Case Study of Two MBCx Projects:
Using M&V to Track Energy Performance

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Overview

This presentation will discuss:

- Role of M&V in RCx
- Application in two UC Berkeley Buildings
- Results
- Discussion & Conclusion

Situation

- RCx is a means to improve a building's energy efficiency
  - Owners
  - EE Programs

- "RCx Measures"
  - Correct and optimize system operations
    - Operational changes
    - Control system changes
  - Justification provided by measure cost-effectiveness

- RCx measure recommendations based on savings ***estimates***

Situation

- RCx measure 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.

Situation

Risks to Owner:

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

EE Program Risks:

- **Program’s claimed savings do not stand up to third party review**
- **Savings lifetimes are short**
- **Negative impact on program realization rates**

Need for Robust M&V in RCx Projects

Needs:

- Demonstrate actual, verified energy savings benefits of RCx
- Provide a mechanism to determine measure savings persistence

Opportunities:

- Standardization of M&V processes for RCx
    - California Commissioning Collaborative Project
- Provide information tools for operators and owners to maintain savings
- Basis for further energy performance improvements

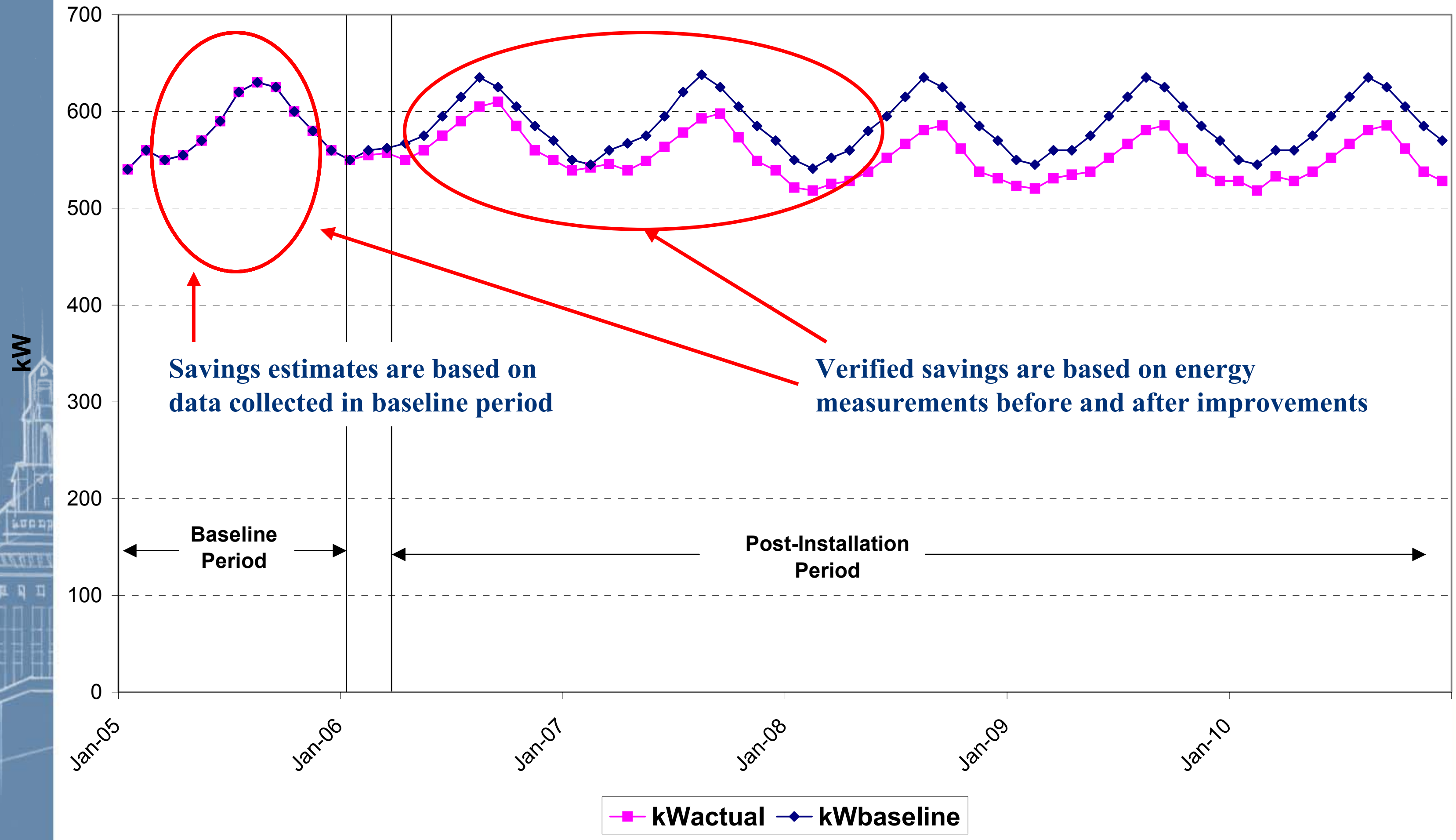
Basic M&V

International Performance Measurement and Verification Protocol (IPMVP) Chapter 3 says:

Energy Savings = Baseyear Energy Use
– Post-Retrofit Energy Use
± Adjustments

- **Baseline energy use is modeled**
- **Model generates what baseline use would have been under post-install conditions**
- **'Adjusted baseline' is compared with measured use to generate savings**

Quantifying Savings



IPMVP M&V Options

Retrofit Isolation Options:

- Option A: Allows stipulation of some parameters
- Option B: Retrofit isolation – continuous monitoring of parameters
  - Focus is on systems and equipment – similar to RCx.

Whole Building Options:

- Option C: Utility bill analysis
- Option D: Calibrated computer simulation
  - Sometimes used with isolated systems, as applicable
- Used when savings distinguishable from variation in use (typ. >15%)

- Option B selected for UC Berkeley
  - Magnifies savings as a proportion of use
  - + addresses savings persistence, provides tracking tools
  - Technique also applied at whole-building level

UC Berkeley MBCx Project

- UC Berkeley has significant monitoring resources to devote to this project
  - Web-based utility information system
    - Whole building kW and steam meters
    - Electric and steam trended at 15 minute intervals
    - Data stored indefinitely
  - Web-based points mapped from BAS
    - Chiller kW
    - BAS points trended at 1 minute intervals
    - Data stored for 6 months

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 RCx 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 Affected Systems

