

Tracking the Benefits of Retro-Commissioning: an Integrated M&V Approach

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Tracking the Benefits of Retro-Commissioning: an Integrated M&V Approach

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Overview

This presentation will discuss:

- Need for more robust M&V in RCx projects
- Practical considerations
- A model M&V procedure developed under the UC/CSU/IOU Partnership Project at UC Berkeley
- Discussion of M&V costs and uncertainties

Need/Opportunities for M&V in RCx Projects

Needs:

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

Opportunities:

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

Related Work

- **Performance Monitoring Systems – Specifications Guide**
 - **Developed as part of a jointly funded CEC PIER-DOE project**
 - **Available at <http://cbs.lbl.gov/performance-monitoring/specifications>**
- **Energy Valuation Organization’s International Performance Measurement and Verification Protocol (IPMVP)**
 - **Available at www.ipmvp.org**

Demonstrate Energy Savings Benefits of RCx

- RCx provides other benefits:
 - Improved indoor air quality
 - Improved thermal comfort
 - Lowers system maintenance
 - Etc.
- However main economic driver for RCx is energy savings
- Most savings are *estimated* based on existing operations data and engineering analysis
- Actual savings requires analysis of data after the improvements have been implemented

Meet Program Impact Evaluation Requirements

- Numerous RCx programs implemented in recent years
- Programs are required to have an evaluation, measurement and verification study done by an independent third party
- Typical Program:
 - RCX agent surveys site, develops monitoring plan, analyzes data, identifies measure, estimates savings
 - Owner implements measures
 - Data provided to EM&V consultant, who develops monitoring plan, analyzes data, estimates savings
 - Redundancy drives up overall program costs
- Other issues:
 - EM&V team not as familiar with building and systems (lower budgets, mean less time)
 - Seasonal timing of data collection

Practical Considerations

- **RCx: data use emphasis is diagnostics**
- **M&V: data use is for energy tracking**
- **Similar activities in RCx as in M&V:**
 - **Set up monitoring plan**
 - **Data: temperature, pressure, power, status, etc.**
 - **Data interval, e.g. 5 min., 15 min., etc.**
 - **Monitoring duration: 2 weeks, 1 year**
 - **Collect and analyze baseline data**
 - **Install measures**
 - **Collect post-installation data**
- **Building Automation Systems**
 - **Used for supervisory control, not energy tracking**
 - **Usually lack direct monitoring of system power**
 - **Use independent data loggers**

Soda Hall MBCx Project

- **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**
 - **M&V**
 - **Soda Hall:**
 - **Electric and steam meters added**
- **MBCx project:**
 - **BAS capabilities expanded with addition of points and programming to enable on-going M&V and diagnostics**

Soda Hall Energy Management System

- **UC Berkeley has significant EMS resources to devote to this project**
 - **Whole building kW and steam meters**
 - **Chiller kW**
 - **BAS points trended at 1 minute intervals**
 - **Data stored for 6 months**

