Measurement & Verification

"You cannot manage what you do not measure" – Jack Welch, former CEO, General Electric

What is M&V?

- "The process of using measurements to reliably determine actual savings created within an individual facility by an energy management program"

Source: IPMVP Volume I – September, 2009

Why Measure & Verify?

- Increase energy savings due to reporting feedback (uncovers new opportunities)
- Creates persistence of energy savings
- Reduce financial risk and create a base for negotiations with energy performance contracts
- Improves credibility of energy efficiency
- LEED EB O&M requires M&V for EA Credit 2.3 “Ongoing Commissioning”
- Pay-for-performance incentives for RCx

EVO and IPMVP

- Efficiency Valuation Organization (EVO)
  - Established to create standards which assist with risk and benefit management in the context of energy efficiency
- International Performance Measurement and Verification Protocol (IPMVP)
  - Created to support and promote energy efficiency and renewable energy worldwide
- Latest Version of Vol. I - January 2012

Elements of M&V

- The M&V Plan
  - Prior to project implementation
  - Establishes method for measuring and adjusting energy use to verify savings
  - Documents requirements for M&V Reports
- The M&V Report
  - Periodic documentation of observed energy use and verified savings after project implementation
  - Includes justification for usage adjustments

IPMVP Options

- The “best” option depends on...
  - Budget
  - Metering
  - Scope of EEM(s)
- Multiple Options may be used within an M&V Plan, depending on the considerations above

IPMVP – Option A

- "Retrofit Isolation: Key Parameter Measurement"
  - Baseline is an engineering calculation which could involve short-term metering, continuous metering, or an engineering estimate
  - Good for measures with consistent energy consumption (i.e. lighting, constant speed fans)

IPMVP – Option B

- "Retrofit Isolation: All Parameter Measurement"
  - Energy use is either measured directly or a calculation *which is based on a measurement*
  - Good for systems with known performance curves where an isolated measurement can be used to calibrate energy consumption (i.e. VSDs)

IPMVP – Option C

- "Whole Facility"
  - Energy use metered at the whole facility level or sub-facility level
  - Good for complex EEMs which affect multiple systems

IPMVP – Option D

- "Calibrated Simulation"
  - Energy use is simulated with energy modeling software (such as eQUEST or EnergyPro) and calibrated using monthly utility bills
  - Good for facilities where no baseline data is available (i.e. new construction)

Creating an M&V Plan

1) Create a list of building systems and system components with their energy consumption characteristics (power draw, firing rates, etc.)
2) Determine goals for M&V (specific EEM isolation = Options A & B, whole facility = Options C &D)

Creating an M&V Plan

3) Determine which quantities need to be metered and which can be estimated (if using Option A or B)

Table 2 Example Lighting

Situation	Measurement vs. Estimation Strategy		Adherent to Option A?
	Operating Hours	Power Draw	
ECM reduces operating hours	Measure	*Estimate*	Yes
	Estimate	Measure	No
ECM reduces power draw	*Estimate*	Measure	Yes
	Measure	*Estimate*	No
ECM reduces both power draw and operating hours:			
Baseline power uncertain, operating hours known	*Estimate*	Measure	Yes
	Measure	*Estimate*	No
Power known but operating hours uncertain	Measure	*Estimate*	Yes
	Estimate	Measure	No
Power and operating hours poorly known	Measure	*Estimate*	No – Use Option B
	Estimate	Measure	

M&V Plan Contents

1) ECM Description, Intent, and Commissioning Procedure
2) Select IPMVP Option and Measurement Boundary
3) Baseline Conditions: Include energy use and quantify factors which affect energy use

M&V Plan Contents

4) Identify the reporting period
5) Identify whether data will be normalized (if so, savings will be "normalized savings", if not savings will be "avoided energy use")
6) Analysis Procedure: define all mathematical models to be used and any limits to their validity

M&V Plan Contents

7) Energy Prices: Identify if they will be fixed or variable for reporting purposes
8) Metering: Identify meter locations and spec's, Cx, and calibration procedures for all non-utility meters. Establish upper limit on acceptable data loss.
9) Monitoring Responsibilities: Identify responsible parties for data recording and reporting