System	Equipment	Affected by ECM?	Available Points
Whole Building		X	
	Main Electric Meters (2)		kW
	Main Steam Meters (2)		lb
Chilled Water System		X	
	Chillers 1 and 2		kW
	Primary Chilled Water Pumps P-5, P-6		Status
	Secondary Chilled Water Pumps, P-3, P-4		VFD speed
Condenser Water System		X	
	Cooling Towers		High/Low Status
	Condenser Water Pumps P-7, P-8		Status
Air Distribution System		X	
	AHU-1, SF-11, EF-12, EF-13		VFD speed
	AHU-2, SF-14, EF-15		Status
	AHU-3, SF-16, SF-17		VFD speed
	AHU-4, SF-18, SF-19		VFD speed
	AHU-5, SF-20		Status
Chiller Room Fans			
	Chiller Room 181, SF-2, EF-2		Status
	Chiller Room 179, SF-3A, SF-3B, EF-1A, EF-1B		Status
AC Units			
	Condenser Water Pumps P-9, P-10		VFD speed
	AC-31 through AC-41		Status
Hot Water System		X	
	Hot Water Pumps P-1, P-2		VFD Speed

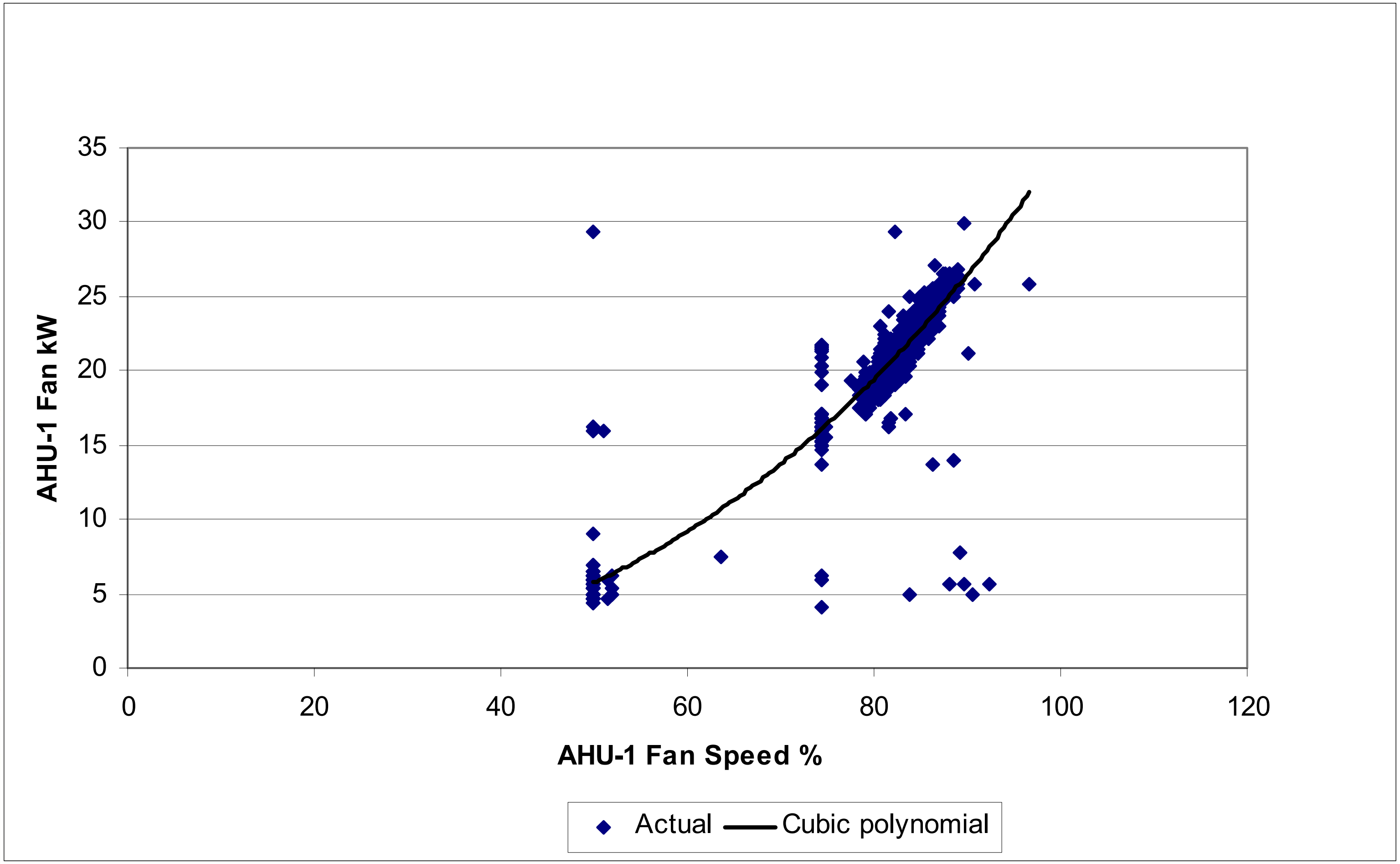
Define the Baseline Period & Collect Data

- **8 months of trended data collected**
- **Baseline period selected to cover widest range of operating conditions ~ 3 months.**

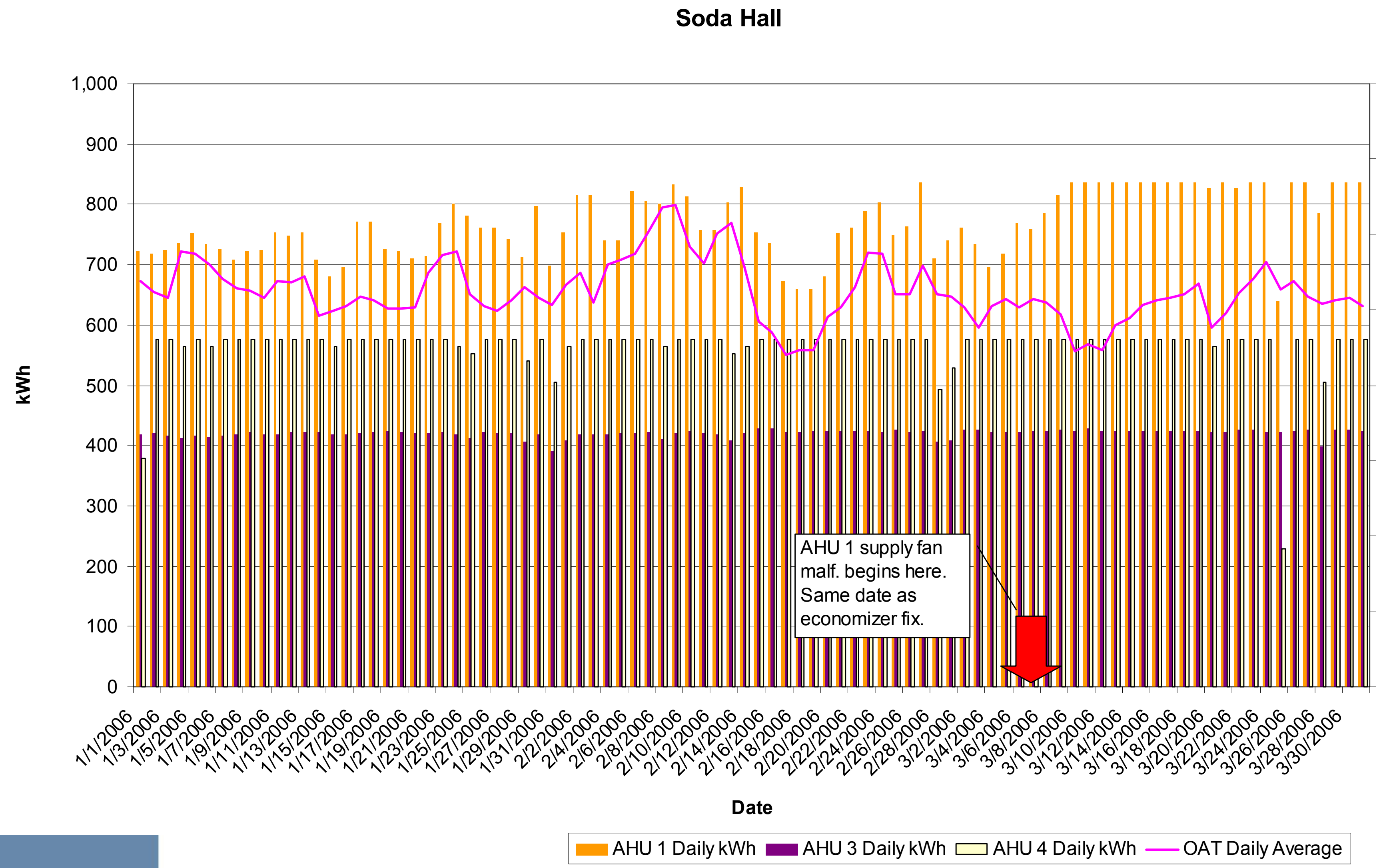
- **Energy use for each system to be totaled each day**
  - **Basis for analysis and reporting**

