

Ignorance is BAS: How EMS/BAS Operator Knowledge

Can Impact Performance

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ABSTRACT

Energy Management Systems (EMS), also known as Building Automation Systems (BAS), are used widely by commercial and industrial (C&I) buildings. Improving the operation of EMS/BAS is a promising source of future energy savings. A 2017 study from the Pacific Northwest National Laboratory found average energy saving of 29% across different building types by implementing a package of control-based energy efficient measures.

However, whether these potential energy savings can be realized depends on the knowledge of the building managers who operate these EMS/BAS systems. This paper explores different aspects of this knowledge including whether building managers run their own systems (vs. outsourcing controls to vendors), how much training they receive, whether they are concerned about EMS/BAS operation expertise leaving the company, how well they can gauge the performance of their systems, and whether they are aware of new improvements in EMS/BAS programming such as ASHRAE Guideline 36.

The paper will address these and other questions by summarizing a 2021 study that involved in-depth interviews with over 40 EMS/BAS operators and EMS/Retro-commissioning (RCx) vendors. The study also analyzed screenshots of EMS/BAS frontends to check whether systems were performing as well as operators had self-reported. Finally, the paper will discuss barriers that prevent operators from improving the performance of their systems.

Introduction

The primary objectives of this study were to identify Industry Standard Practices (ISPs) for EMSs in existing buildings and better understand the impacts of these practices. Specific research objectives the study covered included:

- How end use customers use their systems including which building functions they manage/monitor, what control sequences are typically installed, who in their company uses the system, what training they typically receive, whether they have concerns about the loss of system operator expertise, and how frequently they use or alter their systems,
- The level of energy savings that EMS/BAS systems and retrocommissioning (RCx) can produce,
- The frequency and impacts of partially functional EMS/BAS systems,
- The frequency and impacts of failed systems,
- The frequency of EMS/BAS upgrades and replacements and what factors drive these upgrades/replacements, and
- The level of vendor and end user awareness of ASHRAE Guideline 36.

Methodology

The study team used five different data collection and analysis activities to understand how EMSs are being used, maintained, and upgraded:

1. *EMS/RCx vendor interviews*: The study team completed in-depth interviews with 17 vendors who install, operate, and maintain EMS/BAS systems as well as those who commission or retro-commission (RCx) systems. These interviews were completed during the December 2020-January 2021 period.

2. *EMS/BAS customer interviews*: The team completed in-depth interviews with 26 C&I customers who operate EMS/BAS systems. These came from the sample frame of a Massachusetts C&I baseline study and included a mix of energy-efficiency program participants as well as nonparticipants. These interviews were completed during the December 2020-February 2021 period.

3. *Analysis of EMS/BAS frontend screenshots*: The team collected screenshots from the frontends of the EMS/BAS systems belonging to interviewed customers who had claimed that their systems were operating in an optimal manner. It then analyzed these screenshots to determine whether these systems were in fact operating in an optimal manner.

4. *Building code review*: The team reviewed Massachusetts state building codes to determine the minimum requirements that EMS/BAS systems in new buildings must meet.

5. *Review of EMS/BAS impact evaluations*: The team reviewed recent estimates of energy savings for EMS/BAS systems that had been produced as part of a custom program impact evaluation.

The sample frame for the EMS/RCx vendors came from 2018-2019 Massachusetts program tracking data and included 61 vendors. The study team attempted to complete interviews with all these vendors through a combination of emails and phone calls. The team was able to complete 17 interviews. There was also one partially completed interview.

The sample frame for the EMS/BAS end users came from a Massachusetts baseline saturation study for existing buildings. The initial frame included 58 companies which had an EMS/BAS. However, after the baseline study team finished contacting many of these firms in November 2020 to collect non-EMS/BAS baseline information, six end users indicated that they did not want to be interviewed a second time to cover their EMS/BAS. So, this reduced the size of the EMS/BAS end user sample frame to 52 companies.