M&V Plan Contents

10) Expected Accuracy: Include meter tolerances, and uncertainty associated with sampling error and any engineering calculations
11) Budget: Include setup cost and on-going reporting costs
12) Report Format: Include a sample report
13) Quality Assurance: Specify steps taken towards QA of savings calculation & reporting

M&V Reporting

- Must follow procedures identified in the M&V Plan
- Include:
  - Complete data sets (justification for any "corrected" data)
  - Description and justification of adjustments
  - Any estimated values
  - Energy price schedule
  - Savings in energy and monetary units

Example:

- 320,000ft^2 office building in Eastern MA with extensive sub-metering
- Option C (sub-facility level), not weather-normalized, baseline still being developed (new facility)

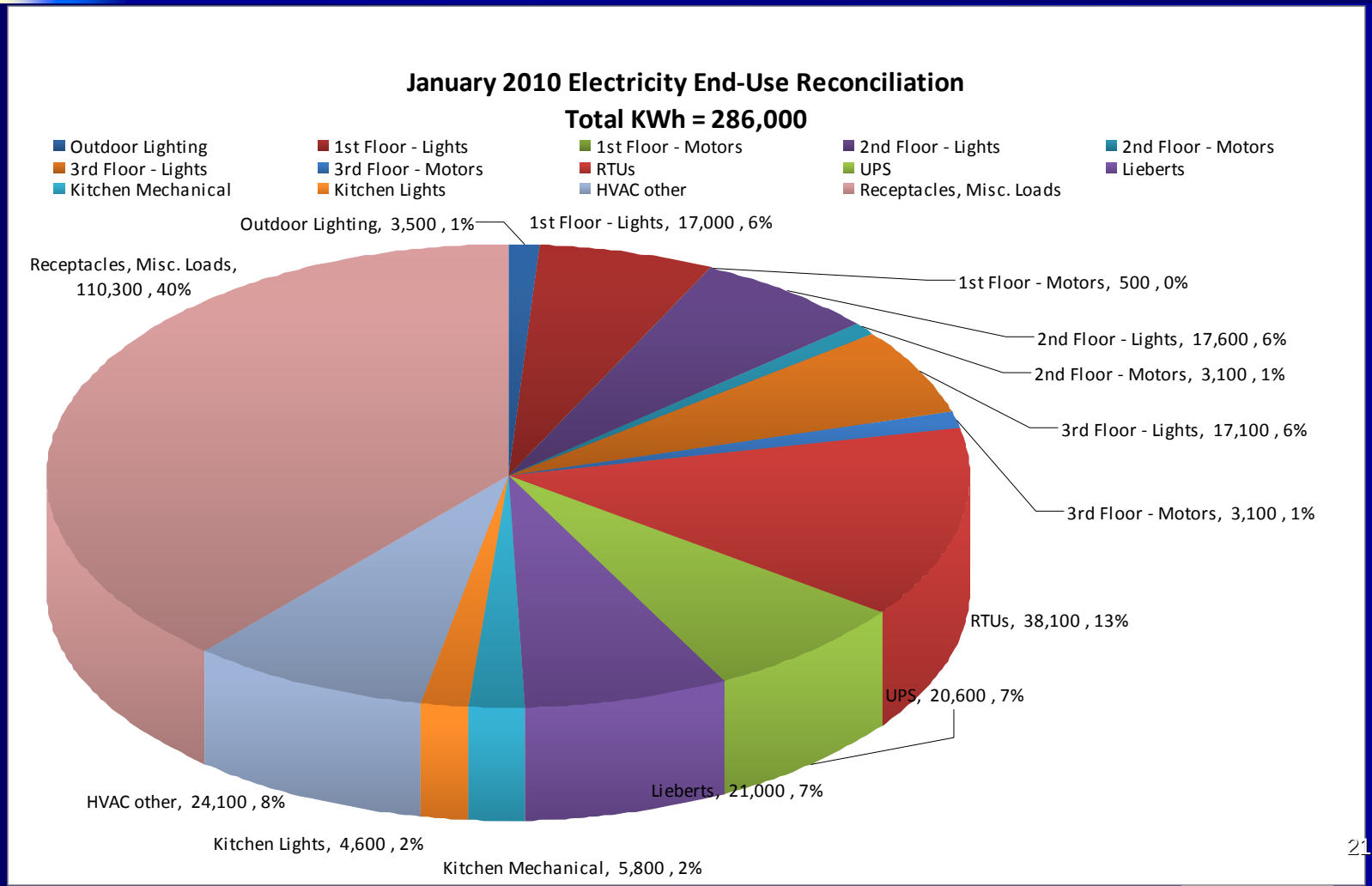
Electricity Use

Sub-Totals					
Raw Values	November	December	%Δ Nov-Dec	January	%Δ Dec-Jan
Outdoor Lighting	3,364	3,548	5.46%	3,523	-0.7%
1st Floor - Lights	15,619	16,861	7.95%	16,987	0.7%
1st Floor - Motors	487	501	2.77%	533	6.1%
