guide**
    - Equipment or End-Use Metering
      - Option A or B
    - Energy Modeling (Option B or C)
    - Energy Use Indexing (Option C)
    - Existing Building Commissioning Application Guide
    - End-Use Metering (absent baseline) Application Guide



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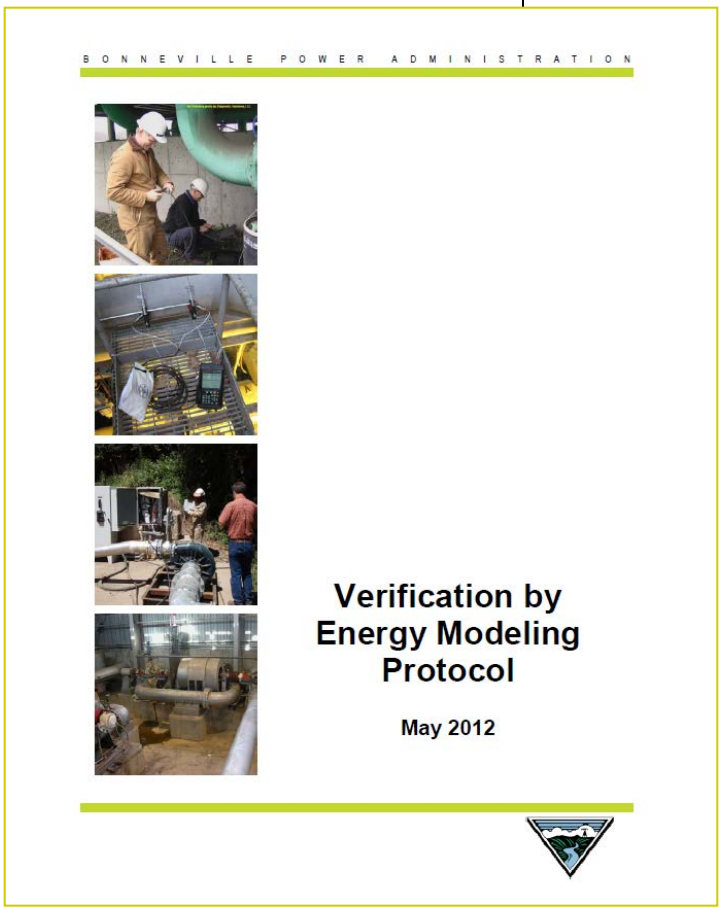
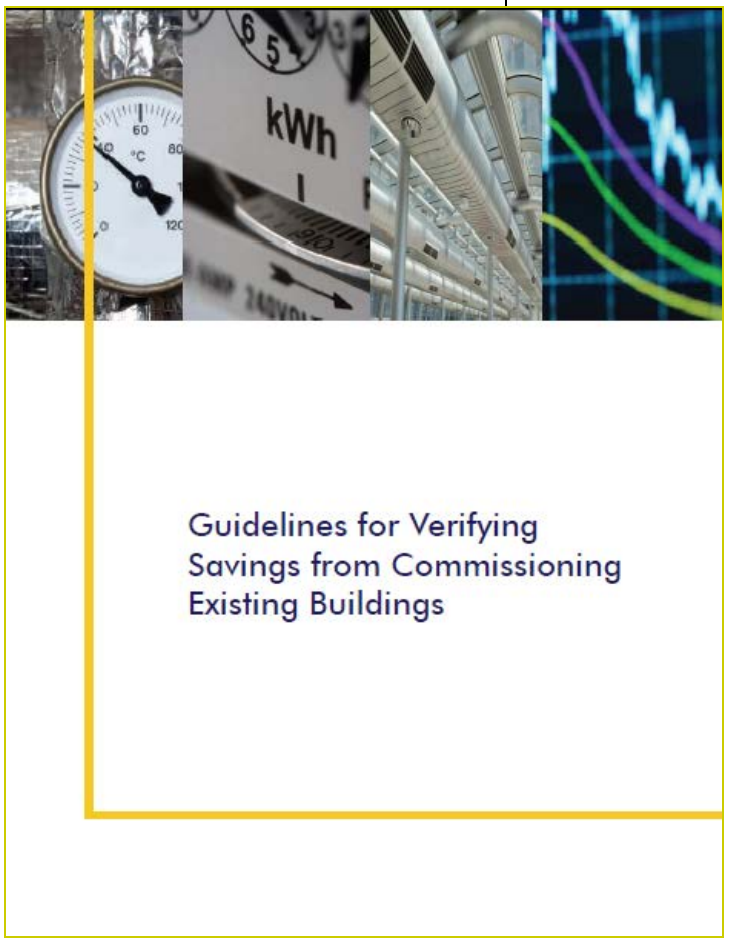