Despite the challenges posed by the pandemic, the DNV team was able to complete 26 interviews, a 50% response rate. There was also one partially completed interview (which explains why some questions have a sample size of 27). The following tables show the sample frame and disposition of EMS/BAS end users by building type (Table 1) and by company size (Table 2). These tables show that the most common building types were office buildings, manufacturing/industrial facilities, and educational buildings. Medium-sized companies also accounted for half the sample.

Table 1: Sample frame and disposition for EMS/BAS end users by building type

End User Building Type	# of End Users in Sample Frame	# of End User Interviews Completed
Campuses	6	3
Education	12	4
Food Sales/Service	3	2
Lodging	3	1
Manufacturing/Industrial	7	5
Office	10	7
Other	2	0
Public Assembly	6	3
Retail	2	1
Warehouse	1	0
Total	52	26

Table 2: Sample frame and disposition for EMS end users by size¹

End User Size	# of End Users in Sample Frame	# of End User Interviews Completed
Large	14	6
Medium	21	13
Small	17	7
Total	52	26

This paper focuses on different aspects of EMS/BAS operator knowledge including the following researchable questions:

- What percent of the systems are run by the building managers vs. being run by outside vendors?
- How much training do building managers receive for operating their systems?
- Are there concerns that in-house knowledge of system operation will be lost due to an aging workforce?
- How well can building managers gauge the performance of their systems?

¹ These end user size designations came from the 2016 Massachusetts baseline study (MA C&I Market Characterization On-Site Assessments And Market Share and Sales Trends Study, November 2016) from which this study's sample frame was derived. This study defined large customers as consuming >4,500 MWh annually, medium customers as consuming 500-4,500 MWh annually and small customers as consuming < 500 kWh annually.

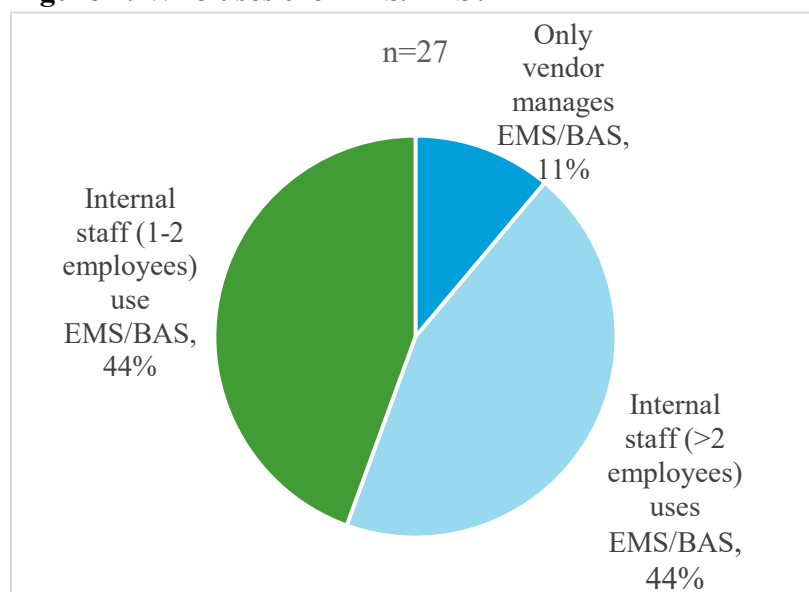
- Are building managers aware of new improvements in EMS/BAS programming such as ASHRAE Guideline 36?

Findings

Who operates the EMS/BAS?

The study team asked the end users: "Who within your company uses the EMS/BAS?" Figure 1 shows that only a small percentage (11%) of the end users ceded management of their EMS/BAS to an outside vendor. It also shows that nearly half (44%) of the companies have only one or two employees using the system. This limited access puts these companies at greater risk of the loss of institutional knowledge if the companies experience staff turnover. However, this limited access also likely reduces the chance that less-knowledgeable employees might override EMS/BAS functions that should not be overridden.

Figure 1: Who uses the EMS/BAS?