2nd Floor - Lights	15,925	17,797	11.76%	17,578	-1.2%
2nd Floor - Motors	2,569	3,024	17.71%	3,138	3.6%
3rd Floor - Lights	15,928	17,563	10.26%	17,094	-2.7%
3rd Floor - Motors	2,838	5,293	86.52%	3,149	-68.1%
RTUs	47,022	45,174	-3.93%	38,133	-18.5%
UPS	20,047	20,608	2.80%	20,552	-0.3%
Lieberts	25,765	21,660	-15.93%	20,954	-3.4%
Kitchen Mechanical	6,293	6,413	1.90%	5,813	-10.3%
Kitchen Lights	4,719	4,810	1.94%	4,604	-4.5%
HVAC other	24,276	24,669	1.62%	24,118	-2.3%
Receptacles, Misc. Loads	94,952	100,403	5.74%	110,267	8.9%
Kitchen Exhaust (included in KL41 meter)	1,977	1,977	0.00%	1,950	-1.4%
HW Pumps (included in MP41 meter)	1,861	1,861	0.00%	2,364	21.3%

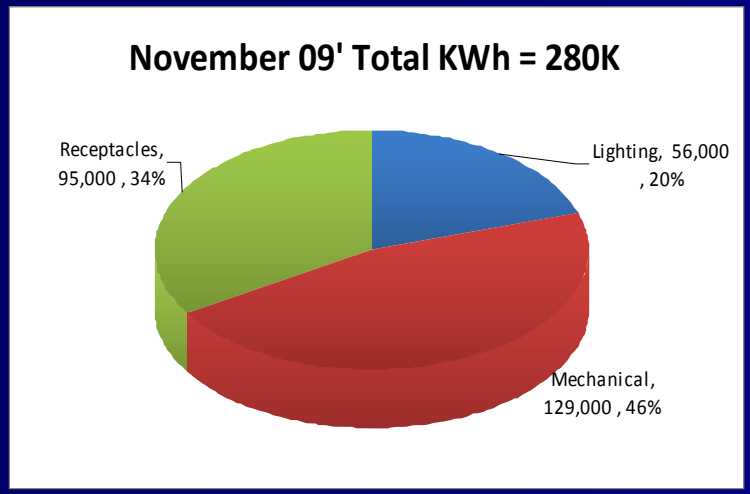
Natural Gas Use

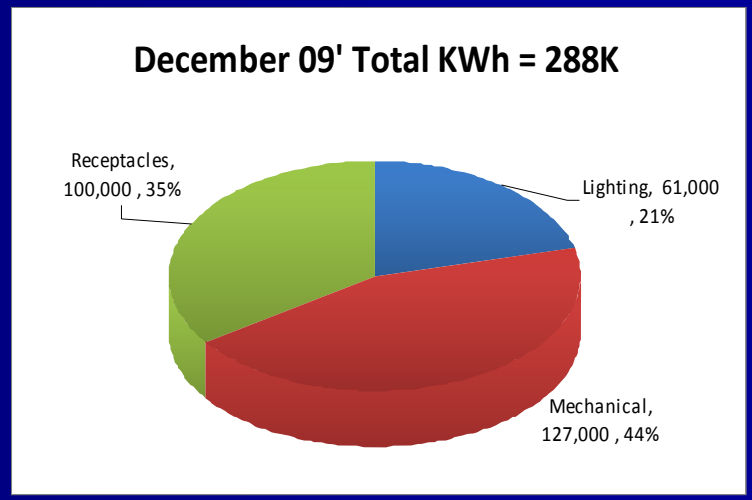
	November	December	January	unit	%Δ Nov-Dec	%Δ Dec-Jan
Kitchen Gas	117,100	146,600	121,700	cubic ft	25.2%	-17.0%
Main Gas	337,000	852,000	962,000	cubic ft	152.8%	12.9%
Total Gas	454,100	998,600	1,083,700	cubic ft	119.9%	8.5%
% Kitchen Gas	25.79%	14.68%	11.23%			
% Main Gas	74.21%	85.32%	88.77%			

