Energy Management and Information Systems (EMIS)

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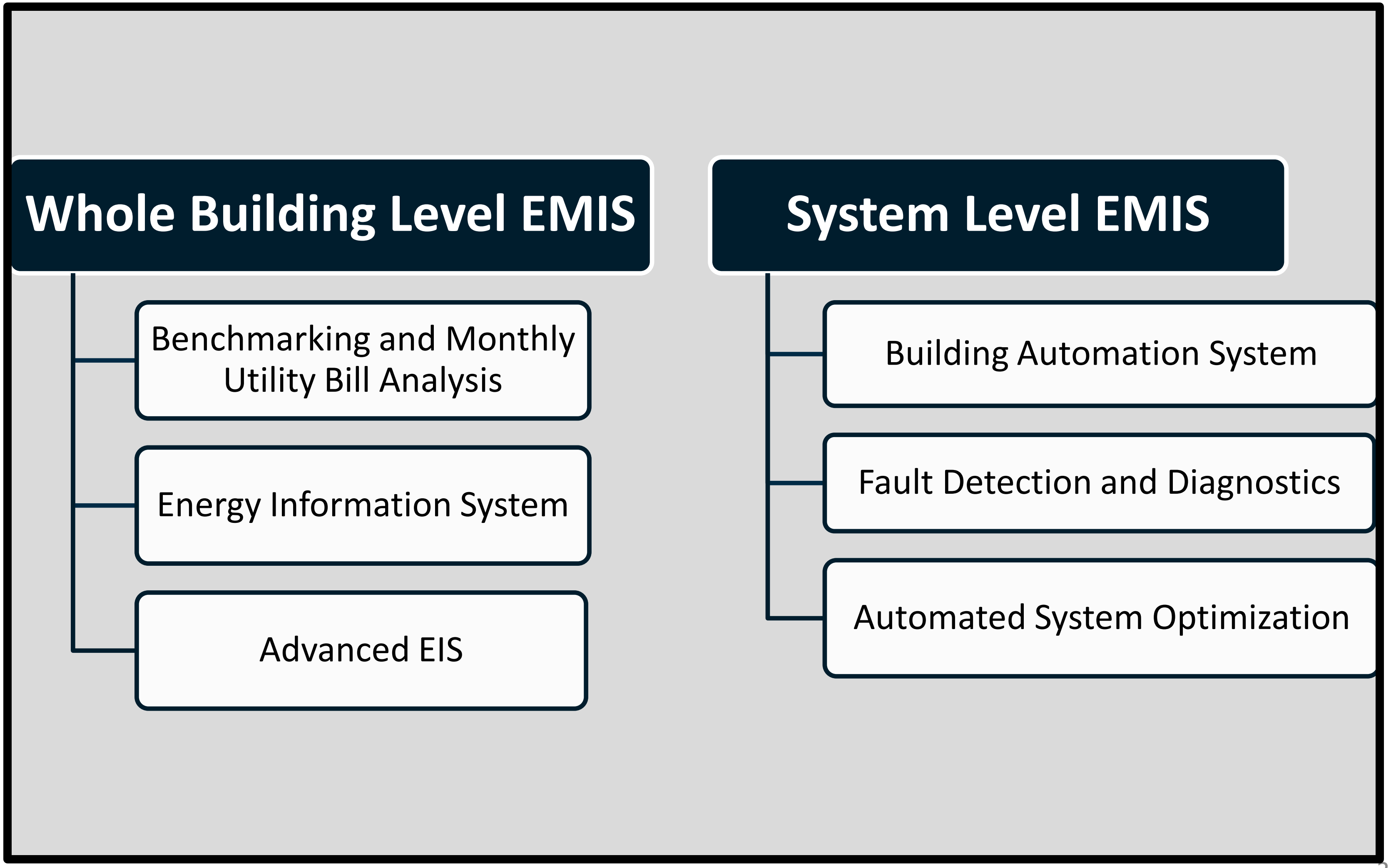
Outline

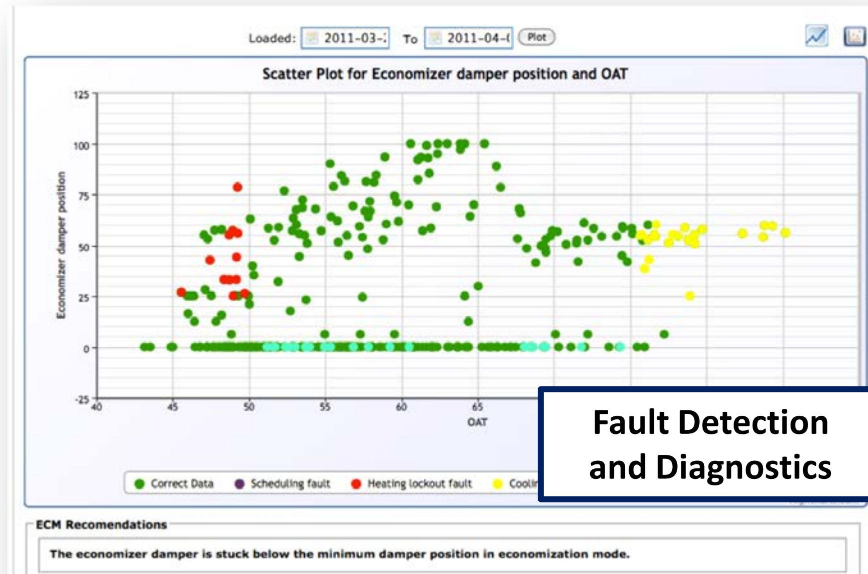
- Definitions, motivation, LBNL work in EMIS
- Common questions about EMIS use, and associated LBNL resources
- Questions, discussion

EMIS Comprise a Family of Technologies

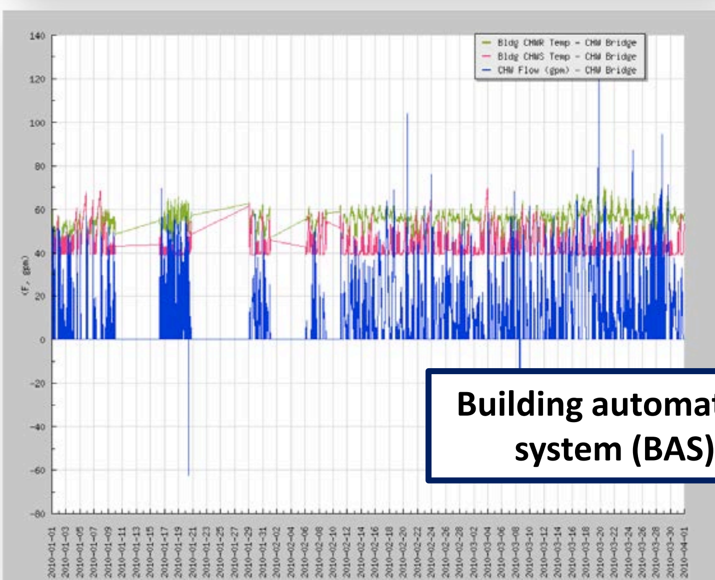


EMIS Examples

Benchmarking and Monthly Utility Bill Analysis



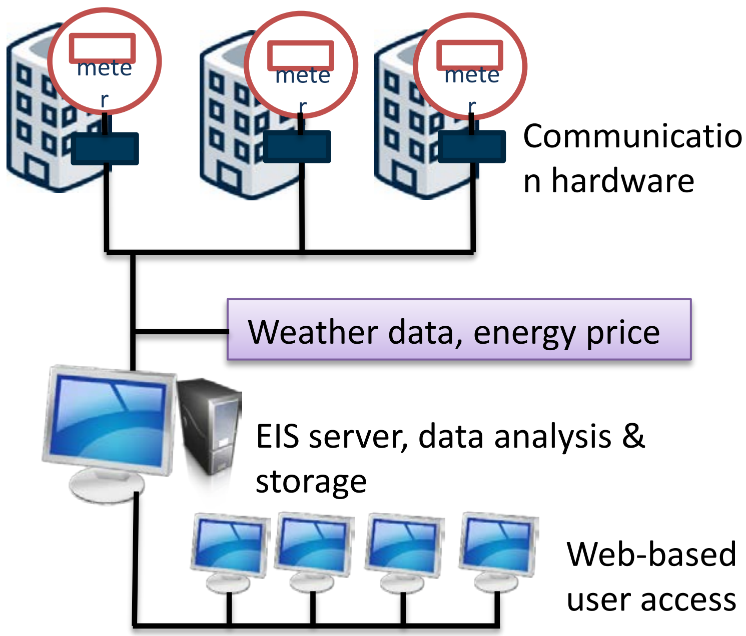
Fault Detection and Diagnostics

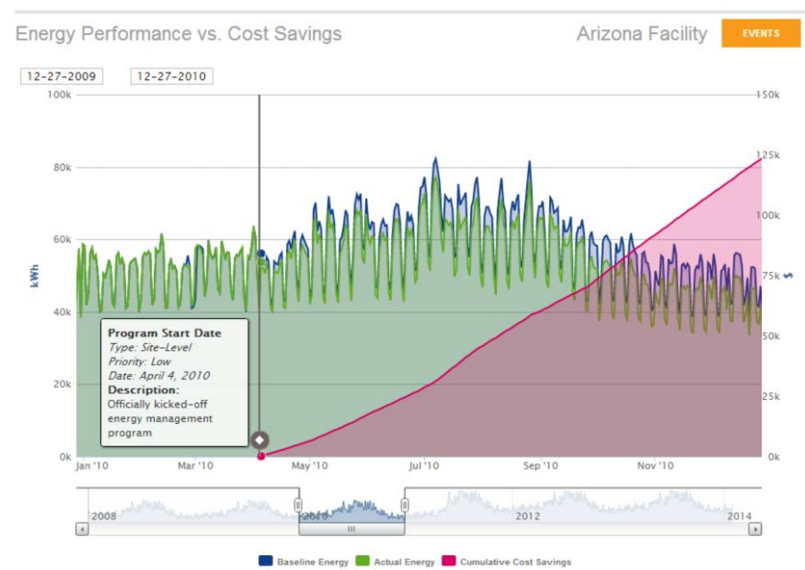


Building automation system (BAS)

Energy Information Systems (EIS)

Hourly to **15-min** interval meter data

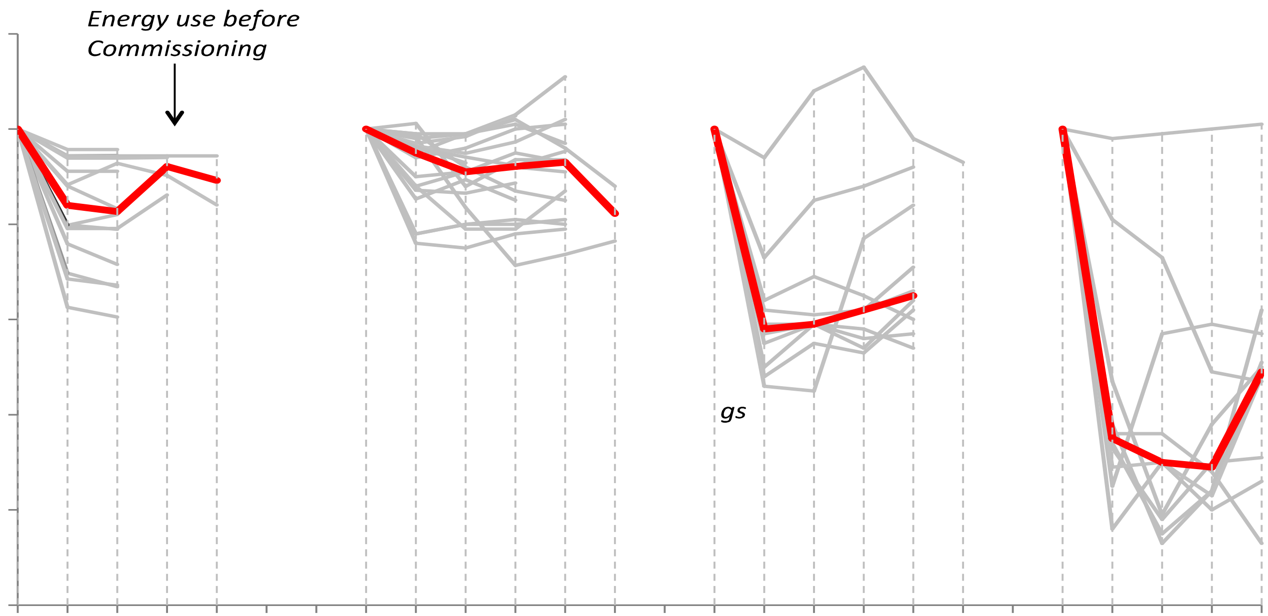




Images: Lucid (top); Sensei (bottom)

Motivating Context for EMIS

- Utility bills alone are insufficient to manage building energy use
- Building performance is not typically monitored and tracked
- Enormous savings are missed, efficiency is not maintained over time



What is Compelling About EMIS?