Soda Hall

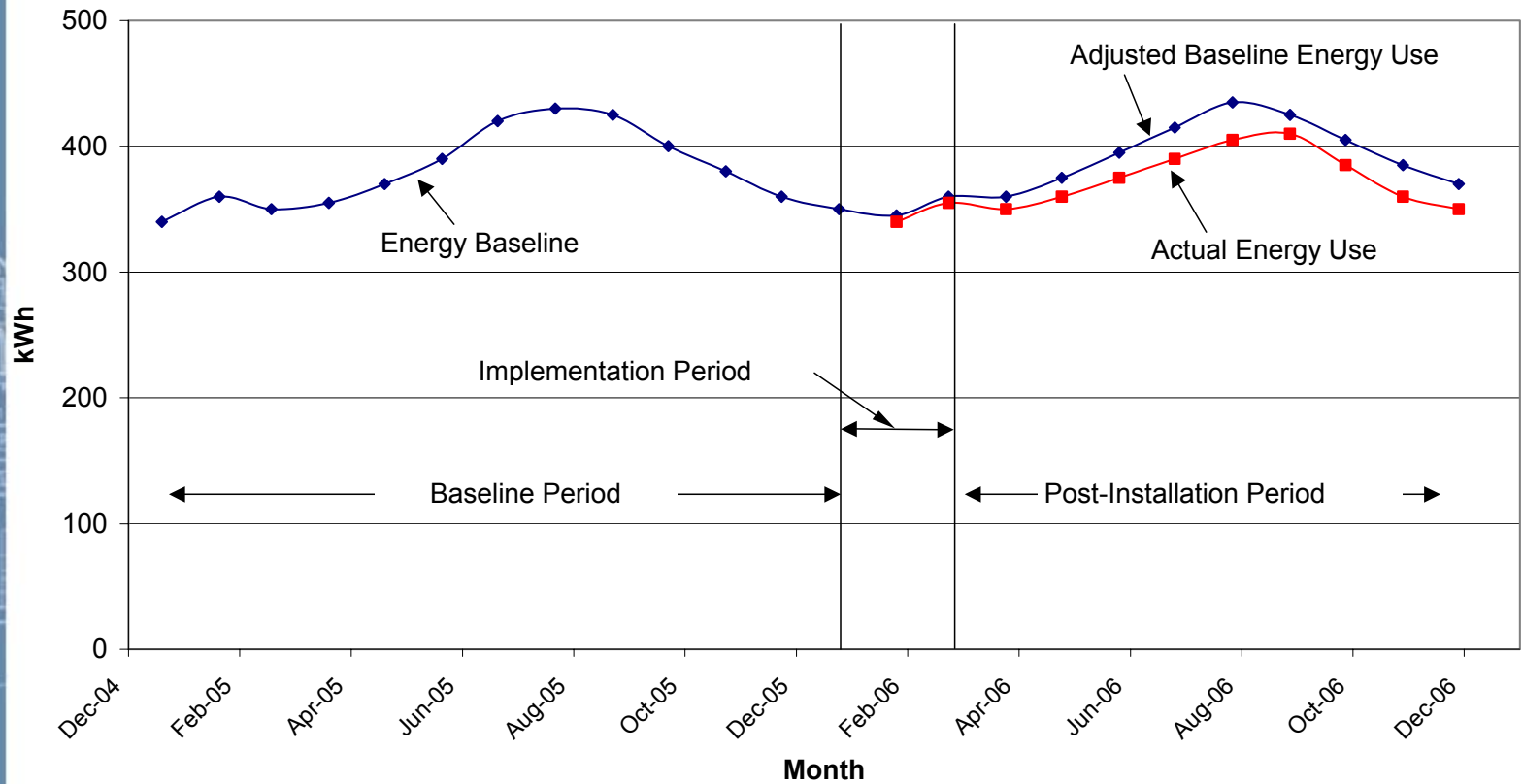
- UC Berkeley's Computer Science Department (24/7 operation)
- 109,000 ft²
- Energy Use Intensity: 174 kBtu/ft²-yr
- 2 - 215 ton chillers (lead/lag)
- Constant Speed Primary/Variable Speed Secondary Chilled Water System
- Two 2-speed, forced draft, open loop cooling towers
- 3 Main VAV AHUs,
 - AHU1 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 Measures

- **Chiller operating at night to serve small loads in computer rooms**
 - **Install mini-split system to replace fan-coil unit**
 - **Re-establish chilled water reset strategy**
- **Minimum VAV Box Damper Positions at 50%**
 - **Causes excessive reheat in perimeter zones**
- **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 700,000 kWh (17%), 2.7M lbs/yr steam (49%)**
- **Cost reduction \$111,000 (18%), Payback 0.5 years**

M&V Plan Requirements



M&V Plan Requirements

- **Based on IPMVP Guidelines**
 - **Select M&V Option**
 - **Identify systems to be monitored**
 - **Define baseline period and collect baseline data**
 - **Install measures**
 - **Collect and analyze post-installation data**
 - **Define reporting requirements**

Select M&V Option

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%)**

- **For Soda Hall, Option B was selected**
 - **Magnifies savings as a proportion of use**
 - **+ addresses MBCx project goals: i.e. persistence, tools, etc.**