Training for EMS/BAS operation

The team asked the vendors what kind of training they provided to customers when they installed or upgraded EMS/BAS systems. All the vendors offered training, but the length of these trainings ranged widely from one hour of remote training to two days of onsite training. One vendor said that the length of the training depended on the size and complexity of the new EMS/BAS. Another said they do an initial training with the customer, then return a couple of months later to re-train the operator after they have had a chance to use the system and to answer any questions they may have. A few of the vendors provided brief descriptions of the content of these trainings:

- *They should know how to log in, who has access to change commands or setpoints, should know how to change things. More importantly what not to do. How to review alarms how to clear alarms. How to set up trends. How to interpret analytics, if purchased.*

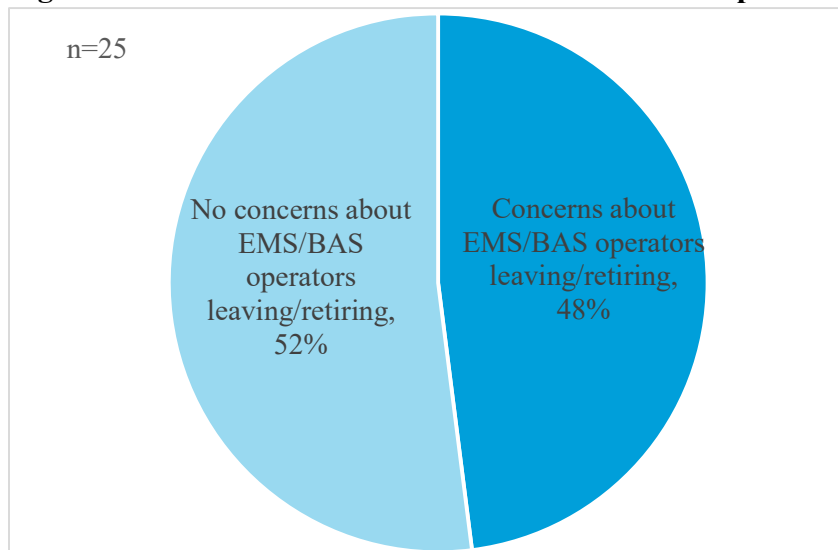
- *It involves going through what the sequences are, and why they were designed that way, what can and should be adjusted, and what should be left alone and not overridden. And a lot of education as to what those sequences should achieve so operators don't override them. We do the 3 seasons of trends (cooling, heating, swing). Are they operating well? Are they operating in different conditions?*

However, one EMS/BAS end user observed the limitations of training: “You can train, but if you don't use [the EMS/BAS] regularly, you forget.”

Concerns about loss of system operator expertise

The team asked the end users: "Does your company have any concerns that the staff operating this EMS may leave/retire?" Figure 2 shows that about half (48%) of them had such concerns.

Figure 2: Are end users concerned about EMS/BAS operators leaving/retiring?



Some of the end users elaborated on these concerns:

- *Absolutely, we really only have two staff who are full time. We rely heavily on contractors. The continuity of having those two guys managing that whole system [is at risk]. Losing one of those guys would be devastating to the university. We are hoping to develop an internal team and an internal programmer. That might alleviate that problem. We really need to build a staff that can share that knowledge – e.g., where everything is.*
- *That is happening with me. When I retire in next two years. That is a problem with all munis. No one sits in and gets trained. We do have contract with a vendor for the next 5 years. They have been with us for 25 years. It is almost a proprietary spec, so we need someone who understands their equipment. Other firms may not have the right expertise or programming knowledge. While many EMS companies say they are not proprietary, I disagree with that. Our systems do not work with other systems. There are programs within programs. For instance, we tried to change a setpoint, we did everything, but it still stayed at current value.*

The EMS/BAS end users who were not concerned about the loss of operator expertise either said that they had an active program for training up junior staff, had some redundancy in their

