Bringing Energy Information and Operational Improvements to Small and Mid-sized Commercial Buildings through a Building Performance Tracking and Control Pilot

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ABSTRACT

Large commercial buildings have long enjoyed the energy efficiency, convenience, and comfort benefits provided by a central building management system (BMS). Smaller commercial buildings have typically lacked BMS systems, instead relying on manual or timer-controlled equipment scheduling. This type of control is frequently susceptible to inefficient operation, which directly affects the bottom-line of a business, yet often goes unnoticed by the owner/operator.

In an attempt to address this problem and to quantify operational savings, Energy Trust of Oregon, in partnership with Lockheed Martin Energy Solutions, initiated the Building Performance Tracking and Control (BPTaC) systems pilot. BPTaC pilot participants utilize web-enabled energy information/management systems, coupled with consultancy support, intended to affect behavior change or provide active equipment control, or both. With savings targets between 5 to 25% of baseline energy use, the goal is that BPTaC systems are effective at substantially reducing energy usage. BPTaC systems are intended for qualifying small and mid-sized business owners who wish to proactively save energy.

This paper explores the development of this unique offering, the overall specifications and goals of the pilot, and lessons learned to date from implementing the pilot. Results of the first case study are presented that point to good potential for energy and non-energy benefits. The paper presents a sound pilot implementation and evaluation plan and offers guidance to other programs looking to pilot deeper, more comprehensive savings in the commercial building market.

Introduction

Building Performance Tracking & Control (BPTaC) system products are emerging as viable energy accounting tools with web-enabled dashboard monitoring and in some cases, active control systems. Dozens of energy information systems are commercially available (Granderson et.al. 2009, 133) and features vary widely within each product category. A large scale impact evaluation of energy information systems in the residential sector (Summit Blue 2009) showed that the energy savings varied seasonally with maximum savings of 2.6% in summer. Another research study on effective behavior change strategies employed in the energy and utility industry (Summit Blue 2010) pointed the need for customized messaging in targeted market segments, creating social marketing tools, empowering change agents, and careful planning of pilots and evaluation.

The basic energy information systems provide feedback on current energy consumption, energy-use trends, and anomalies. An additional consultancy support module provides end users with quarterly recommendations for operational improvements (Brown, Anderson, Harris 2006) or mechanical equipment upgrades. The systems are able to generate text-alert notifications to the end user when automatic controls are overridden or when mechanical failures occur. Many of these products are rapidly evolving with built-in automated optimization capabilities which reduce the need for human responses.

In 2011, Energy Trust of Oregon (ETO) in association with Lockheed Martin (LM) initiated the BPTaC systems pilot for their Existing Buildings Program (Program). The pilot initiative aims to test the effectiveness of building energy information and management systems when applied to small and mid-sized commercial buildings, and to quantify energy savings resulting from the implementation of these devices. Based on the savings data obtained during the pilot period, ETO will evaluate the ability of these devices to save energy, the incentive levels needed to spur market adoption, and determine the product specifications necessary to make energy information and management systems a viable source of Operations and Maintenance (O&M) savings for the Program in the long term.

Pilot Development

The purpose of the BPTaC systems pilot is to explore three approaches to energy tracking and control through three different products commercially available in the market. The main goals of the pilot are:

- Verify product savings claims
- Verify persistence of savings over the course of the pilot
- Identify product specifications necessary to meet and maintain a cost-effective program
- Expand the portfolio of BPTaC systems product offerings for full measure roll-out, based on developed specifications

The products can save energy either through: 1) behavioral changes 2) combined active control and behavioral changes 3) corrective actions of operating deficiencies identified by monitoring consultants, 4) or via automated optimization. The products will be observed and analyzed based on their own functionality to determine their success in achieving cost-effective savings for the program.

