2022 RESEARCH HIGHLIGHT

Commercial Building Sensors and Controls Systems: Barriers, Drivers, and Costs

National Renewable Energy Laboratory: Dr. Kim Trenbath, Dr. Ryan Meyer, Dr. Korbaga Woldekidan, Kristi Maisha, and Morgan Harris

A commercial building sensors and controls system can save energy, enable a building to be grid-interactive, and help accelerate decarbonization of the U.S. electric grid. Nearly 60% of commercial buildings over 50,000 square feet in the United States have a building automation system (BAS) to control heating, ventilating, and air conditioning (HVAC), lighting, and more. But only 13% of small- to medium-size (<50,000 square feet) buildings have adopted the technology, leaving over 75% of all commercial buildings in the U.S. primed for opportunity. To support widespread adoption of commercial building sensors and controls systems, the National Renewable Energy Laboratory (NREL) and Joint Institute for Strategic Energy Analysis (JISEA), under the Clean Energy Manufacturing Analysis Center, assessed barriers and drivers for adoption and created a breakdown of costs, including hardware and various installation labor costs. NREL/JISEA collected qualitative data from 21 interviews with 28 experts representing five key industry roles: building owners, contractors, controls vendors, analytics vendors, and researchers. NREL/JISEA also gathered quantitative cost data from original sources, including project invoices and estimates, the RSMeans (RSMeans 2021), available U.S. General Services Administration schedule cost information from various manufacturers, and other cost data provided by interviewees.

Snapshot

- The barriers to adopting building sensors and controls systems include high cost, difficulty in quantifying savings, product incompatibility, inconsistent terminology in vendor communication, lack of economies of scale, system complexity, and lack of expertise.
- The drivers for implementing building control systems include operational benefits, insight into operations, remote access to data, cost savings, energy savings, and ease of use.
- Controllers could be embedded into equipment, similar to how edge computing networks are operated, reducing the number of devices and controllers and the need for specialized labor—potentially offering a more cost-effective solution.
- Consistency and standardization across controls technologies that enhance system interoperability and increase usability may support greater adoption of the systems, especially for buildings that historically have not implemented these technologies.

CEMAC
Clean Energy Manufacturing Analysis Center

Results: Barriers for Implementing Building Control Systems

Interviewees identified different barriers to implementing commercial building sensors and controls systems. Table 1 summarizes the major barriers, or the ones mentioned by multiple interviewees. As shown in Figure 1, barriers fall naturally into three categories: confusing and/or complex systems, lack of user skills, and financial considerations. Notably, high first costs and a lack of quantified nonenergy benefits leads to a perception that return-on-investment targets and short payback periods cannot be achieved. Yet studies have shown that the aggregated impact of widespread adoption may yield a 29% energy cost reduction across the commercial building section (Fernandez et al. 2017).

Results: Drivers for Implementing Building Control Systems

Interviewees identified drivers explicitly or through discussions of what motivated building owners to implement sensors and control systems. Table 2 on the following page summarizes the major drivers in order of emphasis placed by interviewees. Notably, building owners are excited about the operational benefits and insights of sensor and controls systems, including automation of building schedules, seasonal changes, and reduced need to call technicians for system troubleshooting with issues that can be diagnosed by the control system. Also, operational insights like energy consumption or building system performance data could help building owners better understand space utilization, occupancy patterns, and building performance.

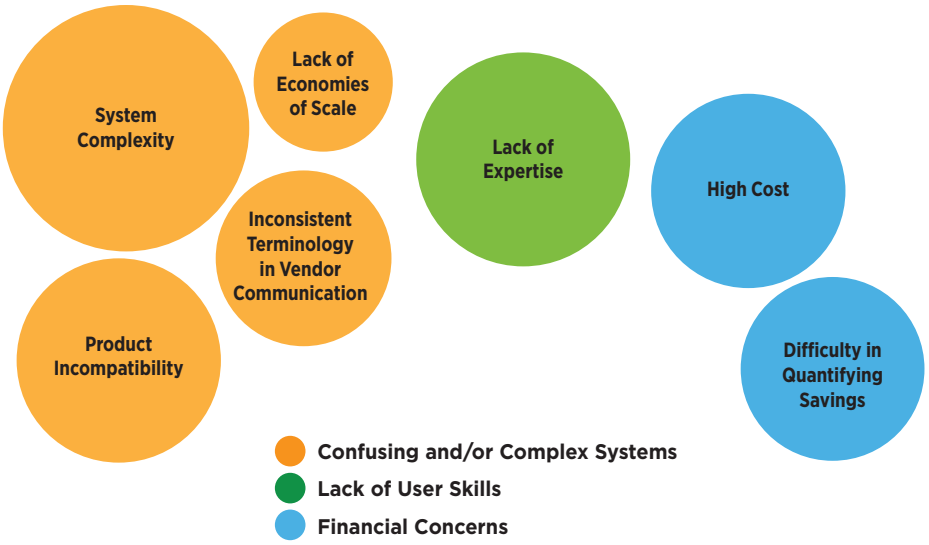

Figure 1. Barriers to implementing commercial buildings control systems

Table 1. Interviewee-Identified Barriers to Implementing Commercial Building Sensors and Controls Systems