- **"Proxy" Variables on EMCS:**
  - **Constant load equipment: measure operating kW**
    - **Equipment status becomes proxy for kW**
  - **Variable load equipment: log kW and VFD speed**
    - **VFD speed signal becomes proxy for kW**

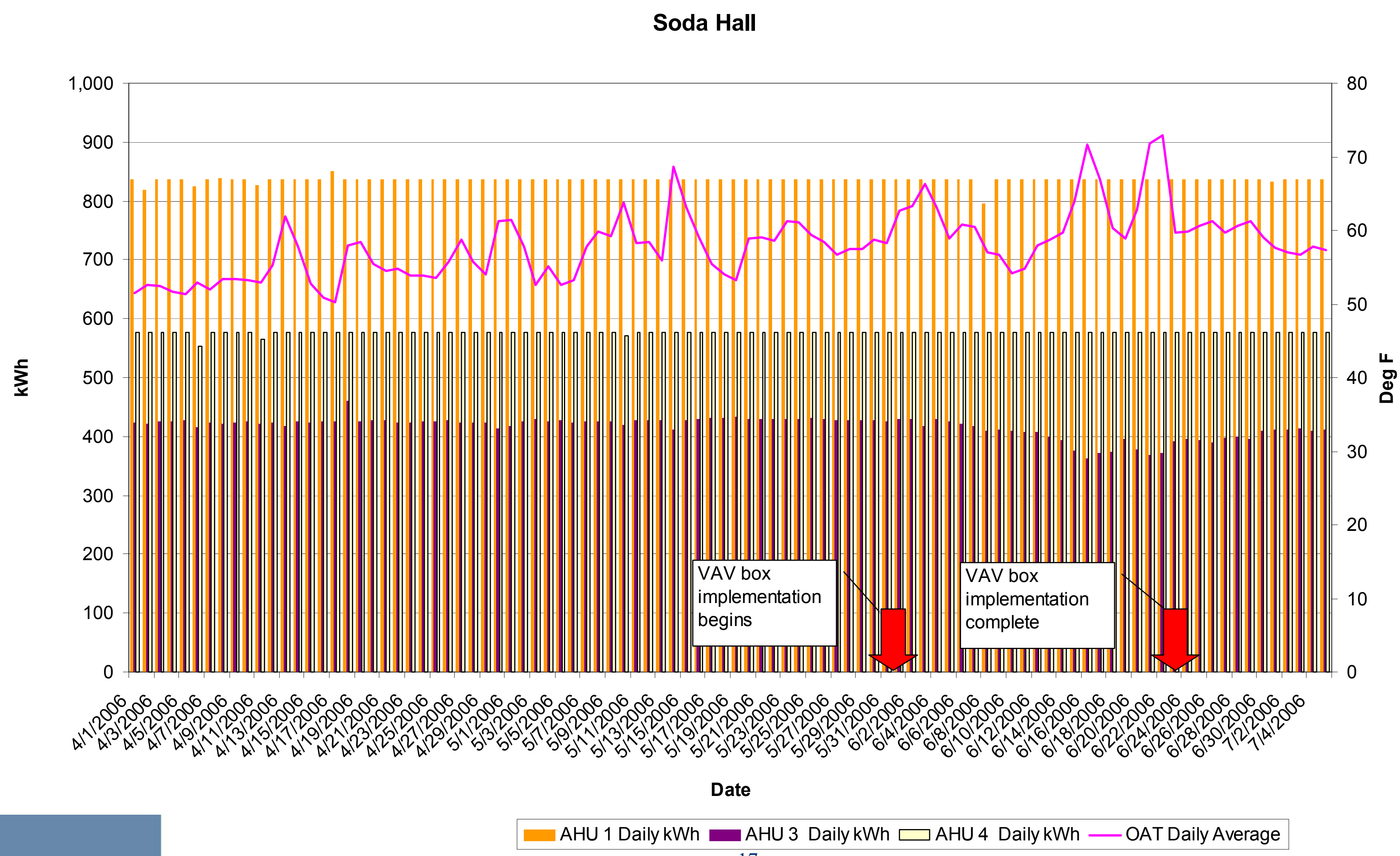
“Proxy” Variable: VFD speed for kW



M&V "Diagnostics"

