EERE Demonstration for Advanced Retro-commissioning Technology: Predictive Energy Optimization (PEO) and Automated Demand Response for Commercial Building HVAC

2016 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Michael Nark, michaeln@buildingiq.com
BuildingIQ, Inc.

Project Summary

Timeline:
Start date: October 1, 2014
Planned end date: September 30, 2017
Key Milestones

1. Stage 1 Site Qualification; 2/28/15
2. Stage 2 Site Qualification; 4/15/15
3. Stage 1 Sites Deployment; 6/30/15
4. Tech2 Market Plan; 6/30/15
5. Stage 2 Site Deployment; 12/30/15
6. 10% HVAC savings in 50% of sites ; 6/30/16

Budget:

Total Project $ to Date:

- DOE: $859,150
- Cost Share: $859,150

Total Project $:

- DOE: $1,762,740
- Cost Share: $1,762,740

Key Partners:

New City Energy	LBNL
DGS-Washington, DC	GSA – US Govt.
Schneider Electric	
Siemens	
Portal CM	

Project Outcome:

Demonstrate PEO (Predictive Energy Optimization) performance in multiple and diverse buildings, monitor their performance, analyze the energy and peak power savings, overall economics and verify with specific tests for performance of the application to deliver energy savings.

Purpose and Objectives

Problem Statement: PEO (Predictive Energy Optimization) still faces real market barriers:

- Relatively unproven as a concept
- Requires a new approach to how building operators manage their HVAC
- Target market is largely risk-averse, skeptical and resource-constrained

- **Target Market and Audience**:
- Target market is the 37,000 commercial buildings in the US
- Office, Government, Health Care and Higher Education
- Covers ~12B SF and spends ~$30B in energy costs per year
- HVAC systems in these buildings consume 8% to 12% of total US energy usage
- Commercial buildings typically represent over 50% of peak demand

- **Impact of Project**:
- Delivery across diverse building types with minimal disruption
- Showcase the no capex business model and validate savings/ cash flow impact
- Demonstrates the potential for cost-effective autoDR
- Verify that PEO provides leverage to building staff rather than adding to workload
  a. Near-term outcomes - 10% HVAC Expense Reduction
  b. Intermediate outcomes – 10% HVAC Reduction, 10% DR HVAC Drop
  c. Deployment / Rollout across GSA Buildings

Approach

Approach: Software overlays existing Building Automation Systems (BAS):

- Automatically adjusts set points
- Based on a learned, building-specific thermal model
- Incorporates predictive algorithms and advanced control strategies
- Utilizes weather forecasts, utility tariffs, event signals and occupant schedules, and adapts to changes.
- **Key Issues**: Requires a diverse set of commercial buildings
- Validation that deployment can be done cost-effectively and without the need for capital investment or highly skilled engineers
- Validation that PEO delivers sufficient savings/other benefits, combined M&V with LBNL
- Integration with applicable utilities or aggregators to bring DR
- Strong leadership, project management and good working relationships
- **Distinctive Characteristics**:
- Measurable and immediate impact on energy use and peak load
- Reduces the need for staff intervention to achieve savings
- Generates positive cash flow – all without upfront capital

Progress and Accomplishments

- **Accomplishments**:
- Completion of the site qualification checklist
- Completion of the site recommendations template
- Recruitment of more than fourteen (14) sites for Stage 1/Stage 2 deployment
- Finalization of the M&V plan and baseline analysis of sites with LBNL
- 12 of 14 sites fully deployed and operational

Market Impact: As we move into M&V validation stage, current results exceed expectation and full validated (via LBNL) results will yield:

- In excess of 10% reduction in HVAC related consumption by year end 2016
- In excess of 10% HVAC load reduction via DR by year end 2016

Awards/Recognition: At this point due the initial start of the project, awards and recognition have not targeted at this stage of the project.

Lessons Learned:

- Independent analysis of buildings for 3rd party M&V added a level of complexity to the building recruitment process
- Connectivity and integration to GSA buildings required unique approach – utilized central GSA data center
- Deployment schedule extended significant for submetering

Project Integration and Collaboration

Project Integration: Since completion of BMS integration

- Weekly meetings with M&V partner (LBNL)
- Bi-weekly status update meetings with each participating site
- Monthly DoE team status update and review

Partners, Subcontractors, and Collaborators: We are working with partners for our technology:

- New City Energy
- Schneider-Electric's regional branches
- Siemens national Energy Services business
- DGS / City of Washington, DC
- GPG / GSA

Communications: At this point since we are still in results validation mode, there have not been any presentation of results and benefits – still underway.

