



California Commissioning Collaborative

Baseline Energy Use: Data Acquisition, Analysis (M&V) and Constant Cx Applications

Constant Commissioning: Technology Solutions for Establishing Baselines and Maintaining Building Performance

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Agenda

Introduction

Energy Metering and BMS Data Acquisition

Energy Baseline Evaluation – M&V

Applications to Constant Cx

Introduction

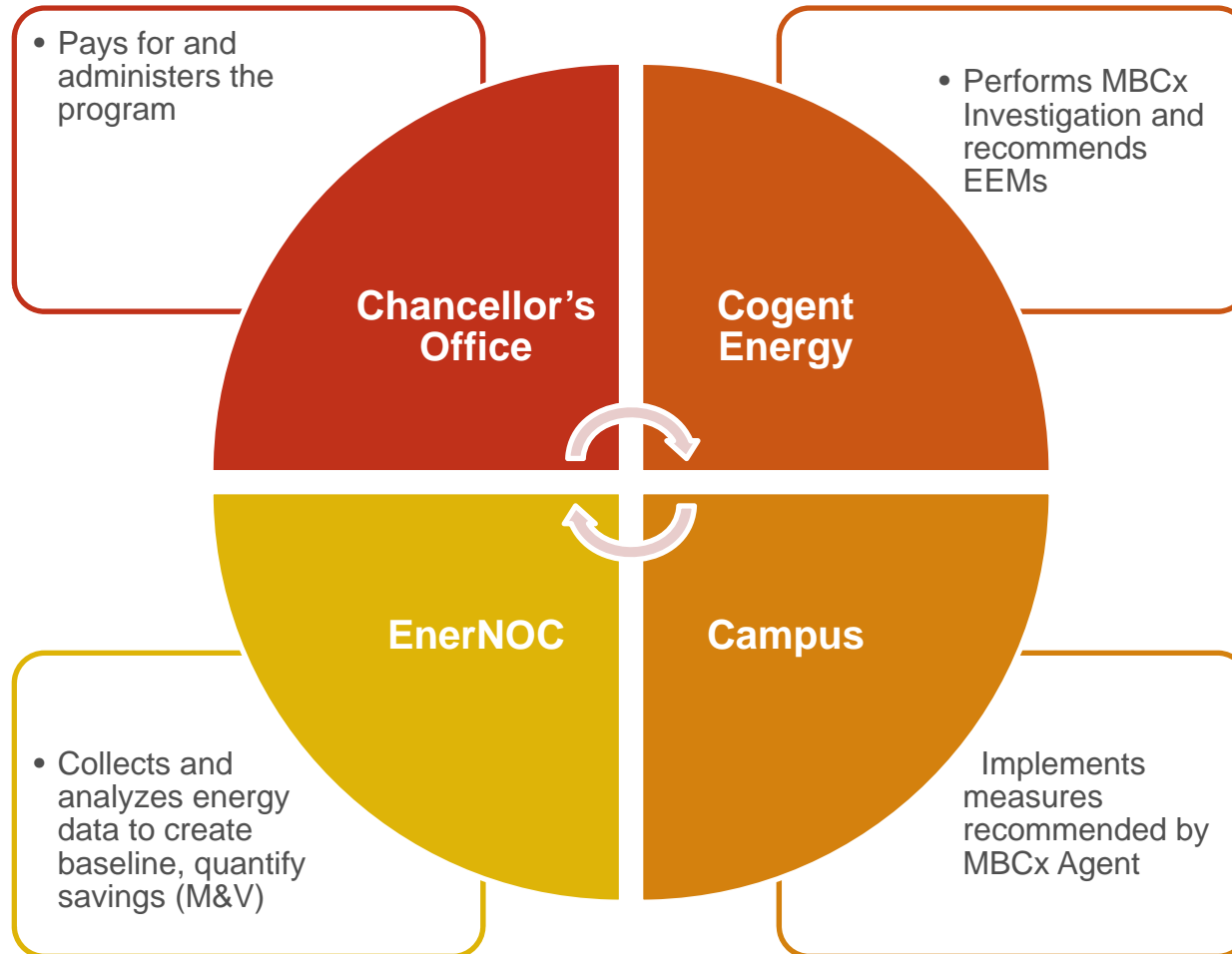
The Project

- California State University Monitoring Based Commissioning (MBCx) Express Program
- 6 campuses
- 20 Buildings

The Team

- California State University
- Investor Owned Utilities (PG&E, SCE, SDG&E)
- EnerNOC
- Cogent Energy
- Installing Subcontractors

Introduction: MBCx Express Program Overview



Agenda

Introduction

① Energy Metering and BMS Data Acquisition

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Energy Metering and BMS Data Acquisition

Energy Baselines Required – By Building

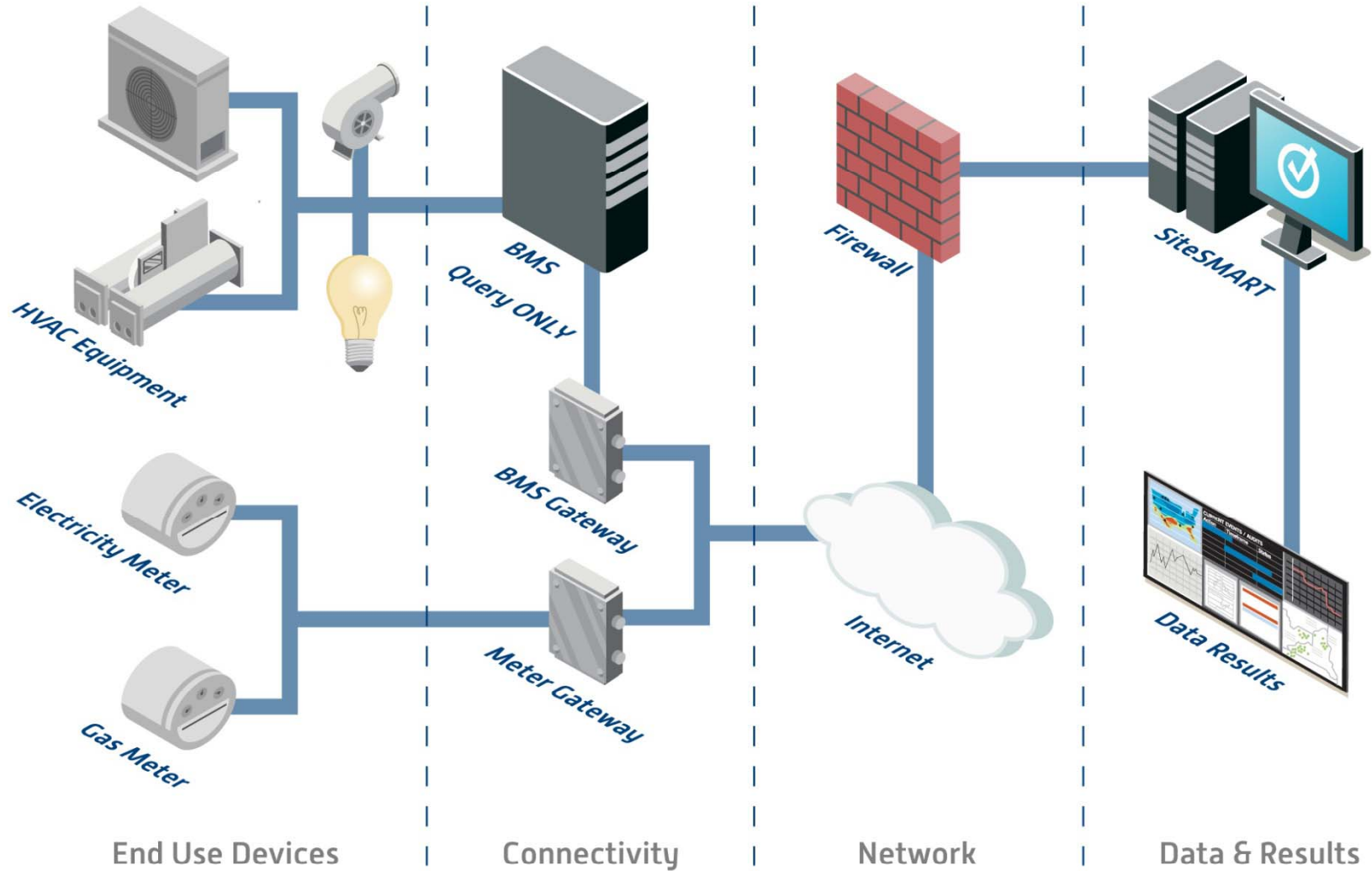
- Electricity
- Natural Gas
- Hot Water
- Chilled Water
- Steam



Goal

- Measure Energy Use Accurately and Store in a Central Database.
- Install meters and data communications equipment without disturbing normal operation.
- Install equipment in an efficient and cost-effective manner.

