Building Energy Management Control Systems for Small and Medium Commercial Buildings

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This brief was written by ACEEE Executive Director Steven Nadel. It is based on research conducted for the Industrial Technology Research Institute in Taiwan. *Copyright Energy Administration, Taiwan.*

Abstract

Building energy management control systems (BEMCS) are commonly used to monitor and control many building systems, particularly energy-using systems such as cooling, heating, ventilation, and lighting. These systems are common in large commercial buildings (floor area over 100,000 sq. ft./10,000 sq. meters). Data from the United States indicate that on the order of 70% of medium-sized commercial buildings and 85% of small commercial buildings lack BEMCS. In the United States, such systems can typically reduce the energy use of small- and medium-sized buildings by 10–20%. Such systems can also help to manage peak electrical demand, which provides additional value given the costs of expanding electric grids to serve rapidly growing power demand.

Small- and medium-sized building owners face time, expertise, and financial constraints that hinder adoption of BEMCS. Education, training, and technical assistance programs, along the lines of the U.S. Department of Energy (DOE) Smart Small Business Campaign can help, as can financial incentives such as those provided by Xcel and the New York State Energy Research and Development Authority (NYSERDA), and building performance standards. Ultimately new business models could be helpful to apply creative approaches for financing and maintaining systems while sharing in the economic value BEMCS can provide. Chains offer a good starting place for these efforts as chains have many similar buildings and projects can often be sold to central management in lieu of building-by-building marketing.

Introduction

Building energy management control systems (BEMCS) are commonly used to monitor and control many building systems, particularly energy-using systems such as cooling, heating, ventilation, and lighting. Other names for these systems are common, such as energy management systems (EMS) and building automation systems (BAS). These systems typically reduce building energy use by 10–25% and can also provide other benefits to building owners and tenants such as remote monitoring, faster identification of problems with building system operations, and improved occupant comfort (Srivastava 2025).

BEMCS typically consist of a central monitor and controller and distributed sensors and controllers to monitor and control building operations. An example of a system is illustrated in figure 1.