Next Steps and Future Plans

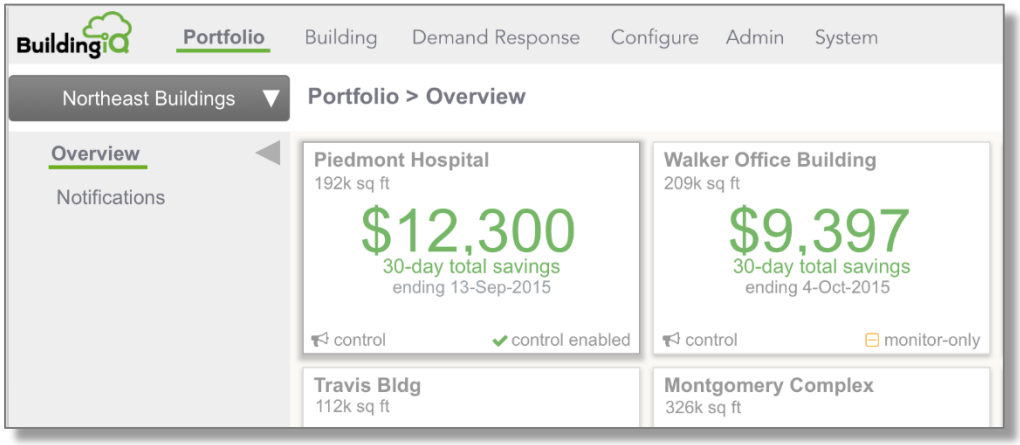
Next Steps and Future Plans:

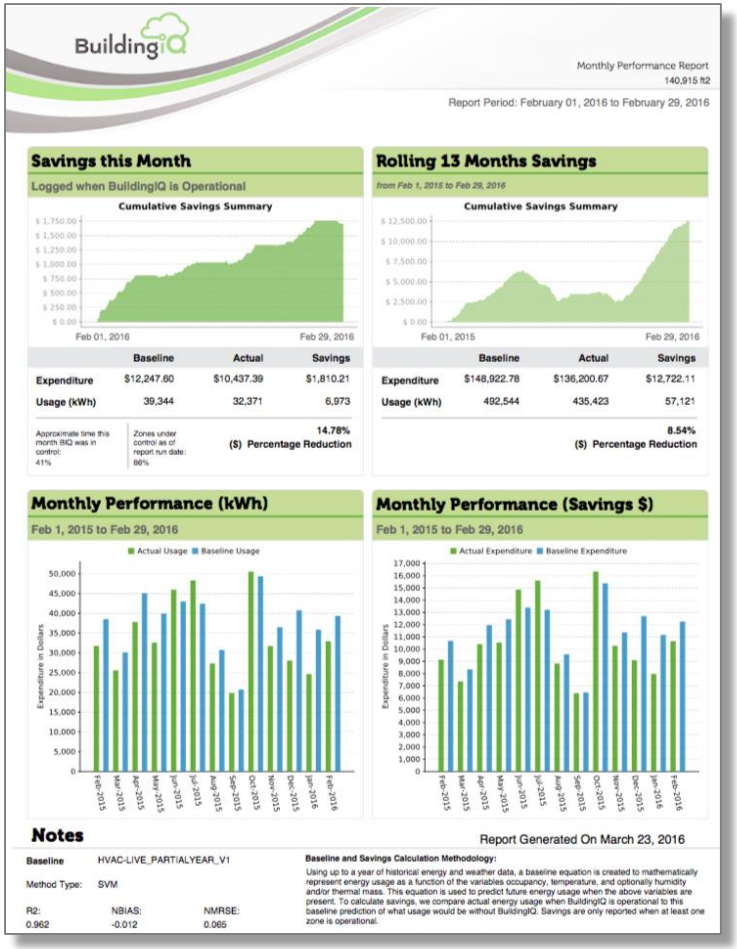
- Completion of Recruitment for Stage 2 Sites – additional eight (8) sites
- Completion of M&V (Measurement and Verification) plan and baseline analysis of sites with laboratory partner LBNL
- Full deployment of configuration of PEO on fourteen (14) Stage 1 and Stage 2 sites that will drive HVAC consumption reduction (Kwh) by 12% - 25%
- Target sites for minimum 10% HVAC consumption reduction (energy efficiency) milestone – June 2016
- Drive 10% HVAC load reduction for DR (Demand Response) qualified sites by end of 2016 (trial) and 2017 (performance)
- Sustain energy efficiency results throughout 2016 and into 2017
- Validate performance and report results via LBNL / case study
- Rollout across GSA