Energy Metering and BMS Data Acquisition



Energy Metering and BMS Data Acquisition

Basic Steps

- Assess Existing Metering
- Develop Scope of Work for installing new metering
- Assess connectivity requirements
- Calibrate/verify existing metering
- Install new metering
- Install IP drops
- Install gateways for BMS-obtained data
- Coordinate with Data Server technicians
- Test System



Energy Metering and BMS Data Acquisition

Assess Existing Metering

- Identify Energy Metering Required
 - Electricity
 - Natural Gas
 - Hot Water
 - Chilled Water
 - Steam

- Decide on Natural Gas or Thermal BTU Measurements for Boilers

- If Using BMS Energy Data
 - Verify correct calculations, multipliers, units, etc.
 - Prepare calibration/verification plan



Energy Metering and BMS Data Acquisition

Develop Scope of Work for Installing New Metering

- Explicitly State New Metering Hardware Requirements
 - Include Manufacturer, Model number of **all** required parts
 - Use standard parts wherever possible (sometimes difficult due to client requirements)
- Electricity Meter Installation Requires Shutdowns
 - Must be done right the first time – Pre-verification is critical!
 - Complexities typically arise as staff plan additional work during shutdown
 - Weekend installation drives up costs



Energy Metering and BMS Data Acquisition

Develop Scope of Work for Installing New Metering (cont.)

- **Require Hot Taps for All Piping Modifications (Temperature, Flow)**
 - Many times no isolation valves, or existing valves inoperative
 - Minimizes introducing air in system
 - Avoids drain downs
 - Avoids dislodging scale or sludge

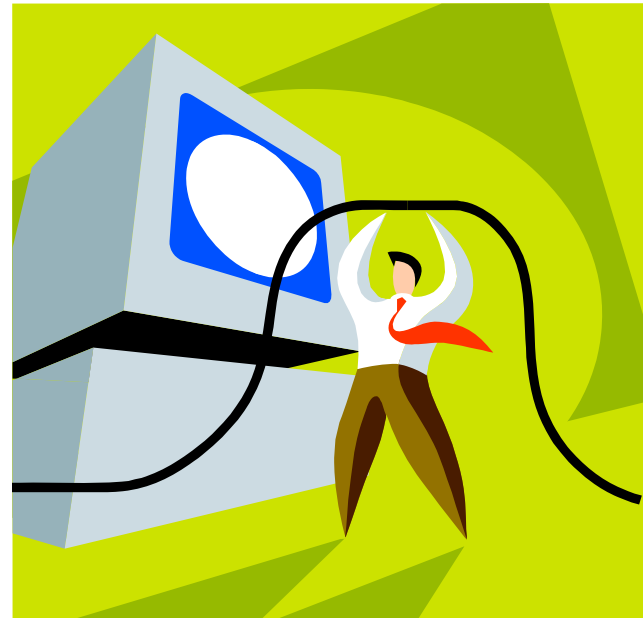
- **Project Required Minimal Gas Metering Due to Central Plant Systems**

- **Required Flexibility in Choosing Subcontractors:**
 - Owner's preferred Subcontractors
 - Our preferred Subcontractors
 - Owner self-install with in-house staff

Energy Metering and BMS Data Acquisition

Assess Connectivity Requirements

- Goal – Meter Straight to IP, Avoid Going Through BMS if Possible
 - Time stamping issues
 - Normalizing Issues
- Get IT Involved Early in Planning
 - Locate required IP drops
 - Assess security requirements for VPN



Energy Metering and BMS Data Acquisition

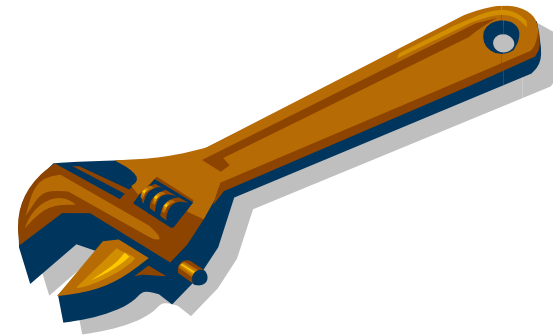
Calibrate/Verify Existing Metering

- For temperatures: Relative calibration more important than absolute
 - Primarily used calibrated thermocouple where possible to remove sensor from well
- For Flow: Budget did not allow verification with ultrasonic/magnetic flux meters
 - Used differential pressure-based calculations whenever possible
 - Most buildings relatively new so meters were in good shape
- Verified BMS derived data
 - A lot of time spent correcting multipliers, conversions, calculations, etc.

Energy Metering and BMS Data Acquisition

Install New Metering

- Require Contingency Plan in event of major leak
- Require electrical equipment to be covered/protected
- Require contractor to wire slug (from hot tap) to tee to verify not left in system



Energy Metering and BMS Data Acquisition

Install IP Drops to new meters

- Typically used Echelon Corp i.LON or Niagara JACE
 - Allowed for multiple pulse inputs (expandable)
 - Allowed for Multiple Modbus inputs
- Meters to Gateway to Server: Preferred Approach
- Connected to Campus Intranet
 - Outbound data required no security requirements
 - Inbound required VPN tunnels (used at all sites)



Energy Metering and BMS Data Acquisition

Install Gateways for BMS-obtained data

- Installation of Gateways:
 - Difficulty on a Scale of 1 to 10: 11
 - Provided cached data in case of power loss
 - All data time-stamped to GMT
 - Project required 5 minute interval data for trend analysis
- Each Campus Required Different Solution:
 - Legacy JCI: OPC required
 - New JCI: Communicated on NAE Bus
 - Siemens: Upgraded to Siemens Insite Workstation to BACnet over IP Compliancy
 - ALC: BACnet over IP Compliancy LGR Controls
 - Barber-Coleman #1: Installed “soft JACE”
 - Barber-Coleman #2: “soft JACE” already installed, implemented proprietary gateway to allow data to stream directly to Internet

Energy Metering and BMS Data Acquisition

Coordinate with Data Server technicians

- Configure servers to receive data

Test System

- Verify data archived properly
- Watch for data degradation



Energy Metering and BMS Data Acquisition

Lessons Learned

- Multiple Parties Required Significant Project Management Expertise:
 - Chancellors Office
 - Campus Facility staff
 - Campus IT staff
 - Electrical contractors
 - Mechanical contractors
 - Utilities (for pulse connections to existing meters)
 - EnerNOC staff
 - MBCx Agent
 - Equipment vendors
- Working with a Knowledgeable MBCxA a Great Asset
- Understand Timeline and Take Into Account Coordination of Various Parties
 - Identify risk of uncontrollable tasks (e.g., IT installation of IP drops)
 - BMS upgrades required substantial effort
 - Client installed metering sometimes caused delays (delays cost \$)

Agenda

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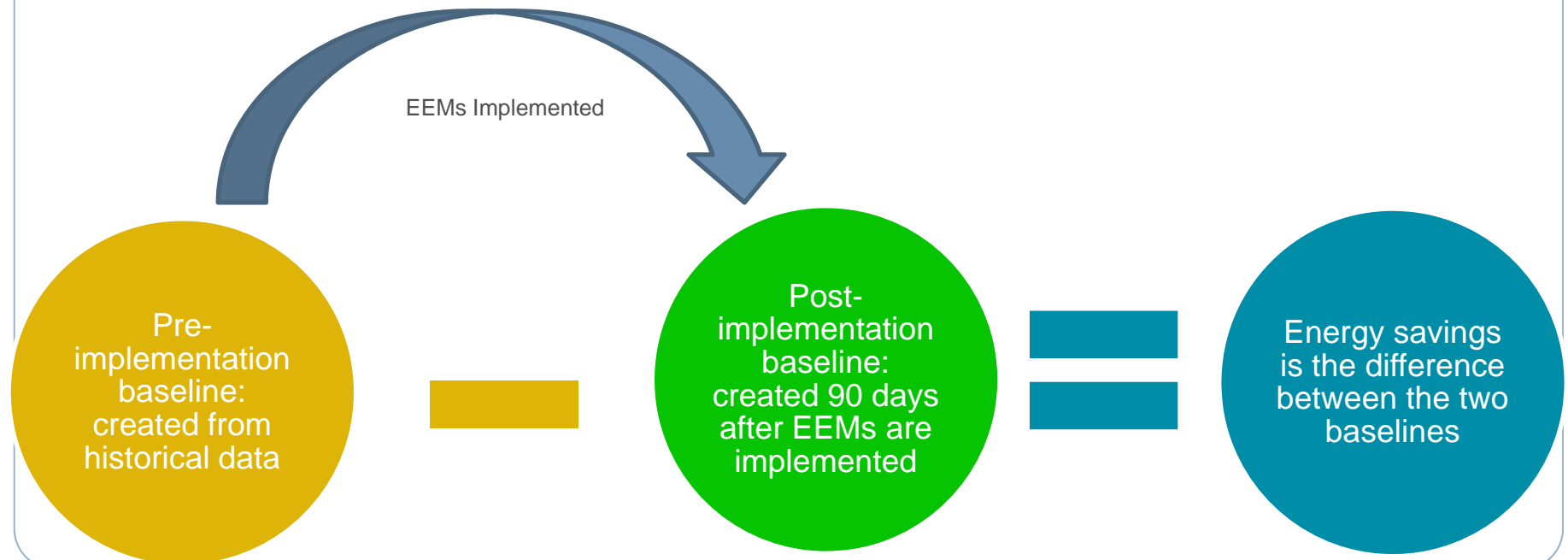
Energy Metering and BMS Data Acquisition