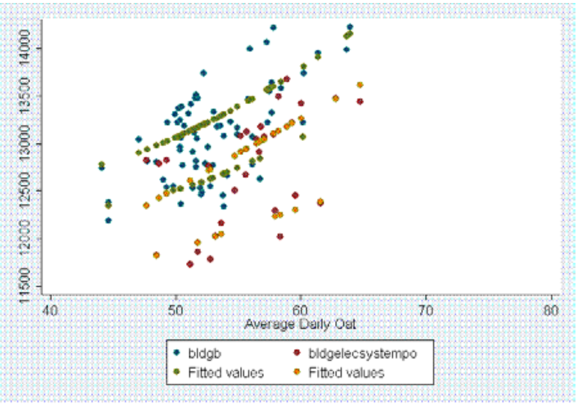


M&V Diagnostics

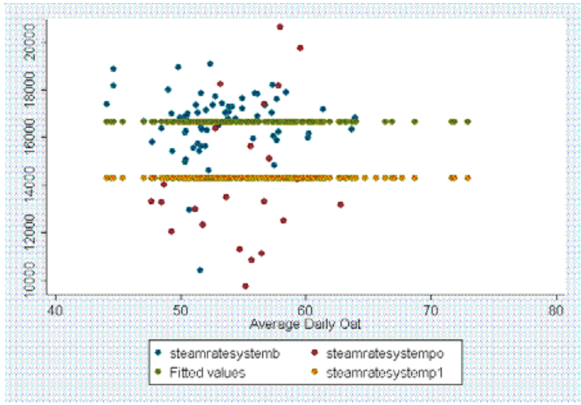


Baseline Model: Soda Hall

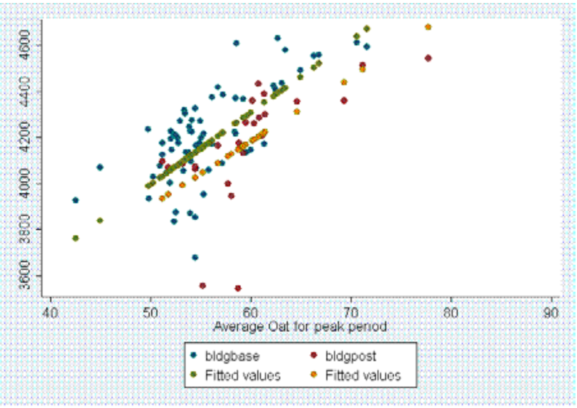
- ## Total Building Electric



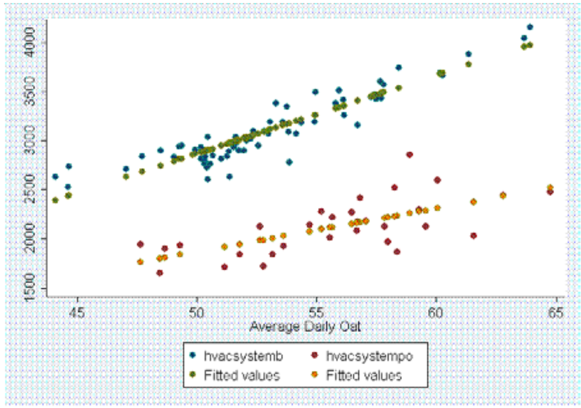
Building Steam



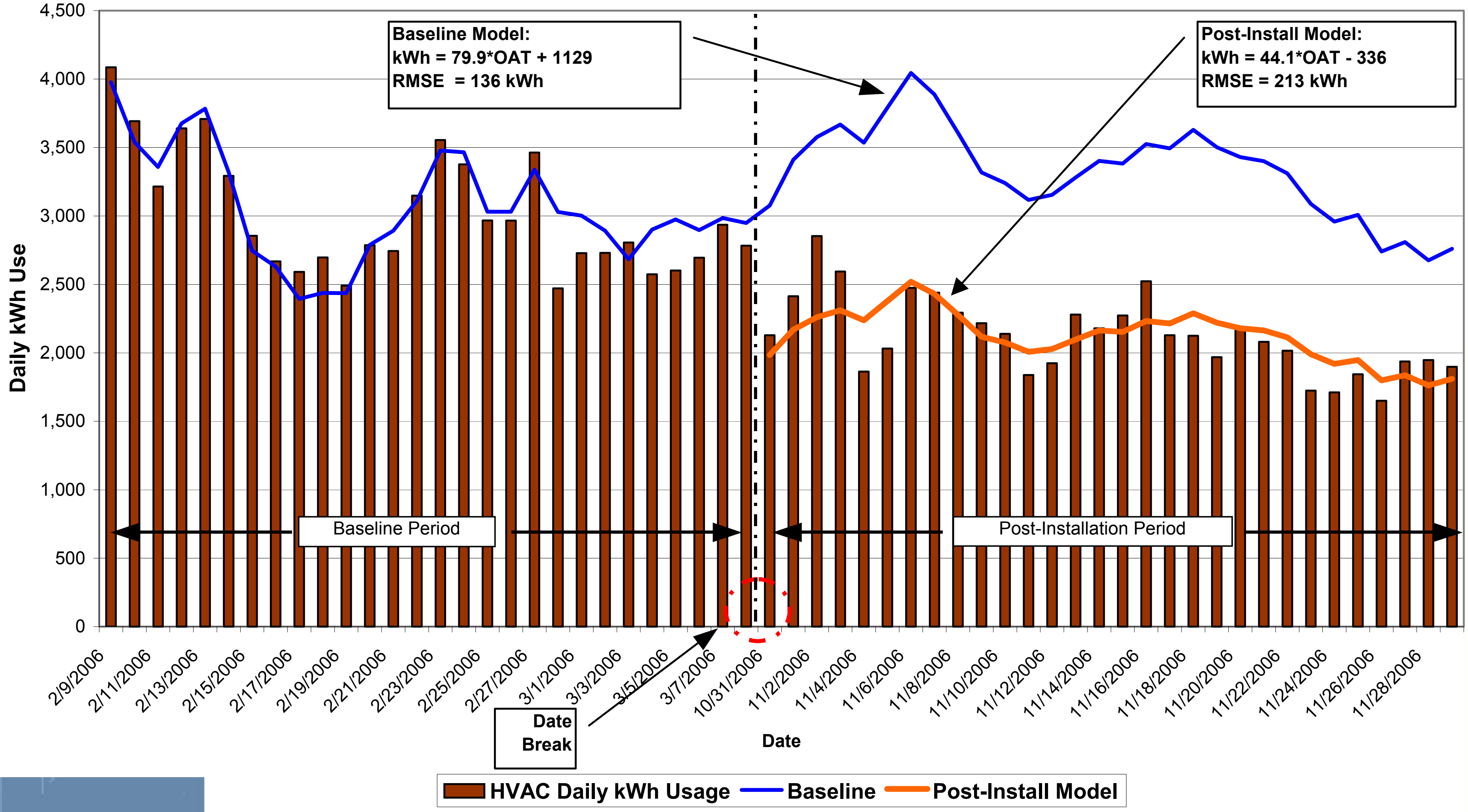
- ## Peak Period Electric



HVAC System Electric



Soda Hall M&V: HVAC Systems



Soda Hall: Estimated vs. Verified Savings

Source	Estimated Savings*	Verified Savings**	
		Whole Building	HVAC System
kWh	483,008	216,716	462,472
kW	-	22	50
Lbs. Steam	2,713,650	854,407	