REFERENCE SLIDES

Predictive Energy Optimization

Portfolio and Building View





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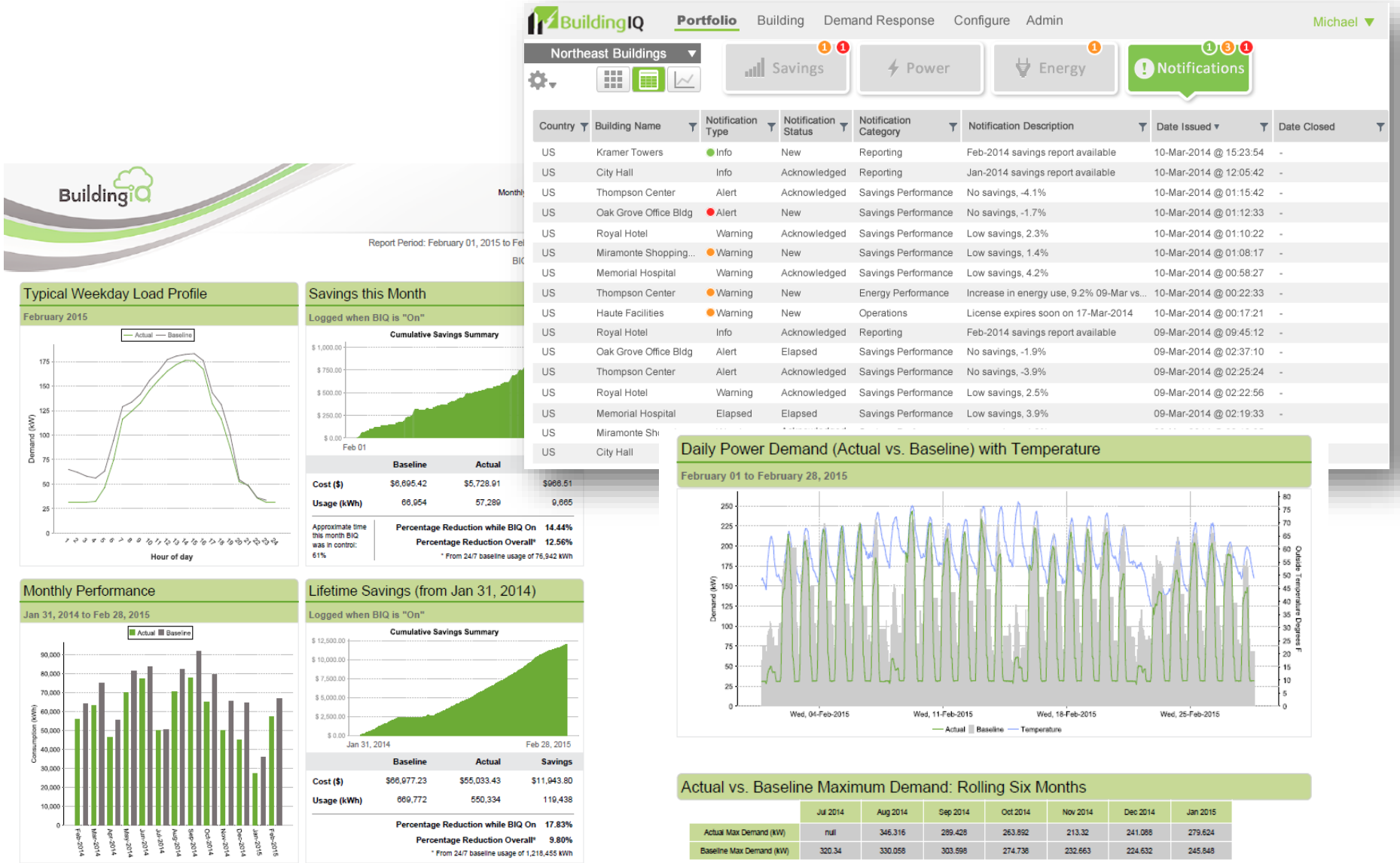
Continuous M&V and Alerting



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Laboratory Evaluation Objectives

Validate the potential of BuildingIQ technology

Technical

- Verify target 10% reductions in HVAC energy, associated utility cost savings, peak demand reductions
- Verify absence of adverse impact on thermal comfort

Market Adoption

- Investigate applicability to different building types, sizes and HVAC systems
- Document benefits to operations/management staff
- Compare/contrast installation, maintenance, warrantee vs. current controls

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M&V Approach: Energy, Utility Cost Savings