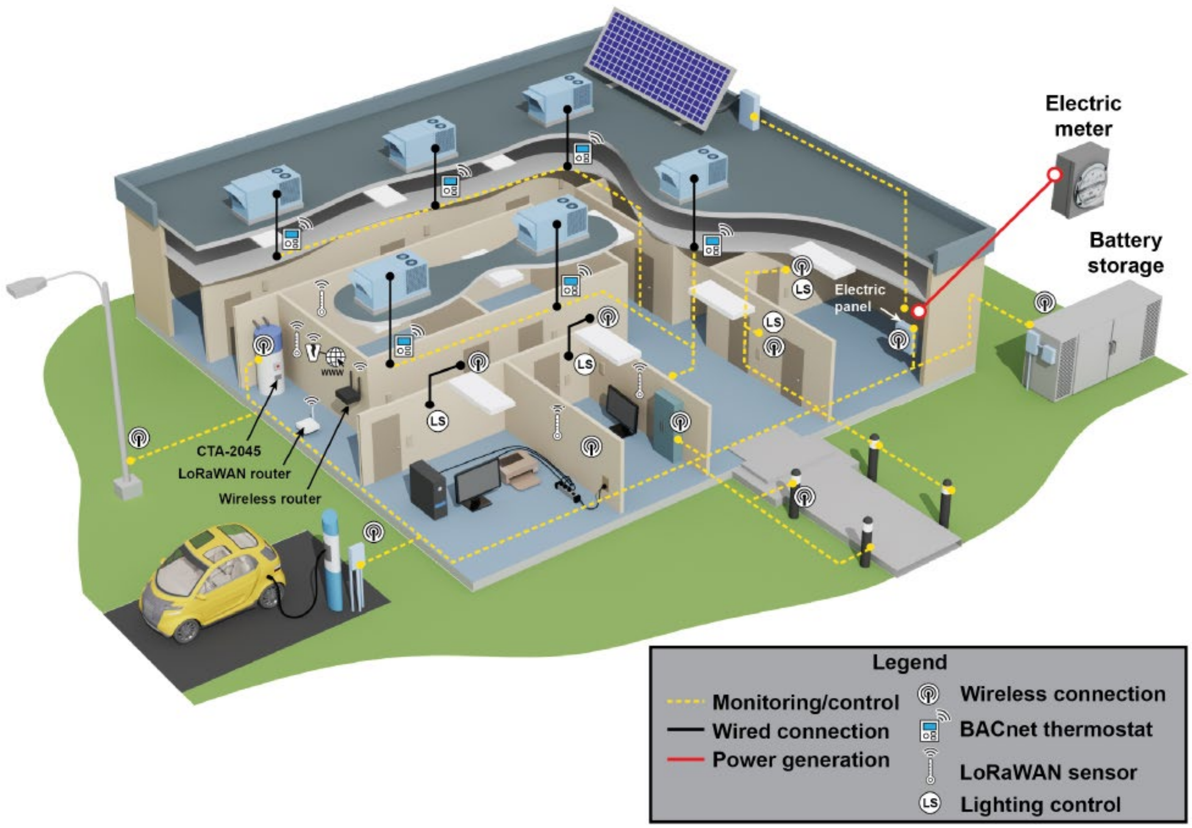

Figure 1. BEMCS system example. Source: Katipamula et al. 2024.

In the United States, a 2018 survey by the Energy Information Administration (EIA) of a representative sample of commercial buildings found that 42% of commercial buildings use such systems, although the percentage of buildings with such systems varies with building size as illustrated in figure 2. About 70% of buildings with a floor area of 100,000 sq. ft. or more (9,290 sq. meters) have BEMCS, while these percentages decline to 26% for buildings of 10,000–50,000 sq. ft. (929–4,645 sq. meters) and 11% for buildings under 10,000 sq. ft. (929 sq. meters).