Systems and Target Markets

The following suite of three energy monitoring and control systems products are selected for use in the pilot:

1. Energy Information Systems (EIS): These systems focus solely on energy information and behavioral aspects. The EIS portion of the pilot is targeting commercial buildings greater than 50,000 sq. ft. with existing Direct Digital Control (DDC) systems. Existing DDC systems will provide ease of incorporating the EIS system and resulting recommendations in the buildings. Energy Expert + Plus™ (NorthWrite 2012) is selected as the EIS product to be tested under this pilot.
2. Energy Management Systems (EMS): This system type includes an element of equipment control in addition to the energy information aspect provided by the EIS systems. EMS systems target commercial buildings between 5,000 and 50,000 square feet

in area that do not have a centralized building management system in place. For the EMS component, Kite & Lightning's UNITY™ (Kite & Lightning 2012) product is selected and the target markets chosen are retail, restaurants, and other small businesses.

3. Automated Optimization Software (AOS): This system uses an in-depth monitoring and sophisticated control algorithms to optimize chiller plants of 600 tons or greater in size. OptimumLOOP™ (Optimum Energy® LLC 2012) is selected as the product to be tested under this pilot.

Pilot System Specifications

Energy Information Systems (EIS)

The EIS solution selected for the pilot is a continuous energy monitoring service provided by Northwrite®'s Energy Expert + Plus™ with AirAdvice providing the consultancy service. At project launch (and as needed for seasonal variations, troubleshooting, etc.) several wireless satellite sensors are installed to monitor building temperature, CO_2, humidity, and lighting levels for a period of two to four weeks in order to generate an initial energy profile.

Once the profile is established, the satellite sensors are removed and web-capable data loggers are installed along with power meters (or pulse output) to allow for real-time monitoring of the buildings' energy usage. The data loggers produce a data stream available through a web-based dashboard and analyzed by a consultant on a monthly basis. Reports of operational deficiencies and recommendations for improvements are discussed with the customer.

The recommendations include behavioral-based low- and no-cost improvements that the customers can act upon quickly with minimal upfront cost investment. Since this system only provides information to the customers and does not actively control equipment, the effectiveness of the EIS is dependent on the ability of the customer to act upon the energy efficiency recommendations provided by the consultant.

Energy Management Systems (EMS)

For the EMS pilot, we will evaluate Kite & Lightning's UNITY™ product which provides low-cost, web-based, centralized control for multiple building systems including HVAC, lighting, freezers and coolers, water heaters, motors, etc.

The central UNITY™ system itself is a Linux based, open protocol software with energy conservation capability. The system employs several monitoring and control devices including wireless thermostats, current transducers, flow meters, current transducers, and various sensors to monitor CO_2, CO, humidity, temperature, and pressure differential. The use and type of controls and sensors used can vary greatly depending on the type of building use and equipment present. These devices are typically controlled wirelessly by the central computer that attempts to optimize all systems simultaneously to achieve the lowest possible total energy usage while meeting the demands of individual zones.

Real-time energy usage, brief historical usage, and equipment operation information are available to participants through a web dashboard and optional touch-screen flat-panel display. Authorized persons can also adjust equipment schedules, view alarms and inspect equipment efficiency ratings. The EMS product combines both direct control of building systems and behavioral changes to achieve energy savings. The system provider, Kite & Lighting, will submit quarterly reports to customers recommending schedule changes, equipment retrofits/ replacements, etc.

Due to the complexity and relatively low cost of the EMS, possible risks include failure of individual components of the system such as system crashes or signal interference to/from equipment controllers. In the event of a system or component failure, equipment operation automatically defaults back to pre-EMS operating conditions.

Automated Optimization Software (AOS)

For the AOS pilot, OptimumEnergy®'s "OptimumLOOP™" product will be evaluated. It is essentially a sophisticated software program designed to continuously optimize large-scale centrifugal chiller plant and air handling equipment. OptimumLOOP™ utilizes a patented relational-control algorithm that, by instantaneously monitoring performance of individual components throughout the system, is able to optimize the operating parameters of these components in relation to one another. This product attempts to manage all equipment within a variable flow HVAC system towards meeting demand at the lowest possible energy consumption of the overall system. Additionally, users gain visualization to system performance and energy consumption via the products' web-dashboard for monitoring, trending, and troubleshooting functions.

Optimal performance of the AOS is largely dependent on the condition of the pre-existing DDC system that it is installed into. The level of energy savings will depend on the presence of associated hardware, such as, Variable Frequency Drives (VFDs), Variable Air Volume (VAV) systems, etc. If these systems are not already present, their necessary installation can constitute a substantial initial investment for the customer.