- Continuous visualization and analysis of interval meter data enables
  - Site energy savings up to 20% through *operational* measures
  - Persistence in efficient performance
- EMIS tools are beginning to offer automated measurement and verification capability
- The same technology that drives the savings can be used to verify the savings

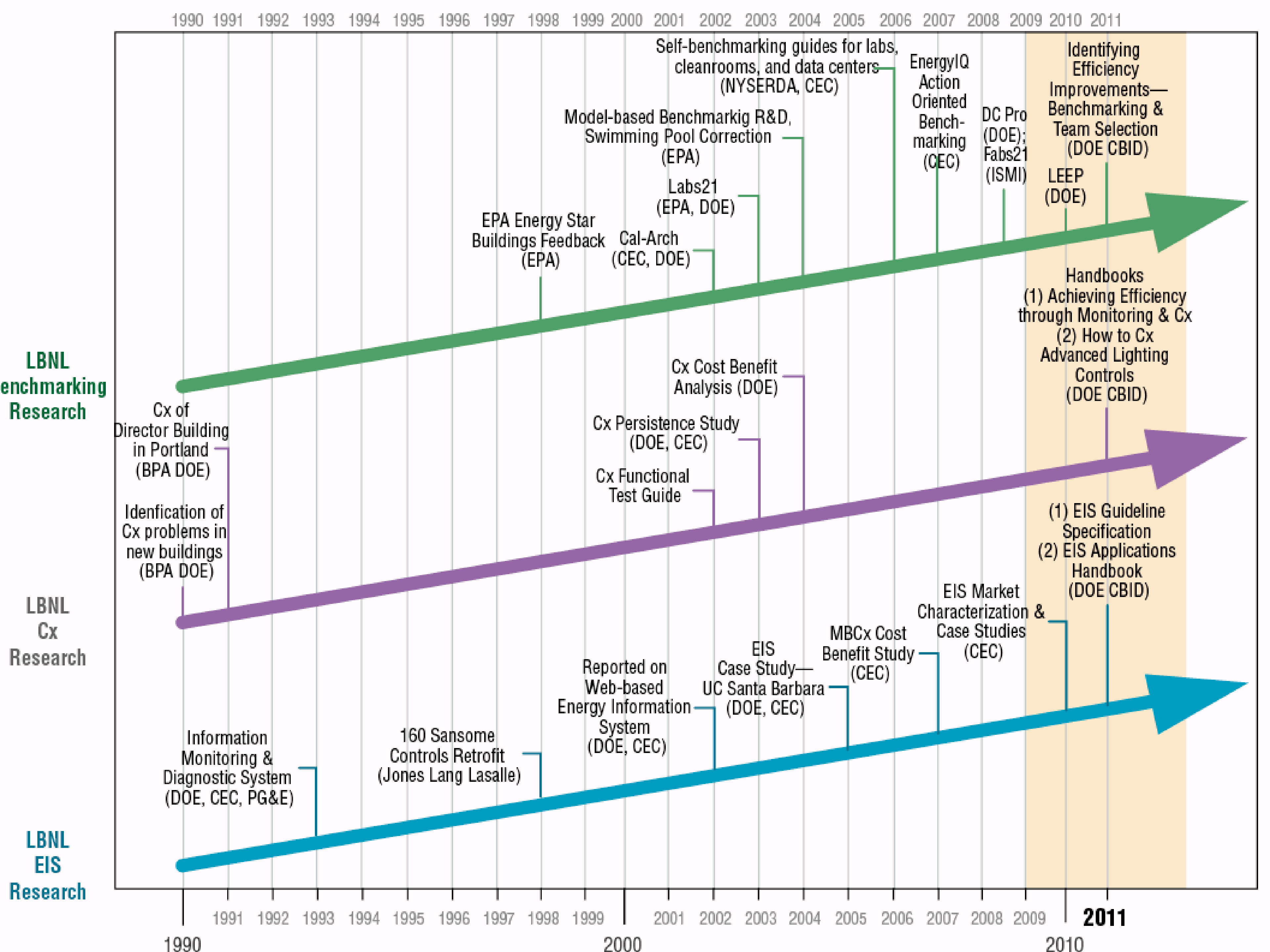
LBNL Work in EMIS

Goals and Objectives

- Increase adoption and capabilities of information systems for monitoring, commissioning, diagnostics and benchmarking

Methods

- Market characterization and best practice uses of existing tools, processes
- Technology enhancement and development of new tools
- Technology cost/benefit, effectiveness assessments
- Design and dissemination of guides, specifications, handbooks



1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
LBNL enchmarking Research
LBNL Cx Research
LBNL EIS Research
EPA Energy Star Buildings Feedback (EPA)
Cal-Arch (CEC, DOE)
Labs21 (EPA, DOE)
Model-based Benchmarkig R&D, Swimming Pool Correction (EPA)
Self-benchmarking guides for labs, cleanrooms, and data centers (NYSERDA, CEC)
EnergyIQ Action Oriented Bench-marking (CEC)
DC Pro (DOE); Fabs21 (ISMI)
LEEP (DOE)
Identifying Efficiency Improvements—Benchmarking & Team Selection (DOE CBID)
Cx of Director Building in Portland (BPA DOE)
Idenfication of Cx problems in new buildings (BPA DOE)
Cx Functional Test Guide
Cx Persistence Study (DOE, CEC)
Cx Cost Benefit Analysis (DOE)
Handbooks (1) Achieving Efficiency through Monitoring & Cx (2) How to Cx Advanced Lighting Controls (DOE CBID)
Information Monitoring & Diagnostic System (DOE, CEC, PG&E)
160 Sansome Controls Retrofit (Jones Lang Lasalle)
Reported on Web-based Energy Information System (DOE, CEC)
EIS Case Study—UC Santa Barbara (DOE, CEC)
MBCx Cost Benefit Study (CEC)
EIS Market Characterization & Case Studies (CEC)
(1) EIS Guideline Specification (2) EIS Applications Handbook (DOE CBID)
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

Common Questions About EMIS Use, and Associated LBNL Resources

1. How Do I Distinguish One EMIS Offering From Another?

- Fault detection and diagnostics, energy analytics, energy management system, optimization system
- Vendor websites look the same, many claim savings of 20%, features sound the same

- Real time performance reports
- Trend analysis
- Carbon footprints
- Automated alerting
- Tailored information displays
- Configurable events/alarms

- KPI reporting
- Load prediction
- Baselining
- Whole-bldg anomaly detection
- ECM identification
- Dashboard views
- x-y plotting
- Highly configurable
- Eminently extensible

EMIS Terminology/Characterization Framework

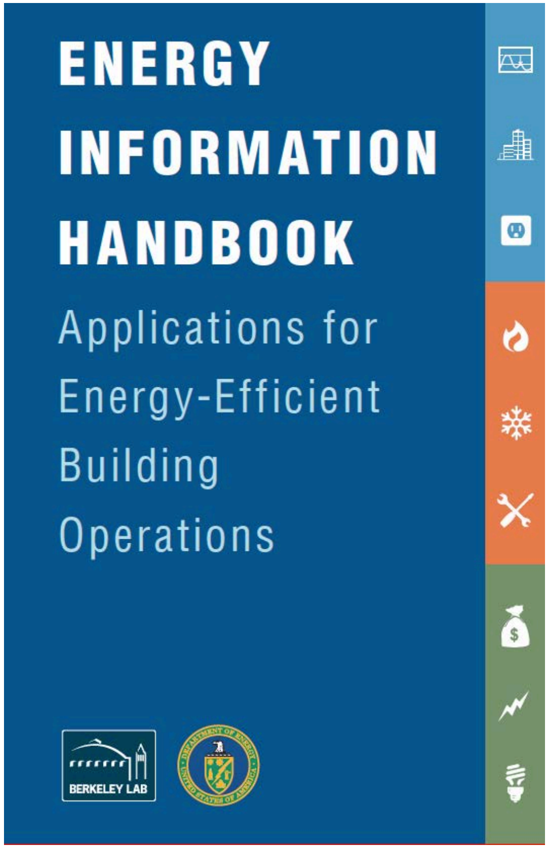
Technology attributes	Tools with a Whole-building Energy Focus			Tools with a System-level Focus		
	Benchmarking and Monthly Utility Bill Analysis	**Energy Information Systems**	**Advanced Energy Information Systems**	**Building Automation Systems**	**Fault Detection and Diagnostic Systems**	**Automated System Optimization**
Typical Data Scope	Whole-building	Whole building May include: submetering	Whole building May include: submetering and system-level monitoring	Systems, components, May include: system submetering	Systems, components, BAS trends May include: whole-building or system-level metering	
Typical Data Interval	Monthly	Hourly to 15-minute		15-minute and less		
Frequency of use	Monthly, annually	Daily, weekly, monthly			Weekly, monthly	
Primary Applications, Principal design intent	Utility bill reconciliation, energy use and cost tracking; peer-to-peer building comparisons of energy use.	Whole-building or portfolio energy tracking, and *data visualization* to identify opportunities to improve building operational efficiency.	Whole-building or portfolio energy tracking, and *automated interval data analysis* to identify opportunities to improve building operational efficiency.	Control of indoor temperature, light, and humidity setpoints based on building schedule; alarming of out-of-range operations.	Automated identification of faults, sometimes with associated causes, usually HVAC focused.	Automated modification of control parameters to optimize efficiency, energy use, and/or energy costs.

Other attributes include "AKA" names used in the industry, representative examples of commercial offerings

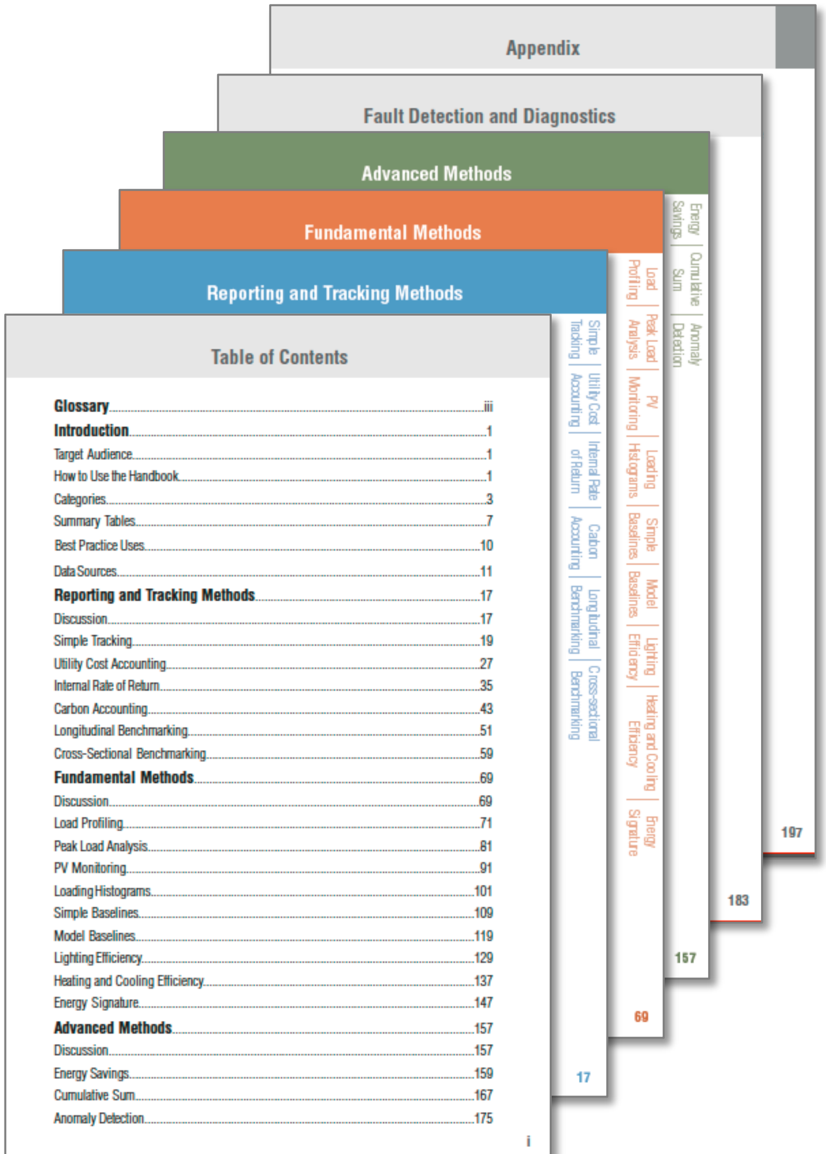
2. Now That I Have Data, What Do I Do With It?

