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

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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

Key Partners:

<table>
<thead>
<tr>
<th>New City Energy</th>
<th>LBNL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGS-Washington, DC</td>
<td>GSA – US Govt.</td>
</tr>
<tr>
<td>Schneider Electric</td>
<td></td>
</tr>
<tr>
<td>Siemens</td>
<td></td>
</tr>
<tr>
<td>Portal CM</td>
<td></td>
</tr>
</tbody>
</table>

Budget:

Total Project $ to Date:
• DOE: $859,150
• Cost Share: $859,150

Total Project $:
• DOE: $1,762,740
• Cost Share: $1,762,740

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:

• 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

Weather (From NOAA)

Forecast

Time of Use
Energy Prices

Price Signals

Open Access Platform
Running Client Software
(Connected to BAS)

Optimal Control Strategy

Secure Servers

Optimization Program

Current Building Condition

Tenant Comfort

Demand Charges

Comfort
Portfolio and Building View

**Portfolio > Overview**

- **Piedmont Hospital**
  - 192k sq ft
  - $12,300 30-day total savings ending 13-Sep-2015

- **Walker Office Building**
  - 209k sq ft
  - $9,397 30-day total savings ending 4-Oct-2015

- **Travis Bldg**
  - 112k sq ft

- **Montgomery Complex**
  - 326k sq ft

**Building > Overview**

- **Tyler Tower**
  - 234k sq ft
  - $10,397 30-day total savings ending 16-Feb-2016

**System Status**

- BMS Comm
- Power Datafeed (10-Feb 10:00)
- Weather Datafeed (10-Feb 14:45)
- Operating Schedule
- Tariff Schedule
- Baseline Model
- Optimizer Model

**7-Day Energy Savings Performance**

**Notes**

- Baseline and Savings Calculation Methodology: Using a 28-year set of historical energy and weather data, a baseline equation is created to mathematically represent energy usage as a function of the following variables: occupancy, temperature, and humidity, and some other factors. This equation is used to predict future energy usage when these variables are present. To calculate savings, we compare actual energy usage with the baseline, and the difference in energy usage is the energy savings.
Continuous M&V and Alerting
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
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

\[ E_i = b_{\text{dayi}} + b_{\text{houri}} + b_{C_{Ci}} + b_{H_{Hi}} \]
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
<table>
<thead>
<tr>
<th>Site/Organization</th>
<th>M&amp;V</th>
<th>Control Mode / Status</th>
<th>December Results</th>
<th>January Results</th>
<th>February Results</th>
<th>March Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSA - Dayton</td>
<td>Combined</td>
<td>45 Day on Control (March)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Expected (Partial)</td>
</tr>
<tr>
<td>GSA - Chamblee</td>
<td>Combined</td>
<td>On Hold</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>District of Columbia - Wilson</td>
<td>BIQ Only</td>
<td>Control (August)</td>
<td>10.10% (total building)</td>
<td>5.01% (total building)</td>
<td>7.5% (total building)</td>
<td>Expected</td>
</tr>
<tr>
<td>District of Columbia - Woodson</td>
<td>Combined</td>
<td>45 Day on Control (February)</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
<td>Expected</td>
</tr>
<tr>
<td>District of Columbia – 200 I Street</td>
<td>BIQ Only</td>
<td>Full Control (September)</td>
<td>11.4% (total building)</td>
<td>8.9% (total building)</td>
<td>6.2% (total building)</td>
<td>Expected</td>
</tr>
<tr>
<td>District of Columbia – Waterfront East</td>
<td>BIQ Only</td>
<td>Full Control (March)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Expected (Partial)</td>
</tr>
<tr>
<td>District of Columbia – Waterfront West</td>
<td>BIQ Only</td>
<td>Full Control (March)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Expected (Partial)</td>
</tr>
<tr>
<td>District of Columbia – One Judiciary Square</td>
<td>BIQ Only</td>
<td>Full Control (March)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Expected (Partial)</td>
</tr>
<tr>
<td>District of Columbia – St. Elizabeth Hospital</td>
<td>BIQ Only</td>
<td>Onboarding – Learning Mode (April)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>District of Columbia – Ballou</td>
<td>BIQ Only</td>
<td>Onboarding – Learning Mode (April) Capable</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>New York Presbyterian – Allen Hospital</td>
<td>Combined</td>
<td>Onboarding – Learning Mode Capable</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Expected (Partial)</td>
</tr>
<tr>
<td>California State University</td>
<td>Combined</td>
<td>Control (held February)</td>
<td>n/a</td>
<td>Minimal (control sequence issues)</td>
<td>Minimal (control sequence issues)</td>
<td>Expected (Partial)</td>
</tr>
<tr>
<td>UCLA</td>
<td>BIQ Only</td>
<td>Onboarding</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Prelim Performance Results – Feb 2016 – Office Building