* based on eQUEST model

** based on baseline and post-installation measurements and TMY OAT data

Tan Hall

- UC Berkeley's Chemistry and Chemical Engineering Departments
- 7 above-grade, 2 below-grade levels
- 106,000 ft^2
- 100% outside air through 4 VFD-controlled 100 HP supply fans
- Steam heating and CHW cooling coils in AHU
- Separate exhaust system on roof: 4 VFD-controlled 60 HP exhaust fans
- 1 475-ton chiller, constant speed primary loop
- Constant speed CW loop – Tower shared among buildings
- Steam-to HW HX system, circulated to perimeter zone boxes

Tan Hall RCx Findings

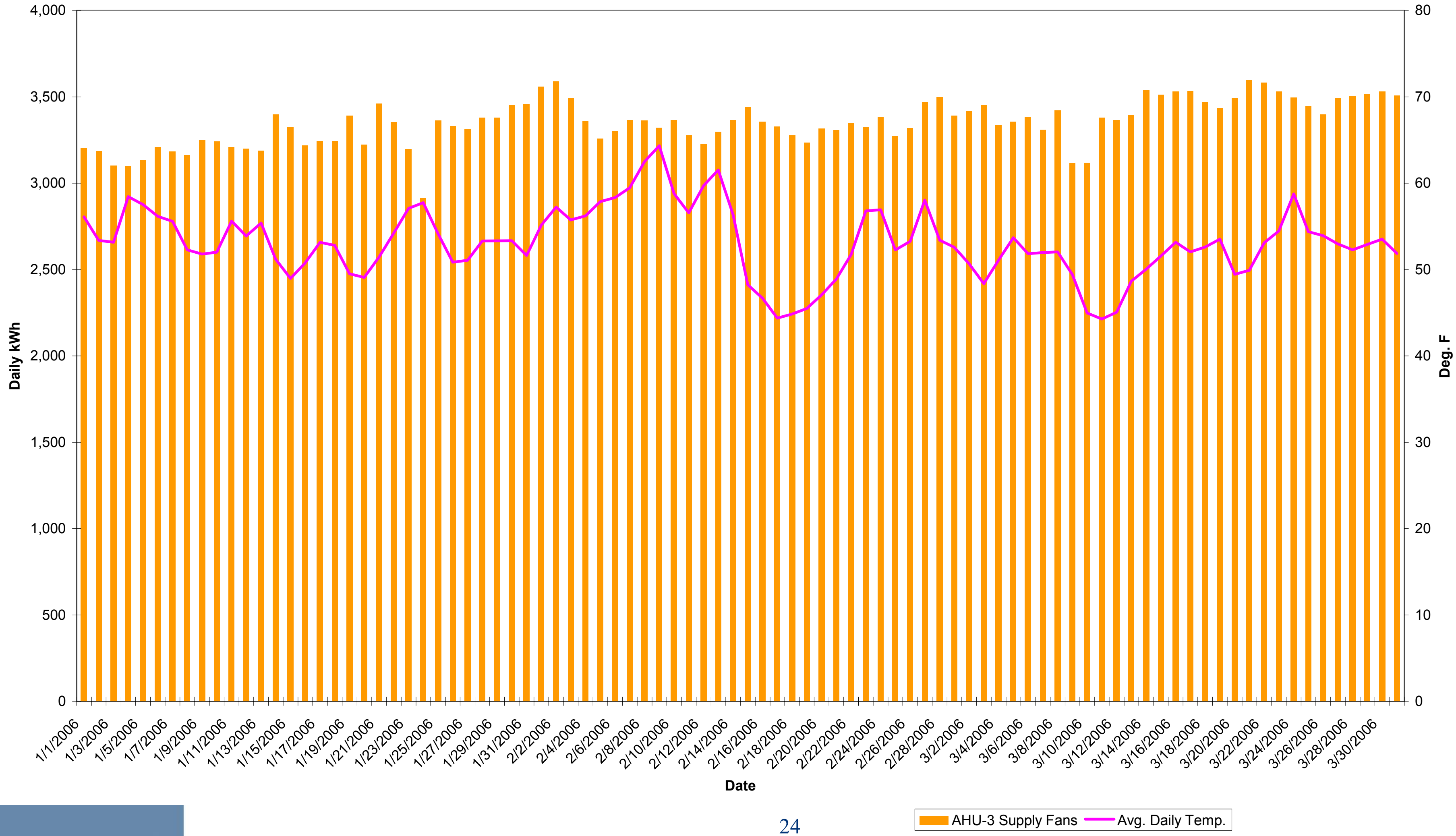
- Chilled water and condenser water pumps operating in parallel instead of lead/lag
  - Balancing vales on each were closed down
  - Shut off one pump, rebalance flow and operate in lead/lag mode as intended
- Chiller outside air lockout temperature sequence not functioning
  - OAT set point also too high
  - Correct operation and lower set point 2 °F
- Leaky steam valve in AHU – caused simultaneous heating and cooling

- Savings: 654,000 kWh (14%), 90 kW, 10.5 M lbs steam (62%)
  - Estimated using bin analysis
- Cost reduction $154,000 (19%), Payback 0.02 years