⊙ Energy Baseline Evaluation – M&V

Applications to Constant Cx

Energy Baseline Evaluation – M&V

- Measurement and Verification (M&V) uses measured data along with other observations, assumptions, calculations, and documentation to define baseline performance, and to estimate improvements in performance that are attributable to the project.
- Incentives are based on top-down energy savings calculations methodology: An IPMVP approach using Normalized Savings



Energy Baseline Evaluation – M&V

Why is Baseline Evaluation Important?

- Needed for determining energy savings from energy efficiency improvements
- Useful in Benchmarking
- Can provide accurate prediction of future energy consumption based on outside air temperature and occupancy levels
- Useful in Constant Commissioning



Energy Baseline Evaluation – M&V

The baseline equation predicts the building's energy consumption

We performed a 2-variable regression on a data-set of historical energy usage

- Mean outside air temperature
- Hours of full load occupancy

Multivariate Change Point Models (MVR-CP) are created with different components

- Baseload
- Occupancy
- Heating
- Cooling

$$\frac{\text{kwh}}{\text{day}} = 11821 + 23.935 \times [48.002 - T_{\text{mean}}]^+ + 153.37 \times [T_{\text{mean}} - 60.611]^+ + 378.96 \times \text{Occ}_{\text{mean}}$$

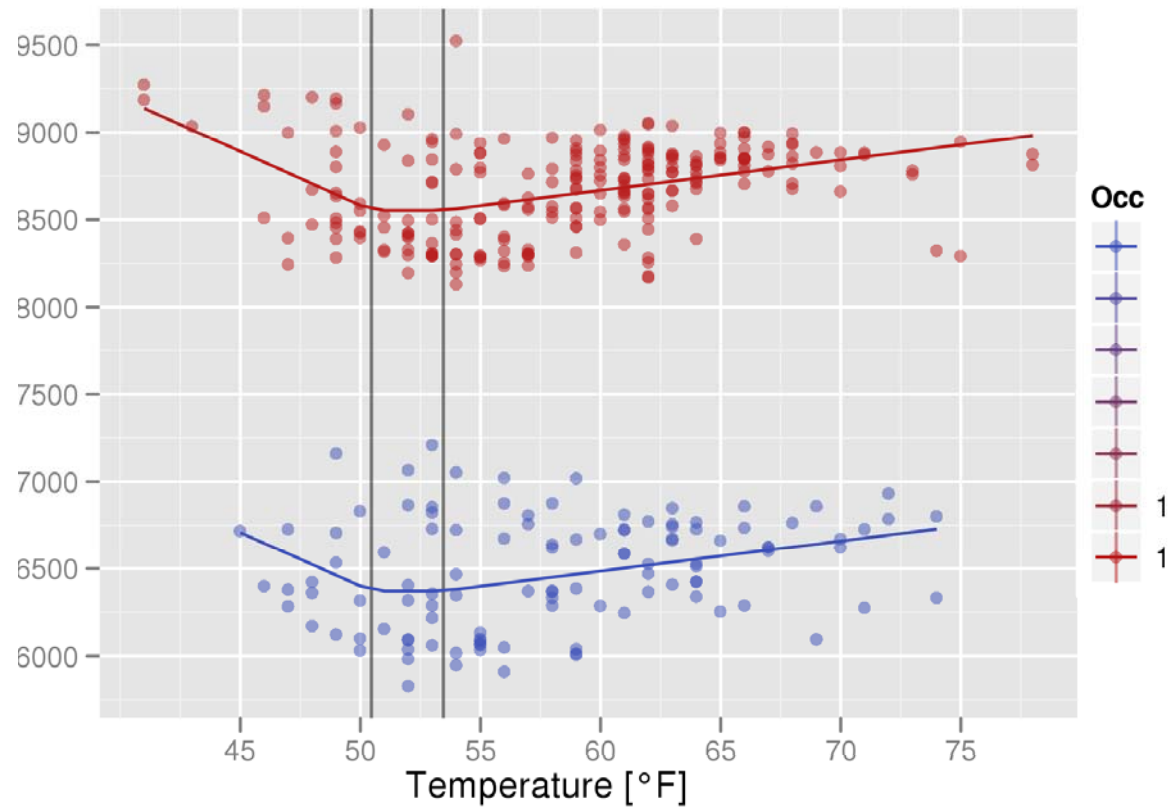
Diagram illustrating the components of the energy baseline equation:

- Base-load Term (11821)
- Heating Term (23.935 × [48.002 - T_{mean}]⁺)
- Cooling Term (153.37 × [T_{mean} - 60.611]⁺)
- Occupancy Term (378.96 × Occ_{mean})

Change points are indicated for the Heating Term (48.002) and Cooling Term (60.611).

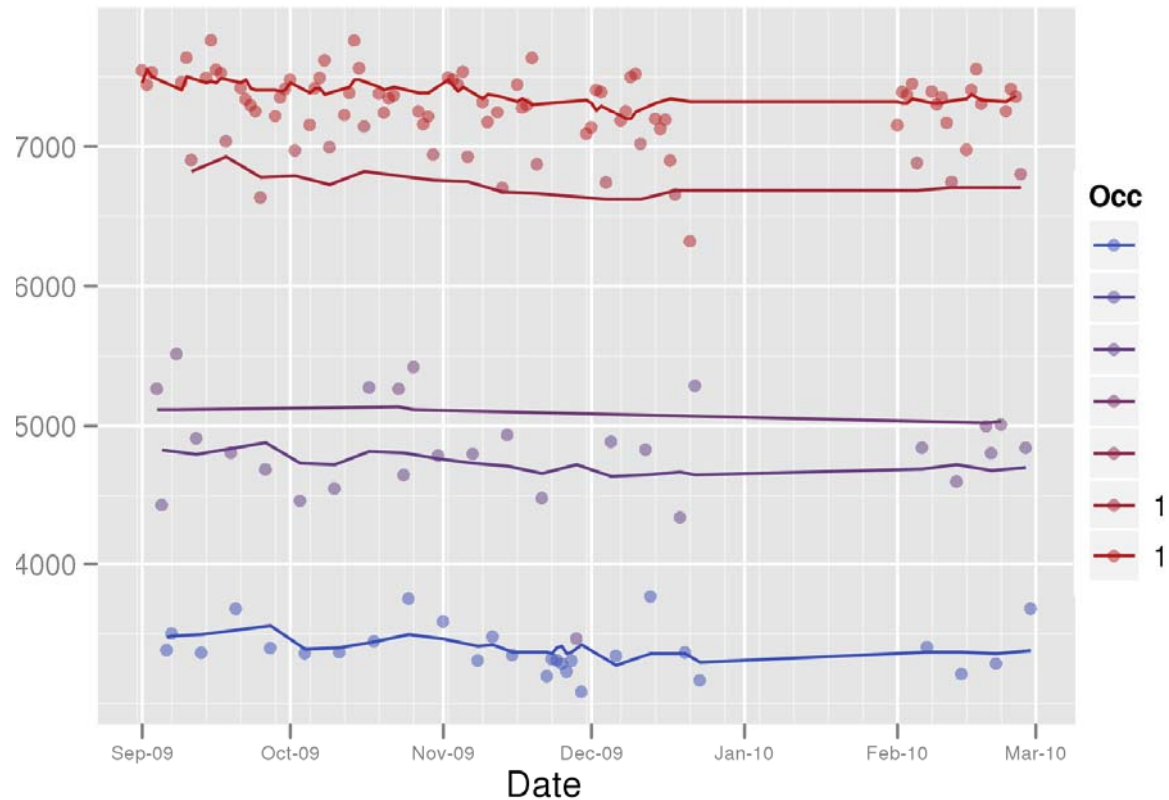
As EEMs are implemented the baseline is the point of reference