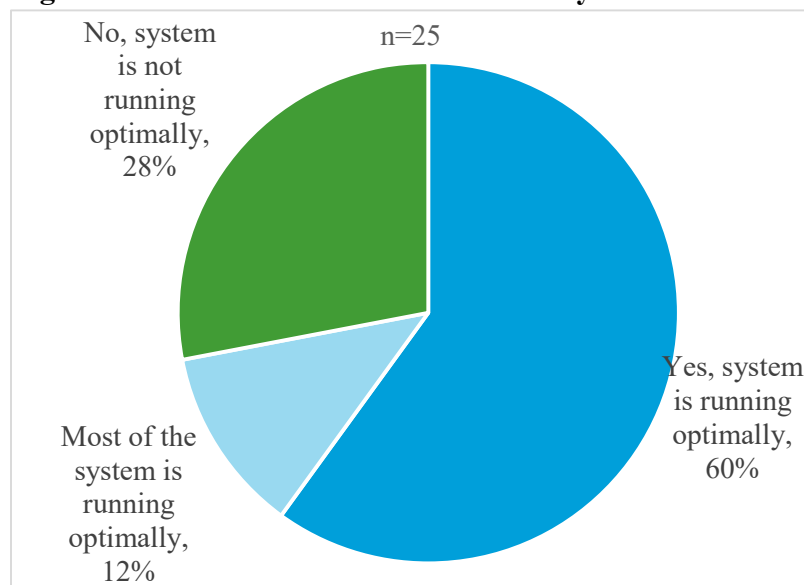
operator expertise, or had a long-term relationship with an EMS/RCx vendor which they thought could compensate for any losses in in-house expertise.

The capability of building managers to gauge the performance of their EMS/BAS

The study asked the end users: "Is your company's EMS/BAS functioning in an optimal manner?" Figure 3 shows that most (60% of respondents) reported that their systems were functioning optimally with only 28% saying that their systems were not functioning optimally.

Some end users who said that their EMS/BAS was functioning optimally added some qualifiers to their responses. For example, one noted that while their system was running optimally, he had not taken full advantage of all the capabilities of the system, such as receiving alarm signals on his smartphone. Another end user reported that while their system was working optimally for the building it controlled, it did not cover some buildings that were still on older pneumatic systems. One respondent commented that 95% of their system was functioning optimally and "the other 5% we can live with."

Figure 3: Whether end users think their systems are functioning optimally



The study team then did additional analysis to determine whether end user claims that their EMSs were functioning in an optimal manner could be assessed through an analysis of the screenshots/pictures of the frontends of their systems. The team randomly selected five EMS end user sites from the subgroup of 15 end users who had said that their EMS/BAS was functioning in an optimal manner.² For each site, the study team tried to answer the following questions:

- 1) What are the indicators of suboptimal performance for this system?
- 2) Was there adequate information from the EMS frontend photos/screenshots to determine if the system was operating in an optimal manner?

² Preliminary analysis from the study team determined that for two of the five initial sites the information in the screenshots/pictures was insufficient to make an adequate determination of EMS functionality. Therefore, the study team replaced these two sites with two new randomly selected sites that had adequate frontend information for the analysis.

- a) [IF YES] What conclusions could be drawn from the EMS frontend photos/screenshots about whether the EMS was functioning in an optimal manner?
- b) [IF NO] What information is missing for determining whether the EMS is functioning in an optimal manner?

The study team analyzed screenshots from these five sample buildings. Figure 4 shows an example of the study's analysis of one of the EMS/BAS screenshots. The red boxes highlight system indicators that suggest suboptimal performance. For this screenshot, the study team identified the following issues:

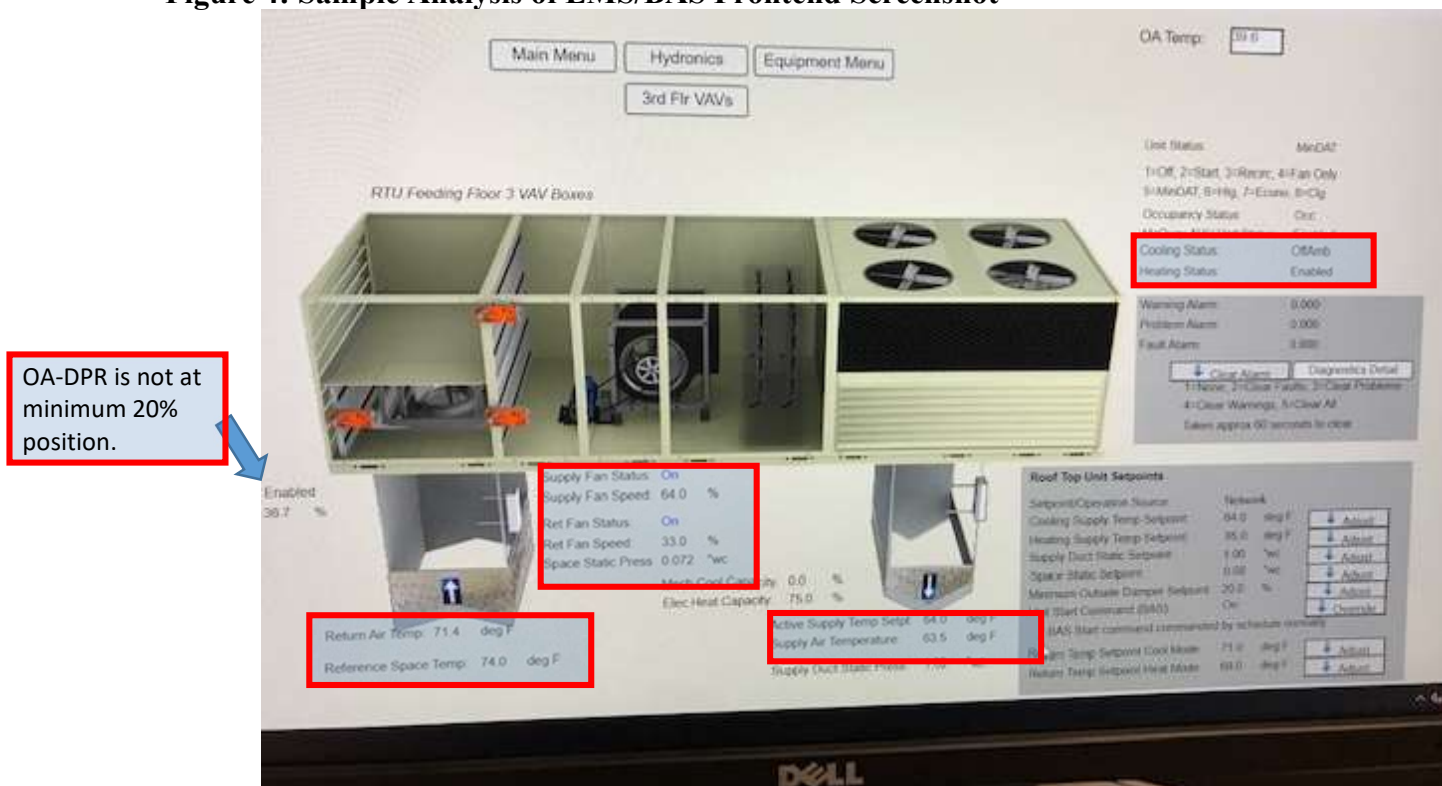
- 1) The return air temperature of 71.4°F should activate the cooling mode but heating is enabled due to the supply air temperature (SAT) being lower than setpoint (SAT-SP).
- 2) The outdoor air damper (OA-DPR) is not at minimum position while the SAT is overshooting its SAT-SP. Modulating the OA-DPR to a minimum position during these instances would reduce overshoot decreasing the unnecessary heating required to raise the SAT back to SAT-SP.
- 3) There is no indication of a DAT reset sequence.
- 4) The supply fan is running at a high speed when compared with the return fan which may be an issue of concern
- 5) The differences between the return and reference space temperatures are potentially high, which may indicate a slight miscalibration.