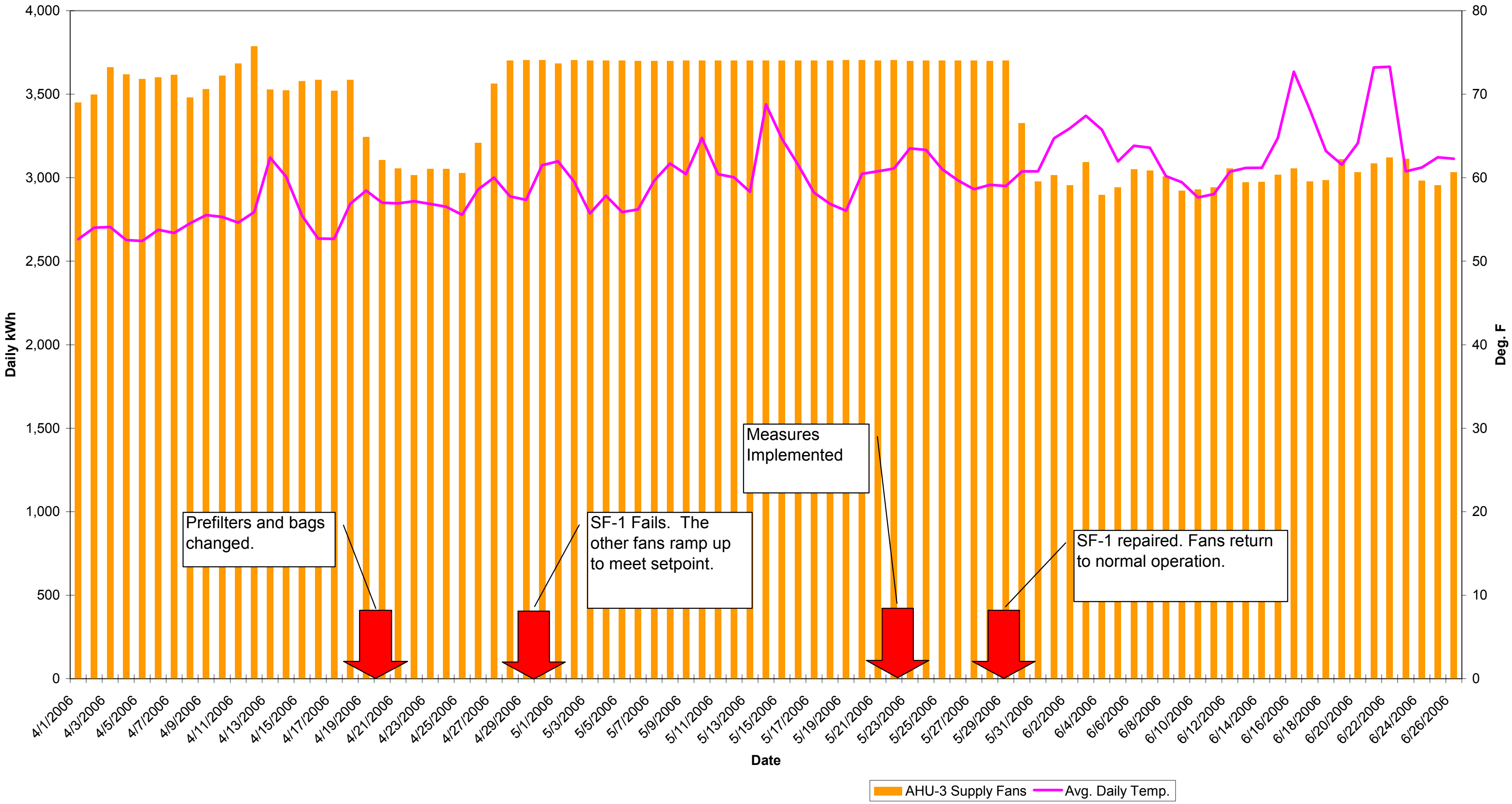
Tan Hall Affected Systems

System	Equipment	Affected by ECM?	Available Points
Whole Building		X	
	Main 480/277 Electric Meter		kW
	Main 220/110 Electric Meter		kW
	Main Steam Meter		lbs/hr
Chilled Water System		X	
	Chiller (VS)		kW
	Primary Chilled Water Pumps CHWP-1, CHWP-2 (CS)		Status
Condenser Water System		X	
	Condenser Water Pumps CDWP-1, CDWP-2 (CS)		Status
	Cooling Tower (CS, 2-speed)		Not Avail.
AHU-3		X	
	AHU-3 Supply Fans SF-1, SF-2, SF-3, SF-4 (CS)		S/S & Speed
	AHU-3 Exhaust Fans EF-1, EF-2, EF-3, EF-4 (CS)		S/S & Speed
	Terminal Boxes and Fume Hoods associated with AHU-3		NA
AHU-1			
	AHU-1 Chemical Storage AH-1, SE-1		Status
AHU-2			
	AHU-2 Chemical Storage AH-2, SE-2		Status
Heating Water System		X	
	Heat Exchanger HWC-1		
	Hot Water Pumps HHWP-1, HHWP-2		Status
Lighting System			
	Lighting Circuits		NA
Plug Loads			
	Plug Load Circuits		NA
Domestic Water			
	Domestic Water Pumps		NA

Tan Hall Diagnostics

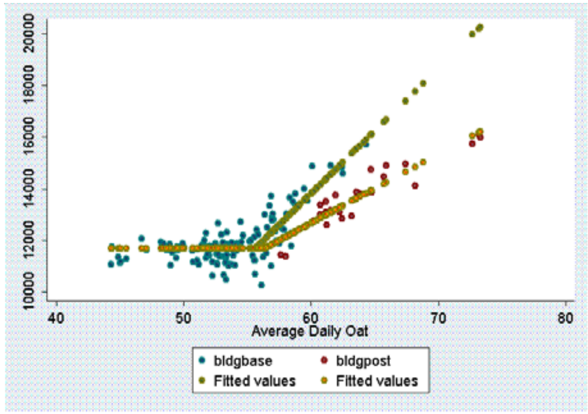


Tan Hall Diagnostics – cont.