Energy Baseline Evaluation – M&V



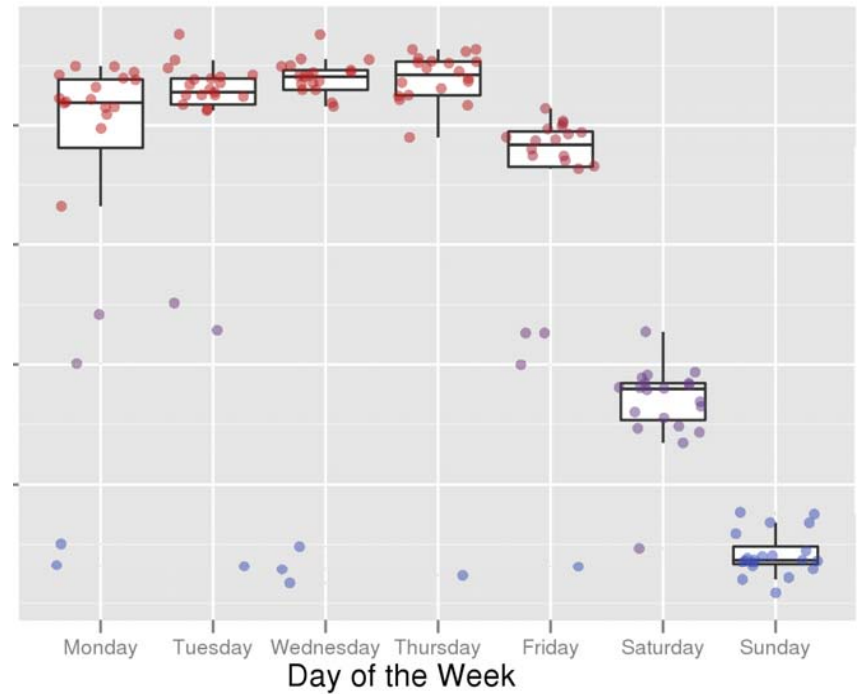
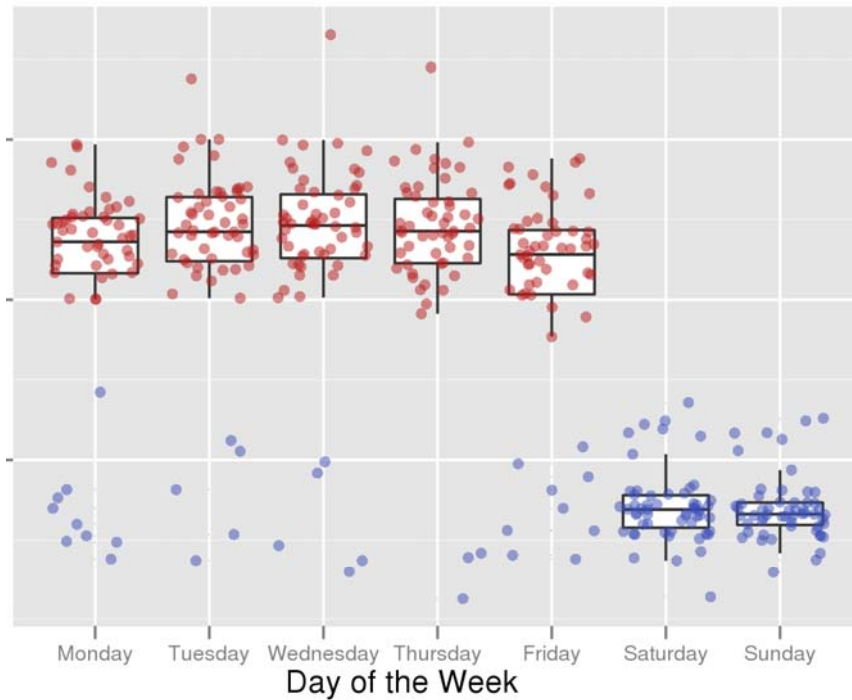
Electricity consumption is directly correlated to outside air temperature

Energy Baseline Evaluation – M&V



Bldg 1: Shows direct correlation of energy consumption to occupancy level

Energy Baseline Evaluation – M&V



Correct identification of occupancy levels is crucial

Energy Baseline Evaluation – M&V

Utilize Normalized Savings per IPMVP:

- Normalized Savings = (Baseline Energy \pm Routine Adjustments to fixed conditions \pm Non-Routine Adjustments to fixed conditions) - (Reporting Period Energy \pm Routine Adjustments to fixed conditions \pm Non-Routine Adjustments to fixed conditions)
- But how is this put into practice?

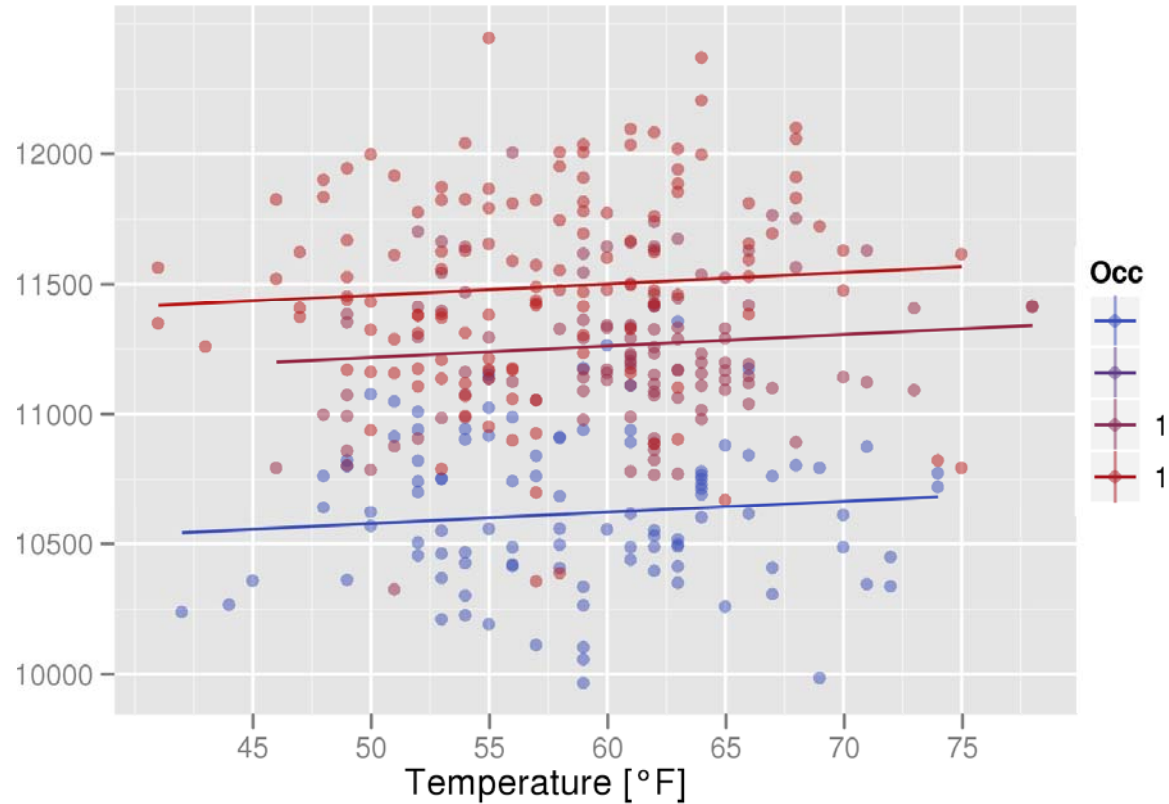


Energy Baseline Evaluation

An Acceptable Approach:

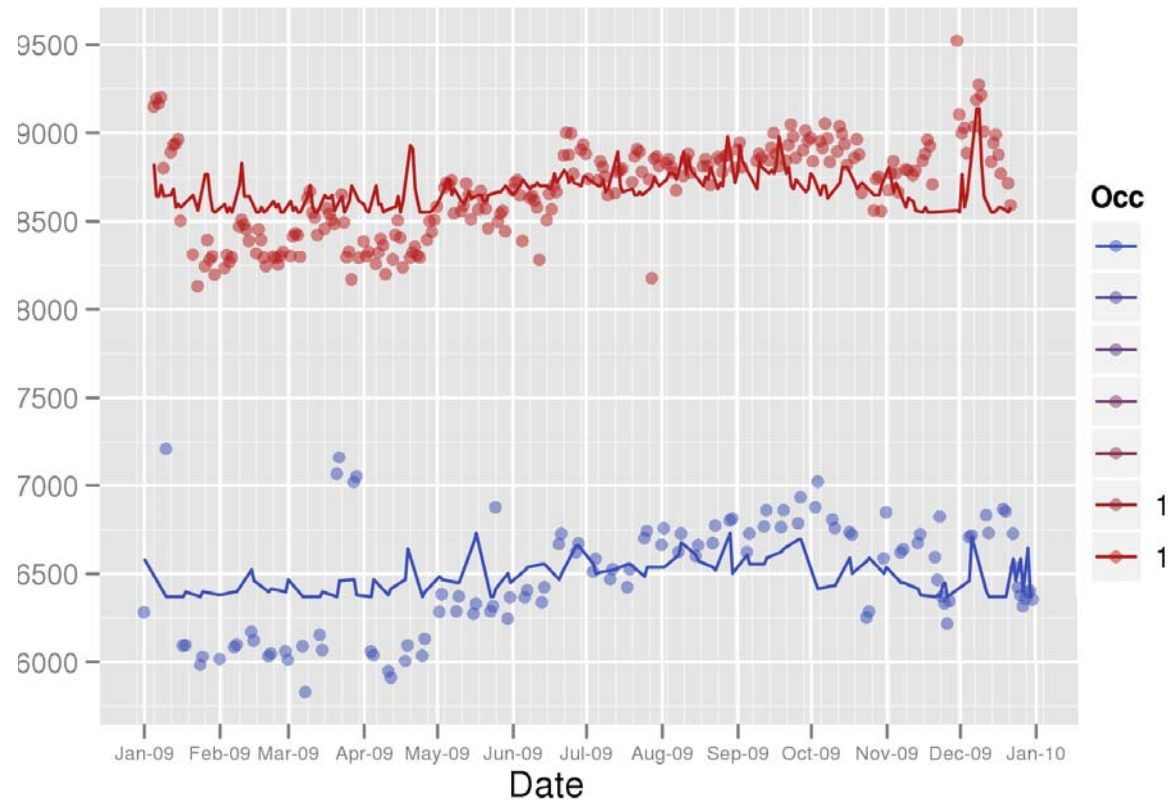
- Develop regression equations from metered baseline data
 - Energy use with daily Mean OSA temperature and Occupancy as independent variables
- Calculate Baseline Annual Energy Use Using TMY Weather Data
- Implement MBCX Project
- Develop regression equations from metered post-project data
 - Energy use with daily Mean OSA temperature and Occupancy as independent variables
- Calculate Post-Project Annual Energy Use Using TMY Weather Data
- Subtract Post Project Energy Usage from Baseline to Calculate Savings
- What Could Be Easier?

Energy Baseline Evaluation



Issue #1: Temperature does not affect electricity consumption

Energy Baseline Evaluation – M&V



Issue #2: Shows increased energy use over the course of a year

Energy Baseline Evaluation – M&V

Many issues arise in developing regression equations:

- Difficulties in accumulating accurate data
- Difficulty in identifying independent variables
 - Process loads, miscellaneous equipment,
- Difficulty in quantifying known independent variables
 - Improperly functioning equipment
- Oftentimes project schedule does not allow enough time to accumulate meaningful energy and independent variable data.
 - Predominantly cold weather during monitoring period can lead to inaccurate warm weather energy use predictions.
 - Predominantly warm weather during monitoring period can lead to inaccurate cold weather energy use predictions.
 - Other variables outweigh impact of weather and occupancy though this is not known during baseline measurement period.
- **If savings are less than CV (Coefficient of Variance), results may be meaningless**



Agenda

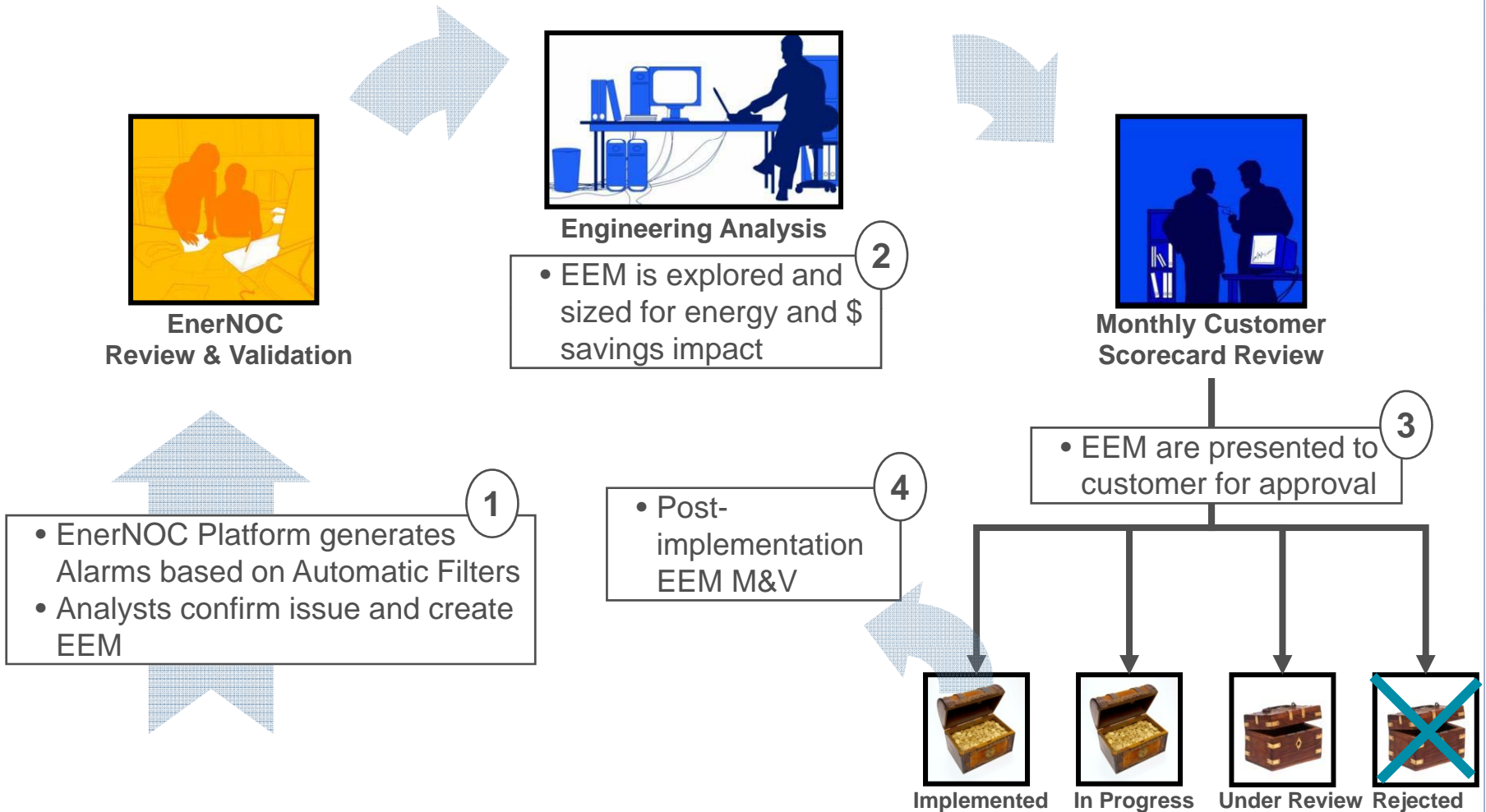
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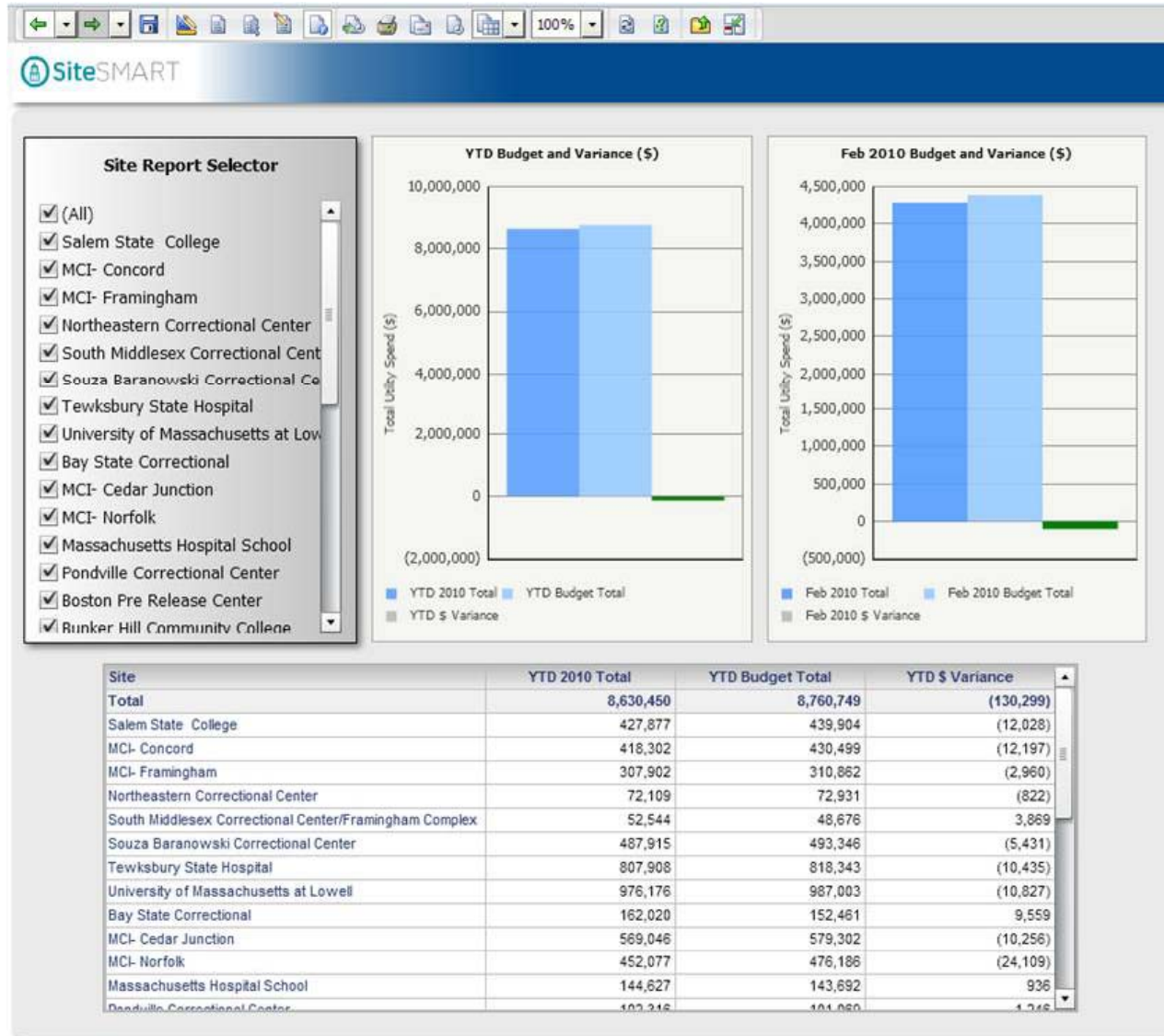
Energy Baseline Evaluation – M&V