2011 Energy Information Handbook

- Purpose: instructional resource detailing energy and performance monitoring methods for commercial buildings
- Audience those with little experience in the use of data
  - Secondary: software developers and service providers, control companies
- Relevant technologies: spectrum of performance monitoring tools



Handbook Organization



Begins with TOC, Glossary, and Introduction chapter

Primary content comprises three chapters of methods, each indicated by color

Last chapters are Fault Detection and Diagnostics, and an Appendix with supplementary material

List and Grouping of Analysis Methods

- **Reporting and Tracking Methods**
  - Simple Tracking
  - Utility Cost Accounting
  - Internal Rate of Return
  - Carbon Accounting
  - Longitudinal Benchmarking
  - Cross-Sectional Benchmarking
- **Fundamental Methods**
  - Load Profiling
  - Peak Load Analysis
  - PV Monitoring
  - Loading Histograms
  - Simple Baselines
  - Model Baselines
  - Lighting Efficiency
  - Heating and Cooling Efficiency
  - Energy Signature
- **Advanced Methods**
  - Energy Savings
  - Cumulative Sum
  - Anomaly Detection

18 analysis methods grouped into three chapters based on shared characteristics

Organized from simpler to more technically complex

Summary Tables

At-a-glance summary tables to help reader identify useful methods given data availability, systems of interest, level of expertise

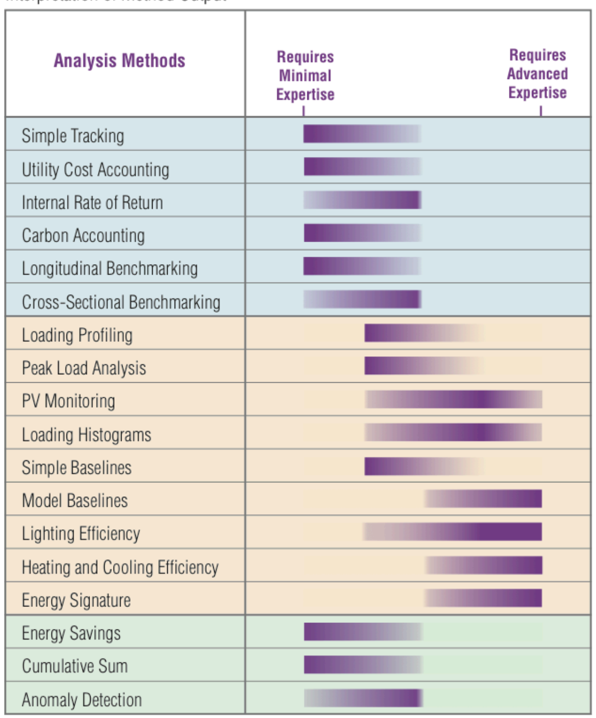
Minimum Data Requirements

Analysis Methods	Utility		Interval Meter		Submeter			Other*
	Gas	Electric	WB Gas	WB Electric	Heating Load	Cooling Load	Lighting Load	
Simple Tracking	●	●						
Utility Cost Accounting	●	●						
Internal Rate of Return	●	●						●
Carbon Accounting	●	●						●
Longitudinal Benchmarking	●	●						●
Cross-Sectional Benchmarking	●	●						●
Loading Profiling			●	●				
Peak Load Analysis				●				
PV Monitoring								●
Loading Histograms					●	●		
Simple Baselines	●	●						●
Model Baselines			●	●				●
Lighting Efficiency							●	●
Heating and Cooling Efficiency					●	●		●
Energy Signature	●	●						●
Energy Savings	●	●						●
Cumulative Sum	●	●						●
Anomaly Detection			●	●				●

Applicable Building Systems

Analysis Methods	Whole Building	Heating	Cooling	Lighting	Plug Loads
Simple Tracking	●	●	●	●	●
Utility Cost Accounting	●	●	●	●	●
Internal Rate of Return	●	●	●	●	●
Carbon Accounting	●	●	●	●	●
Longitudinal Benchmarking	●	●	●	●	●
Cross-Sectional Benchmarking	●	●	●	●	●
Loading Profiling	●	●	●	●	●
Peak Load Analysis	●				
PV Monitoring*	●				
Loading Histograms		●	●		
Simple Baselines	●	●	●	●	●
Model Baselines	●	●	●	●	●
Lighting Efficiency				●	
Heating and Cooling Efficiency		●	●		
Energy Signature	●	●	●		
Energy Savings	●	●	●	●	●
Cumulative Sum	●	●	●	●	●
Anomaly Detection	●	●	●	●	●

Interpretation of Method Output



Sample Method, Summary Page

Purpose

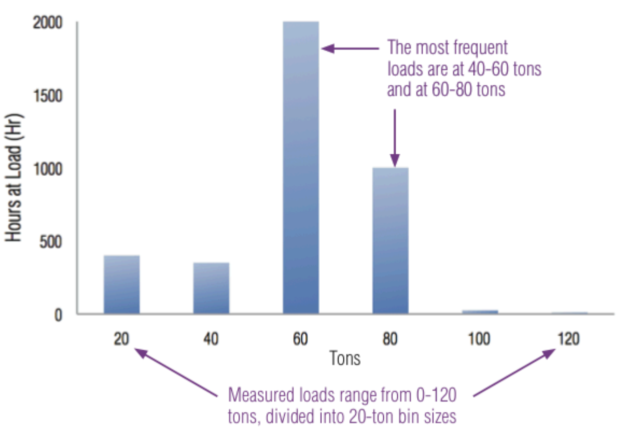
Loading histograms are used to evaluate whether HVAC equipment is properly sized and staged, given the operated condition of the building. They are useful in identifying potential retrofit solutions and optimizing control of multi-unit staging.

Applicable Systems				
Whole Building	Heating	Cooling	Lighting	Plug Loads
	●	●		

Interpretation		Frequency of Use		
Requires Minimum Expertise	Requires Domain Expertise	Continuous	Monthly	Annual
				●

Technical Approach

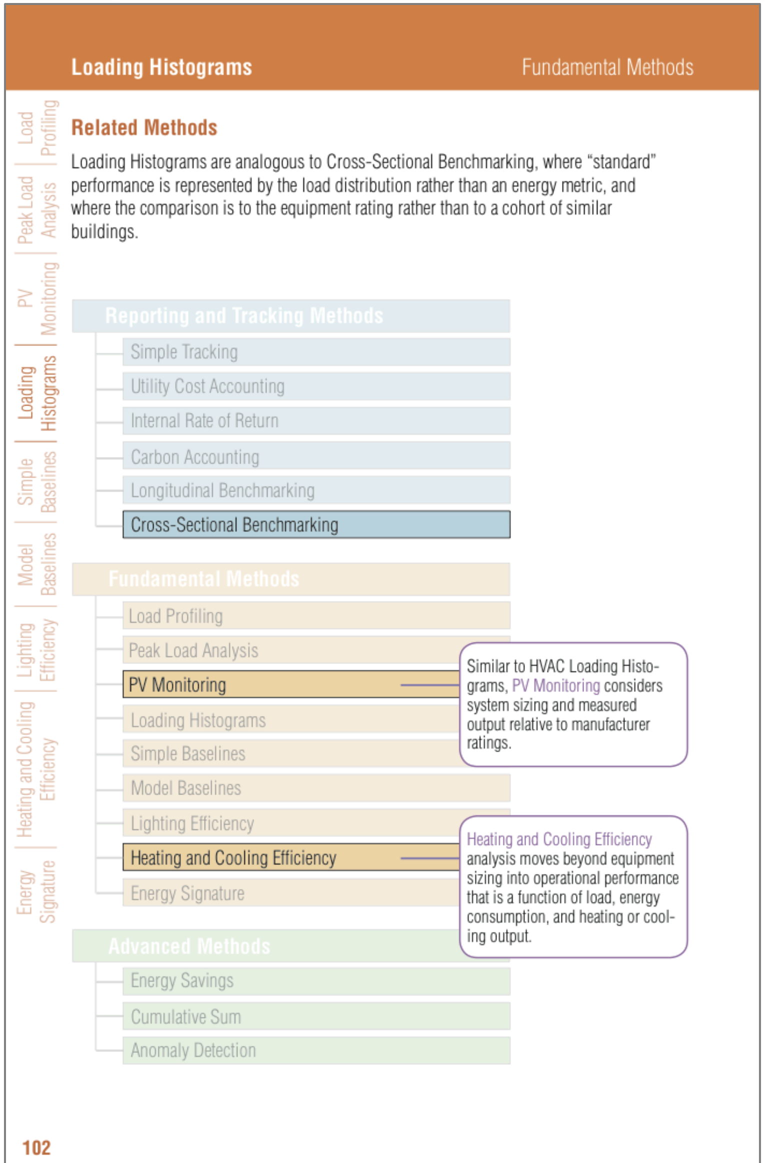
Group system load measurements into "bins," or ranges, and count the number of hours at which the system operated within each range. Construct a bar chart with load plotted on the x-axis and the number of hours at each load plotted on the y-axis. Then compare the distribution of operational hours at each load to the manufacturer load ratings and equipment staging sequences.



Each method begins with a summary page that includes:

- **Purpose and use, including a summary table**
- **Icons indicating the target audience**
- **Technical approach and a representative image**

Sample Method, Related Methods


Loading Histograms — Fundamental Methods

Load Profiling | Peak Load Analysis | PV Monitoring | Loading Histograms | Simple Baselines | Model Baselines | Lighting Efficiency | Heating and Cooling Efficiency | Energy Signature

Related Methods

Loading Histograms are analogous to Cross-Sectional Benchmarking, where "standard" performance is represented by the load distribution rather than an energy metric, and where the comparison is to the equipment rating rather than to a cohort of similar buildings.

Reporting and Tracking Methods
- Simple Tracking
- Utility Cost Accounting
- Internal Rate of Return
- Carbon Accounting
- Longitudinal Benchmarking
- Cross-Sectional Benchmarking

Fundamental Methods
- Load Profiling
- Peak Load Analysis
- PV Monitoring
- Loading Histograms
- Simple Baselines
- Model Baselines
- Lighting Efficiency
- Heating and Cooling Efficiency
- Energy Signature

Advanced Methods
- Energy Savings
- Cumulative Sum
- Anomaly Detection

Similar to HVAC Loading Histograms, PV Monitoring considers system sizing and measured output relative to manufacturer ratings.

Heating and Cooling Efficiency analysis moves beyond equipment sizing into operational performance that is a function of load, energy consumption, and heating or cooling output.

