Driverless Buildings: Harnessing Software for Uber Deep Savings

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ABSTRACT

As baseline equipment efficiencies continue to progress, commercial and industrial (C&I) energy savings are increasingly dependent on improved system control through building automation. Unfortunately, most building automation systems (BAS) fail to deliver reliable savings and measures have limited persistence, because they are poorly programmed and habitually overridden.

There is a path to driverless buildings that will run without need for constant adjustments. Industry experts working on the leading edge of building controls programming for delivery of comfort, fresh air and lumens share direct experience with moving the market toward optimally efficient system operation. Using example projects, we review the approaches that are delivering energy savings from BAS control improvements and Energy Management Information Systems (EMIS). We discuss direct experience with applying American National Standards Institute (ANSI)/American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Guideline 36 in the field, including lessons learned and performance results. Guideline 36 revolutionizes the control of variable air volume (VAV) air handling systems, one of the most common heating, ventilation and cooling (HVAC) system types in medium-to-large commercial buildings. This paper addresses the need and approach for creating an EMIS with dynamic feedback loops that will identify additional efficiency opportunities and performance issues. It also addresses the supporting services necessary to enable customers to successfully undertake these projects. When controls upgrades are maintained and can quantify the benefits of true building automation systems, long-term energy savings can be achieved.

Introduction

Because equipment efficiencies have dramatically increased over the past 20 years, improved system control offers one of the largest remaining opportunities for reducing commercial building energy consumption. Since their introduction in the 1980s, BAS are controlling an increasing share of commercial building HVAC systems; unfortunately, in many cases, systems are badly controlled and the feedback loops necessary to identify and resolve deficiencies don't exist.

Investment in HVAC controls is commonplace, but expected returns are not consistently produced. Yet designers, contractors and operators are largely unaware of the deficiencies, because BAS can be black boxes that fail to provide the information needed for problem identification and resolution. This lack of transparency, coupled with the common preference of building operators to operate manually, results in buildings that waste energy and fail to deliver comfort.

If control systems are failing to achieve their potential, how can Energy Efficiency (EE) programs and building owners know that investments in controls measures will provide an adequate return? If the controls do work, how long will they persist? The inability of HVAC controls projects to consistently deliver savings over time presents a challenge and opportunity for the EE industry.

This paper draws on the experience of the authors' work in designing, evaluating, commissioning, programming and controlling commercial, industrial and institutional buildings to compare traditional engineering-based solutions (Human Based Energy Management – HBEM) to EMIS data driven solutions. We propose an outline for an Automation Based Energy Management (ABEM) program design which uses EMIS to provide ongoing commissioning to advance data driven solutions, increasing market penetration and maximizing persistence of control and monitoring investments.

The State of the Market

In the era of Big Data, the market is looking for data driven solutions to building energy management. While there are growing pockets of success, most buildings are not using the available data to understand and manage operations. Even when EMIS are deployed, they often don't provide the level of granularity needed to move towards driverless buildings. EE programs have an opportunity to move the market towards more effective and continuous feedback loops that guide continuous improvement in HVAC controls design, programming and operation. The following summarizes some of the issues in the current market.

In this paper, EMIS refers to a data acquisition and analytics platform that captures and analyzes building performance data pertaining to component, system, and building level operations to identify issues and verify their resolution. While EMIS can operate at the meter level, to support ABEM, a strong interconnection with the BAS is necessary. The authors focus specifically on the HVAC BAS/EMIS interface while recognizing that the EMIS can and should be deployed across all energy using systems in the facility.

Engineering

Engineers are involved at several key points in most HVAC system optimization and energy management projects, providing analysis, designing solutions and performing commissioning. Schedule, fee and knowledge constraints can result in sub-optimal engineering solutions. One clear area of deficiency is in the specification of the Sequences of Operation (SOO) for the BAS which provides the recipe for correct building operations. Design engineers tend to leave room for the controls programmers to improvise the building control program by failing to provide adequate detail in the SOO. The resulting controls do not reflect the original design intent because the programmers are not educated in systems optimization. In addition, the control contractor's business model limits their deliverable to what's needed in the specification. Any vagueness in the SOO allows for interpretation.