Ⓞ Applications to Constant Cx

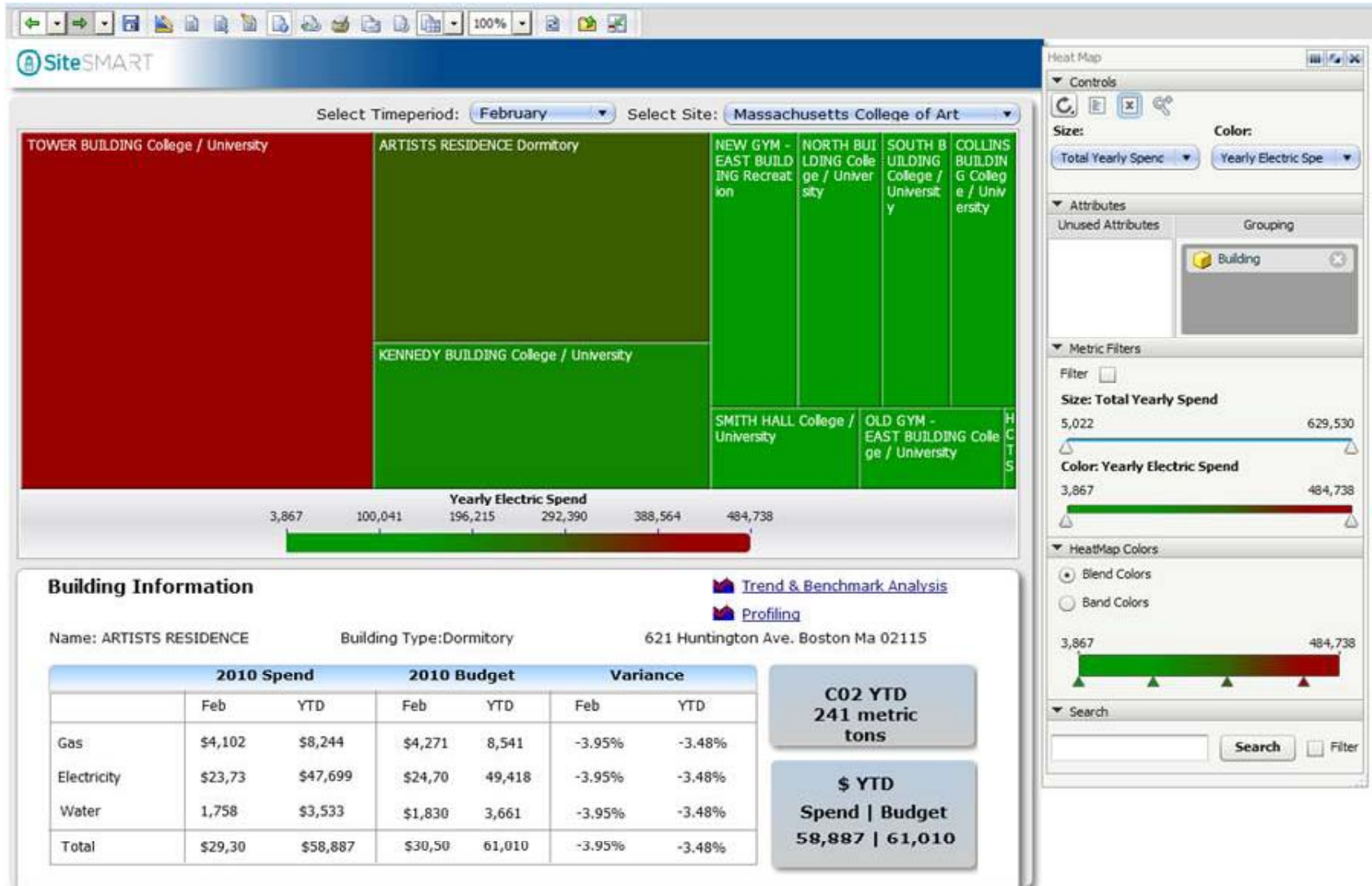
SiteSMART Workflow for Energy Efficiency Measures (EEMs)