California Commissioning Collaborative

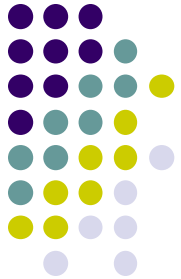
- Guidelines for Verifying Existing Building Commissioning Project Savings
- www.cacx.org
- Engineering Calculations with Field Verification
- System or Equipment Energy Measurement (Option A or B)
- **Energy Models Using Interval Data (Option B or C)**
- Calibrated Simulation (Option D)



M&V Tool: What is it?

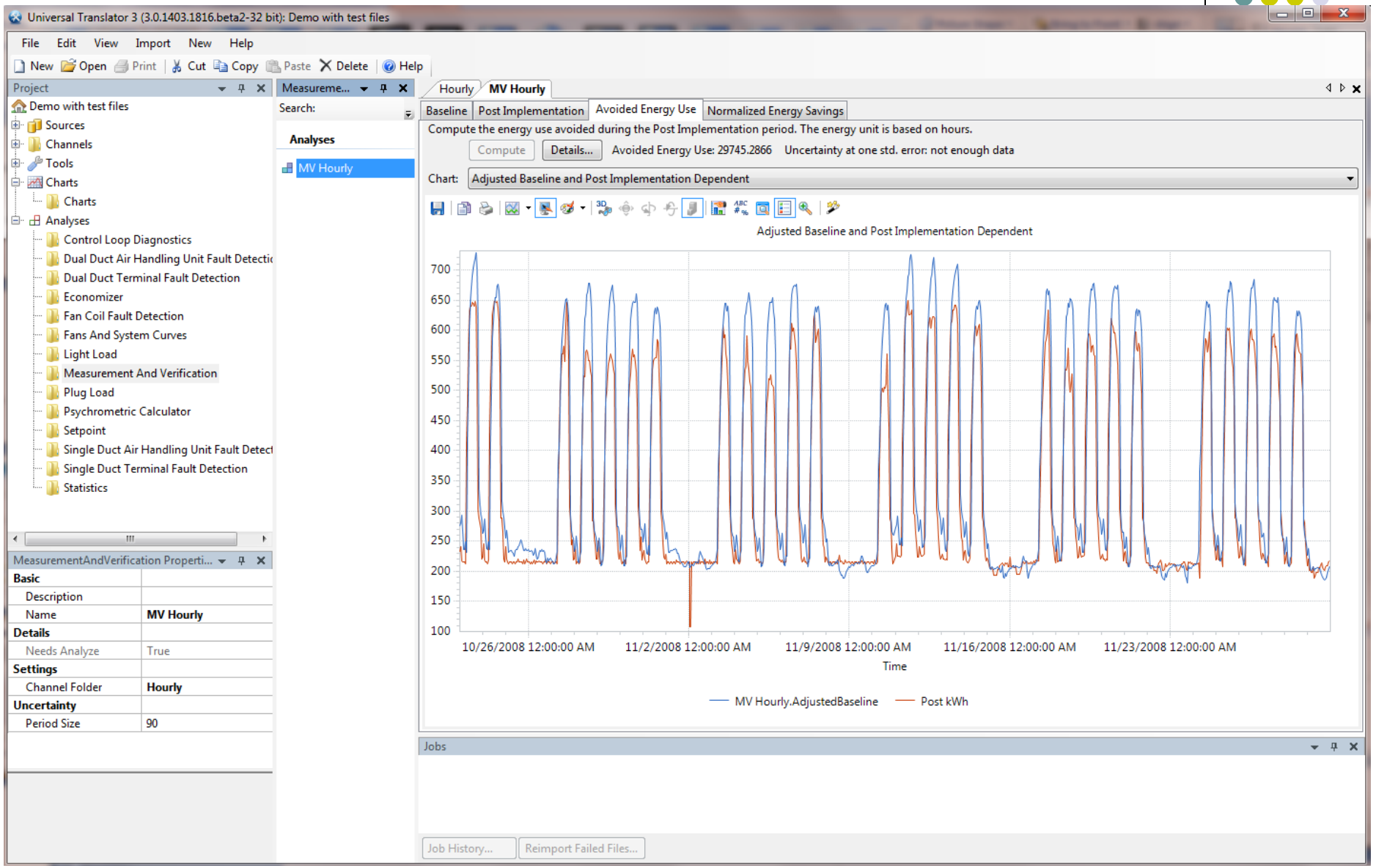
- Analysis Module within Universal Translator (v3)
  - UT3 provides:
    - Data merge
    - Time interval re-sampling
    - Charting – data quality checks
  - M&V Analysis Module provides:
    - Advanced regression modeling
      - Time of week and temperature (LBNL)
    - Model fit and sufficiency checks
    - Savings quantification
    - Uncertainty analysis (beta)