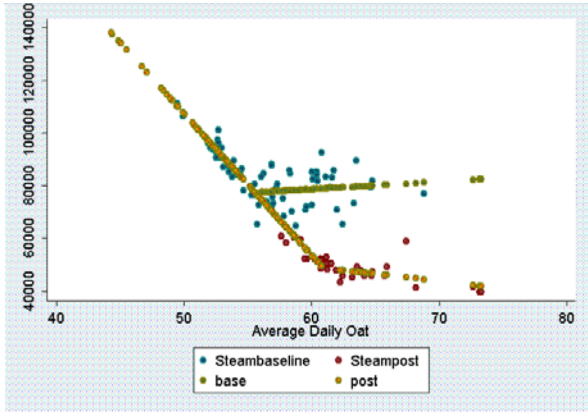


M&V Models: Tan Hall

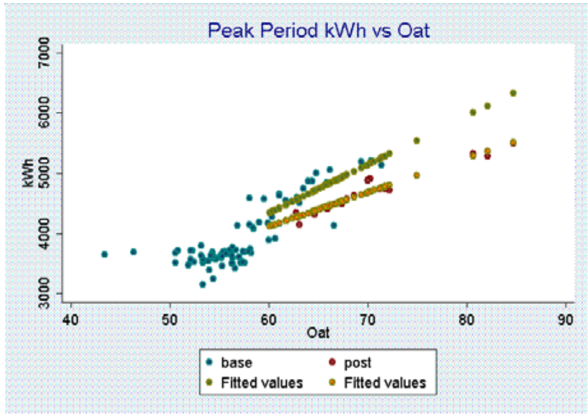
Whole Building Electric



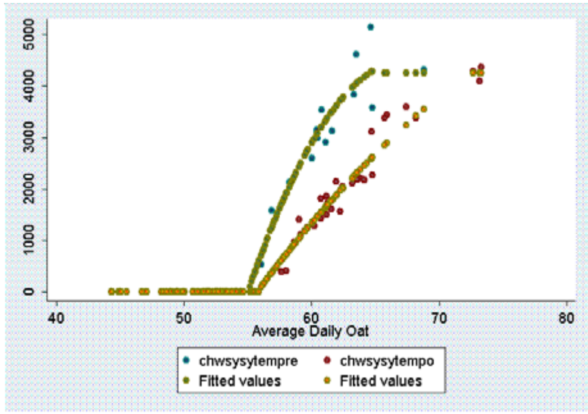
Whole Building Steam



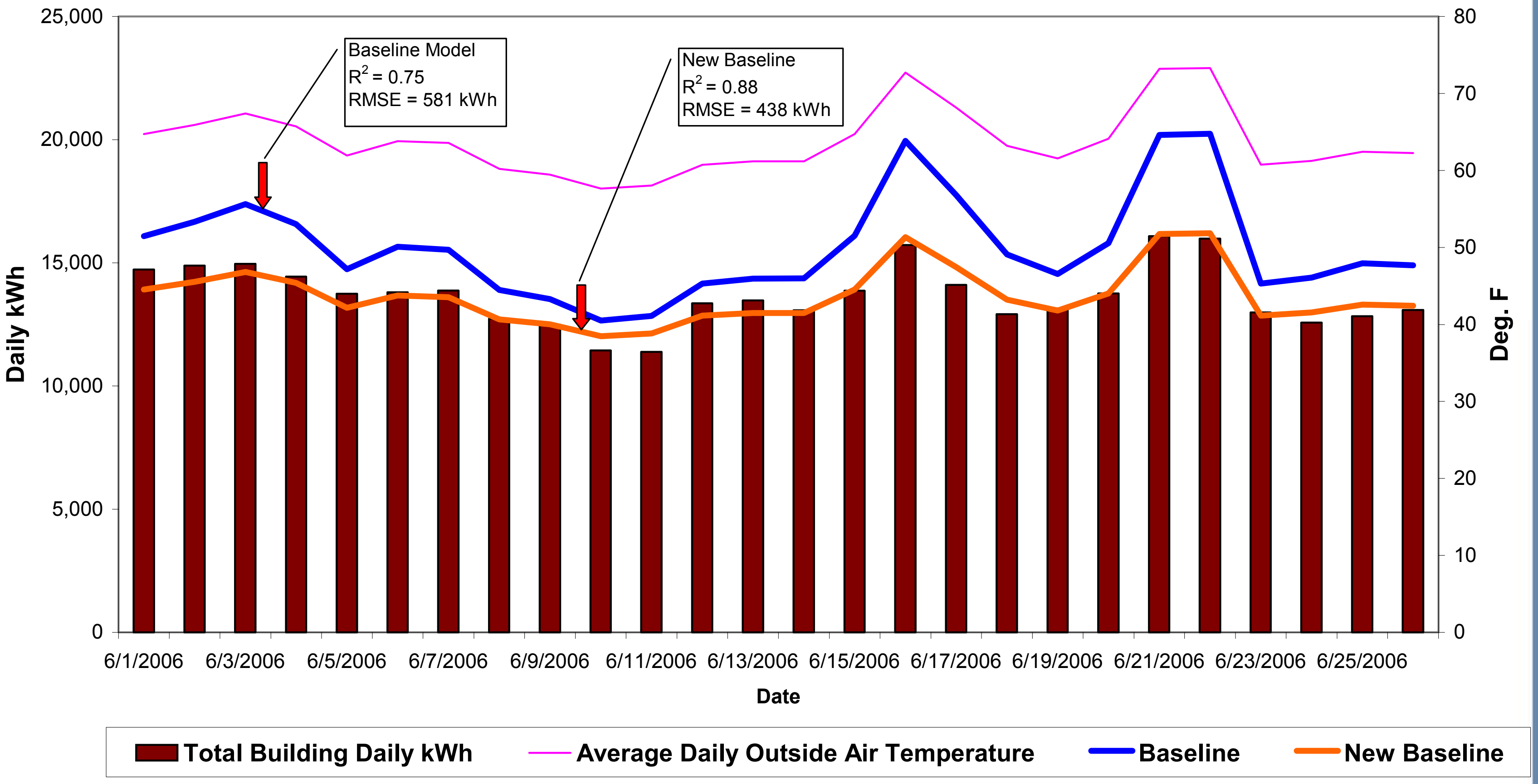
Peak Period Electric



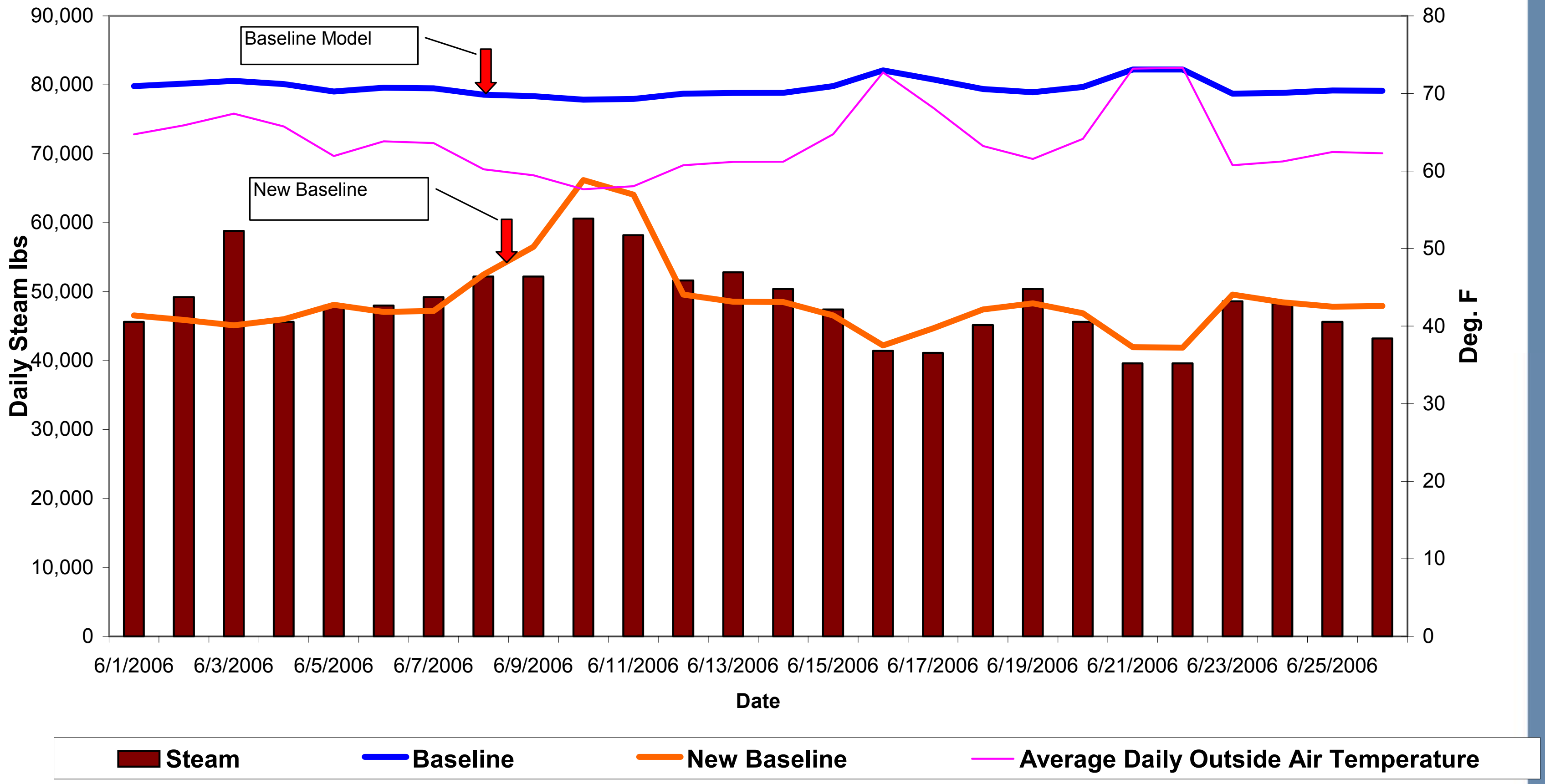
Chilled Water System Electric



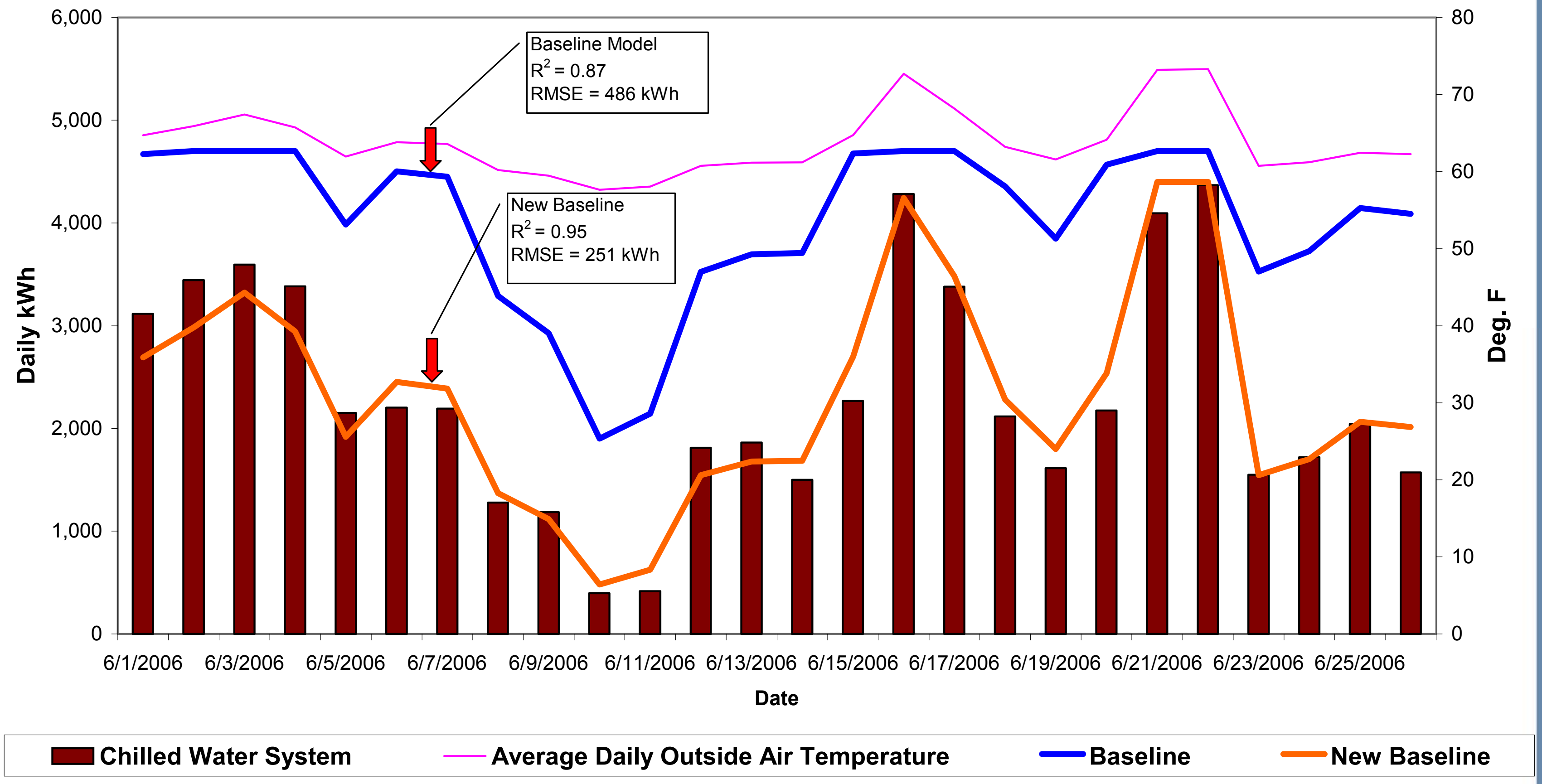
Tan Hall M&V: Whole-Building Electric



Tan Hall M&V: Whole-Building Steam



Tan Hall M&V: Chilled Water System



Tan Hall: Estimated vs. Verified Savings

Source	Estimated Savings*	Verified Savings**	
		Whole Building	CHW System
kWh	653,575	663,184	686,519
kW	91	69	
Lbs. Steam	10,543,991	5,995,232	

* based on engineering calculations

** based on baseline and post-installation measurements and TMY OAT data

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**
- **In private sector – metering costs lower**
  - **Existing electric meters**
  - **Sophisticated BAS systems**
  - **MBCx approach should be viable**

Discussion

- Consider new approach:
  - Focus project resources on verified savings instead of estimated savings approach
    - More rigorous savings analysis, more reliable results
    - Install all low-cost measures
    - Estimate savings for only higher cost measures
    - Leave in place capability to track & tally savings
    - Diagnostic benefits of approach
    - Addresses savings persistence
- Barrier
  - Lack of understanding of M&V
  - M&V training required

Conclusion

- Soda & Tan Hall projects showed technique to integrate M&V into RCx
- Technique as tools:
  - Diagnostic capability,
  - Verify savings, track energy use
- Other benefits
  - Persistence of RCx savings
  - Less uncertainty in savings
  - Establish new baselines for next project

Related Work

M&V Guidelines:

- Energy Valuation Organization's International Performance Measurement and Verification Protocol (IPMVP)
  - New 2007 release available now at: www.evo-world.org
- ASHRAE Guideline 14: www.ashrae.org
- California Commissioning Collaborative: Verification of Savings Project
  - Review current M&V methods within RCx projects
  - Recommend best practices for M&V in RCx
  - Disseminate results