Commissioning providers are typically unaware of the design intent underlying the SOO and don't have information on incentives associated with specific control measures. There is a wide range of quality for commissioning services, ranging from check-the-box functional testing to true systems optimization commissioning in which the commissioning provider is highly engaged in helping the team deliver a high performing system to the end user.

Finding engineers who have the depth of system and analytics knowledge necessary to identify and solve system deficiencies and optimize systems for maximum comfort and minimum energy use can be difficult. Quality engineering services are more expensive. Because professional services are often treated as a commodity, the lowest cost service providers are frequently designing and commissioning BAS.

Building Automation and Energy Management Systems

BAS are generally proprietary; only authorized vendors can sell, program and maintain the control systems. The proprietary nature of the equipment means that once a building owner purchases a BAS, they are locked in with their vendor until they replace their system. In addition, the proprietary controls can constrain the engineers, operators and commissioning providers from attaining a full understanding of the programmed sequences.

Market forces often result in BAS vendors under-bidding projects to get in the door for long-term contracts. To keep prices down, they may deliver new BAS that deploy dated components with limited capability. Some control companies are simply unable to keep up with the explosive capability of current technology and there is a dearth of skilled controls programmers due to the appeal and compensation structures of firms like Google and Amazon.

EMIS are increasingly available with a range of systems and services delivered under a wide variety of cost structures (Granderson, Lin, and Piette 2013). DOE's Better Building Solution Center has launched the Smart Energy Analytics Campaign, providing marketing and resources to increase both the market for and the adoption of EMIS. As noted above, EMIS often do not provide the analytical depth to enable ABEM.

Efficiency Programs

C&I EE programs have relied heavily on lighting as a major contributor to achieving goals over the past several decades. As lighting efficacies increase, lighting is a decreasing contributor to building efficiency and HVAC is the largest end-use in commercial buildings. HVAC system optimization is complex. EE programs have deployed a variety of strategies to capture HVAC savings, including:

- Custom engineered solutions for retrofit and new construction
- Retrocommissioning (RCx) and Monitoring-based Commissioning (MBCx)
- Pay-for-performance programs
- Prescriptive control incentives often structured as $/BAS point

EE programs often have a *Field of Dreams* mentality towards incentive programs: "if we provide $$, participants and vendors will take action." While pay-for-performance has benefits in that it mandates a feedback loop, a necessary part of system optimization, this approach fails to address crucial market barriers like customer risk aversion and inferior products offered at lowest first cost that fail to deliver results, skewing the market against higher quality providers. Additionally, HVAC system optimization requires skills that are not widely available in the market; programs cannot rely on the market to take off without supporting skill development.

An important barrier to EMIS adoption as an EE program measure is that EMIS does not directly save energy. Like an energy audit or RCx investigation, the EMIS identifies projects that, when implemented, will reduce energy use, increase equipment life, and improve comfort. Additionally, it provides information that, if used, will increase the persistence of savings. However, the resulting savings are often not linked to the EMIS. A recent evaluation of a site with an EMIS system found no savings, even though the system had identified multiple projects that had been implemented, because the savings for the projects were claimed separately by the utility.

Programs are making the foray into supporting EMIS. For example, BC Hydro included EMIS as a component of its successful RCx program with the intent of using the EMIS data for program evaluation. While the RCx program itself worked well, the EMIS component did not deliver the expected benefits because, at the time of evaluation, it was found that many customers were not maintaining their EMIS, data was inaccurate and other changes in operations that could affect energy were not tracked by the EMIS (Yu, MacKenzie, and Jubb 2017). Efficiency Nova Scotia's EMIS program for industrial customers is showing good results for a very small number of participants (Henwood and Bassett 2015). It deploys strategies consistent with Strategic Energy Management to garner a corporate commitment to the EMIS as a threshold for engagement.