Tool Benefits



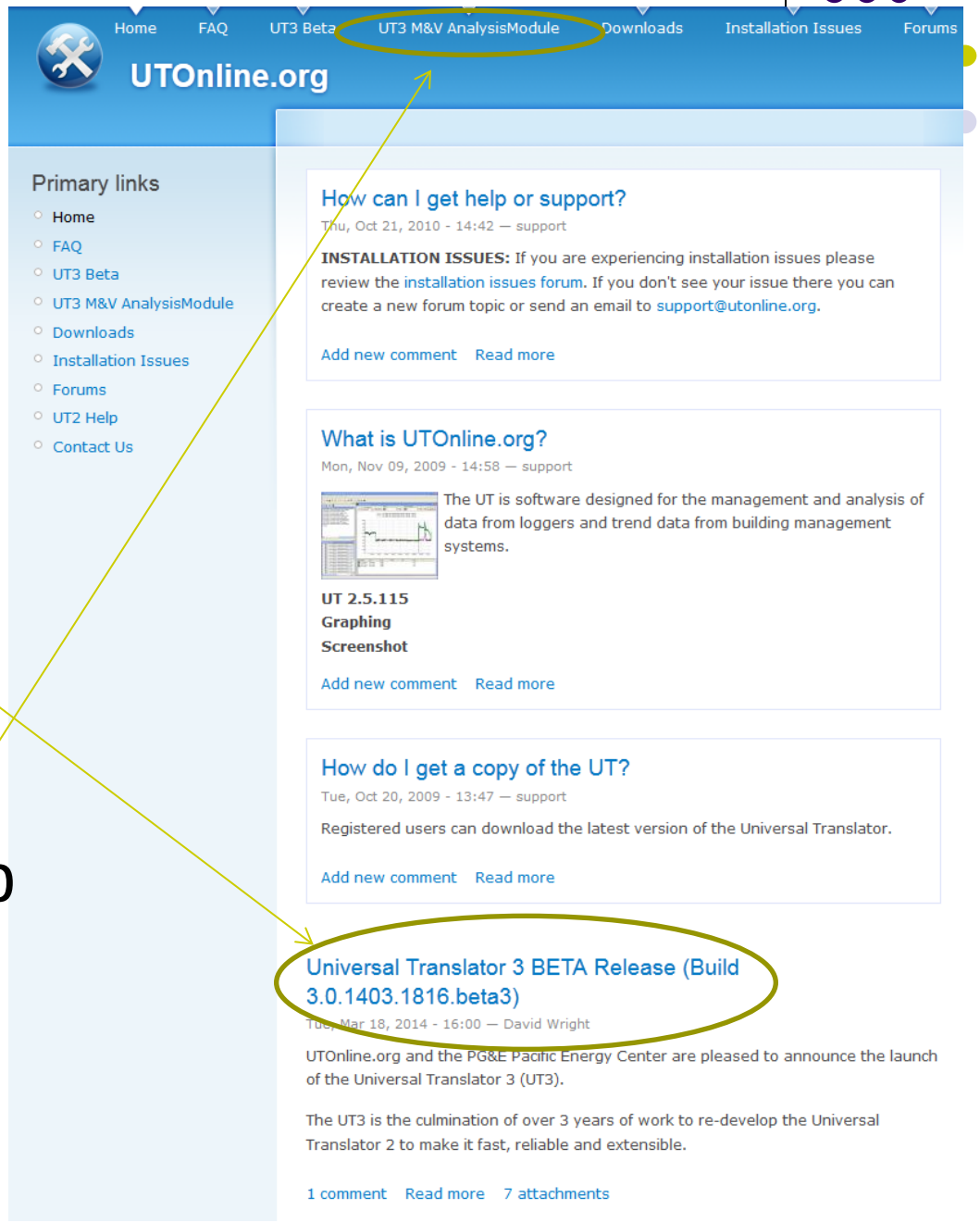
- Streamline arduous data preparation functions
  - Data set merging
  - Re-sampling to common time interval
- Streamline difficult analysis
  - Regressions, statistics, uncertainties
- Standardized & Transparent Savings Calculations
- Leverage commonly available 15-min interval data
  - TOU, Smart Meters, sub meters
  - Data loggers