Pilot Requirements

Participants. Participants will agree to provide the Program with up to three years of historical and ongoing utility data for the duration of the pilot period. They will commit to using the product (and hopefully implement identified actions for improvement) for a minimum period of three years. Participants will provide the Program with access to their product's web-based dashboard to allow the Program to monitor energy consumption and savings. They will participate in short interviews conducted by an independent evaluation team appointed by ETO. These interviews will be designed to gauge customer satisfaction and product and consultant effectiveness and shall take place on a schedule designated by the evaluation team at the end of the pilot phase. A financial executive or building or business owner will be included on all reports issued by the vendor consultant. The participants will appoint a dedicated end-user for the system with some level of building operations training. Those participating in the Energy Information Systems (EIS) portion of the pilot may be required to implement a low/no cost bundle of energy efficiency measures.

Vendor & contractor. Vendors will be required to warranty their software and hardware for a minimum period of three years from time of installation. They will be responsible for quality control of the installation and will be required to adequately train participants on use of the system. Vendor consultancy services will submit recommendation reports to the Program before submission to participant in order to maximize recommendations with any existing Program incentives or to include any recommendations that may not have been included in the original report. Vendor consultant will forward the final recommendation reports to participant. Vendor shall notify Program which recommendations were acted on by participant so Program can log any savings that occurred as a result of implementing a recommended energy saving measure. They will inform Program of system alerts, cause of alerts, corrective actions, and results. Vendor will be the first responder on any system alert related to software malfunction. Contractor will be responsible for installing the hardware at each site and be first responder to correct any hardware malfunction. Contractor will also be first responder on any alert issued by the product for mechanical issues.

Costs, Incentives, and Expected Savings

Costs and Incentives

Costs of the products selected for this BPTaC pilot generally scale to the building size and to the number of mechanical equipment components involved. Therefore, the bigger the building, the more expensive the overall installation cost, but the smaller the cost per square foot. Pricing information from vendors was used to determine the likely cost of installation for each system depending on the target building type. Program incentives are paid upfront to help cover the cost of installation and have been set at appropriate levels to spur interest in each product.

Each BPTaC system type is shown below at the prescribed maximum incentive levels:

Table 1. Incentive Levels for the Pilot Systems

Energy Information Systems (EIS)	Energy Management Systems (EMS)	Automated Optimization Software (AOS)
Semi-prescriptive; Maximum Program Incentive: 50% of installation and 3 year subscription fee	Semi-Prescriptive; Maximum Program Incentive: 50% of installation and 3 year subscription fee	Custom; Maximum Program Incentive: 50% of installation and 3 year subscription fee capped at $0.25/kWh saved

Expected Savings

For products included in the pilot, vendor's energy savings estimates and past case studies were used to determine the expected energy savings over baseline consumption. Whenever possible, empirical data from the Program were used to estimate the expected savings for each BPTaC product, based on real baseline consumption figures.

For the EIS product by Northwrite®, which focuses solely on the information and behavioral aspects of a BPTaC product, a 5% savings over baseline consumption was targeted by the Program based on average savings realized from past vendor installations. To correlate these savings to Program data, past participants that entered the program through the custom-track were analyzed based on target building types (in this case, offices) to test for measure cost-effectiveness using a 5% savings target. The vendor's pricing scale was used in the analysis for an average building size to estimate expected installation costs.

For the EMS component, the target savings were set at 15% of baseline energy consumption, primarily due to the inclusion of a control element absent in the EIS product.

Restaurants have been the primary target for the UNITY™ product and therefore an average cost and savings of their past participants were used to test for cost-effectiveness. To minimize the risk of over-estimating savings, baseline consumption data was also calibrated to reflect the Energy Use Index (EUI) of an average restaurant building in the Pacific Northwest.

For the AOS system (OptimumLOOP™) a stated 25% savings of the baseline consumption is estimated based on vendor data and past case studies. Since this product is primarily targeted at buildings with large chiller plants, and requires that the vendor perform a detailed analysis of the site to evaluate its savings potential prior to installation, the success of this particular product as a custom measure is the primary focus for inclusion in the pilot. Vendor pricing and results from a previous hospital project that entered the Program custom-track were used to demonstrate the cost-effectiveness of implementing this system.