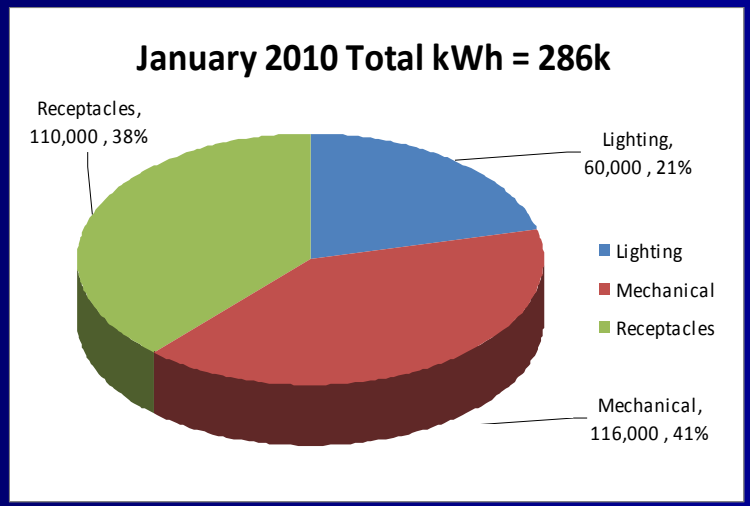
One-Month End-Use Reconciliation



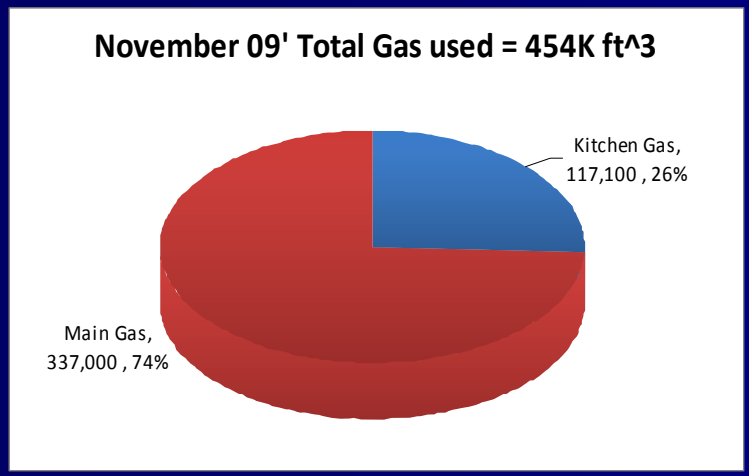