Identified Barrier	Barrier Description
High Cost	Systems may fail to meet building owner's investment criteria becsaue of high first costs. In addition, there is a perception that the costs for building sensors and controls systems are too high. This includes installation costs, replacement costs, and operations and maintenance costs.
Difficulty in Quantifying Savings	It is difficult to quantify the full value of building controls, including energy cost savings associated with control system installation and nonenergy benefits such as operations savings.
Product Incompatibility	There is a need for an industry standard ontology for building control systems, enabling plug-and-play applications across vendors.
Inconsistent Terminology in Vendor Communication	Vendor communication to owners can be complicated and inconsistent. Owners and representatives may not have adequate background knowledge of these systems, leading to an inability to make the most appropriate decision.
Lack of Economies of Scale	There is limited cost advantage to scaling down control systems for smaller commercial buildings.
System Complexity	Systems are complex—they consist of numerous devices and controllers that require expertise to effectively and efficiently operate systems.
Lack of Expertise	Often personnel at individual facilitieshave limited training, and have multiple roles, including control system operation; and may have to interface with multiple systems at various facilities.
Other Barriers	Other barriers include equipment complexities, split incentives and associated challenges, and cybersecurity considerations.

Results: Complete System Cost Breakdown

NREL/JISEA identified several categories of labor costs for a complete control system, as shown in Figure 2, including:

- **General contractor fee:** Contractor markup is typically a percentage of project costs
- **Commissioning:** Dynamic confirmation of system performance
- **Installation labor:** Physical labor to install hardware components
- **Testing and balancing labor:** Testing of system operation
- **Programming and graphics labor:** Labor for software programming of control algorithms as well as front-end labor for graphics
- **Engineering labor:** Engineering oversight, design, and specification
- **Hardware costs:** Costs for control system components.

Table 2. Interviewee-Identified Drivers for Implementing Commercial Building Sensors and Controls Systems

Identified Driver	Driver Description
Operational Benefits	These systems modernize building operations and make the building easier to operate, which could translate to other benefits such as improved comfort, energy savings, and other nonenergy benefits.
Insight Into Operations	These systems compile building data that allow building owners to objectively assess the building's status and make appropriate changes. The data allow operators to perform root cause analysis of problems, understand space utilization, and adjust operation to improve performance.
Remote Access to Data	Systems often provide the building engineer with remote access to building operation data, so the engineer does not need to be in the building to control the building.
Cost Savings	These systems can help optimize building performance, saving the owner money over time.
Energy Savings	Sensors and controls systems save energy and reduce peak loads.
Ease of Use	Sensors and controls systems can be straight forward to integrate and they make building operations simpler.

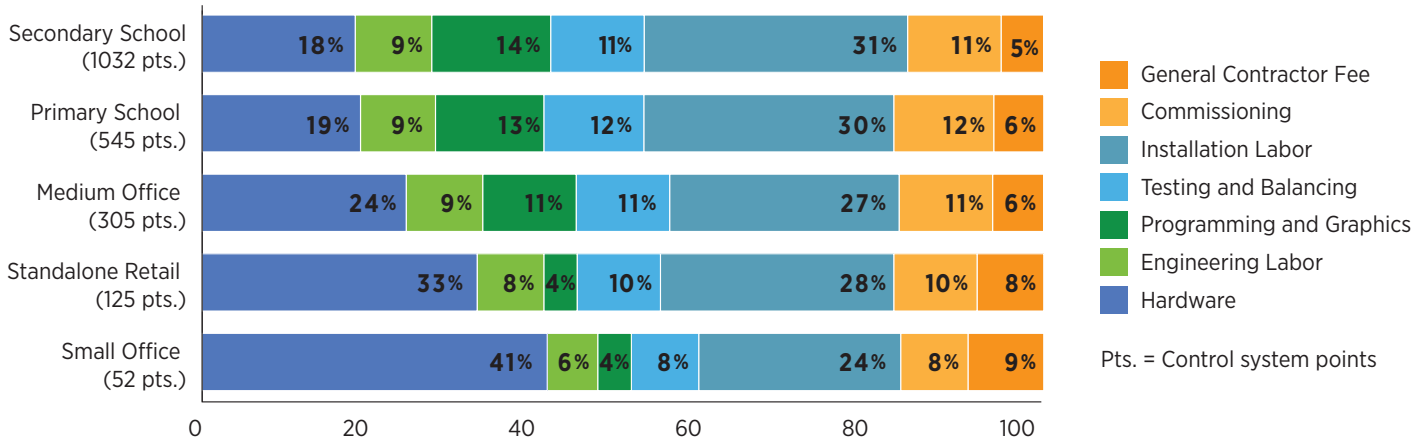

Figure 2. Cost breakdown comparison for complete control systems. More complex HVAC systems require additional time and labor to not only install hardware, but also program control algorithms into the automation system.