Incentive Qualifications

Site requirements for participating in the BPTaC pilot are presented in Table 2. Should a site not qualify under these conditions, the Program reserves the right not to provide an incentive on the system.

Table 2. Site Requirements for the Pilot Systems

Energy Information Systems (EIS)	Energy Management Systems (EMS)	Automated Optimization Software (AOS)
Buildings greater than 50,000 sq. ft. with DDC Controls; Dedicated end-user with appropriate facility management training experience; Cost-effectiveness based on expected savings is achieved	Buildings under 50,000 sq.ft.; Ductwork and building Shell is adequate (not porous); HVAC equipment is reasonably up-to-date and appropriately sized; Dedicated end-user appropriately trained on use of the system; Cost-effectiveness based on expected savings is achieved	Chiller Plants 600 tons or greater; Buildings with VAV Systems; Cost-effectiveness per custom calculations is achieved.

Savings Analysis

The pre-screening process involves a walk through energy audit at each site that participates in the BPTaC systems pilot in order to gather as much data and intelligence about the site prior to system installation. This audit is provided as part of regular Program delivery cost so that the pilot and the participants are not burdened with this additional cost. Also the cost of performing this audit is not included in the cost-effectiveness of the measure.

Participants provide the Program with up to three years of historical billing data which is analyzed to determine the appropriate annual baseline energy use. The Program will analyze the billing data using EZ-Sim software to pre-screen for potential low energy savers based on EUI estimates. Once a site has passed the pre-screening process and installed the BPTaC product, the participant is required to provide the Program with ongoing utility data for the duration of the pilot to compare against the historical building energy data.

After a period of six months from product installation, billing data from the site will be compared to baseline energy use to ensure the building is on target to meet expected savings goals. The achieved savings after six months will be projected out to a period of 12 months and the annual savings thus estimated will then be deemed for that site for the pilot life period. At the end of a year after the product installation, the energy data will again be analyzed to ensure the annual savings projected at the six month interval was accurate. The pilot savings will be adjusted to reflect this new estimate if it differs significantly from the previous projection.

Persistence. Participants in the BPTaC System Pilot will be required to subscribe to the vendors consultancy service for a period of three years. For the EMS component, the participants have the option to subscribe up to a maximum five year period. During this time vendors will warranty software and hardware installed at the site. In order to evaluate the products for cost-effectiveness, this three year period was used as the expected measure life in the pilot, even though product life is likely much longer. If the pilot is continued beyond the three year period, measure life will be reconsidered and refined to account for actual observed persistence.

Exceptions. For the pilot effort, incentive will be paid to the participant based on the signing of a minimum 3-years subscription for the installed system. Alternately, the incentive can be paid directly to the Trade Ally (or Vendor in this case) if, and only if, the participant assigns payment of the incentive to them. In this case, the Vendor would be passing on the savings to the participant and that would be spelled out in the subscription agreement.

In addition, based on overall savings potential, percentage EUI reduction, and general performance expectations through participant interactions, the Program may opt to move forward on pilot project installations that achieve a Benefit to Cost Ratio (BCR) slightly less than 1.0 during the preliminary screening. It is expected that because conservative savings estimates were used for screening pilot projects, and because occupant willingness and overall enthusiasm may greatly affect savings over time, the Program has some leeway during this pilot effort to allow marginally non cost-effective projects into the pilot that appear to be good candidates.

It should be noted that this BCR leniency is not intended to be used to set a new threshold for cost-effectiveness, but instead will provide the Program with the opportunity to serve projects that they consider good candidates but that may otherwise appear non cost-effective during the pilot screening. Similar to all projects, these cases (if they do exist) will be reviewed at the 6-month check-in period to test for expected savings over the 3 year measure life, and adjusted to account for any differences found.

Case Study - Family Fun Center

This section details a case study of a Family Fun Center where an EMS Kite and Lightning UNITY™ system installation was completed in October 2011. The Family Fun Center presented in this case study was built in 1994 for family entertainment and features a laser tag room, arcade gaming room, batting cages, rock climbing wall, miniature golf course, go-cart race track and a pizza kitchen with adjoining dining/birthday party areas. The facility operates an average of 66 hours per week.