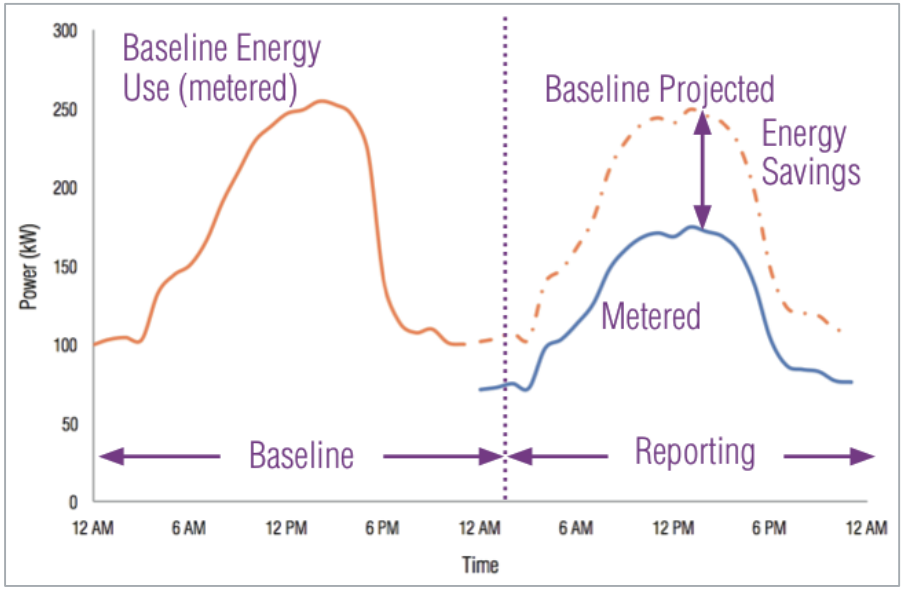
IPMVP Option B, HVAC system isolation via submetering

Avoided energy use based on pre/post comparison of energy use, normalized for weather, other key parameters

Utility cost savings based on site-specific tariffs applied to energy savings

Below: Example normalized baseline energy use equation; models selected, tuned for best fit to site data

$$E_i = b_{dayi} + b_{houri} + b_C T_{Ci} + b_H T_{Hi}$$



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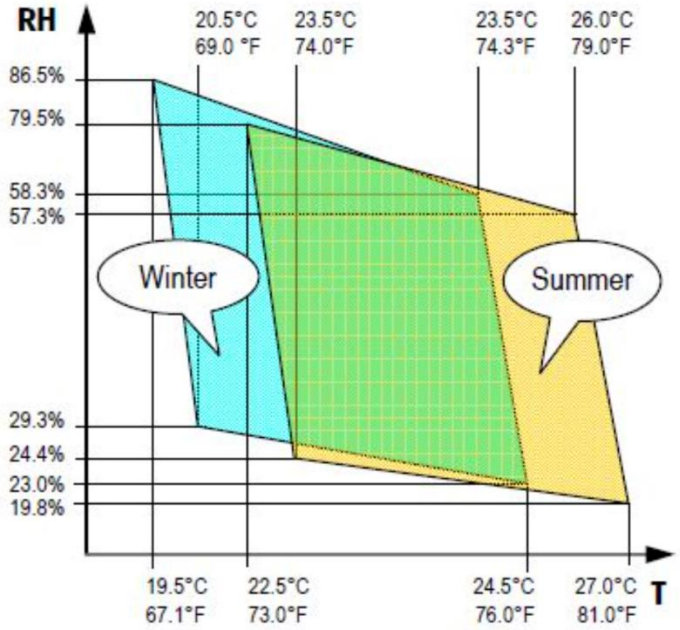
M&V Approach: Thermal Comfort

Use of simplified ASHRAE comfort model

Compare zone ambient temperature and humidity with and without PEO, based on BAS trend logs; compare logs of hot/cold complaints with and without PEO