Monthly Electric Use Comparison

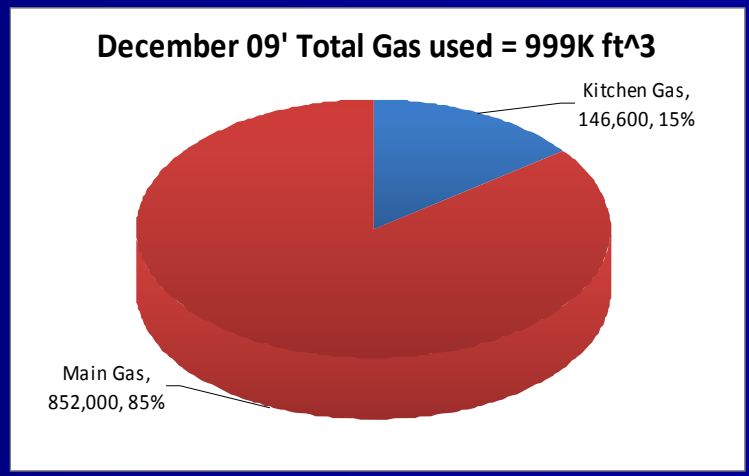


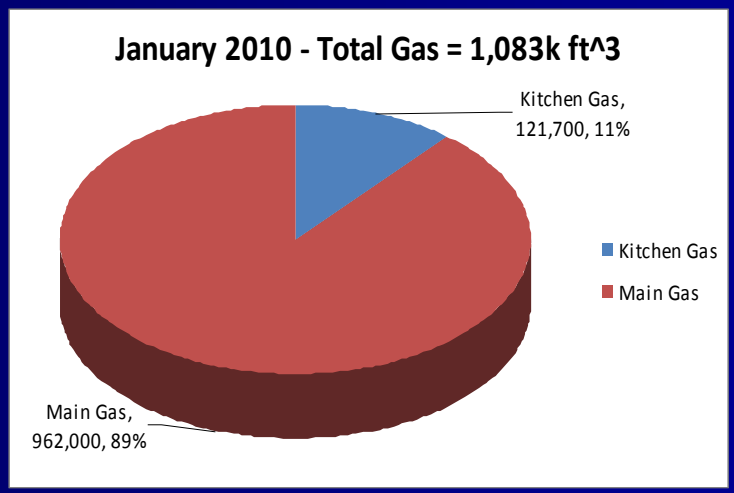