Building Description

The main building is approximately 24,000 sq. ft. of cement block construction with an upper and lower level. The main floor (lower level) contains a large gaming floor, restaurant and dining areas, and the upper level holds additional gaming areas and employee offices. The main building is conditioned with (10) Rooftop Units (RTUs) of varying tonnage and efficiency ratings. The gaming floors hold an average of 100 arcade gaming machines manually controlled by breakers. These machines make up the majority of the plug load demand and contribute significant heat gain to the main building. The gaming areas are serviced by two RTUs. The kitchen contains (1) gas fryer, (1) gas grill, (2) gas conveyor ovens, (3) electric refrigerated prep tables, (2) reach-in freezers and (1) walk-in freezer. The dining areas and party rooms are serviced by three RTUs.

The grounds include extensive lighting throughout to allow for night-time operation of the entire facility and are controlled by timer. Interior lighting is mainly 4' T8 fluorescents with incandescent lights scattered throughout for visual effect. The office space contains standard office equipment such as computers, printers, etc. The exterior grounds consist of a miniature golf course, bumper boats, rock climbing, go-kart track, dining area, and batting cages. These areas are unconditioned but are serviced by lighting, pumps, and motors which operate continuously during business hours.

EMS Equipment & Description

The following UNITY™ interface and control equipment are installed in the facility:

1. One UNITY™ controller w/20" touch screen interface and RF repeaters as necessary for complete coverage of facility
2. Ten HiFeC HVAC controllers on rooftop RTU's
3. Five economizer damper controllers on RTU's
4. Nine contactor boxes w/ contactor controllers (controlling 66 circuits and 2 plug load devices)
5. One override control in restaurant eating area
6. One walk-in freezer/cooler temperature monitor w/ door alarm
7. Two reach-in temperature sensors
8. Nine batting cage motor controllers
9. One outside light and temperature station
10. Eight timer box wireless relay controllers
11. Four relays to break-up the golf area contactor load
12. One 800 amp pulse type power meter

A major cost-saving component to this system is the ability to monitor and control respective building equipment wirelessly. This method of control reduces the cost of labor for installation and reduces wire clutter. The UNITY™ system dashboard is the main interface the customer has with their building operation and control. The dashboard is available via the web and from a touch screen monitor installed on-site. The dashboard layout has a smart-phone style layout which is intuitive and simple to navigate. This makes it popular among managers and supervisors without extensive technical backgrounds as it is easy to access the system to check equipment status and make any necessary adjustments. All controls on the dashboard map to and/or control various equipment and sensors throughout the facility. Each icon can be selected to display relevant information such as current operation status and a 24-hour equipment profile.

Similar to building management systems found in some larger buildings, the UNITY™ system assumes control of HVAC and lighting systems and able to continuously balance and monitor building pressures, light levels, temperatures and humidity within the facility. The system is also able to monitor the temperature of freezers/coolers and report if a door is left open. A threshold level can be set within the UNITY™ system that will attempt to meet all service demands while not exceeding a specified amount of kW. If the total kW consumption of the facility is nearing the threshold level, the system will delay service to lower priority areas in preference to higher priority ones until power becomes available or until the area exceeds a specified temperature deviation.

Prior to the EMS system installation, extensive mechanical inspection of the building systems was completed. The inspection included the building lighting systems, HVAC systems including RTUs, building shell, existing sensors, and ductwork. Also, prior to system installation, repairs were made to the RTUs as needed, to ensure proper operation of economizers and sensors. The initial RTU repairs were completed prior to EMS installation so that energy savings from EMS could be effectively quantified excluding any additional savings resulting from RTU repairs. Also, the cost of RTU repairs was excluded from the cost effectiveness calculation. After system installation was complete, on-site technicians conducted a thorough system quality check and optimized equipment schedules.

Cost and Savings Analysis

The system cost, incentives, and target savings are presented in the following table. The target energy savings are set at 15% of the average 3-year energy usage. The target cost savings are calculated using the average electricity rate of $0.09/kWh and gas rate of $1.10/therm.