Right: Illustration of simplified ASHRAE comfort model



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M&V Results To-Date

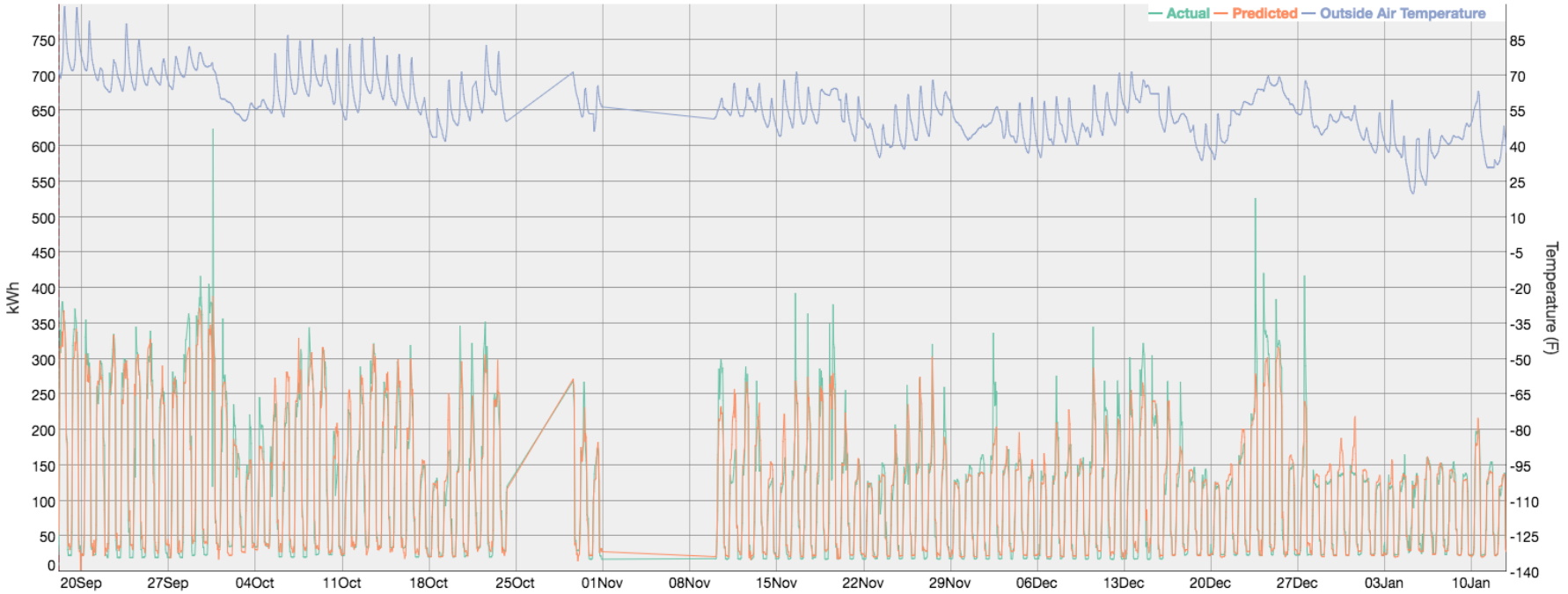

Image: Actual and model-predicted energy data, overlaid with outside air temperature

Advanced machine learning model using Temperature and Time of the week as input parameters

Model goodness-of-fit to baseline data (total HVAC electricity use):

- Coefficient of Determination: $R^2 > 93\%$
- Coefficient of Variation of the Root Mean Squared Error: CV(RMSE) < 22%
  - less than the 25% threshold suggested in ASHRAE Guideline 14

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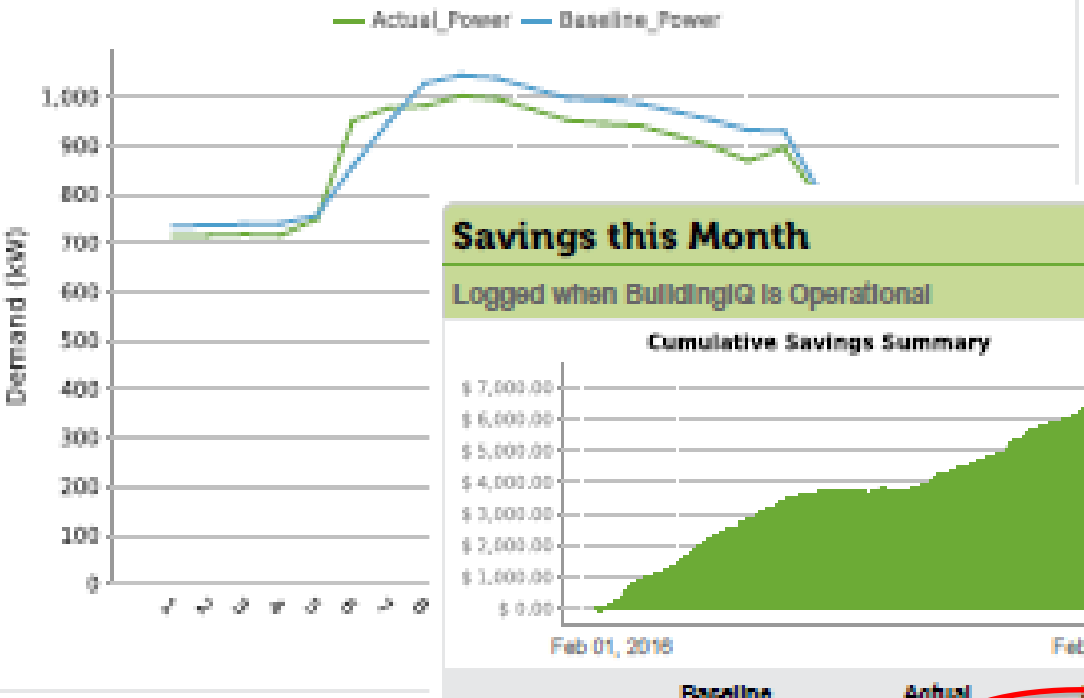
Site Performance Matrix / Preliminary / Non Laboratory Validated Results