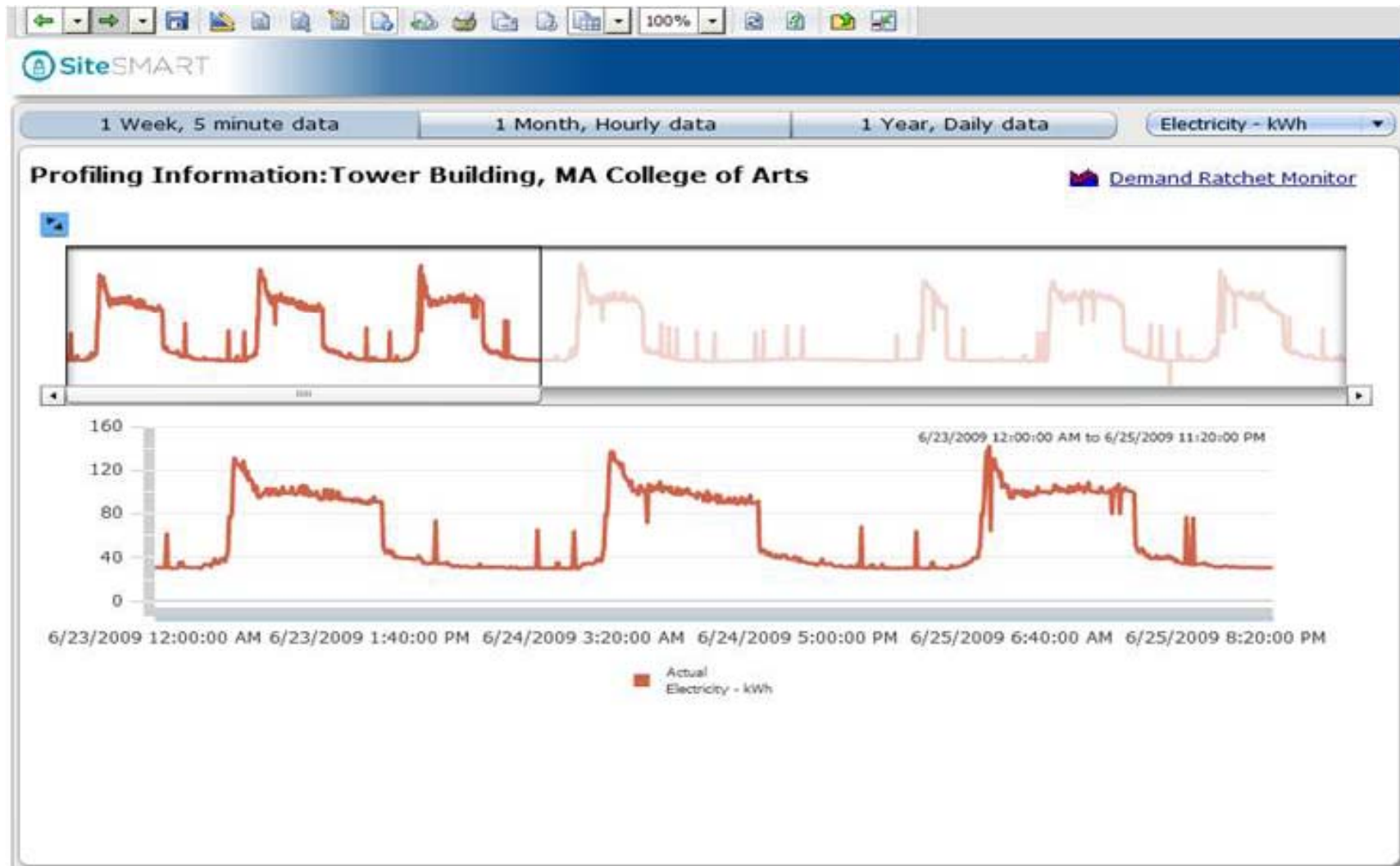
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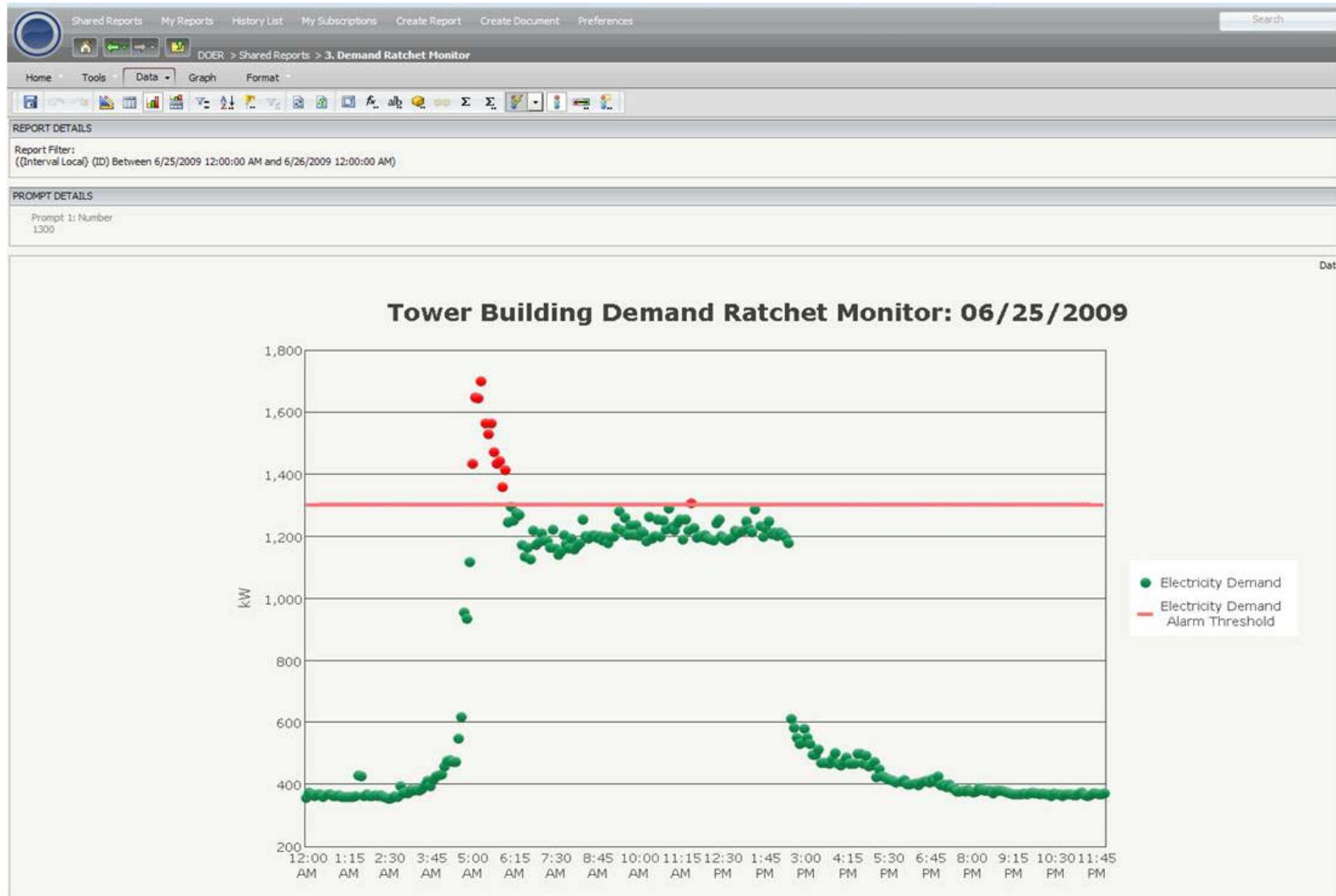
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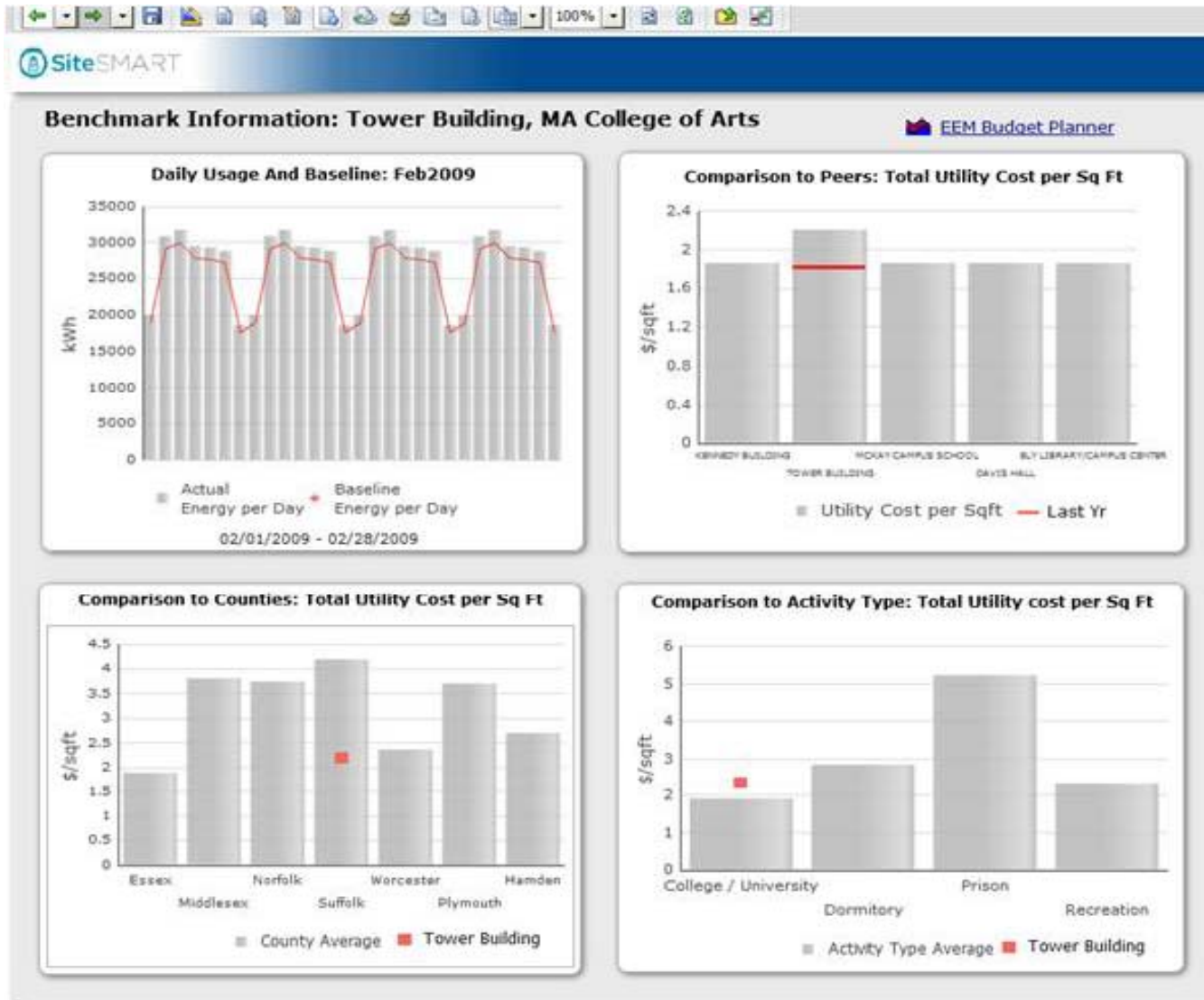
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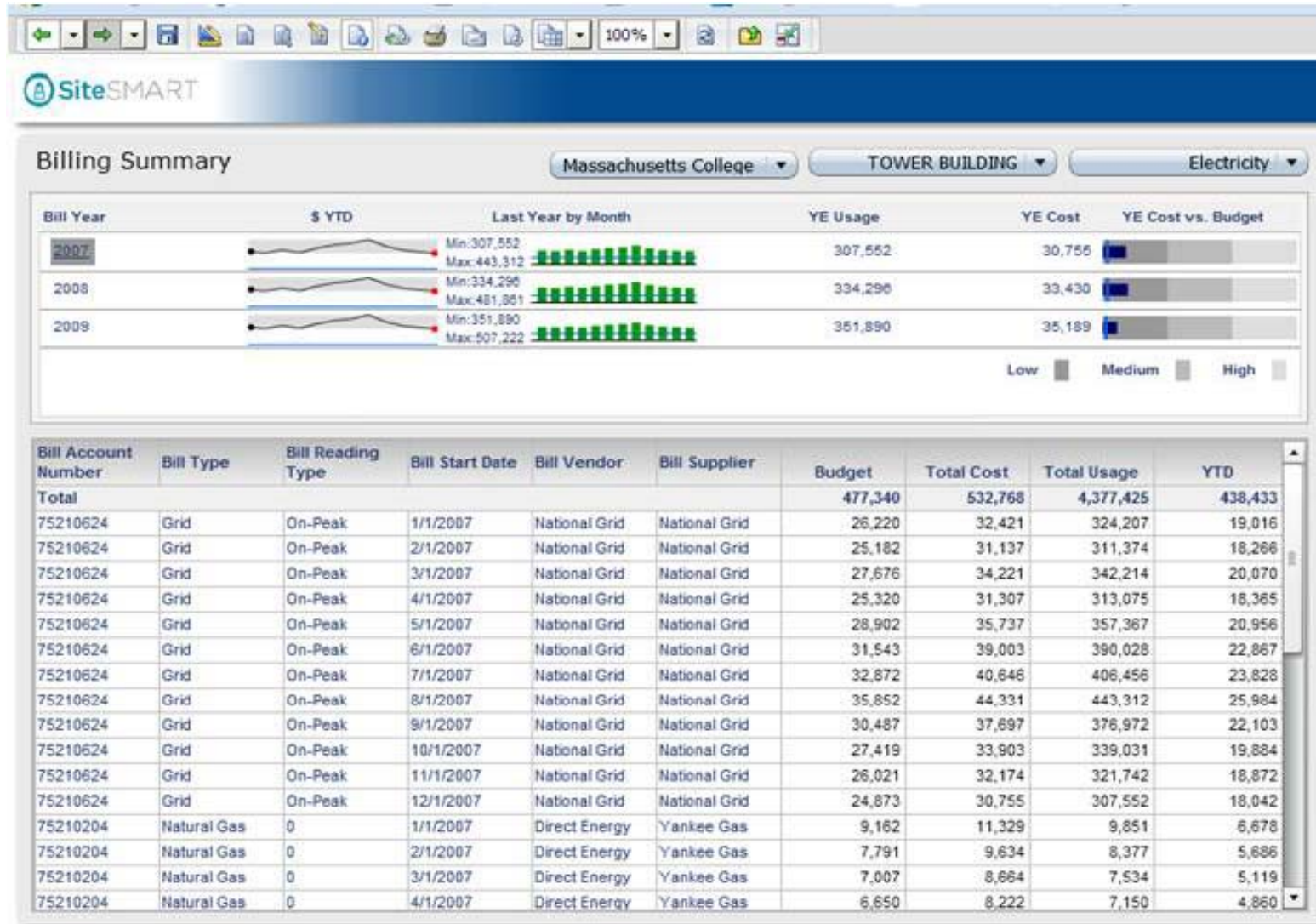