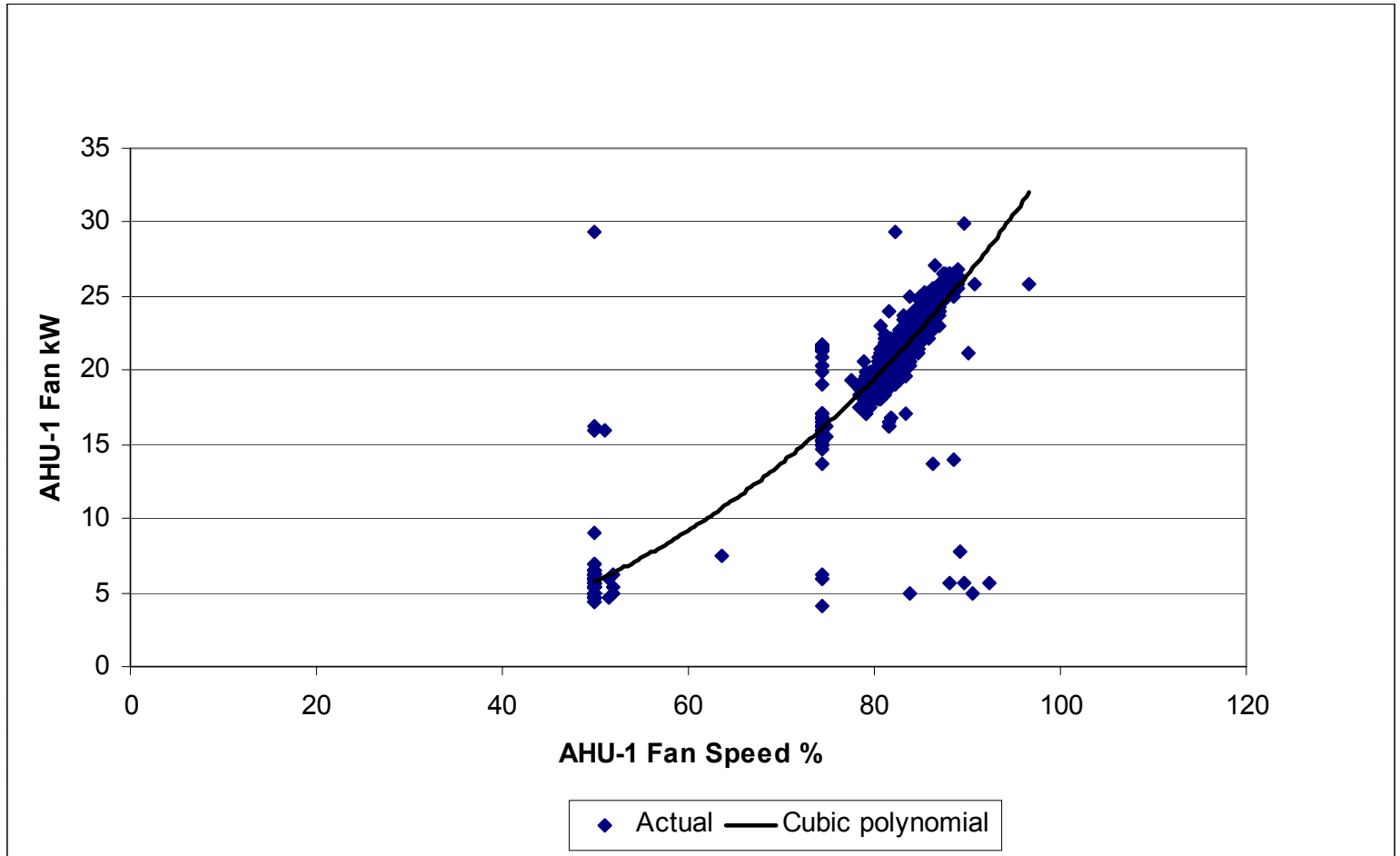
Identify Systems to be Monitored

System	Equipment	Available Points
Whole Building	Main Electric Meter	kW
	Main Steam Meter	lb
Chilled Water System	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	Cooling Towers	High/Low Status
	Condenser Water Pumps P-9, P-10	VFD speed
	Condenser Water Pumps P-7, P-8	Status
Air Distribution System	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 183, SF-1, EF-3	Status
	Chiller Room 181, SF-2, EF-2	Status
	Chiller Room 179, SF-3A, SF-3B, EF-1A, EF-1B	Status
AC Units	AC-31 through AC-41	Status
Hot Water System	Hot Water Pumps P-1, P-2	VFD Speed