UT3 M&V Tool


Universal Translator 3 (3.0.1403.1816.beta2-32 bit): Demo with test files
File Edit View Import New Help
New Open Print Cut Copy Paste Delete Help
Project
Demo with test files
Sources
Channels
Tools
Charts
Charts
Analyses
Control Loop Diagnostics
Dual Duct Air Handling Unit Fault Detecti
Dual Duct Terminal Fault Detection
Economizer
Fan Coil Fault Detection
Fans And System Curves
Light Load
Measurement And Verification
Plug Load
Psychrometric Calculator
Setpoint
Single Duct Air Handling Unit Fault Detect
Single Duct Terminal Fault Detection
Statistics
Measureme...
Search:
Analyses
MV Hourly
MeasurementAndVerification Properti...
Basic
Description
Name MV Hourly
Details
Needs Analyze True
Settings
Channel Folder Hourly
Uncertainty
Period Size 90
Hourly MV Hourly
Baseline Post Implementation Avoided Energy Use Normalized Energy Savings
Compute the energy use avoided during the Post Implementation period. The energy unit is based on hours.
Compute Details... Avoided Energy Use: 29745.2866 Uncertainty at one std. error: not enough data
Chart: Adjusted Baseline and Post Implementation Dependent
Adjusted Baseline and Post Implementation Dependent
700
650
600
550
500
450
400
350
300
250
200
150
100
10/26/2008 12:00:00 AM
11/2/2008 12:00:00 AM
11/9/2008 12:00:00 AM
11/16/2008 12:00:00 AM
11/23/2008 12:00:00 AM
Time
MV Hourly.AdjustedBaseline
Post kWh
Jobs
Job History...
Reimport Failed Files...

Where to Find It?

- www.utonline.org
  - Create account, obtain access
- M&V Analysis Module User Group
  - FAQ, Discussion Forum



Questions?

Thank you!!

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