

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

Reduce HVAC Costs with BuildingIQ

Predictive Energy Optimization™ takes building performance to the next level



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

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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.

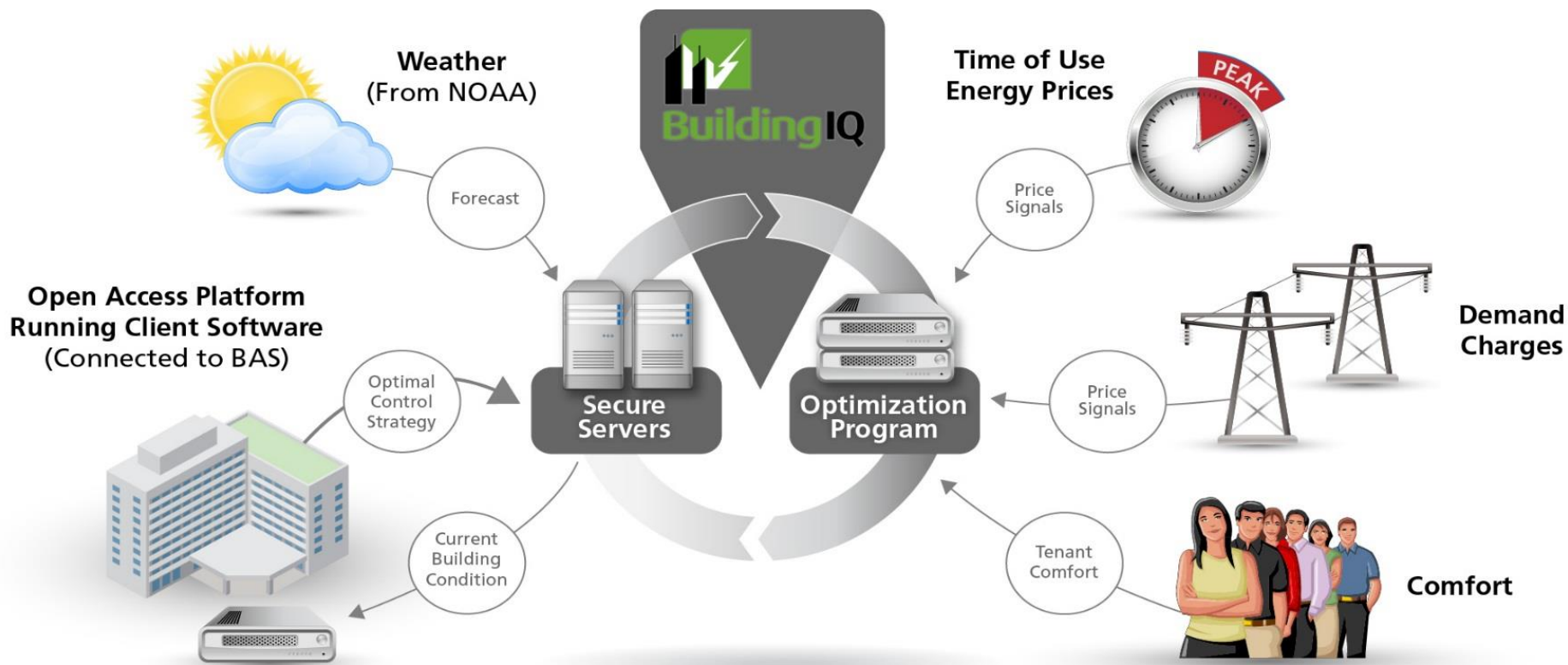
Next Steps and Future Plans

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

BuildingIQ Portfolio Building Demand Response Configure Admin System

Northeast Buildings **Portfolio > Overview**

Overview Notifications

Piedmont Hospital
192k sq ft

\$12,300

30-day total savings
ending 13-Sep-2015

control ✔ control enabled

Walker Office Building
209k sq ft

\$9,397

30-day total savings
ending 4-Oct-2015

control ☐ monitor-only

Travis Bldg
112k sq ft

Montgomery Complex
326k sq ft

BuildingIQ Monthly Performance Report 140,915.92

Report Period: February 01, 2016 to February 29, 2016

Savings this Month
Logged when BuildingIQ is Operational

Cumulative Savings Summary

	Baseline	Actual	Savings
Expenditure	\$12,247.60	\$10,437.39	\$1,810.21
Usage (kWh)	39,344	32,371	6,973