Protocols and Tools

Because virtually every large C&I building is unique and, therefore, has custom designed HVAC systems, there is minimal standardization in controls and even less so in controls programming. ASHRAE has recognized this issue and developed Guideline 36 – *High Performance Sequences of Operation for HVAC Systems* (ASHRAE 2018a). ASHRAE is also working on standardizing HVAC system point naming, ASHRAE Standard 223P - *Designation and Classification of Semantic Tags for Building Data* (ASHRAE 2018a), which will streamline interfaces for integrated EMIS providers.

DOE's Smart Energy Analytics Campaign includes tools to support specification and procurement of EMIS (Better Buildings 2015). This campaign is a valuable asset to the advancement of EMIS, yet it focuses primarily at the energy meter level which is not granular enough to automate ongoing optimization of HVAC systems.

From Personnel Based to Computer Based Optimization

We are at a transition point for building system optimization. RCx has provided a platform for engaging customers in a process of continuous system optimization as shown in two of the examples below. This paper is using the term "Human Based Energy Management" (HBEM) for ongoing system optimization through continuous monitoring of BAS data and trends coupled with development of remediation projects and ongoing energy assessment conducted by engineers. The downsides of HBEM include the carbon impacts of transportation associated with delivering the service due to the need for on-site presence and the limited pool of professionals with the knowledge and skills necessary to deliver value to the investors. The alternative approach is to provide skilled engineers with an energy analytics platform that guides them in their search for non-performing building systems and components from a remote computer. This paper uses the term "Automation Based Energy Management" (ABEM) to describe this approach. The following three example projects deployed HBEM or ABEM over a similar period.

Project 1 (P1): A certified ENERGY STAR office complex (540,000 ft^2, circa 1960) had an ENERGY STAR score of 69 and an average annual energy consumption of 115 $kBtu/ft^2/yr$. Due to rising electric costs, they undertook a project that began with an RCx study and evolved to HBEM in which the engineering team is on site at least once per month, has the ability to monitor trends remotely and is actively engaged with the facility operators. The project engineering team identifies and supports the implementation of projects on an ongoing basis. In addition to a series of controls optimization projects, two capital projects were driven through this engagement: a chiller plant upgrade and replacement of the BAS.

Project 2 (P2): A resort hotel (300,000 ft^2, circa 2010) was experiencing comfort and energy use problems. Similar to P1, this project commenced with an RCx study. The owner recognized that they needed controls and HVAC system training and support for their young staff in addition to assistance implementing the measures identified in the study. The engineering provider was engaged to support staff with ongoing training and issue resolution as well as to lead implementation of the selected measures. This arrangement resulted in an opportunity to engage in HBEM, like that described above. Through this engagement, opportunities to upgrade and optimize controls have been regularly identified, and the project has expanded to additional buildings on the grounds. Measures have included controlling the 180+ room heat pumps, integrating the BAS with the reservation system to achieve automated occupancy scheduling, reductions in nuisance alarms, gaining control of the hotel's dedicated outdoor air systems (DOAS), and improved capability of facilities staff to manage the building and systems.

Project 3 (P3): As part of a larger campus EMIS and continuous improvement project, a mixed-use college building (113,000 ft^2, circa 2010) was identified with an energy use intensity (EUI) of 140 $kBtu/ft^2$, the highest in its cohort. The building had comfort issues and required significant effort to maintain. Using an ABEM approach, an engineer was assigned to analyze the building data via a remote EMIS and develop an action plan. The analysis used 2,463 trends to assess the building's primary, secondary and terminal HVAC systems. The building was evaluated operationally, from both an equipment and systems standpoint, and from a design perspective, reviewing the SOO in terms of their ability to meet ASHRAE standards. The resulting project included updated design specification and control sequences with clear logic consistent with modern standards, a complete rewrite of the automation programming to meet or exceed ASHRAE Standards 55, 62.1 and 90.1 and a follow-up evaluation by the engineer upon project completion to verify that sequences were programmed as intended.