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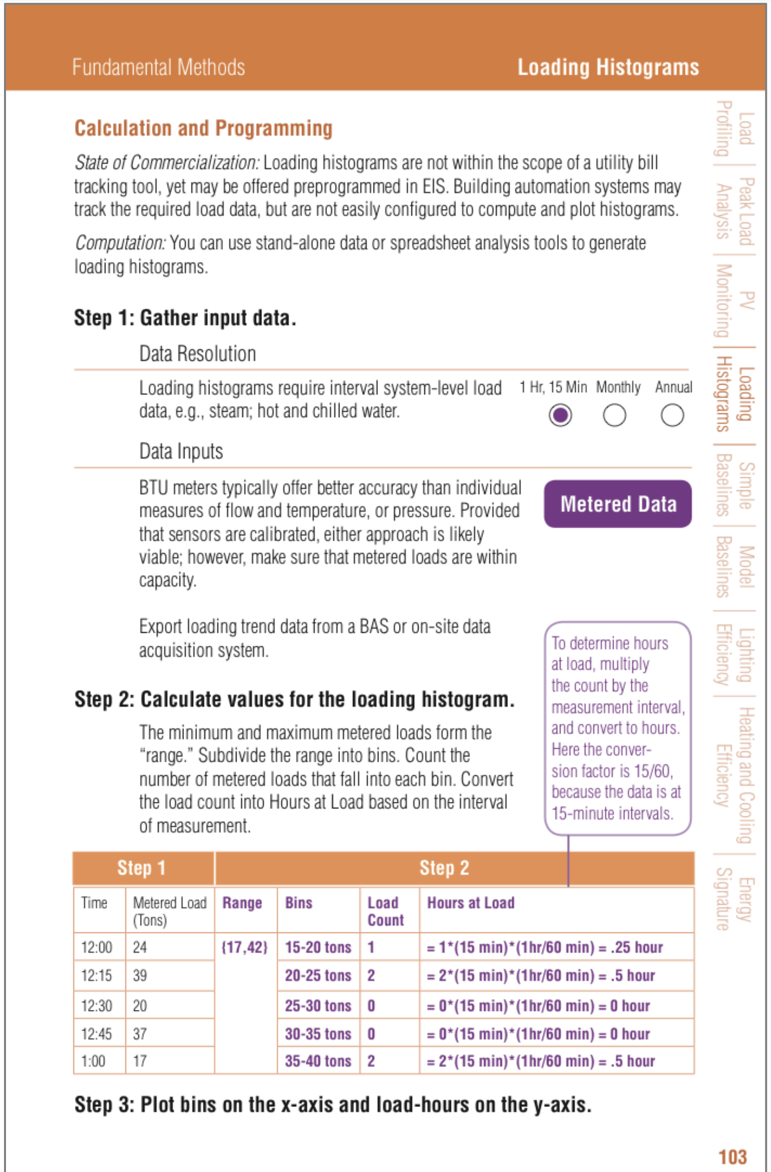
Following the summary page, related methods are presented:

- **Shading and highlighting to indicate relationships with other methods in handbook**
- **Description of the relationship in short paragraph and call outs**

Sample Method, Calculation and programming



Calculation and Programming

State of Commercialization: Loading histograms are not within the scope of a utility bill tracking tool, yet may be offered preprogrammed in EIS. Building automation systems may track the required load data, but are not easily configured to compute and plot histograms.

Computation: You can use stand-alone data or spreadsheet analysis tools to generate loading histograms.

Step 1: Gather input data.

Data Resolution

Loading histograms require interval system-level load data, e.g., steam; hot and chilled water.

1 Hr, 15 Min (selected) | Monthly | Annual

Data Inputs

BTU meters typically offer better accuracy than individual measures of flow and temperature, or pressure. Provided that sensors are calibrated, either approach is likely viable; however, make sure that metered loads are within capacity.

Metered Data

Export loading trend data from a BAS or on-site data acquisition system.

Step 2: Calculate values for the loading histogram.

The minimum and maximum metered loads form the "range." Subdivide the range into bins. Count the number of metered loads that fall into each bin. Convert the load count into Hours at Load based on the interval of measurement.

To determine hours at load, multiply the count by the measurement interval, and convert to hours. Here the conversion factor is 15/60, because the data is at 15-minute intervals.

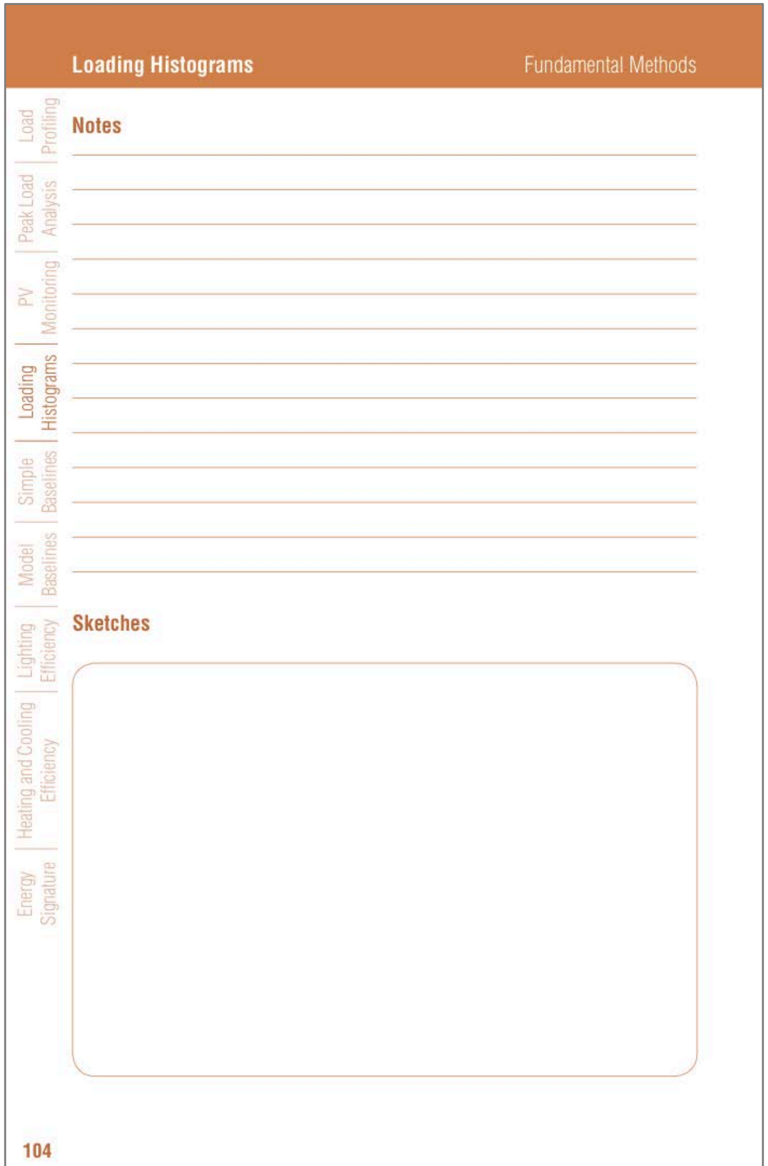
Step 1		Step 2			
Time	Metered Load (Tons)	Range	Bins	Load Count	Hours at Load
12:00	24	{17,42}	15-20 tons	1	= 1*(15 min)*(1hr/60 min) = .25 hour
12:15	39		20-25 tons	2	= 2*(15 min)*(1hr/60 min) = .5 hour
12:30	20		25-30 tons	0	= 0*(15 min)*(1hr/60 min) = 0 hour
12:45	37		30-35 tons	0	= 0*(15 min)*(1hr/60 min) = 0 hour
1:00	17		35-40 tons	2	= 2*(15 min)*(1hr/60 min) = .5 hour

Step 3: Plot bins on the x-axis and load-hours on the y-axis.

A page dedicated to calculation and programming:

- **State of commercialization**
- **Required data**
- **Step-by-step instructional numeric example**

Sample Method, Notes and Sketches


Loading Histograms   Fundamental Methods

Load Profiling | Peak Load Analysis | PV Monitoring | Loading Histograms | Simple Baselines | Model Baselines | Lighting Efficiency | Heating and Cooling Efficiency | Energy Signature

Notes

Sketches

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Following computation, a page for notes and sketches

Sample Method, Application Examples

Application Examples

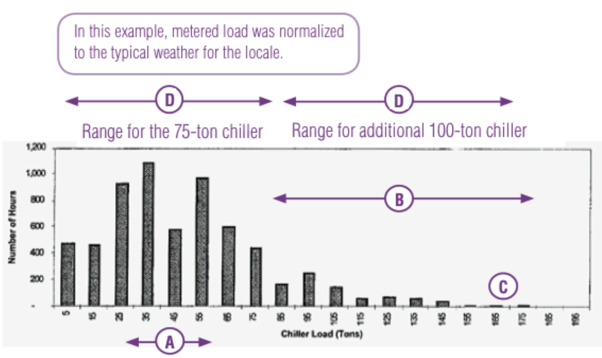
Interpretation: Equipment is sized according to *expected* building loads at the time of design, and a margin of safety. If the histogram shows frequent operation at loads much smaller than the rating, downsizing may be appropriate. For example, a chiller's efficiency sweet spot is typically at 70%- 80% of full load. Boilers, on the other hand, often cycle at loads below 20%, introducing energy waste and part wear. If multiple parallel units are present, the histogram can be also used to confirm staging sequences.

Example 1: Chiller Retrofit Analysis

A loading histogram is shown for one year for a 220-ton chiller installation.

- (A) Although 220 tons were available, only 35- 55 tons are required most of the year.
- (B) Only 13% of load hours are at 75 tons or greater.
- (C) The highest observed loads (hourly steady state averages) were around 165 tons.
- (D) The ideal design would have been a 75/100-ton combination.

A 100-ton unit could save $3,411/yr, but was cost prohibitive at $25K.



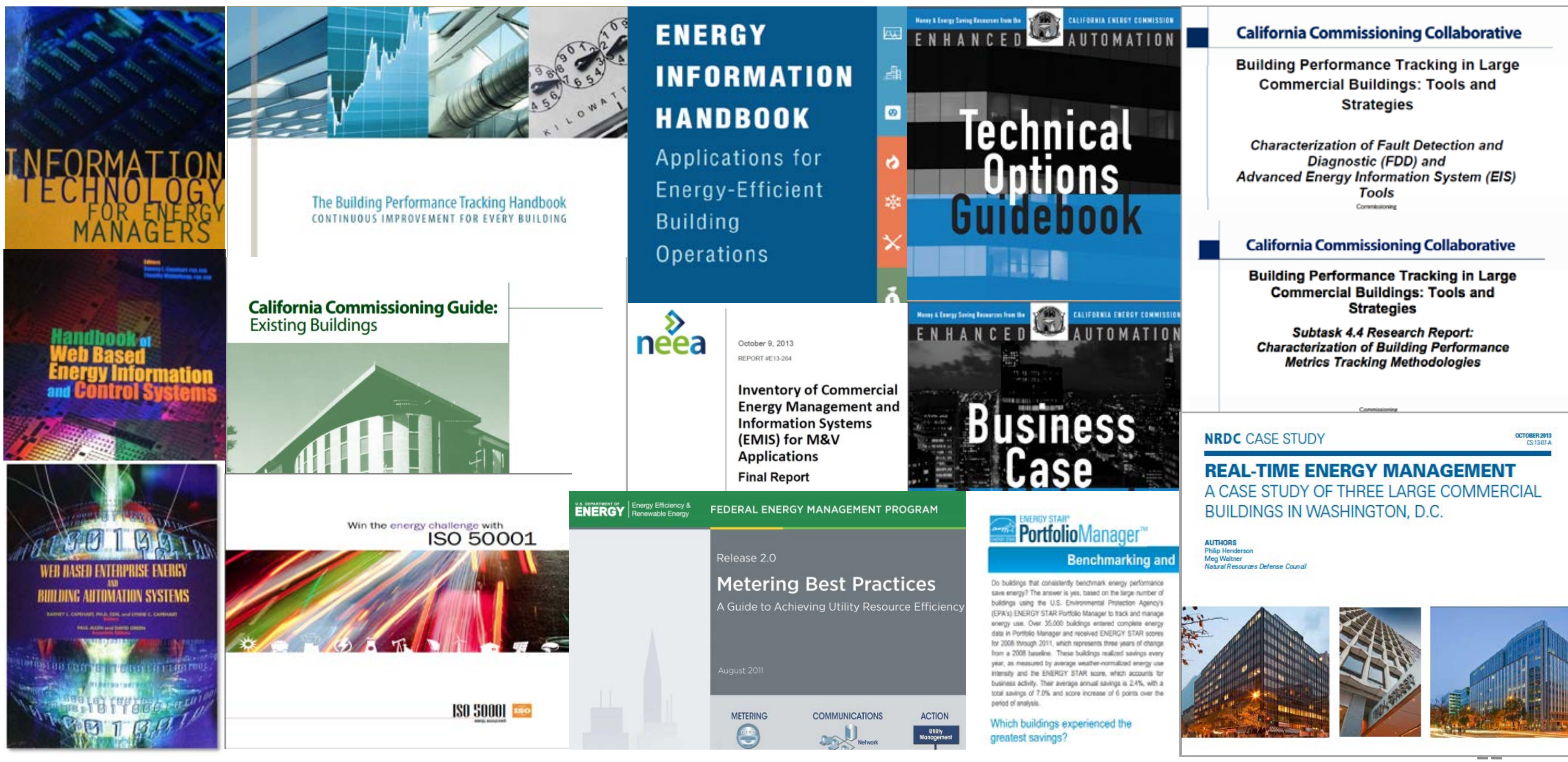
Source: Piette et al, Model-based chiller energy tracking for performance assurance at a university building. LBNL#40781, 1997.