Table 3. Project Cost and Target Savings

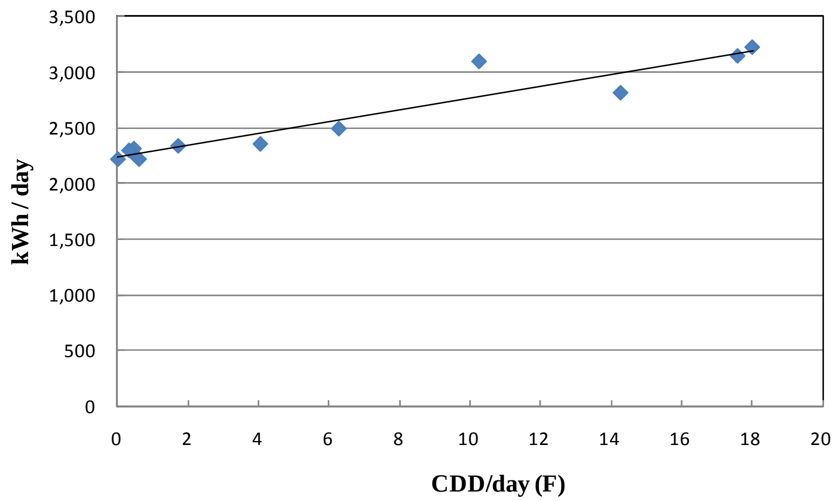
Project Cost	ETO Incentive	Target kWh savings	Target therm savings	Target Cost Savings	Simple Payback
$35,420	$17,710	140,920	1,860	$14,636	1.2 Years

Due to a combination of ETO incentives and good overall savings, the projected payback period for the EMS (assuming a 15% energy savings realization rate) is 1.2 years. The small upfront cost investment after the incentives and the short payback period should make it an attractive measure for small to mid-sized businesses.

In order to determine the actual energy savings realized from the system so far, the following methodology is used. First, a 12 month consumption baseline estimate is selected by analyzing the three year energy usage pattern and setting the baseline prior to the initiation of any measures associated with the project. The baseline period selected for this analysis is the 12 month period from June 2010 to May 2011, which is prior to the system installation, and reflects an average annual consumption estimate. After the baseline period is established, the energy usage during this period is normalized for possible weather fluctuations to generate appropriate correlations against Heating and Cooling Degree-days. This analysis was carried out using an industry standard energy accounting system called Metrix4 (AEC 2012) that meets the International Performance Measurement and Verification Protocol (IPMVP) guidelines.

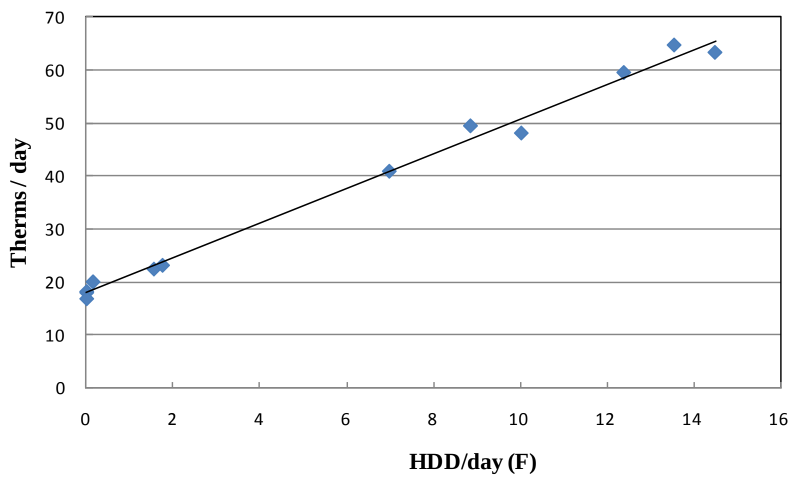
The monthly baseline electric usage shows a linear correlation with Cooling Degree-days (CDD) as shown below. The weather independent base usage is 2,226.3 kWh/day and the weather dependent factor is 53.80 kWh/CDD using a 50 F balance point temperature. The baseline correlation has a Net Mean Bias of 0% and a Monthly Mean Error of +/- 4.8%. The underlying regression has a R^2=0.907.