Project Comparisons

There are noteworthy similarities between these projects, including:

- Control systems were found not to be programmed for efficient operation of equipment.
- Projects were undertaken to improve control including writing new sequences of operations and supporting their implementation.
- Engagement was continuous over several years.
- Performance was verified and used to support additional investments.
- Projects had champions internal to the organization.

Given these similarities, it is useful to compare the project costs and savings. This comparison includes the capital measures at P1 because the savings have been analyzed on a cumulative basis. Table 1 shows the similarities in costs.

Table 1. Comparison of costs between projects

Project	Approach	Engineering Costs (~5 years)	EMIS Cost (Set-up and Ongoing ~ 5 year)	Construction/ Implementation Costs	Total Investment
P1	HBEM	$150,000	$0	$425,000	$575,000
P2	HBEM	$90,000	$0	$35,000	$125,000
P3	ABEM	$52,000	$35,000	$34,000	$121,000

While the project totals are similar for P2 and P3, the engineering costs are lowest for the ABEM project and the allocation of funds is significantly different, with about 1/3 of the cost allocated to the set-up and first five years of EMIS data analytics. This is what we expect. One of the benefits of increased automation of data acquisition and analysis is that there is more consistency, credibility and comprehensiveness of the outputs. Engineering time is reduced, enabling those engineers with the technical expertise for in-depth system optimization to contribute to the successful operation of more buildings. If we can effectively deploy the limited available engineering talent across more buildings, we will capture more savings.

Table 2 documents the energy savings and simple payback for the projects before utility incentives. Again, we note that P1 includes both controls optimization and capital measures.

Table 2. Energy savings and simple payback prior to utility incentives for each project

Project	Approach	Annual Energy Cost Savings	Simple Payback	Area (ft^2)	Cost per Square Foot
P1	HBEM	$192,000	3	540,000	$1.06
P2	HBEM	$42,000	3	300,000	$0.42
P3	ABEM	$40,000	3	113,000	$1.07

The uniformity in simple payback as shown in Table 2 is noteworthy. The differences in cost per square foot are understandable. These services, whether human or automation based, have fixed costs that are not proportional to building size. This means the thresholds for application of these approaches is a factor in program design. However, the success of applying ABEM and assessment to a 113,000 square foot building indicates that the strategy can achieve application across most of the range of square footage in the C&I market, if EE programs can move the market to increased adoption.

Benefits of ABEM: System Change

In addition to delivering reliable energy savings, the ABEM approach has non-energy benefits that will drive market level change over time. The following are examples of market changes that have followed from the deployment of ABEM across a large portfolio of buildings.

The ABEM program started with mandates to achieve energy reduction goals and track and report on energy usage and spending. That led to the deployment of an EMIS which collects over 200,000 BAS trends from six different controls manufacturers across 175 buildings. The data analytics outputs are displayed through a common set of reports and diagnostic analytics enabling ABEM. The system tracks weather-normalized energy savings, based on utility bill data, from 1,300 buildings across 72 cities.

The ABEM process helped the customer identify common problems across their portfolio regardless of control contractor, engineering firm, or internal staff. Having a systematic, cost-effective approach to identify issues and implement operational improvements across hundreds of buildings enabled the customer to change the way they did business. By changing contractor procurement and building operational strategies, they've increased the success of their building performance investments. The project has accompanied a $5.7M annual reduction in energy costs for an institutional customer.

The following are key impacts the program has had on the design, construction and verification of facilities improvements.