Approximate time this month BQ was in control: 41%
Zones under control as of report run date: 86%
14.78%
(\$) Percentage Reduction

Rolling 13 Months Savings
from Feb 1, 2015 to Feb 29, 2016

Cumulative Savings Summary

	Baseline	Actual	Savings
Expenditure	\$148,922.78	\$136,200.67	\$12,722.11
Usage (kWh)	492,544	435,423	57,121

8.54%
(\$) Percentage Reduction

Monthly Performance (kWh)
Feb 1, 2015 to Feb 29, 2016

Monthly Performance (Savings \$)
Feb 1, 2015 to Feb 29, 2016

Notes Report Generated On March 23, 2016

Baseline: HVAC-LIVE_PARTIALYEAR_V1	Baseline and Savings Calculation Methodology: Using up to a year of historical energy and weather data, a baseline equation is created to mathematically represent energy usage as a function of the variables occupancy, temperature, and optionally humidity and/or thermal mass. This equation is used to predict future energy usage when the above variables are present. To calculate savings, we compare actual energy usage when BuildingIQ is operational to this baseline prediction of what usage would be without BuildingIQ. Savings are only reported when at least one zone is operational.
Method Type: SVM	
R2: 0.962	NMBIAS: -0.012
	NMRSE: 0.065

BuildingIQ Portfolio **Building** Demand Response Configure Admin System

Tyler Tower **Building > Overview** °F °C sq ft sq m

Overview Analysis Graphs Custom Queries Timeline Management Control On/Off Points & Parameters Reports Modelling Optimization Control Logic Monitoring Simulation

Communication Status
Control of BMS ✔ Enabled
Mode ✔ Control

Tyler Tower
234k sq ft

\$10,397

30-day total savings
ending 18-Feb-2016

Control ✔ Control Enabled

Zone Temps & Weather

Current Zone Temps

Now 72.9 High 75 Low 55 Hum 45%

System Status

- ✔ BMS Comms
- ✔ Power Datafeed (19-Feb-19:00)
- ✔ Weather Datafeed (19-Feb 14:45)
- ⚠ Operating Schedule
- ✔ Tariff Schedule
- ✔ Baseline Model
- ✔ Optimizer Model

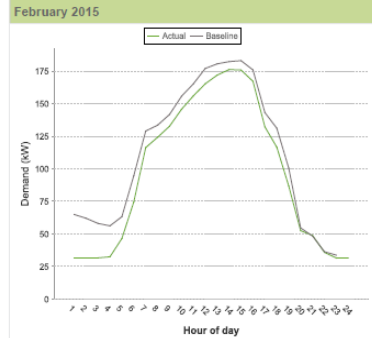
7-Day Energy Savings Performance

Legend:
 - Actual Weather Temperature
 - Actual Usage
 - Baseline Model
 - Energy Overage
 - Energy Savings
 - Operating Hours

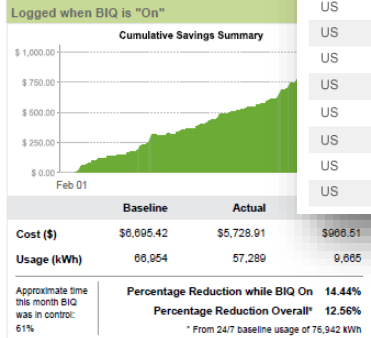
Continuous M&V and Alerting



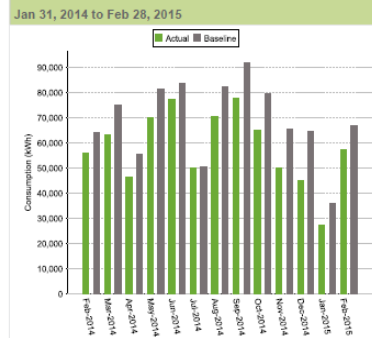
Typical Weekday Load Profile



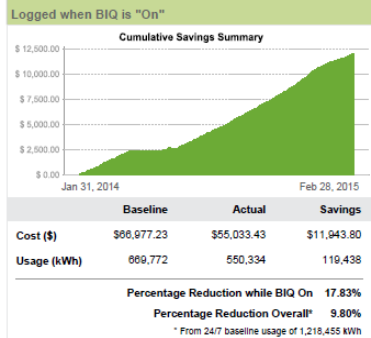
Savings this Month



Monthly Performance



Lifetime Savings (from Jan 31, 2014)