Site/Organization	M&V	Control Mode / Status	December Results	January Results	February Results	March Results
GSA - Dayton	Combined	45 Day on Control (March)	n/a	n/a	n/a	Expected (Partial)
GSA - Chamblee	Combined	On Hold				
District of Columbia - Wilson	BIQ Only	Control (August)	10.10% (total building)	5.01% (total building)	7.5% (total building)	Expected
District of Columbia - Woodson	Combined	45 Day on Control (February)	n/a	n/a	Expected	Expected
District of Columbia – 200 I Street	BIQ Only	Full Control (September)	11.4% (total building)	8.9% (total building)	6.2% (total building)	Expected
District of Columbia – Waterfront East	BIQ Only	Full Control (March)	n/a	n/a	n/a	Expected (Partial)
District of Columbia – Waterfront West	BIQ Only	Full Control (March)	n/a	n/a	n/a	Expected (Partial)
District of Columbia – One Judiciary Square	BIQ Only	Full Control (March)	n/a	n/a	n/a	Expected (Partial)
District of Columbia – St. Elizabeth Hospital	BIQ Only	Onboarding – Learning Mode (April)	n/a	n/a	n/a	n/a
District of Columbia – Ballou	BIQ Only	Onboarding – Learning Mode (April)	n/a	n/a	n/a	n/a
New York Presbyterian – Allen Hospital	Combined	Onboarding – Learning Mode Capable	n/a	n/a	n/a	Expected (Partial)
California State University	Combined	Control (held February)	n/a	Minimal (control sequence issues)	Minimal (control sequence issues)	Expected (Partial)
UCLA	BIQ Only	Onboarding	n/a	n/a	n/a	n/a

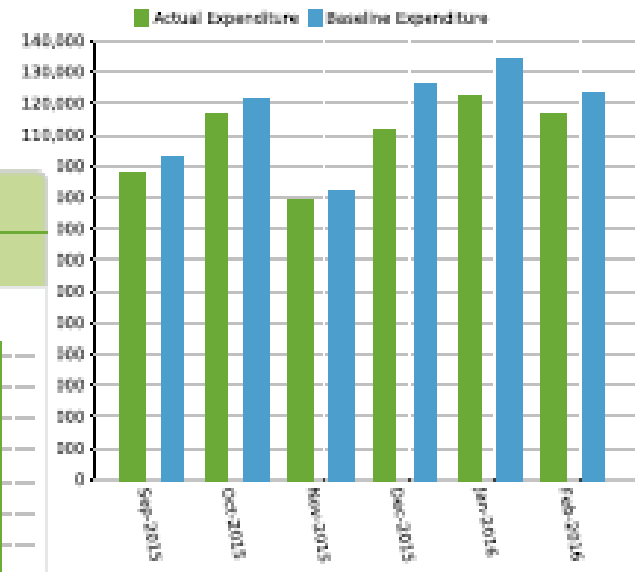
Prelim Performance Results – Feb 2016 – Office Building

Weekday Load Profile



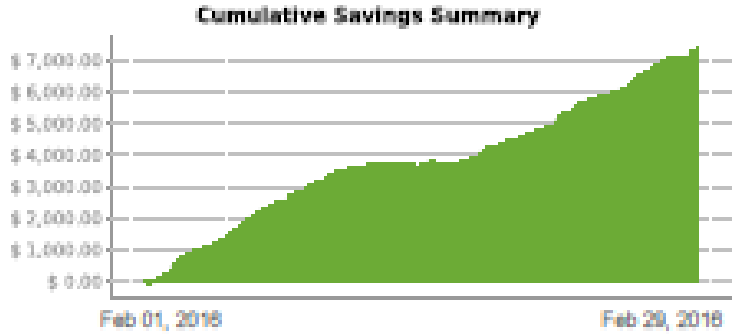
Monthly Performance (Savings $)

Sep 4, 2015 to Feb 29, 2016



Savings this Month

Logged when BuildingIQ is Operational



	Baseline	Actual	Savings
Expenditure	$123,654.86	$116,259.71	$7,395.14
Usage (kWh)	618,274	581,299	36,976
($) Percentage Reduction			6.88%