- A dedicated team of people are responsible for the portfolio - managing the EMIS's expansion, energy tracking, building analysis and remediation.
- A *High-Performance Building Standard* was created to establish a BAS point-naming convention and standardize the trend data collected for common equipment types.
- A new level of design review was implemented with emphasis on the SOO specification.
- Engineering firms and commissioning providers use the EMIS to evaluate control contractor work in parallel and to review the functionality after occupancy.
- The client effectively evaluates service providers (engineers, controls contractors, commissioning agents, etc.) and the high performers receive more work.
- The EMIS is being used to analyze the results of Energy Savings Performance Contracting projects and may be used to develop an ESPC model that makes performance guarantees based on EMIS.

Creating feedback loops that enable building owners, operators, service providers and utilities to understand building performance, more effectively recognize best practices and improve the caliber of services delivered in the market has tremendous value.

Energy Efficiency Programs

EE programs face barriers to capturing the savings and market benefits that can be driven by supporting EMIS and ABEM. In this section we outline some of the key program attributes, costs and savings that can be anticipated from an ABEM program.

Capacity Building

Due to market barriers such as unfamiliarity with and the upfront cost of an EMIS, EE programs will need to foster some of the capabilities necessary to support broad deployment of the ABEM approach. Two key areas for capacity development are green champions who can help to advance these projects at customer sites and engineering and programming skills development.

Green Champion Development

In researching the literature, creating "Green Champions" has not been undertaken by the EE industry. While many papers recognize the importance of champions in advancing energy efficiency, the concept of efficiency programs developing champions has not been explored.

Project champions fulfill a variety of critical roles, including ensuring organizational alignment, matching the project objectives to the organization's strategic plan, identifying and proactively addressing project barriers, communicating project status and needs with management, and resource management to support project completion (Miles 2013).

While EE programs support operator training, there is no evidence that they have engaged in supporting their customers in developing the internal resources necessary to foster a culture of energy efficiency. While programs often target the largest customers with programs like Strategic Energy Management, and those customers frequently place high value on the cultural change, there is a lot of room for programs to help businesses develop internal champions who can assist in improving operations. Scotland has an online program for Green Champion development which could serve as a model (Green Champions Training).

Support the Provider Field

EE programs should work with the market to identify resource constraints. Working with job training programs, they can provide policy and potentially economic support to develop the workforce necessary to design and deploy EMIS, engineer solutions, program controls effectively and operate buildings at peak performance.

The EE programs are well positioned to provide and support training on advanced SOO so that engineers and controls programmers are familiar and increasingly comfortable with leading-edge mechanical system optimization.

Market Potential and Economic Case

Drawing on data available from recent studies completed in Massachusetts, we developed estimates of the market potential for an ABEM program in that state. The MA Market Characterization study showed that over 80% of customers with annual electric consumption over 4,500 MWh annually and more than half of the customers with consumption between 500 and 4,500 MWh annually have BAS systems (Massachusetts Program Administrators Research Team and Energy Efficiency Advisory Council EM&V Consultants 2016).

Using these data on BAS market penetration and customer data from the MA Customer Profile Report, we analyzed the potential for an ABEM Program to deliver savings for the largest customer cohorts in MA, as shown in Table 3 (Massachusetts Program Administrators and Energy Efficiency Advisory Council 2018). Assumptions include (1) applying the average market penetration evenly within each size cohort, (2) assuming all facilities with BAS have the technical potential to implement ABEM, (3) ABEM savings estimates of 20% to 10% and achievable potential ranging from 65% to 75% from med-large to the very large cohorts, and (4) a measure life of 15 years due to the ongoing monitoring of the EMIS. This analysis shows significant potential for ABEM programs.

Table 3. MA ABEM savings potential (annual MWh)

Size Cohort	Accounts	2015 Total Consumption	Consumption: Accounts with BAS	Tech Potential	Achievable Potential
Med - Large	6,787	2,352,618	941,047	188,209	122,336
Large	6,142	6,529,587	3,917,752	587,663	411,364
Very Large	1,647	12,139,136	9,711,309	971,131	728,348
Total					1,262,048

Savings persistence and transparency are inherent in the ABEM approach. Rather than claiming the typical 3 to 7-year measure lives associated with RCx programs and hoping that when the project is evaluated the M&V contractors can find the measures and quantify the savings, deployment of ABEM ensures that measures persist and are verified as delivering savings on an ongoing basis. This increases annual savings and reduces coefficients of variation, driving down the cost of evaluation over time.