The study found common issues within the EMS/BAS screenshots for each of the five buildings. These included sensor calibration issues, systems not meeting temperature and pressure setpoints, failed actuators, and missed opportunities to reduce heating/cooling loads. In summary, the analysis suggested that several of the systems which customers described as operating “optimally” were likely not operating “optimally.”

It should be noted that “optimal” is a subjective term that can take on different meanings for various customers. Customers often focus on whether their building zones are meeting setpoints and occupants are comfortable. As a result, they can overlook system and energy efficiency issues and opportunities.

It is also important to point out that the information from these frontend screenshots were only preliminary indicators of EMS/BAS performance issues. To properly verify these issues and assess their impacts, it would have been necessary to examine a broader range of information including sequences of operations, drawings, information on programming logic, and trend logs.

Figure 4: Sample Analysis of EMS/BAS Frontend Screenshot



Awareness of ASHRAE Guideline 36

ASHRAE Guideline 36, High-Performance Sequences of Operation for HVAC Systems, provides uniform sequences of operation for HVAC systems that are designed to reduce energy consumption, cost, and system downtime with more resilient systems, control sequence compliance, and diagnostic software. The guideline also promotes communication between specifiers, contractors, and operators by creating a language of common terms. Guideline 36 sequences can be incorporated into the design of new EMS/BAS systems or programmed into existing systems to improve energy efficiency and system performance.

The study team asked both vendors and end users whether they were familiar with ASHRAE Guideline 36. Only 4 of the 15 vendors (27%) and 2 of the 25 end users (8%) said they were familiar with this guideline.

The team asked the end users: “Are you interested in implementing sequences from Guideline 36 if they can help reduce energy use?” Eighty-eight percent of the end users said they were interested with 12% saying they were unsure.

The team asked the four vendors who were familiar with Guideline 36 how frequently they recommend sequences outlined in Guideline 36. Of the three vendors providing estimates, two said “always” and one said “often.” The team also asked these three vendors: “How frequently are your customers asking for sequences outlined in ASHRAE Guideline 36: Best in Class HVAC control sequences?” Two of these vendors said, “very rarely” and one vendor said “sometimes.”

CONCLUSIONS

Key conclusions that the study reached included:

- *Most end users lack the technical knowledge to adequately assess the performance of their systems.* This study showed that even end users who were confident enough in their knowledge to say that their EMS/BAS systems were operating optimally were unaware of system performance issues that were showing up on their systems' frontend screens. In addition, this study observed that many end users judge their EMS/BAS's performance using narrow criteria such as whether building occupants are complaining about their comfort levels. This causes them to overlook important considerations such as whether their EMS/BAS is saving energy. This lack of knowledge can also cause them to think that energy-saving activities such as retrocommissioning are not needed.
- *There are legitimate concerns about the loss of EMS/BAS operator expertise.* When the study team asked end users whether they had concerns that the staff operating their EMS/BAS systems might leave or retire, about half (48%) of them voiced such concerns. The study also found that many legacy EMS/BAS systems had components that had been cobbled together over many years. This suggested that new system operators would need to get detailed knowledge transfer from the leaving/retiring operators to properly monitor and manage the EMS/BAS.
- *More education on ASHRAE Guideline 36 is needed:* This new guideline High-Performance Sequences of Operation for HVAC Systems provides uniform sequences of operation for HVAC systems that are designed to reduce energy consumption, cost, and system downtime with more resilient systems, control sequence compliance, and diagnostic software. The guideline also promotes communication between specifiers, contractors, and operators by creating a language of common terms. However, this study found that only 27% of the vendors and only 8% of the end users were familiar with this guideline. In addition, when the team asked the end users: "Are you interested in implementing sequences from Guideline 36 if they can help reduce energy use?", 88% of the end users said they were interested with 12% saying they were unsure. This high level of interest among the end users suggests that any educational efforts would have a greater chance of success.

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