Wherever possible, real-world examples of how method can be applied:

- **Description of how method output is interpreted, rules of thumb**
- **Heavily annotated to support reader interpret data, draw conclusions**
- **3-5 examples per method, illustrating different investigations/questions and energy saving benefits of use**

3. What References Might Answer My Questions About Monitoring and Analysis?

'Cliff's Notes' synthesis of ~40 existing guides, handbooks, case studies, specifications



4. How Do I Plan for And Implement an EMIS?

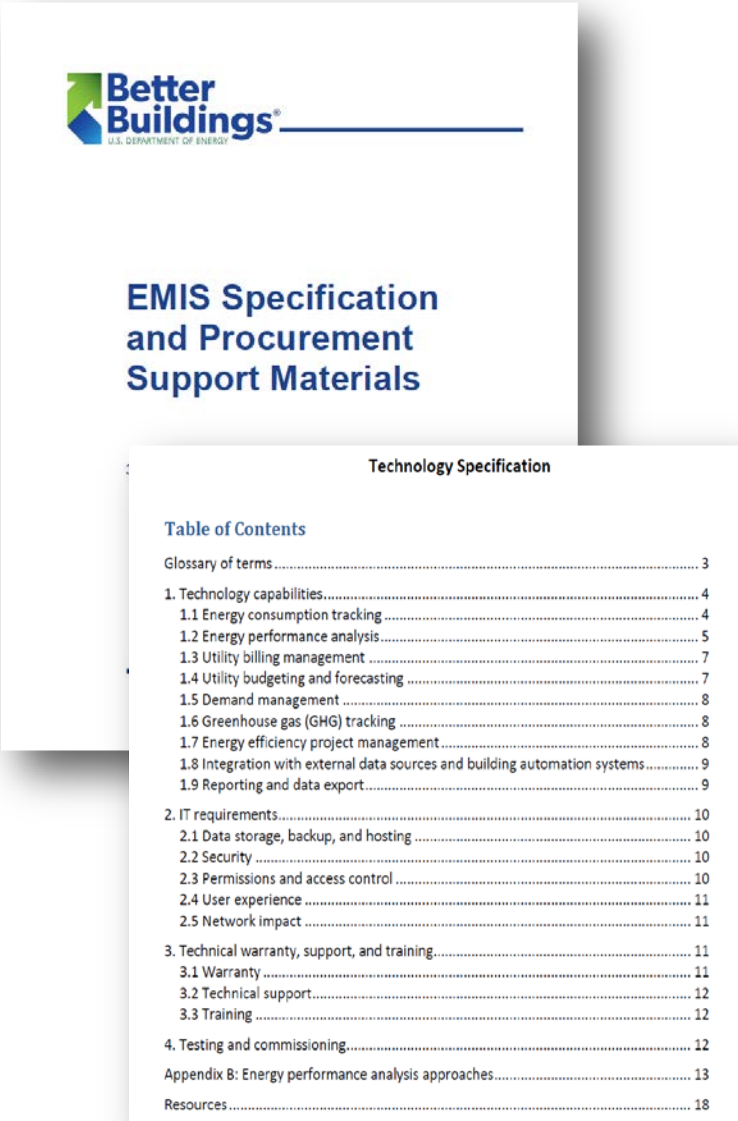
6 step process to plan, select a EMIS

- Set organizational goals
- Establish roles & responsibilities
- Understand organizational conditions
- Define activities to meet goals
- Identify required sensing, metering
- Select a tool(s)

Summary of EMIS Tools

EMIS tools	Data scope	Key uses	Costs	Energy Savings
Benchmarking& utility bill analysis	Monthly utility bills	▪ Peer-to peer comparison ▪ Utility bill analysis	Free -$	2.4% (median) (whole building, enabled savings)
EIS & Advanced EIS	Hourly or 15-min meter data	▪ Energy dashboard/kiosk ▪ Benchmarking ▪ Energy anomalies alert ▪ Demand response ▪ Auto M&V	$$-$$$	8% (median), 0-33% (range) (whole building, enabled savings)
BAS	15-min or less interval sub-system data	▪ Building system control ▪ Manually troubleshooting by investigating trends	$$$$	10-15% (whole building)
FDD		▪ Auto system or component fault notification ▪ Fault causes identification	$$$	2-11%(whole building, potential savings)
ASO		▪ Optimal HVAC settings prediction	$$$	-

EMIS Procurement Support Materials


Better Buildings
U.S. DEPARTMENT OF ENERGY

EMIS Specification and Procurement Support Materials

Technology Specification

Table of Contents

- Request for Proposal
  - Template to create a project-specific RFP for vendors
- Technology Specification
  - Template of technology features that can be specified according to org. specific needs
- Evaluation Criteria
  - Several criteria to help choose between multiple competing proposals that satisfy the spec.

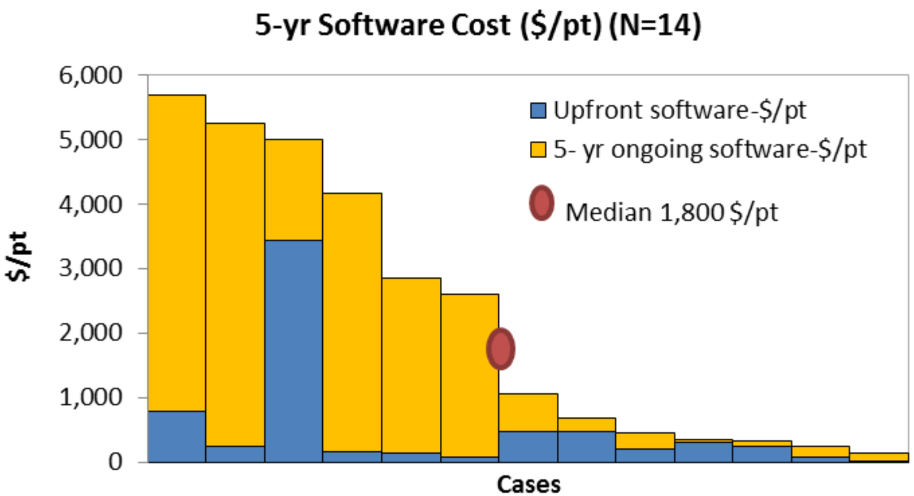
5. What Do EIS Cost, and What do They Save?

Synthesized case investigations to identify as-implemented costs, over-time energy savings, best practices, factors associated with larger savings

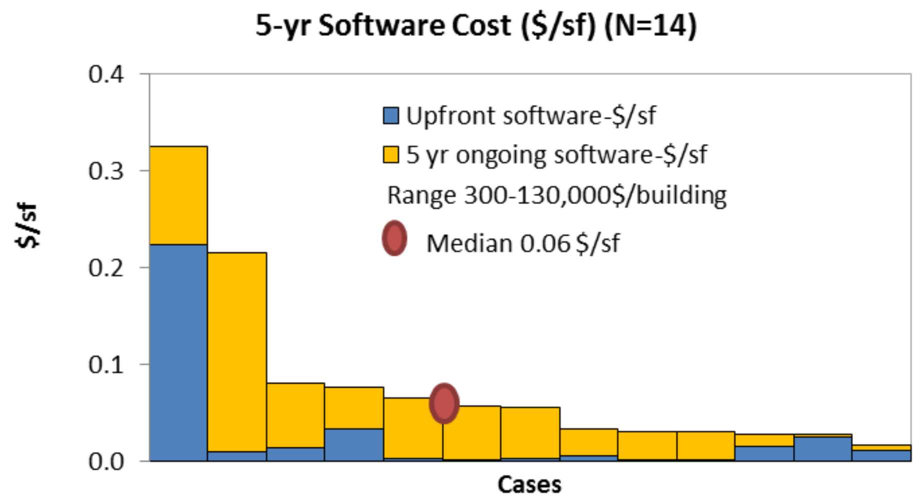
26 participating organizations, 260M sf install base, 17 unique EIS

EIS Costs Reported by Study Participants

Median 5-yr cost of ownership = $150K, 1800$/pt, .06$/sf



Not plotted but included in the calculation of median:16,000



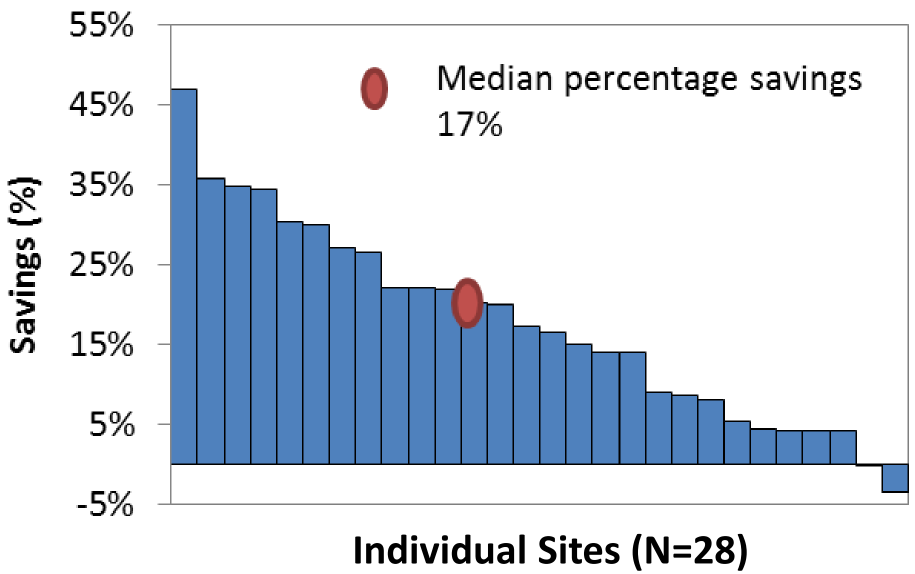
Not plotted but included in the calculation of median: 1.1

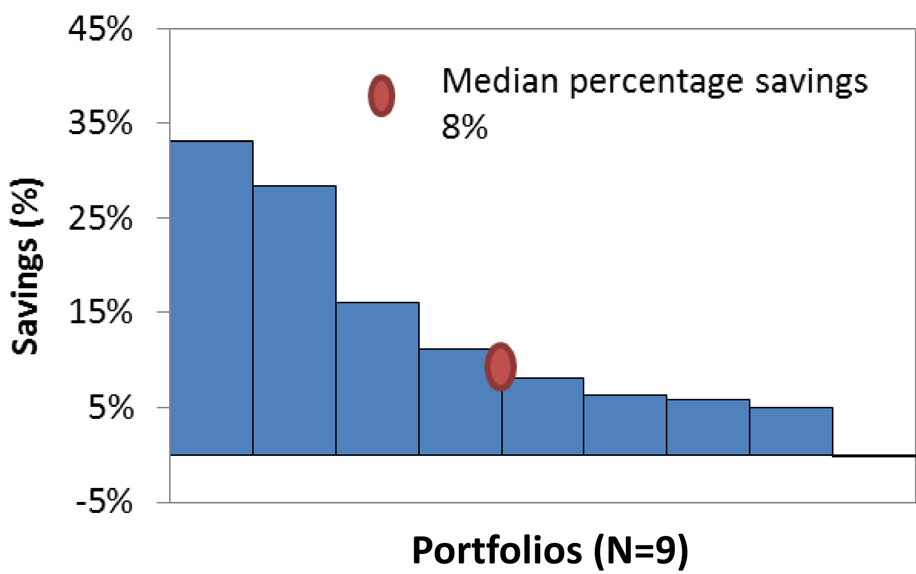
- Note the wide distribution of costs paid by study participants
- Some economies of scale with size of implementation

Savings: Year Prior to EIS Installation vs. Most Recent Year of Data

- Median building and portfolio savings of 17% and 8% would not be possible without use of the EIS
  - Median building and portfolio utility savings of $56K, and $1.3M

- Key benefits
  - **Operational efficiency**, utility validation and payment, data for other analyses