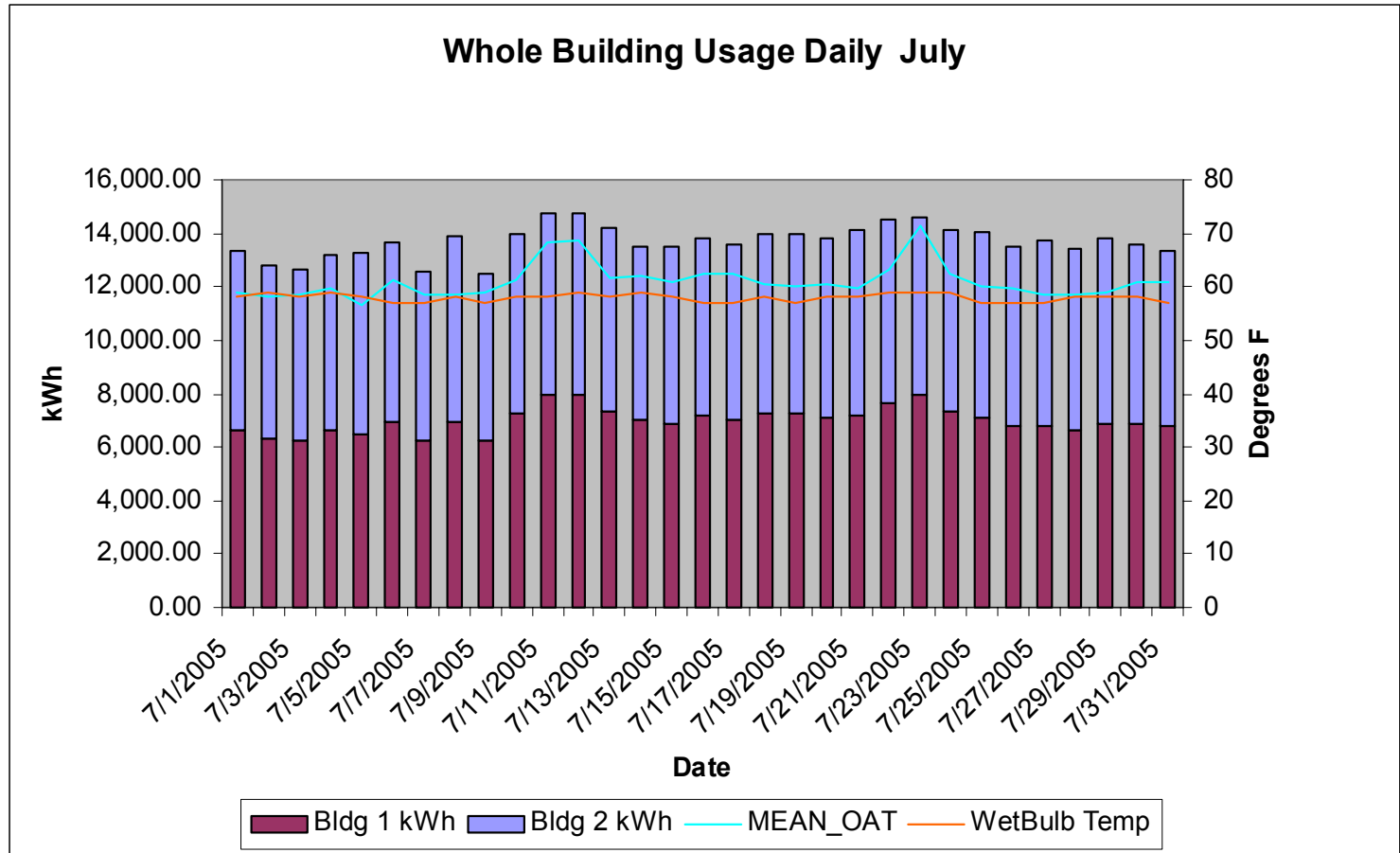
Define the Baseline Period & Collect Data

- **Baseline period is the year prior to implementation of measures**
- **8 months of BAS data collected**
- **Energy use for each system to be totaled each day**
 - **Basis for analysis and reporting**
- **“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**