Figure 1. Electrical Baseline versus CDD



The monthly baseline natural gas usage shows a linear correlation with Heating Degree-days (HDD) as shown below. The weather independent base usage was 17.9 Therms/day and the weather dependent factor is 3.28 Therms/HDD using a 55 F balance point temperature. The baseline equation has a Net Mean Bias of 0% and a Monthly Mean Error of +/-4.5%. The underlying regression has a R^2=0.993.

Figure 2. Natural Gas Baseline versus HDD



The energy savings realized since the completion of the project are presented in the following tables. Table 4 shows the monthly electrical savings achieved over the five month period from September 2011 to January 2012. An overall reduction of 13% of baseline energy use has been achieved which is tracking slightly below the targeted 15%.

Table 4. Monthly Electrical Savings

Electric Scenario	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Total
Baseline kWh	94,901	74,382	78,898	63,119	76,109	387,409
Actual kWh	72,500	63,500	71,500	57,500	70,800	335,800
Savings (kWh)	22,401	10,882	7,398	5,619	5,309	51,609
% Savings	24%	15%	9%	9%	7%	13%

The natural gas savings over the period from October 2011 to January 2012 is shown in Table 5. Gas savings are not expected for the month of September as gas measures were not complete by then. The savings show an inconsistent trend since system installation, varying from a high 14% to a low -4%. The building management has confirmed that a game room gas pack heating system was activated in December resulting in increased gas use. This system addition will be trended and quantified in order to evaluate the true energy savings from the EMS system. The annual savings can be reliably estimated once the data for the full heating season becomes available in the second quarter of 2012.

Table 5. Monthly Natural Gas Savings

Gas Scenario	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Total (Oct to Jan)
Baseline Therms	520	633	1,638	2,095	2,078	6,444
Actual Therms	546	547	1,480	2,188	2,048	6,263
Savings (Therms)	-26	86	158	-93	30	181
% Savings	-5%	14%	10%	-4%	1%	3%

Participant feedback. The pilot EMS project continues to receive positive feedback from the management at the Family Fun Center. The management team is pleased with the ability to monitor and control their operating schedules and conditions from the dashboard, and the staff are happy with the system feature that automatically controls the equipment on the gaming floor turning them on and off, as needed, saving time. Additionally, the manager once received a text message from the UNITY^{TM} system alerting him to a freezer door that had been left open after hours. He was able to notify on-site personnel to close the door, saving both energy and potential product spoilage.

The Path Forward

This paper presented the details of an innovative pilot incentive program addressing the pilot specifications, implementation, and savings evaluation plan. For the pilot, a total of 10 EIS, 15 EMS, and 2 AOS are planned for installation in 2012. The relatively higher cost of AOS combined with the limited number of qualifying chiller plants has reduced the number of target installations for AOS from the original five to two. The two participating facilities are likely to be much larger in size than the minimum recommended chiller plant size of 600 tons. Limitations on multi-year leases within governmental organizations are limiting participation by those facilities in the EIS arena.

At the time of this paper submission, sufficient post-installation data was available only for one EMS which was presented here as a case study. This case study showed average electrical savings of 13% over the five month post-installation period and 3% in gas savings over the four month post-installation period. The reason for the lower gas savings was established as the addition of new load after the EMS was installed; this points to the need to monitor and quantify any significant variations in building system load so that the savings due only to the pilot systems can be captured accurately. Despite a limited amount of post-installation data, the EMS has demonstrated the potential to produce cost-effective energy savings with additional labor-saving non-energy benefits.

Comprehensive data collection and savings analysis will be ongoing for a post-installation period of one year for all systems installed under this pilot. At the end of the pilot period, we will be able to quantify the impact of all three types of systems over a full cycle of heating and cooling season. Weather-normalized energy billing will be compared to baseline-normalized energy use and the computed savings compared to the target value for each system type. The intention is to to quantify a full year of savings at the whole building level for all installations so that savings can be booked as a percentage of baseline energy once the pilot is completed. Based on the complete pilot results, energy savings estimates will be adjusted and the systems' cost-effectiveness reevaluated. For the successful system-types, incentive levels and savings estimates will be adjusted and a full set of hardware and software specifications developed that meet the basic requirements of the piloted systems. The authors intend to present the complete findings in a future paper after the completion of the pilot program.

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