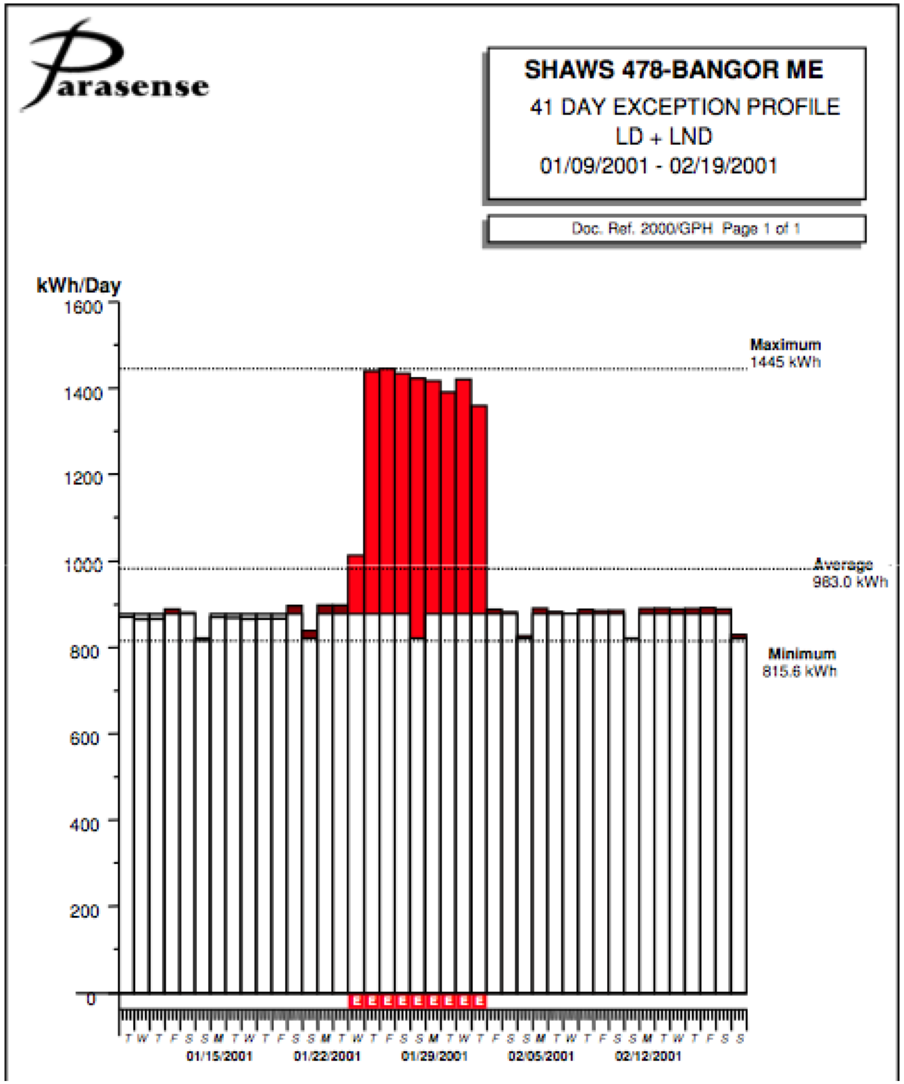


Key Factors and Best Practices

- Initial EUI, extent of efficiency projects, depth of metering, and total years of installation correlated with higher savings
  - EIS rarely if ever implemented as sole strategy
  - All but two participants reported savings could not have been achieved without the EIS
  - Those with less aggressive efficiency projects still saved 5%

- Best practices
  - Installation of submetering, beyond whole-building level
  - Load profiling on a regular basis
  - Use of automated energy anomaly detection features
  - Monitoring peak load and managing demand charges
  - With regular usage over time, savings can accrue and deepen

Examples of EIS Uses



Smart Moves

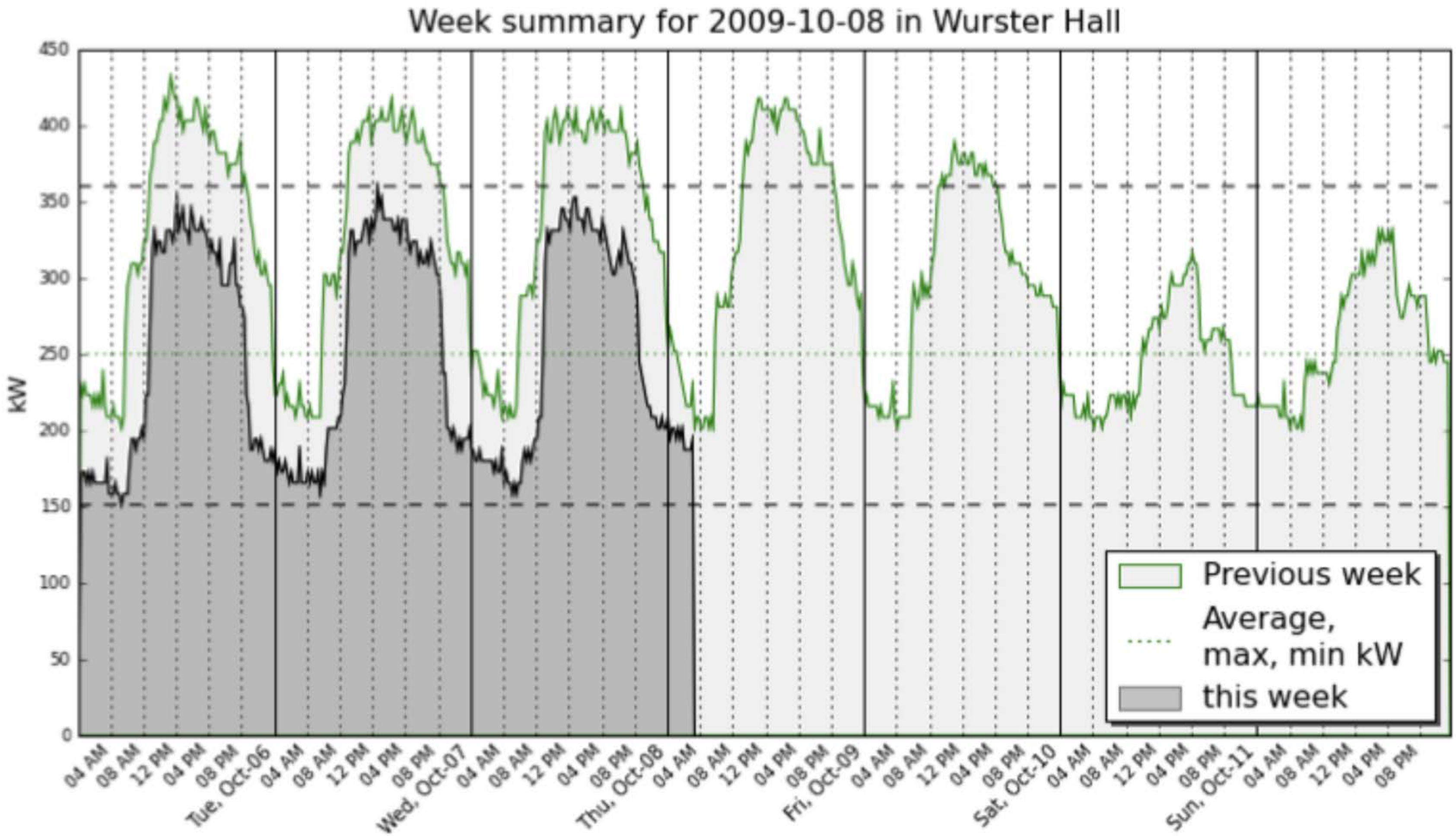
Performance Based Maintenance

Lighting

Control Override

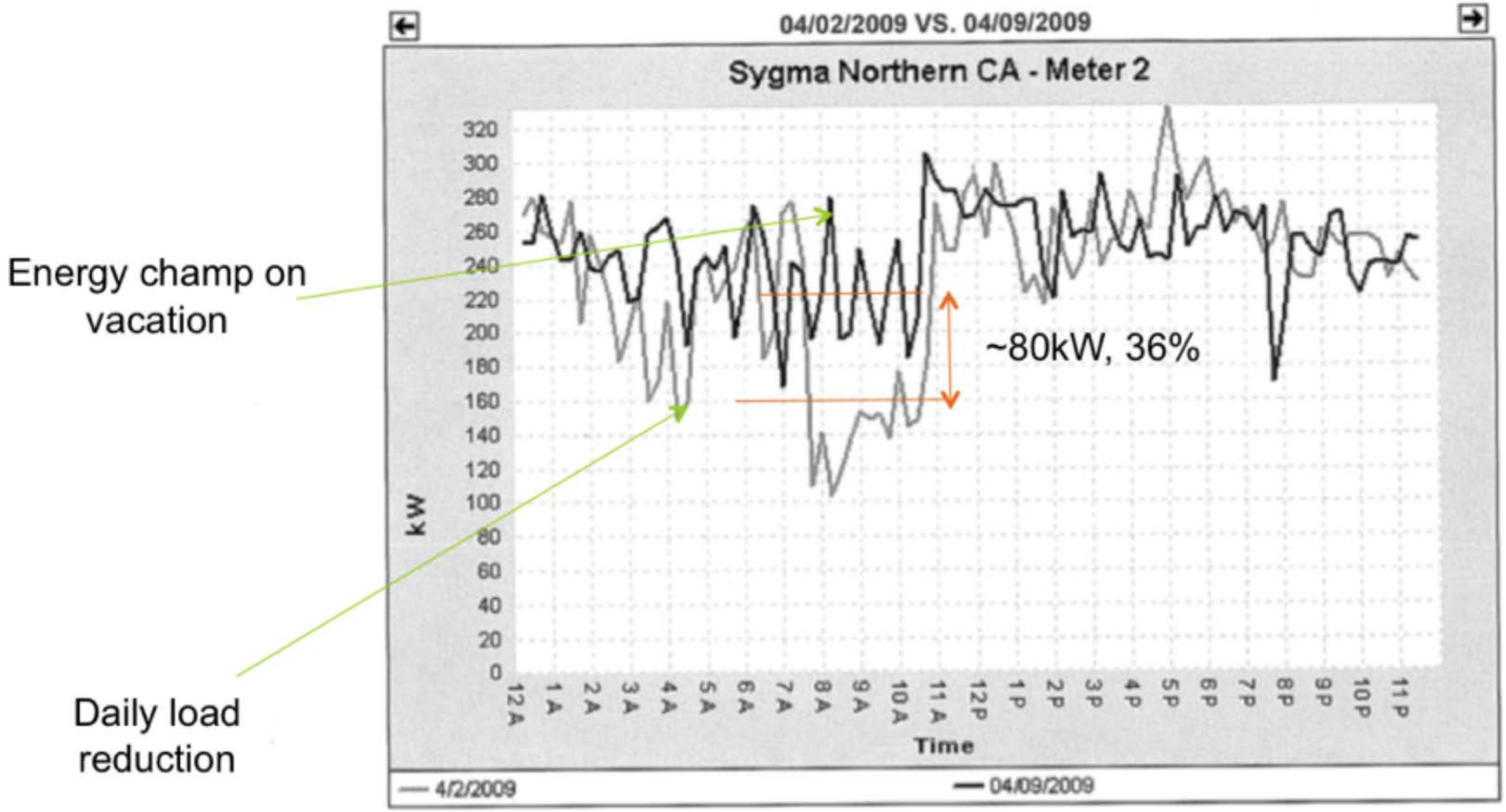
- Exception Report Generated
- Problem Rectified