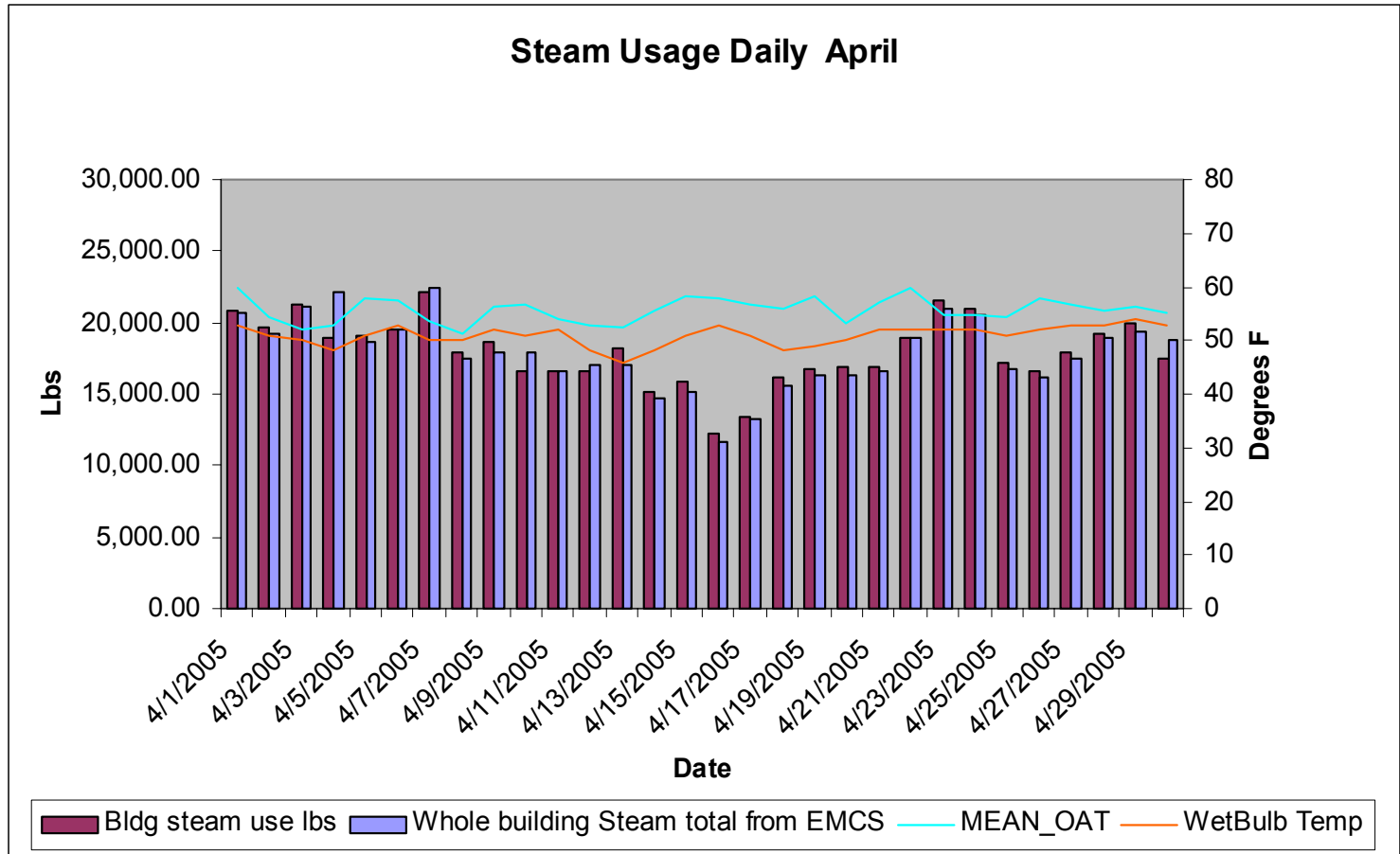
Define the Baseline Period, cont.