Program implementation costs shown in Table 4 assume incentives at 50% of the project cost, including the upfront engineering, hardware and software necessary to deploy ABEM as well as the implementation of efficiency measures.

Table 4. ABEM EE program cost effectiveness

Project Count	Average Project Cost	Total Project Cost	Utility Cost (Incentive)	Cost per MWh Annual	Cost per MWh Lifetime	Cost per kWh Annual	Cost per kWh Lifetime
1765	$100,000	$176,462,000	$88,231,000	$721	$48	$0.72	$0.05
2580	$200,000	$515,928,000	$257,964,000	$627	$42	$0.63	$0.04
988	$600,000	$592,920,000	$296,460,000	$407	$27	$0.41	$0.03
5332		$1,285,310,000	$642,655,000	$509	$34	$0.51	$0.03

These numbers compare favorably with current spending levels for C&I energy efficiency (Mass Save Data 2017), which reports $0.32 annual and $0.03 lifetime cost per kWh. Mass Save had about 50% of savings coming from typically lower cost lighting measures.

Program Design

The program design that we recommend for supporting the increased application of ABEM, shown in Figure 1 below, is similar to an approach that has been successful in increasing market adoption and success for traditional RCx projects. As part of the program design, EE programs should use longer contract terms for customers and vendors and claim savings and provide incentives over time as improvements are identified and implemented. Evaluation should look at the projects with an understanding of the links between ABEM investments and savings year over year.

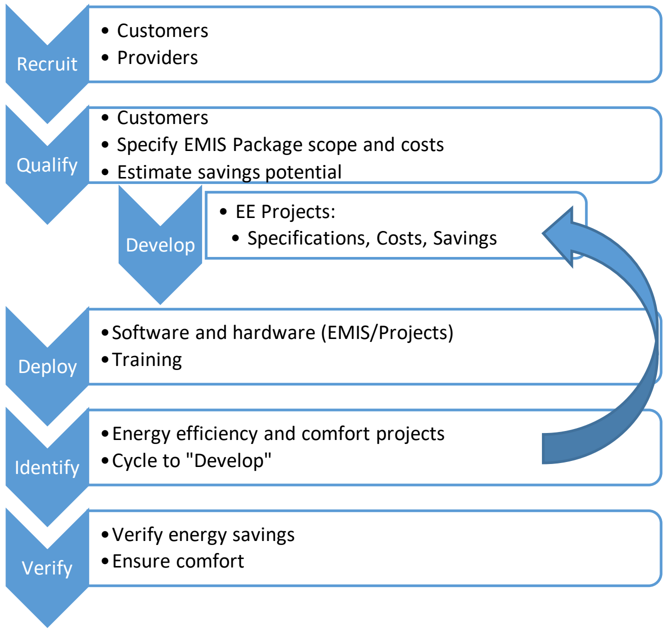

Figure 1. ABEM program design

EE programs play a critical role in recruiting projects for the ABEM approach. All managed accounts should be directly targeted with outreach and matchmaking with qualified vendors. Medium-large customers who may not have an account manager should receive mailings and be encouraged to inquire about the potential to enroll in the ABEM program. The program administrator should have clear internal channels to address inquiries about ABEM. The customer economics of these investments are very strong and should be incorporated in sales materials. With a 50% utility incentive, our analysis shows that projects are typically cash-flow positive by year three.

The EE program should assist in the ABEM vendor selection process. Because the availability of EMIS services is rapidly expanding, we recommend that programs develop a pool of EMIS providers rather than sole sourcing these programs. Selection of ABEM providers should occur using a negotiated process during the qualification phase. Lowest first cost is not an indicator of success for ABEM projects. A standard format for providers to submit qualifications and typical price structures should be provided by the EE Program. Interviews with ABEM providers should focus on customer service and technical capability to identify and support execution of mechanical system operational optimization over time. Ultimately the selected ABEM provider will have a long-term relationship and will need to be highly compatibility with the customer.