Examples of EIS Uses



Examples of EIS Uses

Electric Demand



Anchor Graph at Zero

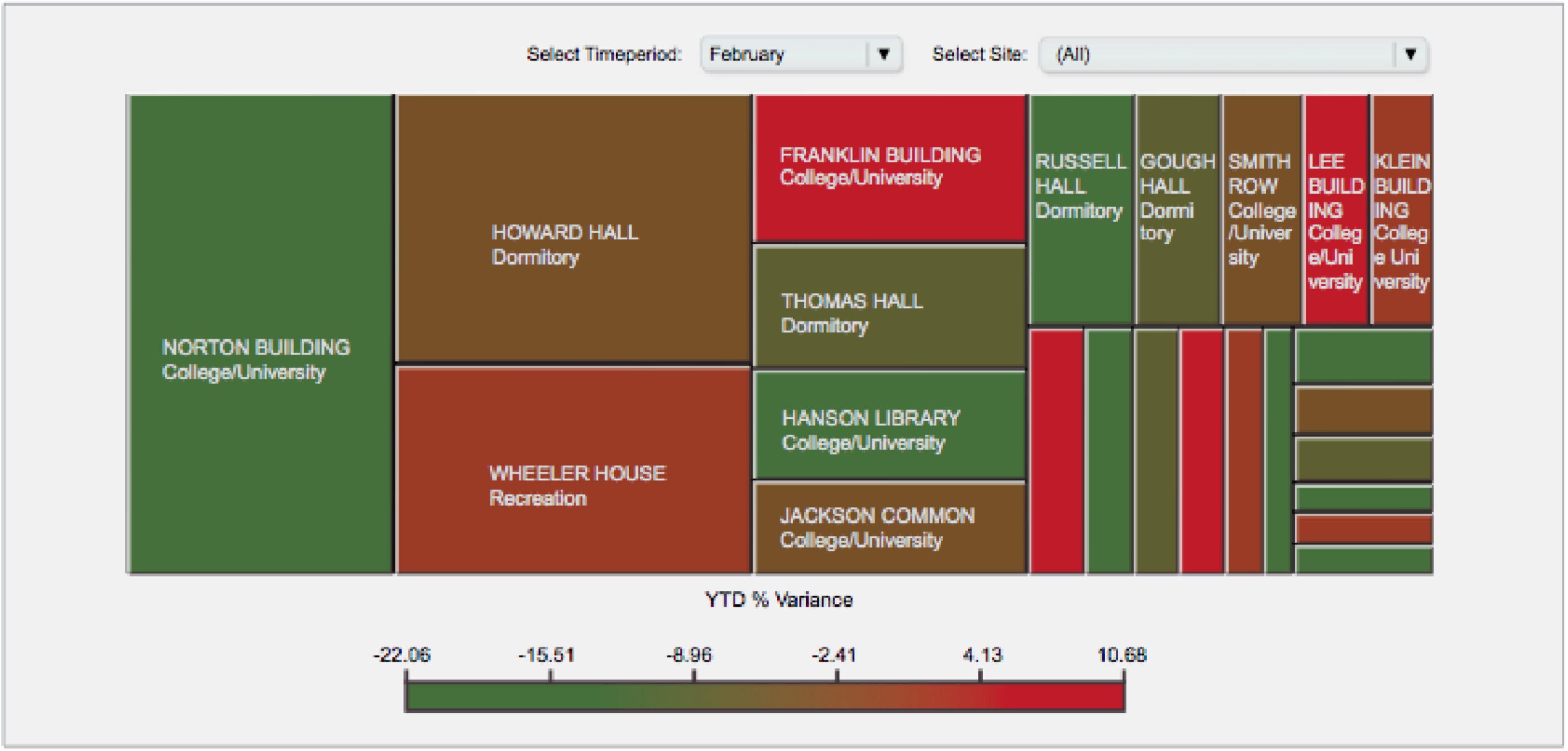
04/09/2009: **5,873 kW**
04/02/2009: **5,567 kW**
Change: **5.5%**

04/09/2009 Average Ambient: **53°F**
04/02/2009 Average Ambient: **57°F**
Temp Change: **-4°F**

Examples of EIS Uses

Figure 2. Use dynamic heatmaps to focus your activities on leaders and laggards.

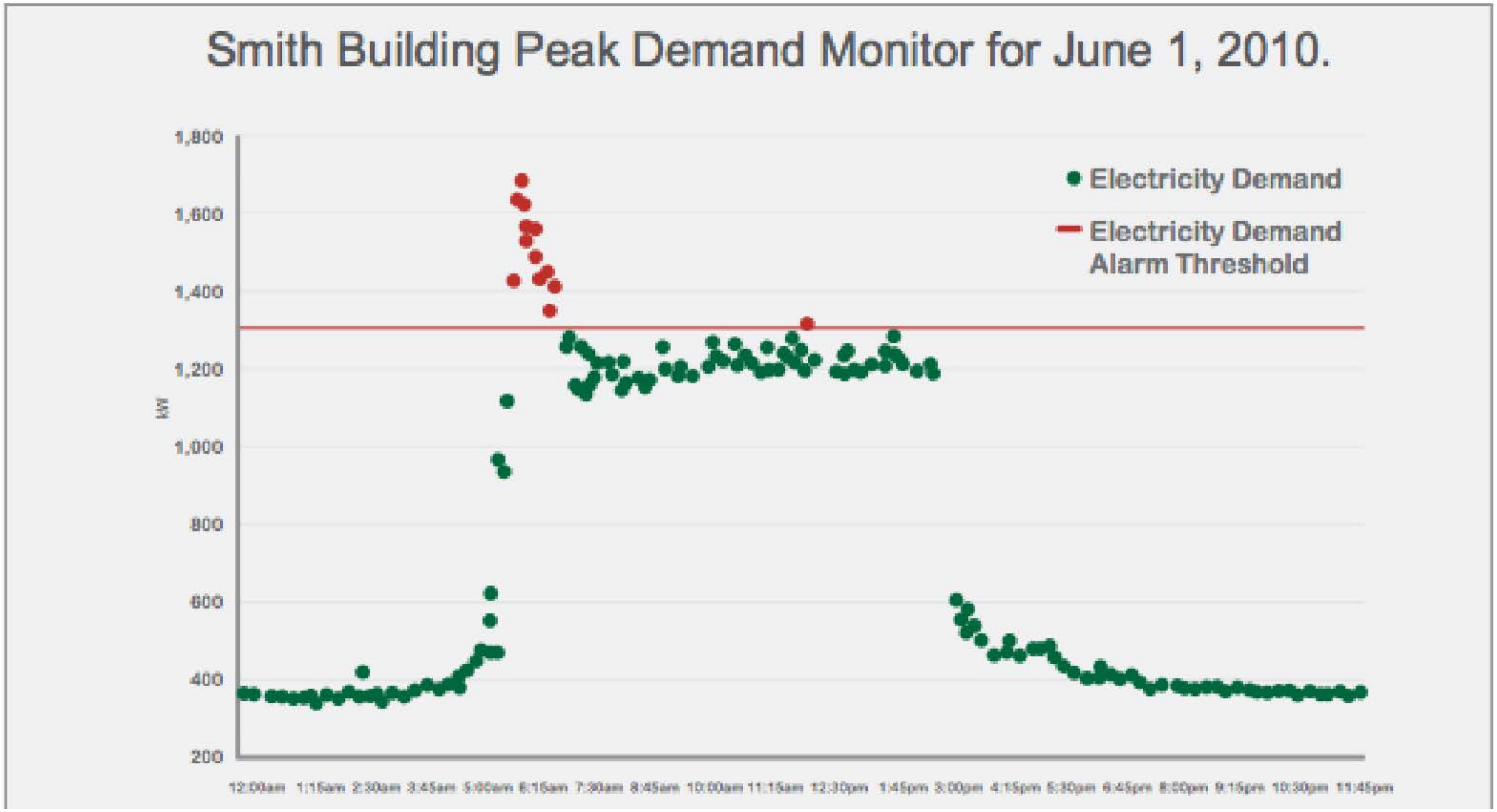
This figure shows a "heat map" of many different facilities, and their energy performance against a YTD average. The color displays energy variance, while the size of the tile represents the total energy spend of the facility. The interactive map lets any user view facilities through a variety of filters, and click on any specific facility for more information.



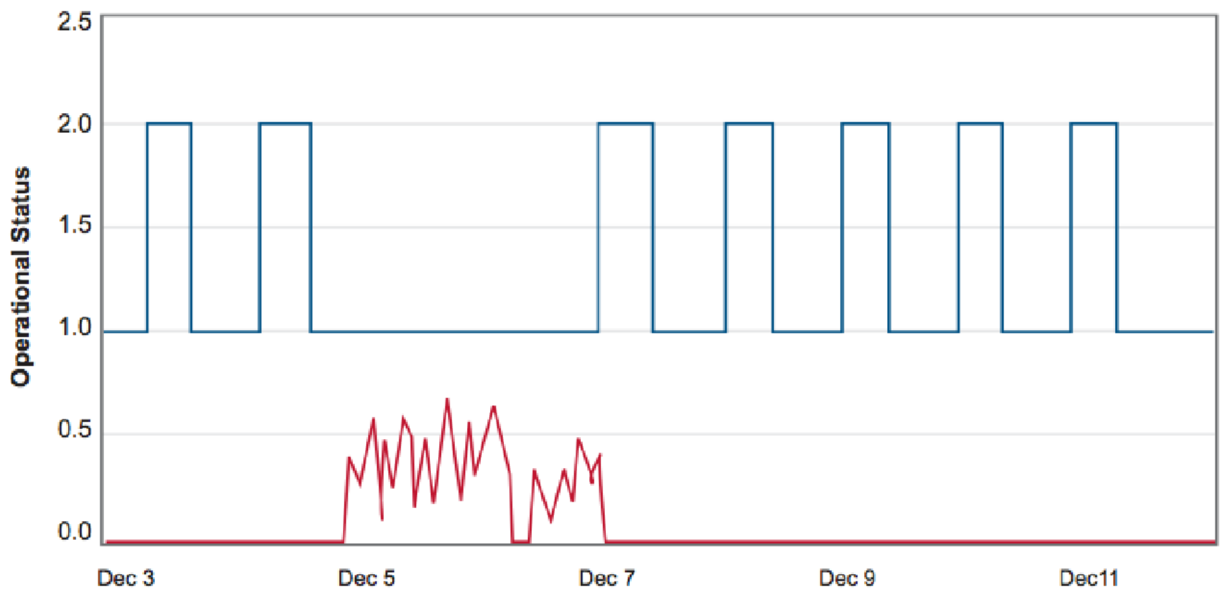
Examples of EIS Uses

Figure 3. Respond rapidly to spikes to keep demand charges low.

This view provides a closer look at the day's energy use profile. When the building's energy use exceeds an established threshold, facility managers will automatically be alerted—and thus have the ability to mitigate runaway energy spikes as they occur.



Examples of EIS Uses



The boiler's red activity line should be flat(off) over the weekends while the building's blue activity line is flat.

6. How Can I Use EMIS to Verify Energy Savings?

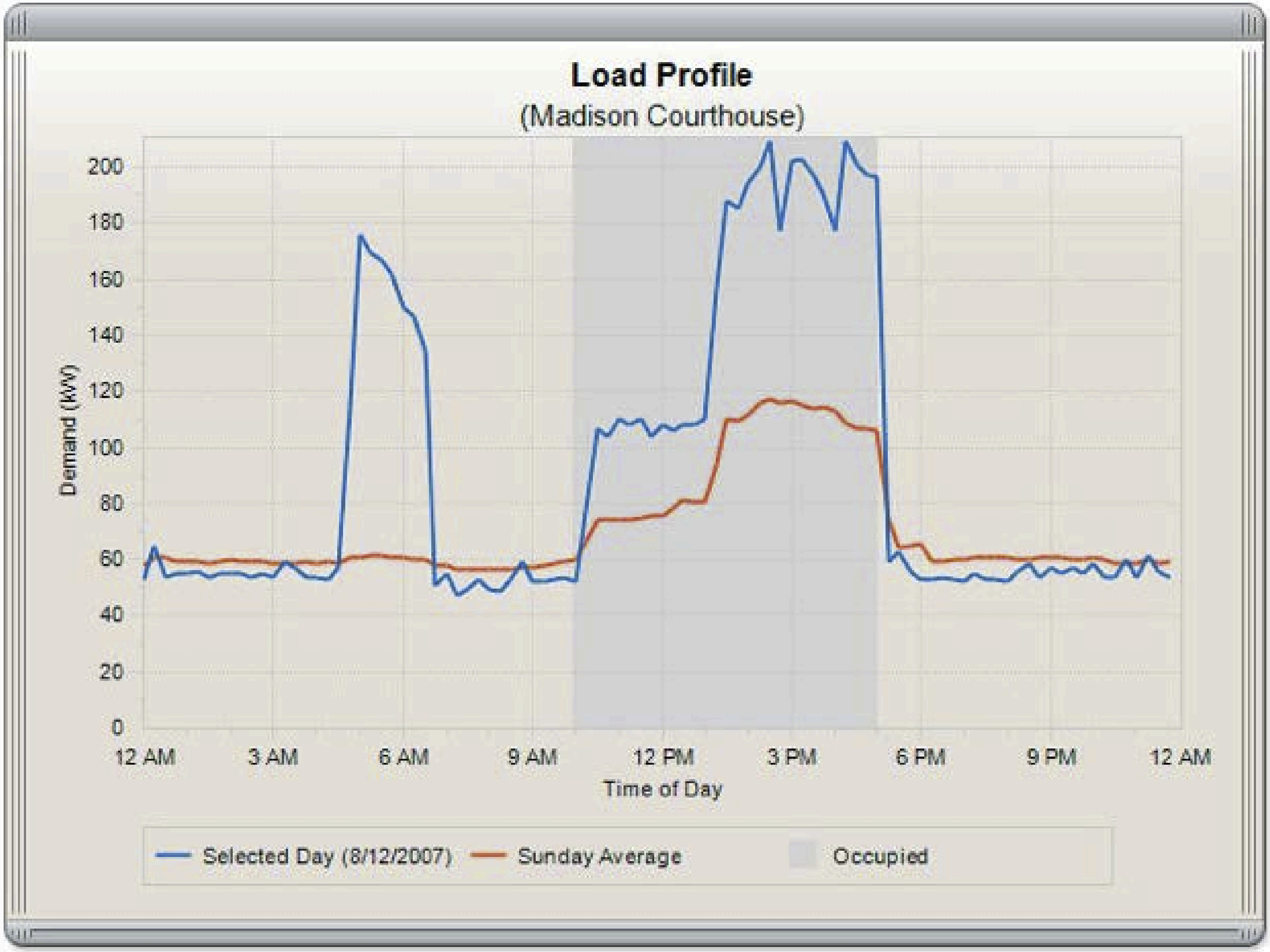
Automated M&V is beginning to be offered in energy management and information systems