Approximate time this month BIQ was in control: 100%

Zones under control as of report run date: 94%

6.98% Total / 13.96% HVAC *kWh Reduction for February 2016*

$7K *Spend Reduction for February 2016*

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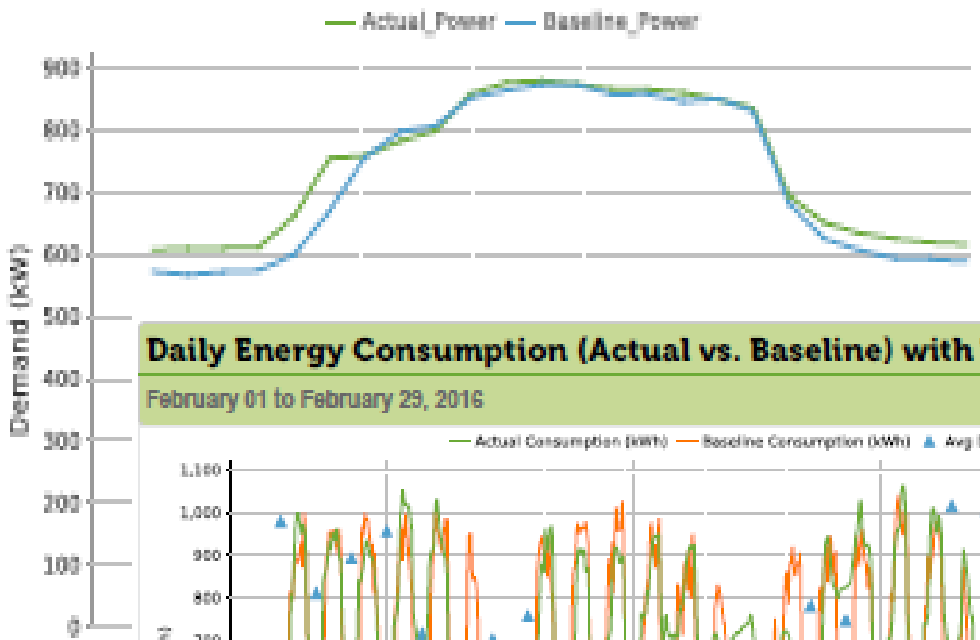
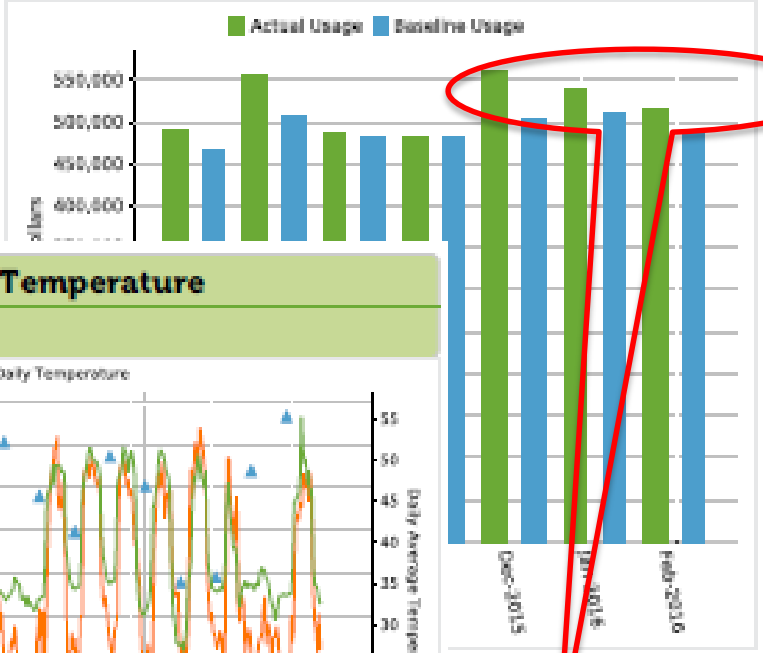
Prelim Performance Results – Feb 2016 – High School

Weekday Load Profile



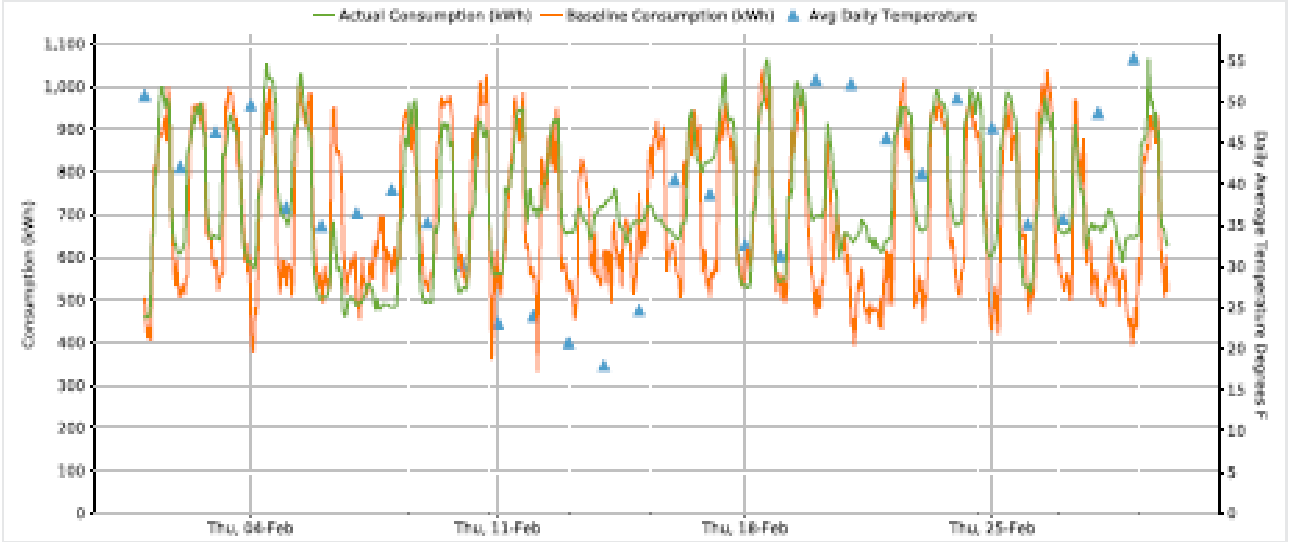
Monthly Performance (kWh)