Project qualification should occur through a collaborative process. The ABEM provider, EE program engineer, and customer site engineers and management should meet to review the current state of operations, assess the potential applicability of the EMIS system, and determine the ability and willingness of the customers to undertake the measures identified through the ABEM service. Using a negotiated approach, the ABEM provider enters the qualification phase as a business development exercise, using it to inform their pricing. The qualification meeting should address pain points, maintenance issues, review of BAS system points and trends, review of IT security protocols and a path for data access in conformance with IT requirements, review of energy consumption and cost information and identify the internal project champion.[1] A site walk through should follow the meeting.

Based on this information, the ABEM vendor should provide a project-specific specification identifying in detail the level of tracking and analysis provided, project price and schedule for implementation of the EMIS and identification of EE projects. The efficiency program lead, the customer champion and customer decision maker, and the EMIS provider should meet to review the cost proposal and negotiate the final scope and costs. The EMIS contract should include language that will ensure timely execution and validation of the EMIS to ensure project execution.

Retainage for such projects should be at least 25% and potentially higher. EMIS systems are of zero value until complete; the last 10% of the project is both the most challenging to execute and essential for results. The efficiency program should provide a 50% incentive for the EMIS similar to what is typically provided for other custom projects for large customers.

Program Implementation

The ABEM vendor works directly with the customer to deploy the EMIS, providing evidence of system completion and validation to both the customer and EE program to receive final payment. The EMIS is then used to identify energy efficiency opportunities and comfort issues with targets for new annual energy savings in the first three years of deployment.

Once the EMIS is fully implemented, the ABEM vendor begins identifying and developing projects. Project deployment includes the EE program, ABEM, customer and third-party professionals and contractors.

Accurate specification of EE projects is an important component of this program. It is essential that the EMIS provider have the capability to develop the detailed SOO necessary to achieve efficient operations of facilities and that the customers and their controls contractors be committed to undertaking new operational protocols. Measures arising from ABEM will include those that can be completed by facilities staff (such as addressing leaking valves and dampers) and those that require engineering and contractors to implement (such as new sequences of operations). Continuous validation of the performance of the upgrades, coupled with transparent reporting, is provided to the customer and the EE program by the ABEM vendor. This allows the EE program to prove persistence of implemented measures and continued benefit of the ABEM program.

Similar to the savings recognition cycle for program-funded RCx studies or energy audits, EMIS-driven savings should be claimed upon the completion of the EE projects for which they accrued and linked to the upfront investment in the system that drove the project's development. Program tracking systems may need to include fields that tie EMIS projects together to enable EE providers, evaluators and regulators to understand the full scope and benefits of investments over time.

Conclusion

At the concept stage, this paper's focus on "driverless buildings" was looking towards a future where buildings require minimal hands-on operational engagement because they are so

[1] IT interface requirements can be a significant time and cost barrier to EMIS deployment and must be addressed early to ensure success.

well connected and monitored that they consistently operate fault free. However, reality tells us that we are long way from such a paradigm. Research on advancing RCx and EMIS to support ABEM indicates that one of the most critical ingredients for success is people. Even with rigorous continuous data analytics, engineers are needed to provide non-routine data assessment, solve problems identified by the data and specify fixes; contractors are needed to implement the fixes; and building operators are needed to facilitate the projects. Our goal in promoting "driverless" is to set up the systems that will reduce the amount of manually controlled systems and buildings. By providing teams with the tools to improve automation and alert operators to degradation of mechanical systems over time, buildings will run more efficiently, delivering the amenities for which they were designed. The end goal is intelligent, human-responsive buildings that measure and balance their energy use and consistently deliver occupant comfort with minimum energy inputs and human intervention.

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