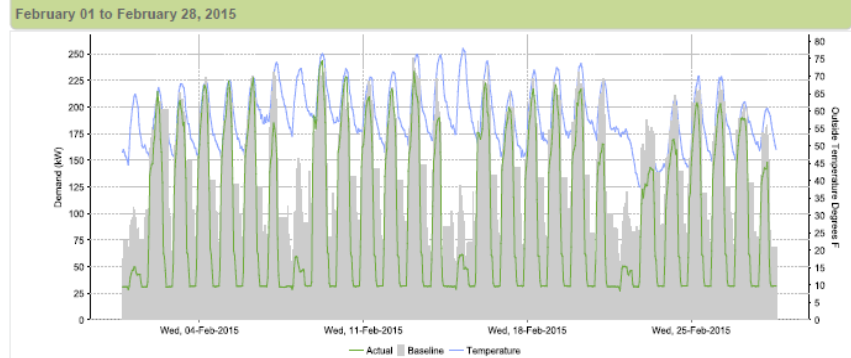
BuildingIQ Portfolio Building Demand Response Configure Admin Michael ▾

Northeast Buildings

Savings Power Energy Notifications

Country	Building Name	Notification Type	Notification Status	Notification Category	Notification Description	Date Issued	Date Closed
US	Kramer Towers	Info	New	Reporting	Feb-2014 savings report available	10-Mar-2014 @ 15:23:54	-
US	City Hall	Info	Acknowledged	Reporting	Jan-2014 savings report available	10-Mar-2014 @ 12:05:42	-
US	Thompson Center	Alert	Acknowledged	Savings Performance	No savings, -4.1%	10-Mar-2014 @ 01:15:42	-
US	Oak Grove Office Bldg	Alert	New	Savings Performance	No savings, -1.7%	10-Mar-2014 @ 01:12:33	-
US	Royal Hotel	Warning	Acknowledged	Savings Performance	Low savings, 2.3%	10-Mar-2014 @ 01:10:22	-
US	Miramonte Shopping...	Warning	New	Savings Performance	Low savings, 1.4%	10-Mar-2014 @ 01:08:17	-
US	Memorial Hospital	Warning	Acknowledged	Savings Performance	Low savings, 4.2%	10-Mar-2014 @ 00:58:27	-
US	Thompson Center	Warning	New	Energy Performance	Increase in energy use, 9.2% 09-Mar vs...	10-Mar-2014 @ 00:22:33	-
US	Haute Facilities	Warning	New	Operations	License expires soon on 17-Mar-2014	10-Mar-2014 @ 00:17:21	-
US	Royal Hotel	Info	Acknowledged	Reporting	Feb-2014 savings report available	09-Mar-2014 @ 09:45:12	-
US	Oak Grove Office Bldg	Alert	Elapsed	Savings Performance	No savings, -1.9%	09-Mar-2014 @ 02:37:10	-
US	Thompson Center	Alert	Acknowledged	Savings Performance	No savings, -3.9%	09-Mar-2014 @ 02:25:24	-
US	Royal Hotel	Warning	Acknowledged	Savings Performance	Low savings, 2.5%	09-Mar-2014 @ 02:22:56	-
US	Memorial Hospital	Elapsed	Elapsed	Savings Performance	Low savings, 3.9%	09-Mar-2014 @ 02:19:33	-
US	Miramonte Sh...						
US	City Hall						

Daily Power Demand (Actual vs. Baseline) with Temperature



Actual vs. Baseline Maximum Demand: Rolling Six Months

	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec 2014	Jan 2015
Actual Max Demand (kW)	null	346,316	299,428	263,892	213,32	241,086	279,624
Baseline Max Demand (kW)	320.34	330,058	303,598	274,738	232,663	224,632	245,848

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, warranty vs. current controls