Aug 5, 2015 to Feb 29, 2016



Daily Energy Consumption (Actual vs. Baseline) with Temperature

February 01 to February 29, 2016



6% Total / 12%
HVAC *kWh Reduction for partial month February 2016*

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Project Budget

Project Budget: Site Selection / Recruitment Began October 2014, Three (3) Year Project, Total Budget of $3.4M

Variances: No variations to report at this time and none are expected

Cost to Date: ~22% of the budget costs at this point - $354K

Additional Funding: Potentially additional lab funding (separate budget) to accommodate full M&V plan for remaining sites.

Budget History					
October 1, 2014 – FY 2015 (past)		FY 2016 (current)		FY 2017 – September 30, 2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$926,273	$926,273	$569,047	$569,047	$271,818	$271,818

Project Plan and Schedule

- Project Initiation Date of October 1, 2014 – Completion Date of September 30, 2017
- Three (3) Main Phases – Phase 1: Deployment, Phase 2: Energy Efficiency (Kwh) and Phase 3: Demand Response (KW)
- Go/No Go Decision Points – June 2015 (Deployment); December 2015 (EE Performance)
- Energy Efficiency Performance / Demand Response – 2016

	Task #		Task		Activities		Timing (months from start of project to end - Oct 2014 - September 2017)																																		
							Oct			Jan			Apr			July			Oct			Jan			Apr			Jul			Oct			Jan			Apr			Jul		
							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
PHASE 1	1		Project Start Up		T2M Analysis/Plan, Detailed Project Planning and M&V planninig		x	x	x																																
	2		Site Selection		Site selection and contracting		x	x	x	x	x	x																													
	3		Implementation Start Up		Site surveys and implementation plans					x	x	x																													
	4		Baselining		LBNL installs equipment and establishes baseline at sites					x	x	x	x	x	x																											
	5		Deployment		BIQ System design, make-ready, commissioning							x	x	x	x																											
PHASE 2	5		Deployment Continuation		BIQ System design, make-ready, commissioning											x	x	x	x																						
	6		Initial Operation		Ramp up PEO and deliver savings, generate reports and provide support											x	x	x	x	x	x	x	x																		
	7		Test Demand Response		DR test drops where appropriate:												x	x																							
	8		Initial Assessment		Assess savings and other metrics against objectives; make go/no go decision																	x	x	x																	
	9		Deployment Materials		Refine market analysis, create initial case studies and outreach																	x	x	x																	
PHASE 3	10		PEO Operation		Ongoing PEO and deliver savings, generate reports and provide support																				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	11		Integrated Demand Response		Integrate with DRMS or DR Aggregator, test integrated autoDR events																					x	x	x	x								x	x	x	x	x	
	12		Annual Assessment		Assess savings and other metrics against objectives; make go/no go decision																									x											x
	13		Deployment Materials		Refine market analysis, complete case studies and outreach																												x	x	x	x	x	x	x	x	x
	14		DOE Reporting		Ongoing DOE Deliverables including Annual Review and Closing Report			x				x			x			x		x	x			x			x			x			x			x			x		xx
			FOA Milestones				1											12	13					18	19																	36
			Goals				Phase 1 Goals: T2M Strategy Complete; Deployment partners committed; 6 sites selected and connected												Phase 2 Goals: >10% HVAC Savings in >50% Phase 1 Sites (*at least 2-3 LBNL submetered sites*); Lack of comfort/ staff issues; Owner commitment						Phase 3 Goals: >10% HVAC savings and 10% HVAC DR drop; Lack of comfort/ staff issues																			
			Go / No Go															x					x																	