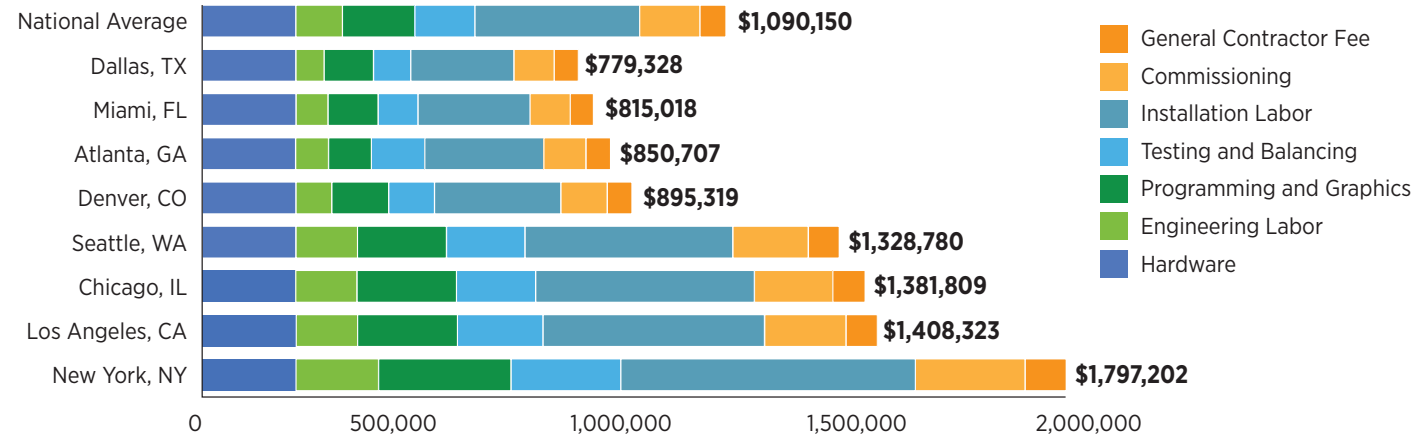

Figure 3. Complete system project cost variations by region for secondary school prototypical building

Labor rates can vary regionally, and contractor pricing and markup can also vary by the service provided and the specifics of negotiations with specific project contractors. Figure 3 shows the complete system project costs for the secondary school prototypical building using labor rates associated with various cities around the United States. As can be seen from the figure, a project that costs $780,000 in Dallas, Texas could cost upwards of $1.8 million in New York City, New York, due to labor rate regional variability.

Conclusion

NREL/JISEA found 50-75% of commercial building sensors and controls system costs come from labor. These systems are complex, which is a significant barrier to adoption that may also lead to specialized labor requirements and associated significant labor costs. Opportunities may exist to more fully utilize embedded controllers directly installed in equipment, similar to how edge computing networks operate. This conceptually reduces the number of devices and added controllers, as well as associated specialized labor to install and program at a building site—potentially offering a more cost-effective solution. Embedding controllers directly into equipment allows for programming functionality to be implemented during manufacturing process in lieu of on-site deployment. Consistency and standardization across controls technologies that enhance system interoperability and increase usability may support greater adoption, especially in buildings that historically have not implemented these technologies.

Only 13% of small- to medium-size buildings have adopted building automation systems, leaving over 75% of all U.S. commercial buildings primed for opportunity. *Photo from iStock 641133838*

References

CBECS (Commercial Buildings Energy Consumption Survey). 2018. "2018 CBECS Survey Data." Washington, DC: U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/index.php?view=characteristics#b6-b10.

Fernandez, Nicholas E.P., Srinivas Katipamula, Weimin Wang, YuLong Xie, Mingjie Zhao, and Charles D. Corbin. 2017. *Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction*. Richland, WA: Pacific Northwest National Laboratory. PNNL-25985. https://doi.org/10.2172/1400347.

RSMeans. 2021. "Construction Cost Estimating Software." Accessed December 2021. https://www.rsmeans.com.

NOTICE

This work was authored by the Clean Energy Manufacturing Analysis Center under the Joint Institute for Strategic Energy Analysis (JISEA). JISEA is operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding for this work was provided by JISEA. The views expressed herein do not necessarily represent the views of the DOE, the U.S. Government, or sponsors.

CEMAC Clean Energy Manufacturing Analysis Center

Operated by the Joint Institute for Strategic Energy Analysis

jisea.org/manufacturing.html

@JISEA1

linkedin.com/company/joint-institute-for-strategic-energy-analysis

CEMAC delivers analysis, benchmarking, and insights of supply chains and manufacturing for advanced energy technologies that can inform decisions to promote economic growth and competitiveness.

NREL/BR-6A50-82750 • May 2022

Cover photo from iStock 1129153792