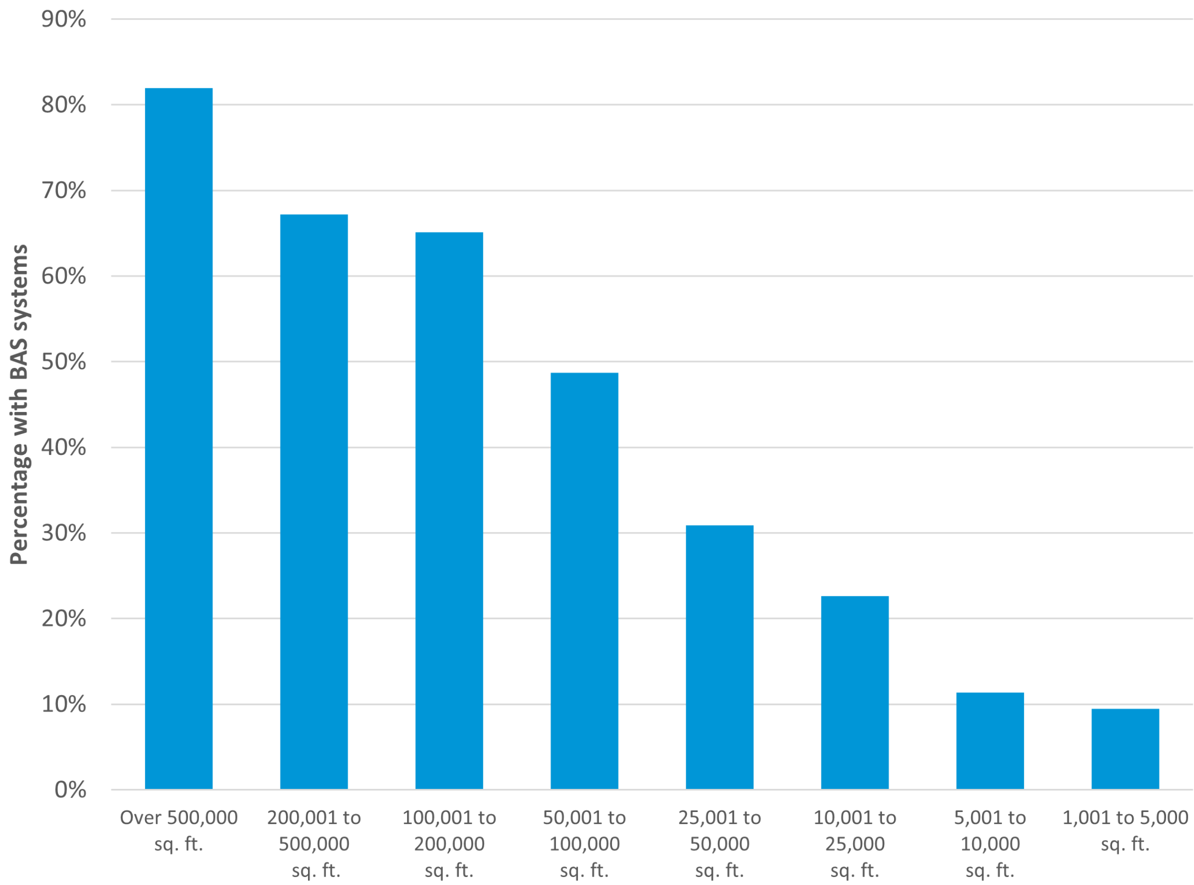

Figure 2. Percentage of U.S. commercial buildings using BEMCS as a function of building floor area. Source: EIA 2022.

This paper focuses on use of BEMCS in buildings of 5,000–50,000 sq. ft. (about 500–5,000 sq. meters). We focus on these buildings because few of them currently use BEMCS despite the fact that they are large and complicated enough to benefit from them. Use of these systems presents a major energy-saving opportunity.

Types of systems and what they control

Lawrence Berkeley National Laboratory (Berkeley Lab), as part of the U.S. Department of Energy (DOE) Smarter Small Buildings Campaign has identified three types of controls used in small buildings (Crowe, Hart, and House 2022):[1]

Networked thermostatic control: Uses networked thermostats communicating to a software platform to enable remote access, monitoring, and control (e.g., setpoint and schedule changes) of multiple single-zone rooftop units from one or more buildings through a single interface of a web or mobile app.

Advanced rooftop unit (RTU) control: Adds control capability that enhances RTU energy efficiency, reduces electrical demand, and/or improves occupant comfort. Examples are demand controlled ventilation, economizer control, variable speed fan control, and dynamic multiunit coordination. These

[1] The campaign targets buildings with floor area under 75,000 sq. ft. (about 7,000 sq. meters).

capabilities can be implemented through the addition of hardware components (e.g., controllers, actuators, sensors) and associated software, or through software alone. These controls also enable remote monitoring of multiple RTUs from one or more buildings through a single interface of a web or mobile app.

Light commercial building automation system: Provides Advanced RTU Control and can integrate and control more complex heating, ventilation, and air-conditioning (HVAC) equipment and systems such as RTUs with variable air volume (VAV) distribution systems. Some of these systems can integrate and monitor other energy end uses and provide on/off control of lighting, pumps, fans, and other equipment.

Of these three types of systems, the last one is essentially a smaller and simpler version of the BEMCS used in larger buildings. The smaller/simpler systems tend to cost less and be easier to install and operate. The controller for these systems tends to cost on the order of $5,000, but this does not include thermostats, sensors, wiring, and installation, which can easily raise the installed cost to $20,000 or more (S. Katipamula, staff scientist, Pacific Northwest National Laboratory, pers. comm. May 2025). The first two types of systems listed above are simpler and less expensive, but confined to just controlling the heating and cooling system.

These definitions emphasize rooftop air conditioning units, a cooling system very common in small commercial buildings in the United States. These systems also often provide space heating via electric resistance coils, a heat pump, or a gas furnace integrated into the RTU. Other common types of cooling systems for small commercial buildings are mini-split systems (separate systems serving just one or a few rooms) and variable refrigerant flow systems (essentially an expanded and sophisticated mini-split). These three types of cooling systems are illustrated in figure 3.

Figure 3. Common cooling systems for small commercial buildings. Rooftop unit on the left, mini-split in the center, and variable refrigerant flow (VRF) on the right.

BEMCS availability and use for small and medium buildings

The DOE Smarter Small Commercial Campaign has identified 28 different BEMCS products for small commercial buildings available for sale in the United States. An extract from their product list is shown in figure 4. These are primarily designed to control rooftop HVAC units.