Baselines are automatically created using historic interval meter data (system level or whole-building) and weather data feeds

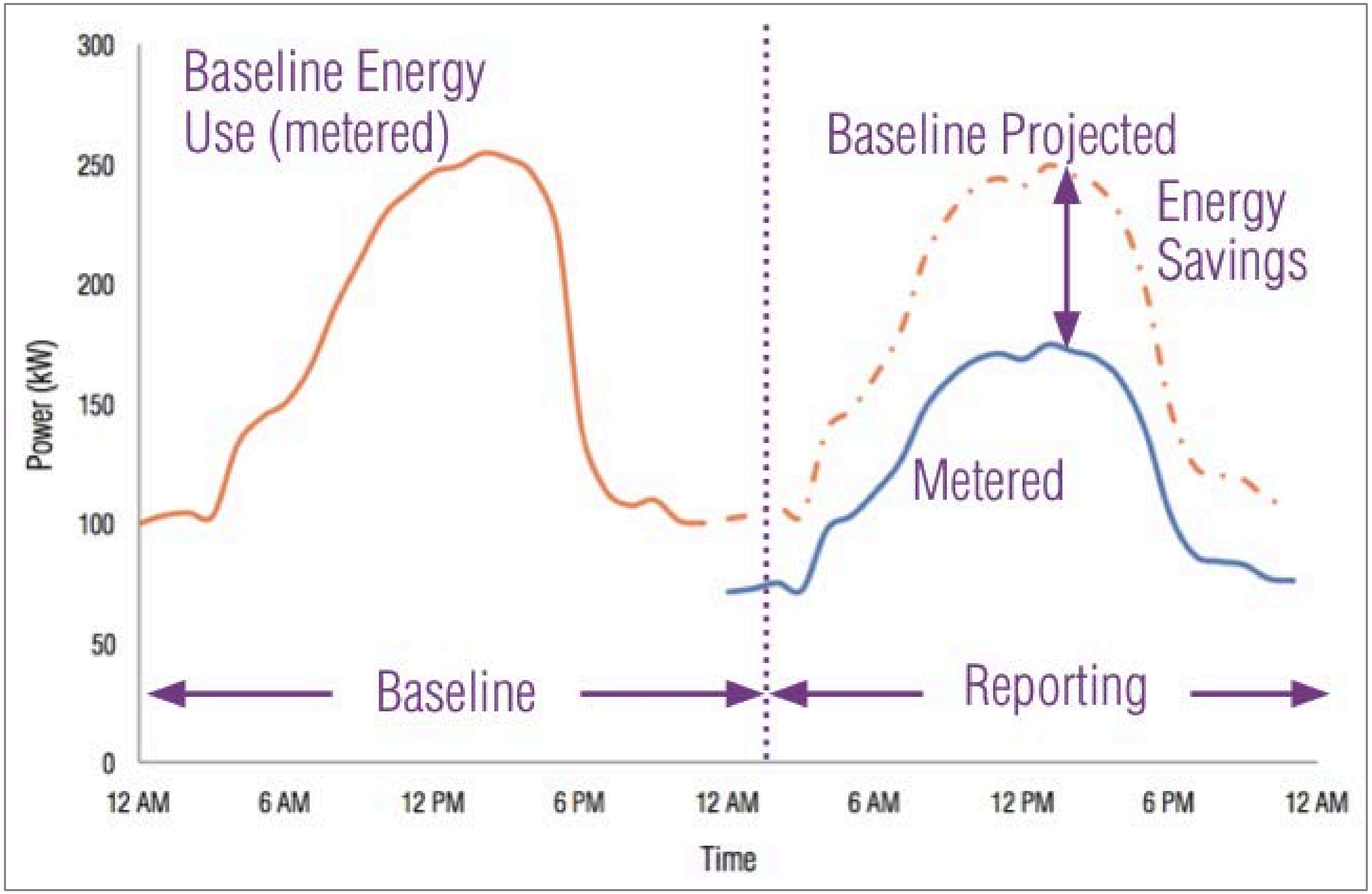
Regression, NN, Bin models most common

User enters the date of ECM implementation, savings automatically calculated

What is an energy baseline?

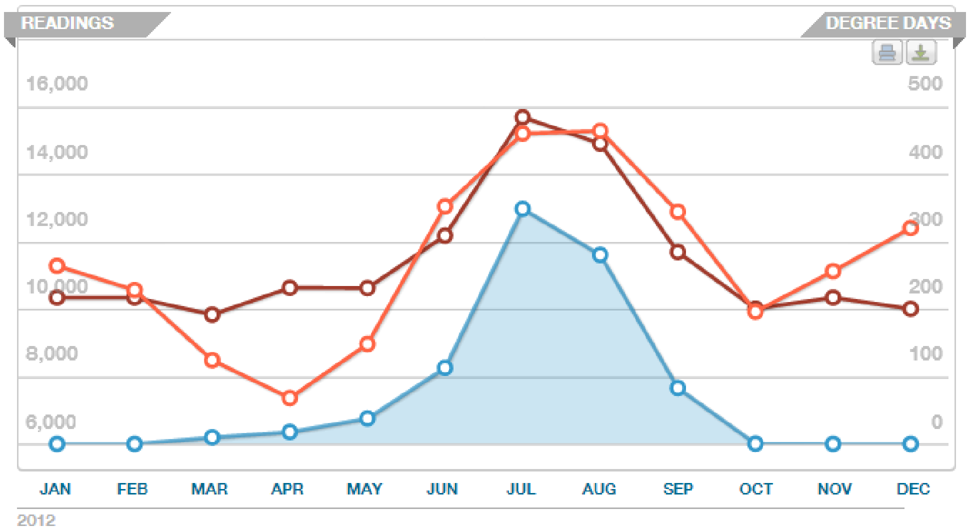


M&V Use Case



Baseline Energy Use (metered)
Baseline Projected
Energy Savings
Metered
Baseline
Reporting
Power (kW)
300
250
200
150
100
50
0
12 AM
6 AM
12 PM
6 PM
12 AM
6 AM
12 PM
6 PM
12 AM
Time

Automated M&V May Use Interval, Daily, Monthly Data



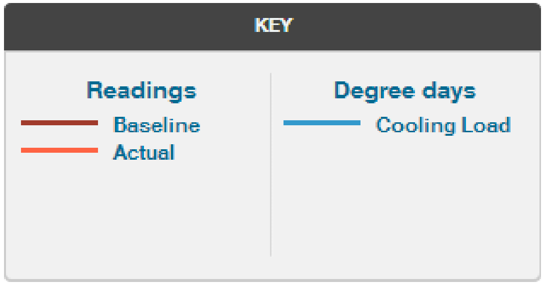
VARIABLES

▾ Included in model

- ✔ 1 **Base** Sensitive (T-stat = 18.6347)
- ✔ 2 **CDD** Sensitive (T-stat = 4.0517)
- 3 **Constant** Not Sensitive
- 4 **HDD** Not Sensitive

OBSERVATIONS 12 MODEL EQUATION kWh = Days x 333.52 + CDD(65.00 °F) x 16.293

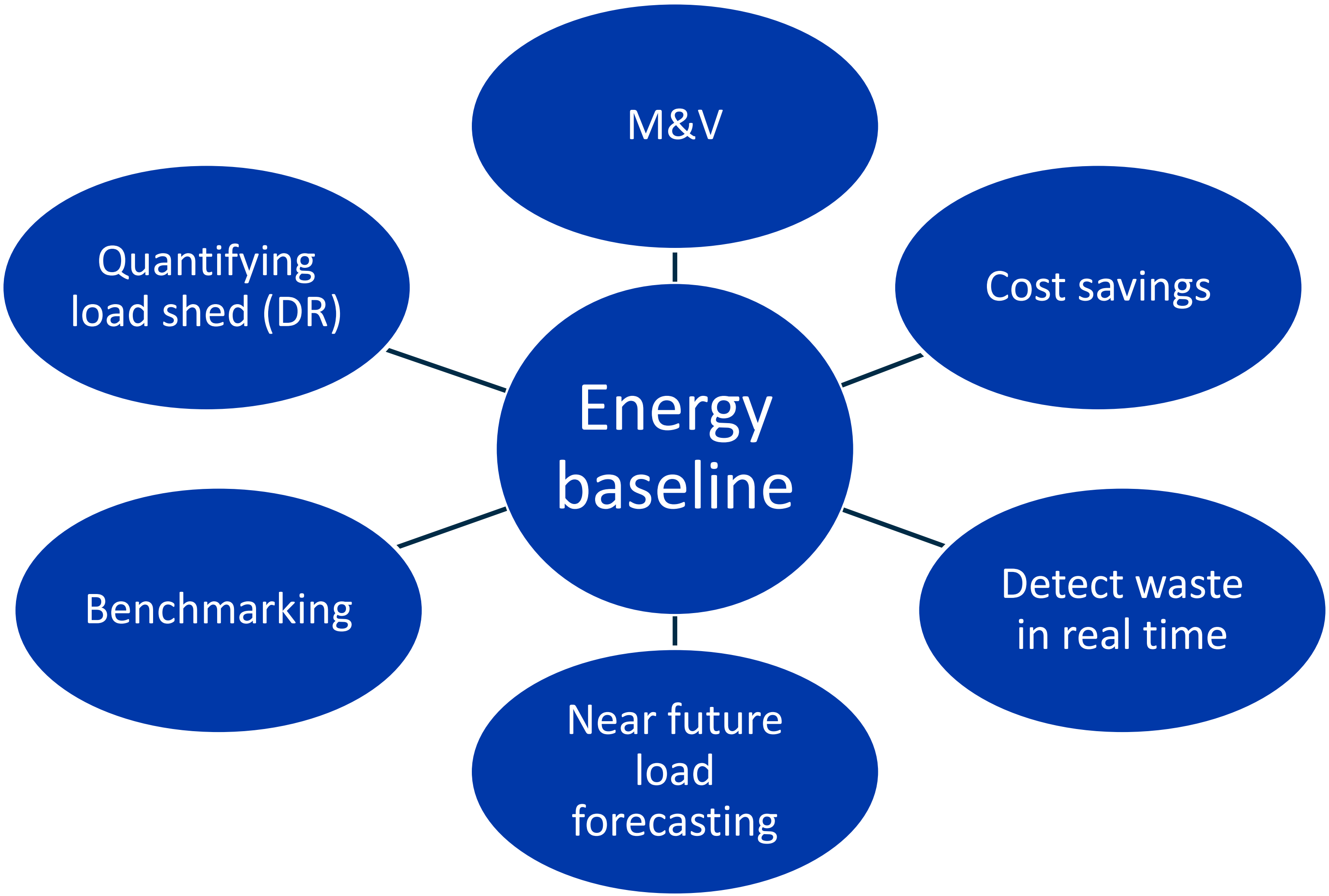
13.926	22.046	0.06	0.072	0.985
CV(RMSE)	CV(STD)	NDB	NMBE	Regression



Example at left from Noesis Energy

While this example uses monthly data; interval data offers the most promise

The Energy Baselines in EMIS Serve Many Purposes



Where Can You Access These Resources?

Visit: eis.lbl.gov

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JGranderson@lbl.gov

Questions?