Monthly Gas Use Comparison



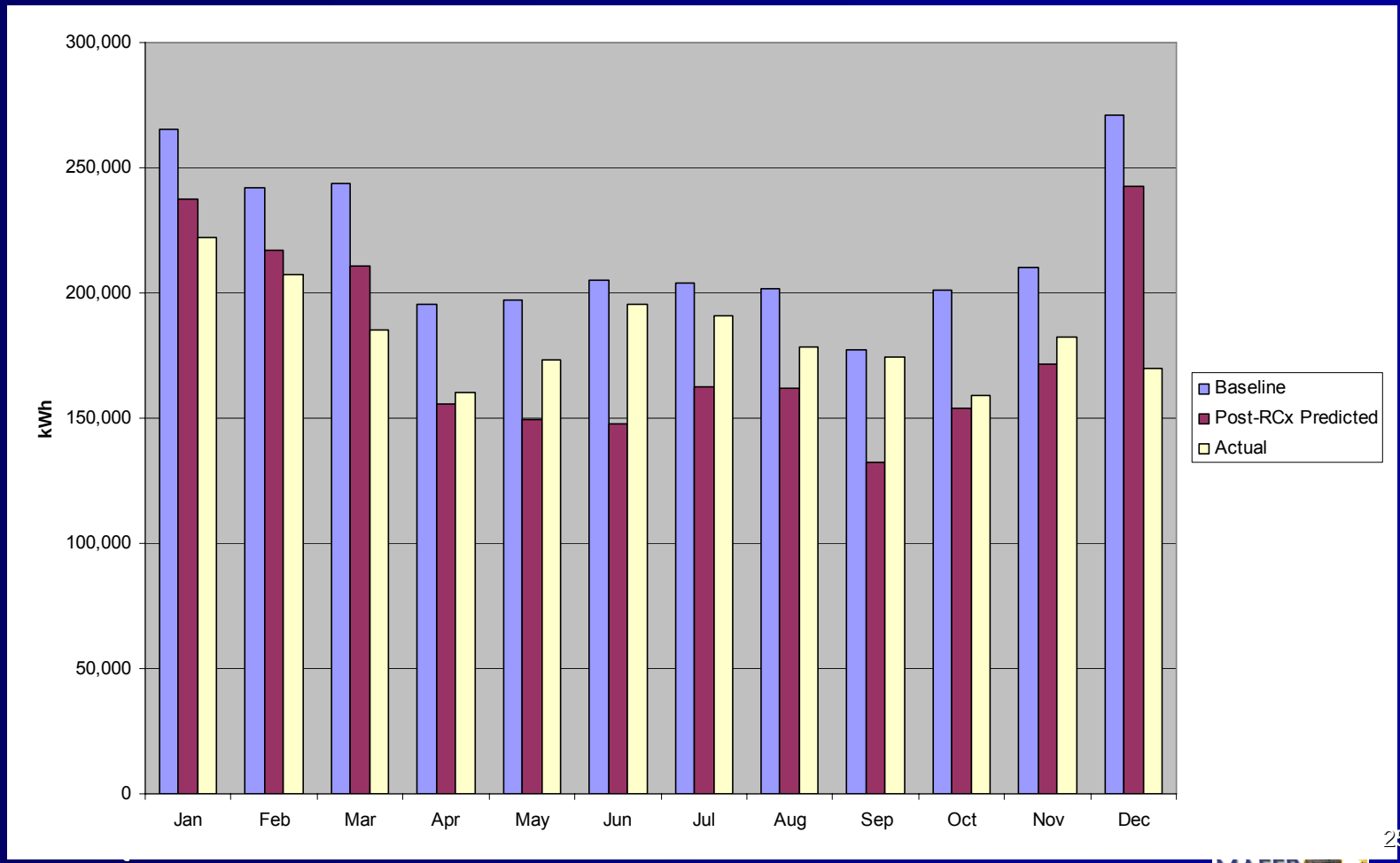




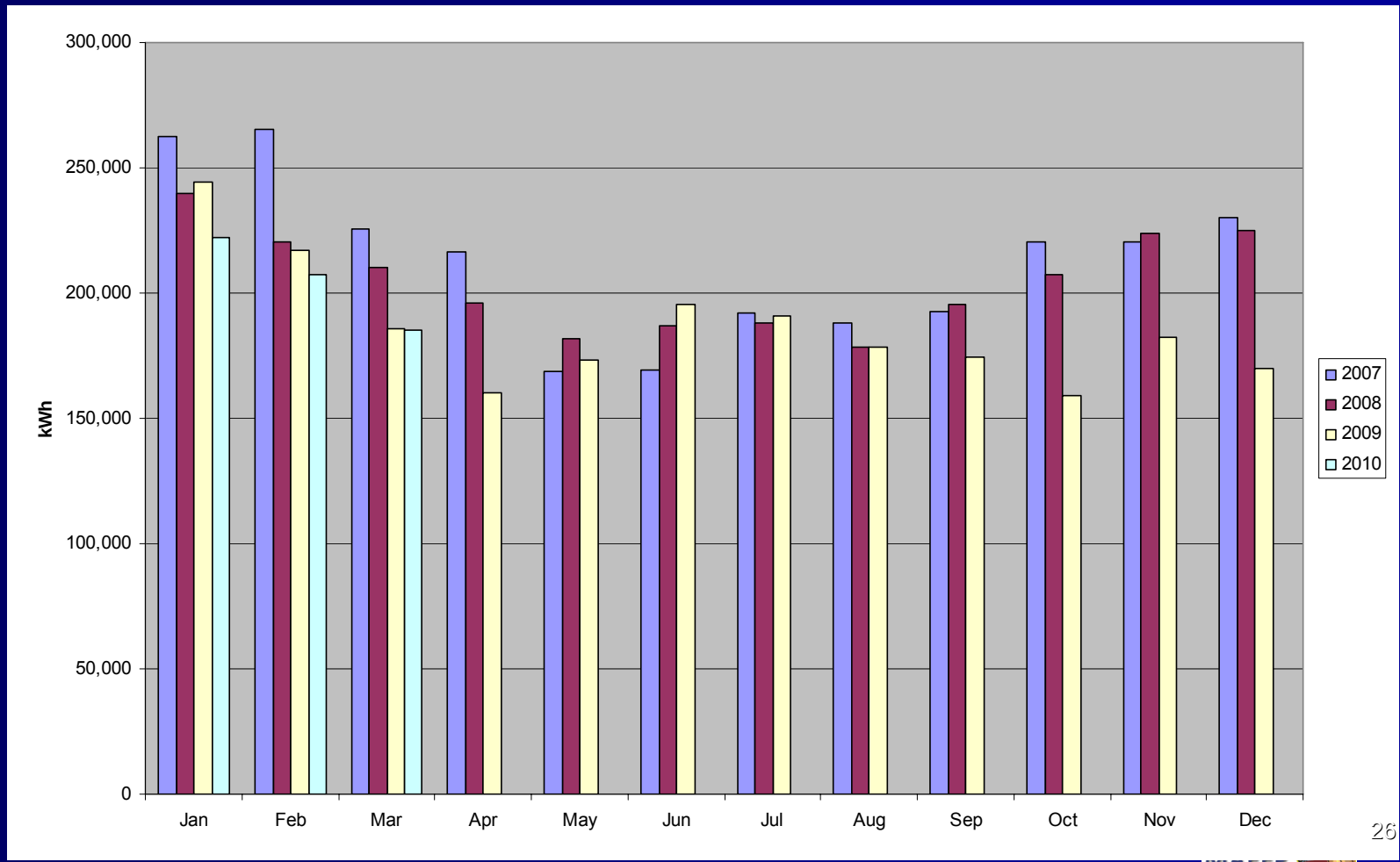
Example:

- A 95,700ft^2 office building in Eastern MA. RCx project began late 2008 continuing through 2009
- Option D: Baseline and Post-RCx both modeled in Trane TRACE
- Reporting Period: April 2009 – March 2010 (Electrical) and November 2007 – September 2008 (Gas)

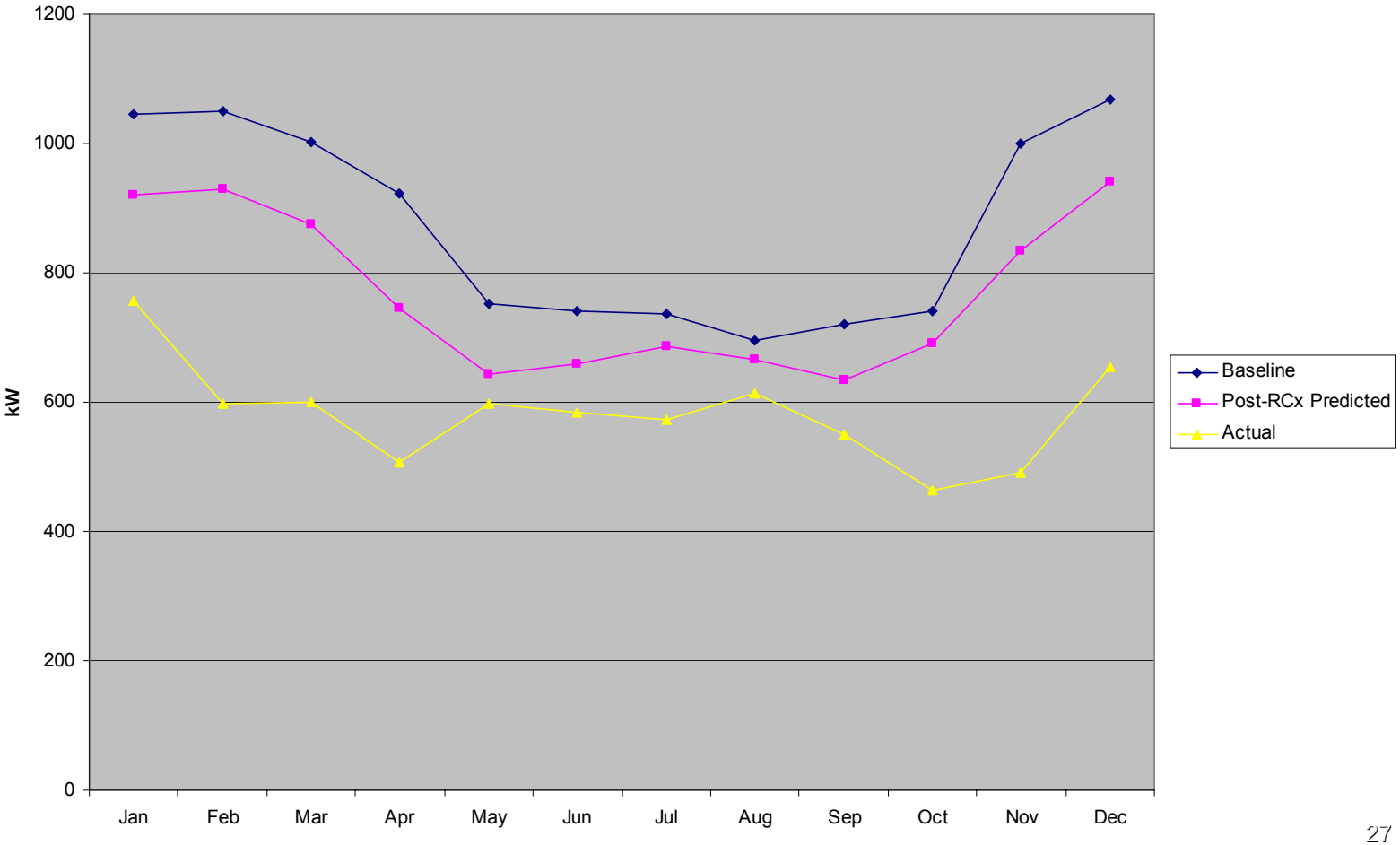
Electricity Use: Model Compared with Actual