M&V Approach: Energy, Utility Cost Savings

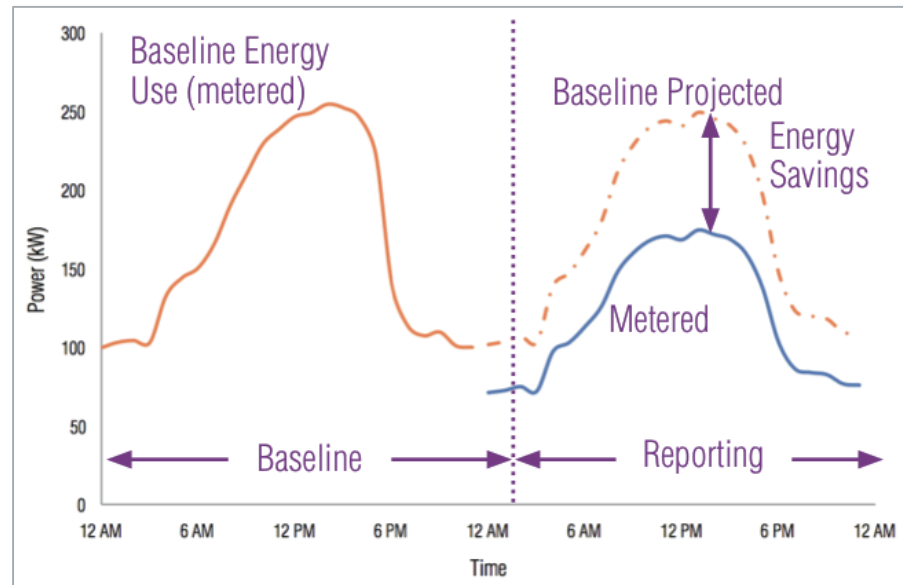
IPMVP Option B, HVAC system isolation via submetering

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

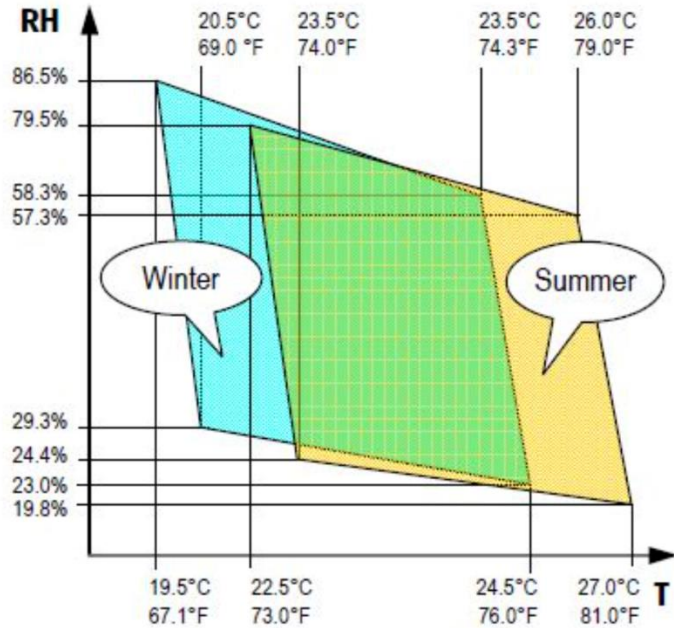
$$E_i = b_{dayi} + b_{houri} + b_C T_{Ci} + b_H T_{Hi}$$