Weekday Load Profile

Monthly Performance (Savings $)

Savings this Month
Logged when BuildingIQ is Operational

Cumulative Savings Summary

<table>
<thead>
<tr>
<th>Date</th>
<th>Baseline</th>
<th>Actual</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 1, 2018</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb 29, 2018</td>
<td>$123,654.86</td>
<td>$116,239.11</td>
<td>$7,395.14</td>
</tr>
</tbody>
</table>

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

$7K Spend Reduction for February 2016
Prelim Performance Results – Feb 2016 – High School

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

<table>
<thead>
<tr>
<th>Budget History</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOE</td>
</tr>
<tr>
<td>$926,273</td>
</tr>
</tbody>
</table>
## Project Plan and Schedule

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

### Project Plan and Schedule Details

<table>
<thead>
<tr>
<th>Task #</th>
<th>Task</th>
<th>Activities</th>
<th>Timing (months from start of project to end - Oct 2014 - September 2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project Start Up</td>
<td>T2M Analysis/Plan, Detailed Project Planning and M&amp;V planning</td>
<td>X X X</td>
</tr>
<tr>
<td>2</td>
<td>Site Selection</td>
<td>Site selection and contracting</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>3</td>
<td>Implementation Start Up</td>
<td>Site surveys and implementation plans</td>
<td>X X X X</td>
</tr>
<tr>
<td>4</td>
<td>Baselining</td>
<td>LBNL installs equipment and establishes baseline at sites</td>
<td>X X X X X X</td>
</tr>
<tr>
<td>5</td>
<td>Deployment</td>
<td>BQ System design, make-ready, commissioning</td>
<td>X X X X</td>
</tr>
<tr>
<td>6</td>
<td>Deployment Continuation</td>
<td>BQ System design, make-ready, commissioning</td>
<td>X X X X</td>
</tr>
<tr>
<td>7</td>
<td>Initial Operation</td>
<td>Ramp up PEO and deliver savings, generate reports and provide support</td>
<td>X X X X X X X X X X X</td>
</tr>
<tr>
<td>8</td>
<td>Test Demand Response</td>
<td>DR test drops where appropriate:</td>
<td>X X</td>
</tr>
<tr>
<td>9</td>
<td>Initial Assessment</td>
<td>Assess savings and other metrics against objectives; make go/no go decision</td>
<td>X X X</td>
</tr>
<tr>
<td>10</td>
<td>Deployment Materials</td>
<td>Refine market analysis, create initial case studies and outreach</td>
<td>X X X</td>
</tr>
<tr>
<td>11</td>
<td>PEO Operation</td>
<td>Ongoing PEO and deliver savings, generate reports and provide support</td>
<td>X X X X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>12</td>
<td>Integrated Demand Response</td>
<td>Integrate with DRMS or DR Aggregator, test integrated autoDR events</td>
<td>X X X X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>13</td>
<td>Annual Assessment</td>
<td>Assess savings and other metrics against objectives; make go/no go decision</td>
<td>X X X X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>14</td>
<td>Deployment Materials</td>
<td>Refine market analysis, complete case studies and outreach</td>
<td>X X X X X X X X X X X X X X X X X X X</td>
</tr>
<tr>
<td>15</td>
<td>DOE Reporting</td>
<td>Ongoing DOE deliverables including Annual Review and Closing Report</td>
<td>X X X X X X X X X X X X X X X X X X X</td>
</tr>
</tbody>
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### 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; Owner commitment