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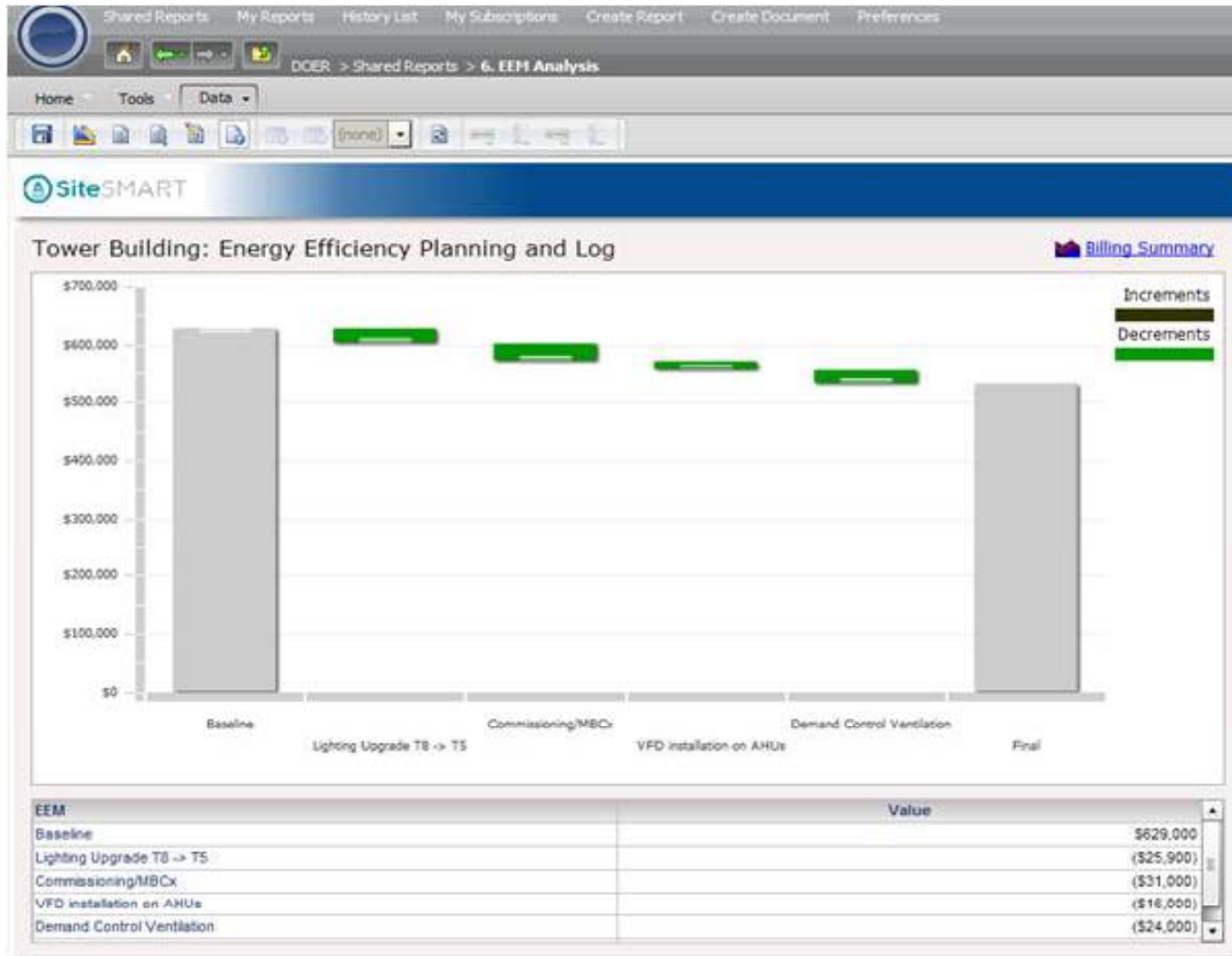
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ENERNOC

Get More From Energy

Thank You!

Thanks to:

John Davis

Tom Arnold

Richard Hart

Prakash Rapolu

Abhijit Rao

Tom Riley