M&V Approach: Thermal Comfort

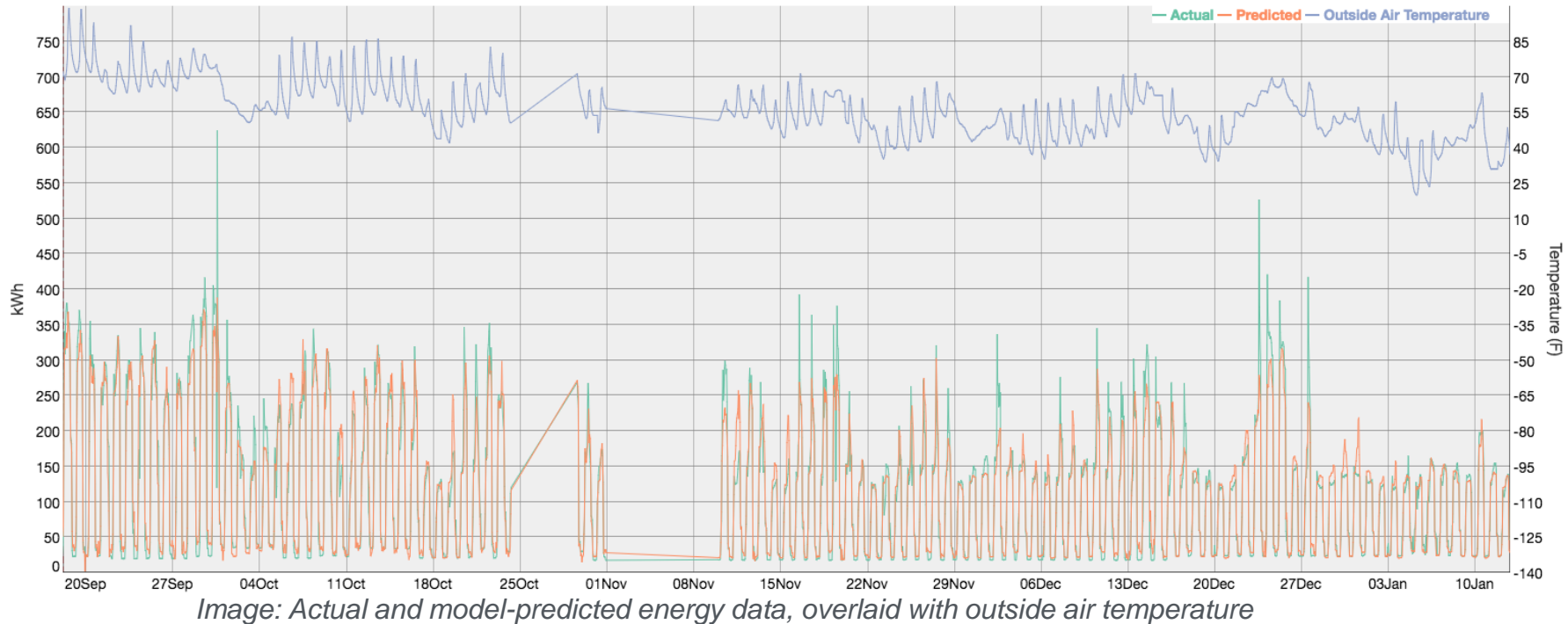
Use of simplified ASHRAE comfort model

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

M&V Results To-Date



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):

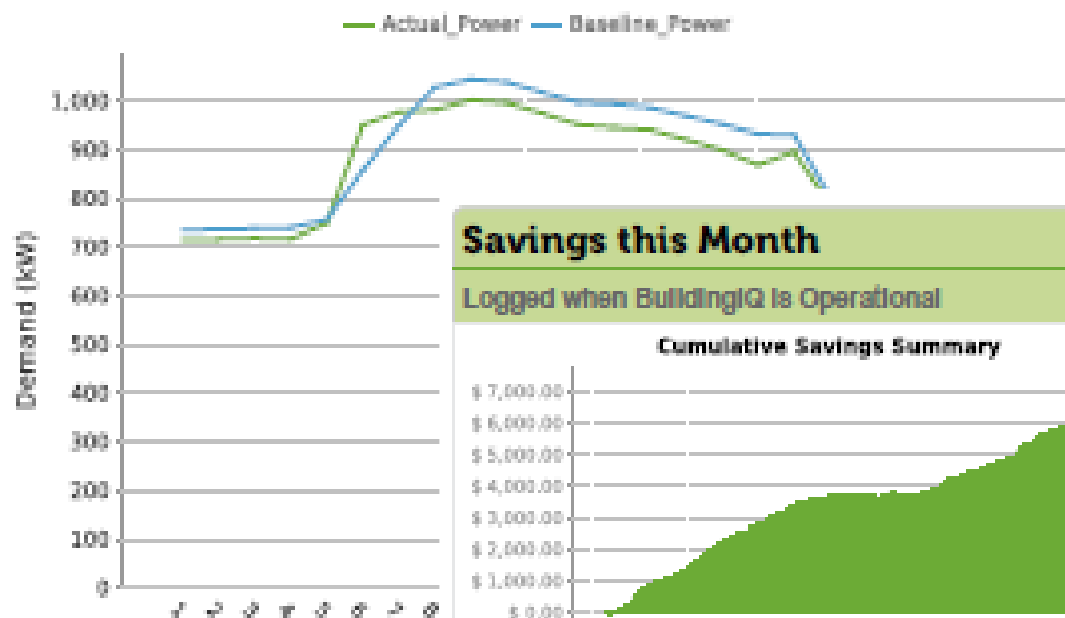
- Coefficient of Determination: $R^2 > 93\%$
- Coefficient of Variation of the Root Mean Squared Error: $CV(RMSE) < 22\%$
 - less than the 25% threshold suggested in ASHRAE Guideline 14