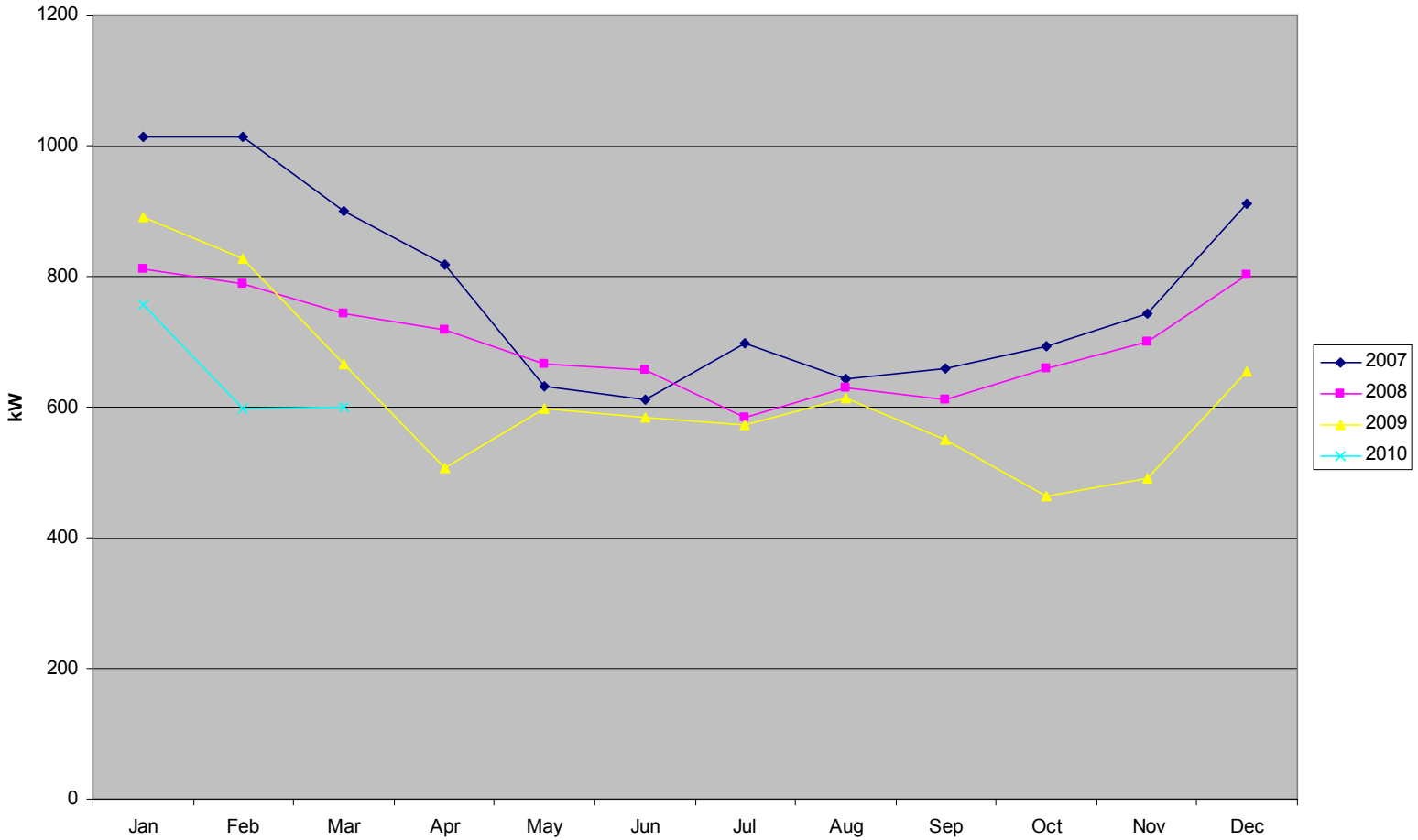
Electrical Use: Historical



Electric Demand: Model Compared with Actual



Electric Demand: Historical



Natural Gas Use: Model Compared with Actual