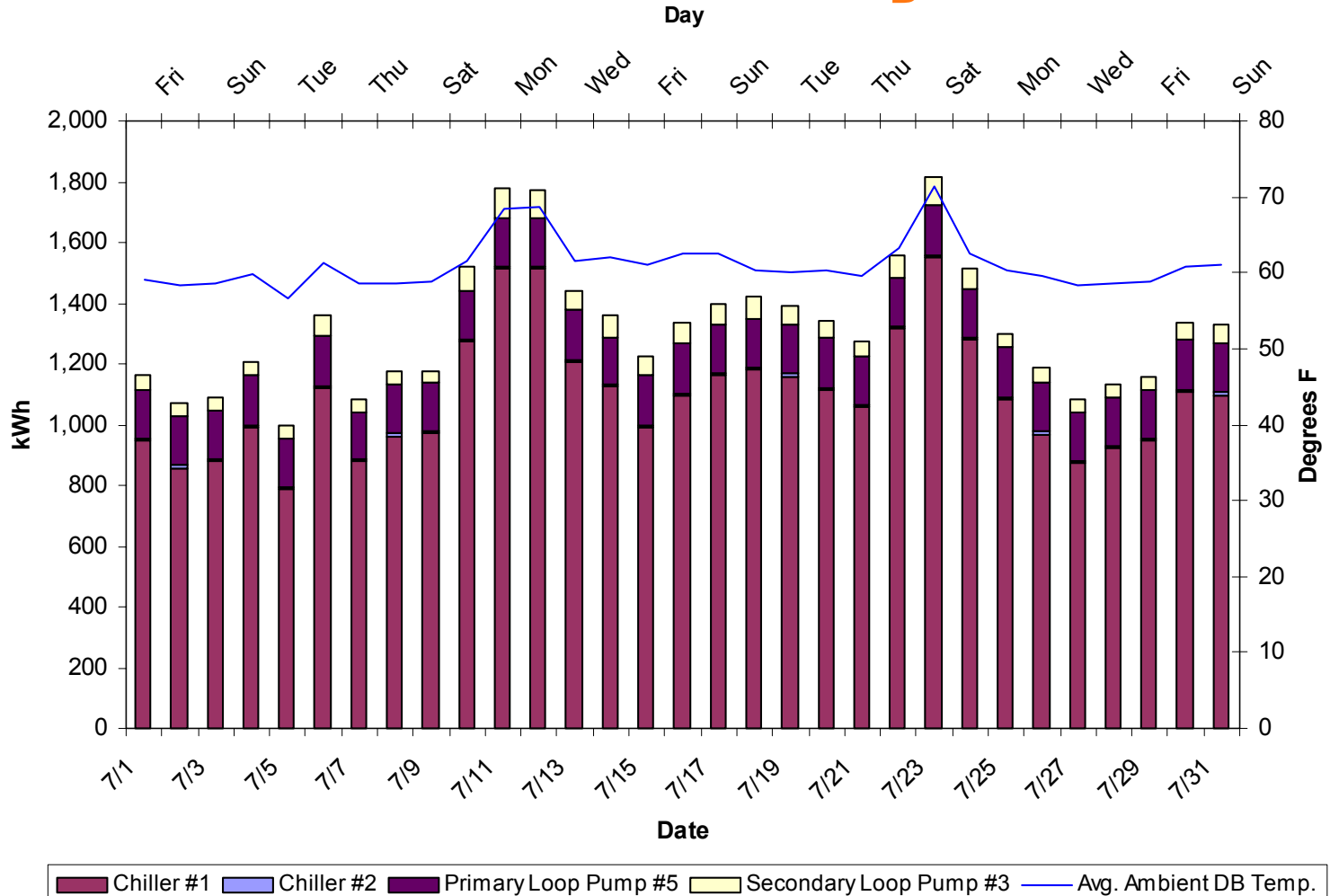
Baseline - Whole Building Electric Use



Baseline - Whole Building Steam Use

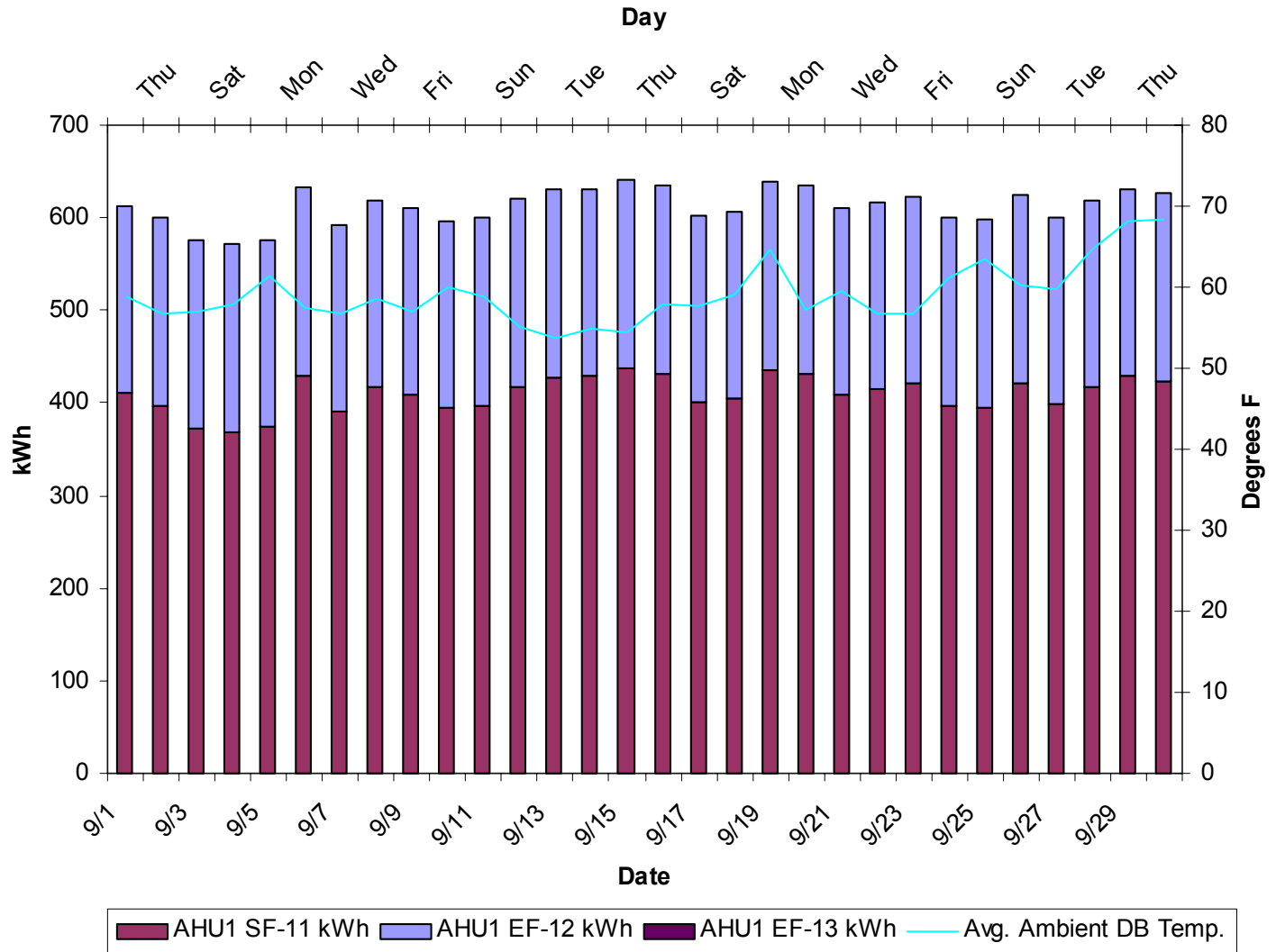


Baseline - Chilled Water System kWh Use



Baseline Model: $kWh_{CHW} = 60.85 \times OAT_{daily_avg} - 2,392$

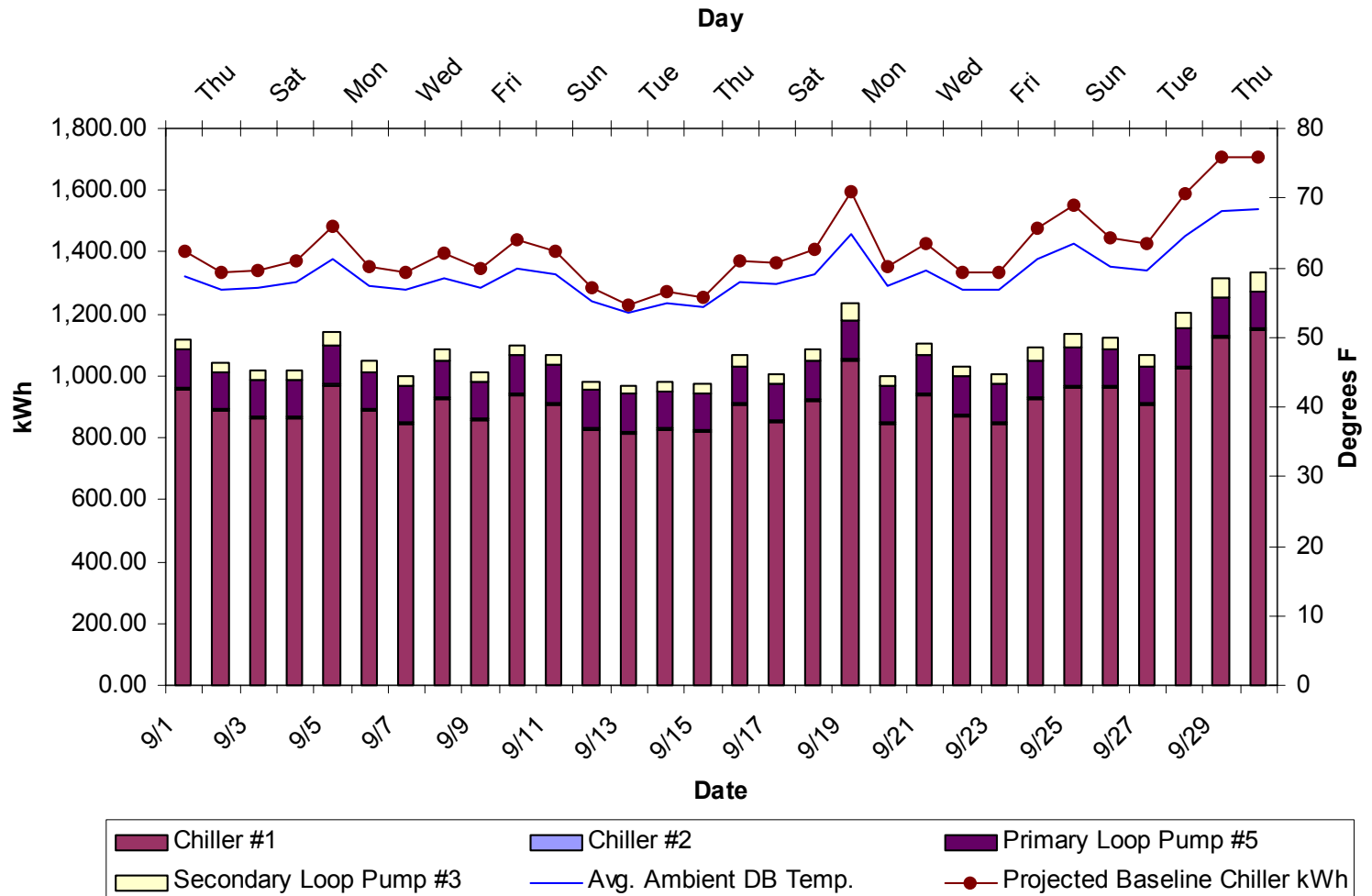
Baseline - AHU-1 kWh Use



Final Steps of M&V Plan

- **Install Measures**
 - **Systems Affected: Whole-Building, Chilled Water, Condenser Water, Hot Water, AHU-1, AHU-3 & 4**
- **Collect and analyze post-installation data**
 - **Chart next page**
- **Provide annual reports**
 - **Monthly and Annual Savings Summary**
 - **Analysis performed**

Post-Installation Mock-Up



Notes on Cost and Uncertainty

- **IPMVP recommends assessment of cost and uncertainty**
 - **Assess best value for extra monitoring costs**
- **Techniques considered:**
 1. **Equipment ON/OFF status combined with independent measurements of equipment power**