Site Performance Matrix / Preliminary / Non Laboratory Validated Results

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

Prelim Performance Results – Feb 2016 – Office Building

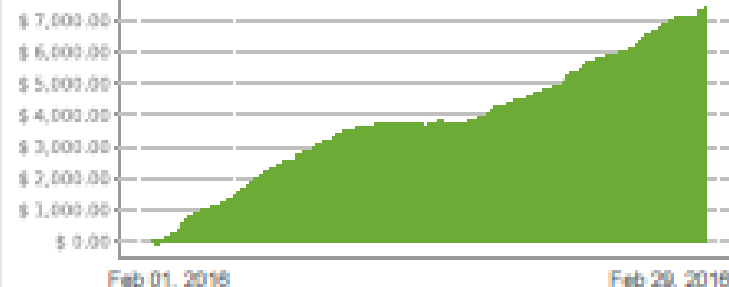
Weekday Load Profile



Savings this Month

Logged when BuildingIQ is Operational

Cumulative Savings Summary

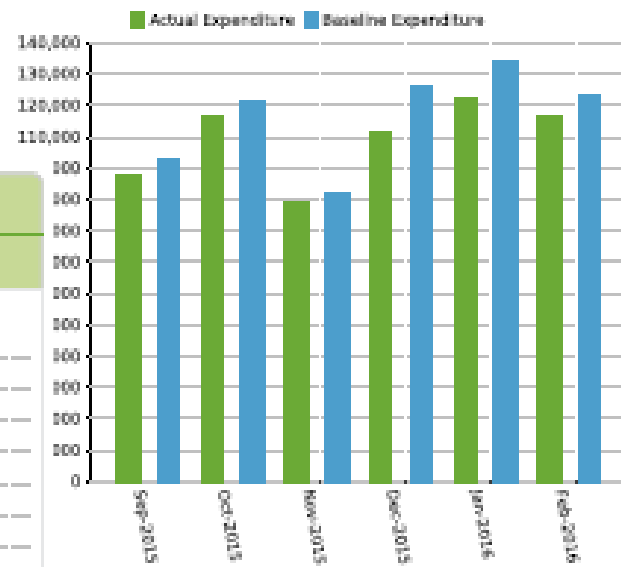


	Baseline	Actual	Savings
Expenditure	\$123,654.86	\$116,259.71	\$7,395.14
Usage (kWh)	618,274	581,299	36,976
Approximate time this month BQ was in control: 100%	Zones under control as of report run date: 94%		6.88%
			(%) Percentage Reduction

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

Monthly Performance (Savings \$)

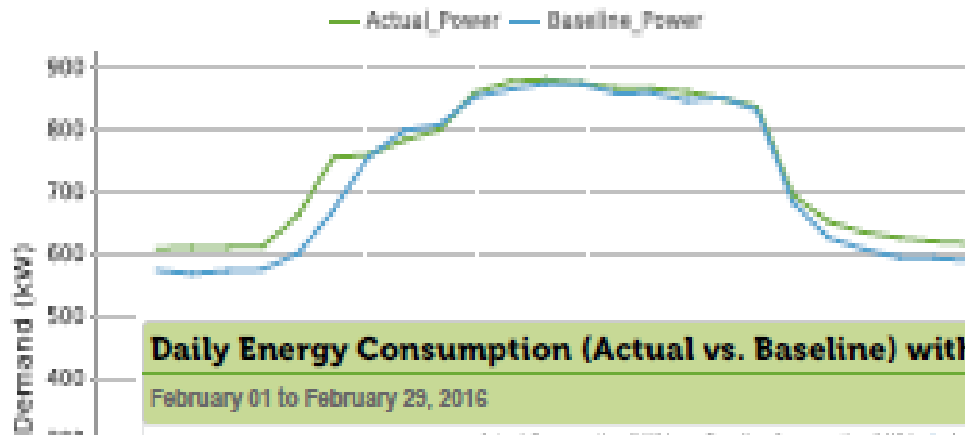
Sep 4, 2015 to Feb 29, 2016



**\$7K Spend
Reduction for
February
2016**

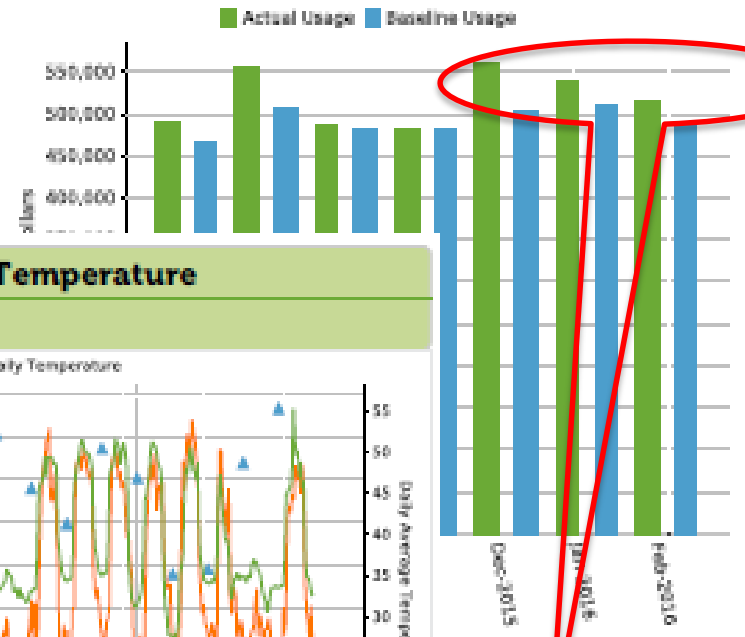
Prelim Performance Results – Feb 2016 – High School

Weekday Load Profile



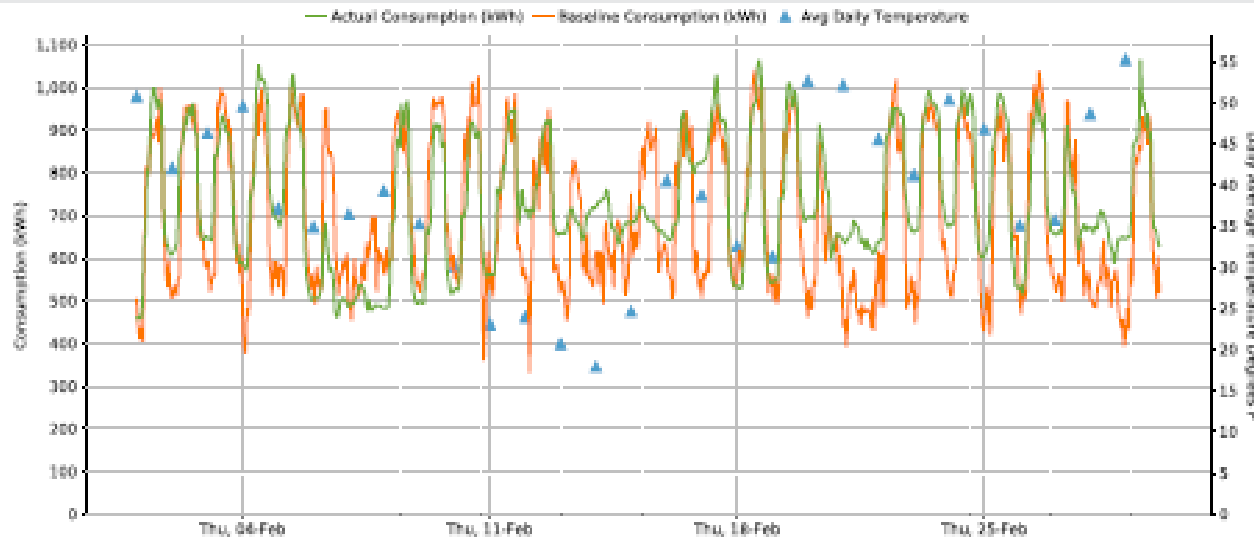
Monthly Performance (kWh)

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**

Project Budget

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

Variations: 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

				Timing (months from start of project to end - Oct 2014 - September 2017)																																				
				Oct			Jan			Apr			July			Oct			Jan			Apr			July			Oct			Jan			Apr			July			
Task #	Task	Activities		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 planning	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	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																		
PHASE 3	9	Deployment Materials	Refine market analysis, create initial case studies and outreach																X	X	X																			
	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	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		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 submitted sites); Lack of comfort issues; Owner commitment												Phase 3 Goals: >10% HVAC savings and 10% HVAC DR drop; Lack of comfort/ staff issues												
Go / No Go																X												X												