 2. **% load variable from BAS combined with independent power monitoring**
 3. **Signal from variable speed drives**
 4. **Add power meter point to BAS**
- **Soda Hall Baseline – used techniques 1 and 2**
- **Currently in process of installing amp output from VFD drives (#3)**

Cost and Uncertainty, cont.

#	Applies To	Material Costs	Labor Costs	Uncert. Factors	Est. Cost per point, \$	Uncert.
1	Const. Load	None	<ul style="list-style-type: none"> • Logger inst./rem. • Collect trend data • Analysis 	<ul style="list-style-type: none"> • Meas. • Std. Dev. • Time 	1,070	5–15%
2	Var. Load	None	<ul style="list-style-type: none"> • Logger inst./rem. • Collect trend data • Analysis 	<ul style="list-style-type: none"> • Meas. • Regression model • Bias • Time 	1,430	10–20%
3	VFDs	<ul style="list-style-type: none"> • Low volt. wire • Conduit 	<ul style="list-style-type: none"> • wire installation • calibration • programming 	<ul style="list-style-type: none"> • VFD power meas. • Time 	1,680	3-8%
4	Const. or Var. Load	<ul style="list-style-type: none"> • Power meter • Low volt. wire • Conduit 	<ul style="list-style-type: none"> • wire installation • calibration • programming 	<ul style="list-style-type: none"> • power meter meas. • Time 	2,350	1-5%

Conclusion/Final Thoughts

- Soda Hall project shows technique to integrate M&V into RCx
- Integrated M&V procedures may become tools for operators and owners:
 - For operators: concrete evidence of achievement
 - For owners: insight on the energy performance of their buildings
- Program benefits:
 - Track RCx savings over time
 - Identify when performance degrading, specific system (diagnostics), tool for maintaining savings (persistence)
- Other benefits
 - Establish new baselines for next project
 - Standardizing the M&V process