Manufacturer	Solution	Networked Thermostatic Control	Advanced RTU Control	Light Commercial BAS: Integrates with Multiple-Zone HVAC Systems	Light Commercial BAS: Integrates with Other Energy End Uses	Components
ENTOUCH	ENTOUCH.one Primary Controller + ENTOUCH.cloud	✓	✓			ENTOUch.one primary controller and ENTOUCH.cloud analytics engine
	ENTOUCH.one Product Line + ENTOUCH.cloud	✓	✓	✓	✓	ENTOUCH.one family of products and ENTOUCH.cloud analytics engine
GridPoint	Energy Optimization Platform	✓	✓		✓	Controller, networked thermostats, sensors, energy meters, and Energy Manager cloud platform
Honeywell	Remote Building Manager Express	✓	✓		✓	Honeywell TC500A commercial thermostat, GW-1000 gateway, IO-10MIXR I/O module, and Supervisor cloud platform
JCI	Verasys	✓	✓	✓	✓	JCI Verasys family of products
Lynxspring	JENEsys Edge®	✓	✓	✓	✓	JENEsys Edge® 534 Niagara 4 Programmable Logic Controller, third-party communicating thermostats, touch screen display, and Connexxion cloud platform
Monaire	Monaire - AI Powered HVAC/R Management	✓	✓			Thermostats, wireless sensors, gateways, cloud-based AI algorithms, web and mobile apps, and contractor services
Network Thermostat	X-Series Thermostats & NetX-Cloud	✓	✓	✓	✓	X-Series thermostats and NetX-Cloud
Pelican Wireless	Pelican Climate Management	✓	✓	✓	✓	Pelican Climate Management family of products

Figure 4. Illustrative extract from Smarter Small Building Campaign Categorized Listing of Packaged Rooftop HVAC Unit (RTU) Controls. Source: www.smartersmallbuildings.lbl.gov/guidance-documents.

The Pacific Northwest National Laboratory (PNNL) is also developing a low-cost BEMCS for small and medium-sized commercial buildings using off-the-shelf components. This system is designed for managing rooftop units, hot-water heaters, connected lighting, solar, and storage in small/medium all-electric buildings. They provide component lists and installation suggestions. They are targeting a cost between $0.6 and $1 per sq. ft. (with a simple payback of less than three years at an electricity price of $0.1/kWh). Initial case studies show energy savings of 20–25% and demand flexibility of 10–20% (Katypamula et al. 2022).

Energy savings in small and medium buildings

Crowe, Hart, and House (2022) estimate 10–20% HVAC savings in small and medium buildings from control improvements, but give some examples of projects that range from no savings to over 50% savings. They summarize savings from seven different studies—their summary is reproduced in the appendix to this paper. Preliminary data from a field test of the PNNL system indicate a similar range of savings.

In the United States, the Commercial Building Energy Consumption Survey (CBECS) estimates that HVAC accounts for an average of 52% of commercial building energy use (EIA 2022). If we assume 10–20% average HVAC energy savings in the United States, across all commercial buildings of 5,000–50,000 sq. ft., energy savings would be 16–32 billion kWh of electricity and 87–173 trillion Btu of natural gas. These figures are 2% of electricity use of all commercial buildings (all sizes and end uses) and 6% of all commercial building natural gas use.

Challenges

A variety of challenges stand in the way of widespread use of BEMCS in small and medium commercial buildings:

- Control technologies for small buildings are not well known by building owners and claims of high energy savings may appear to be too good to be true.
- Advanced controls cost money and take time to implement. Small and medium commercial building owners often lack the money, time, and expertise to undertake these projects. Few of these firms have an energy manager and instead energy might be just a small part of someone's job.
- HVAC firms that work with small- and medium-sized commercial buildings are set up to sell new systems but not controls. Their staff are often not proficient on selling, installing, and maintaining advanced control options and when staff are trained, they sometimes move to other jobs and the process may need to begin again.
- It takes time to educate customers on controls and convince them to make investments. Small building owners can be particularly hard to reach. The time required will often earn a greater monetary return by emphasizing bigger medium-size buildings as well as large buildings that do not yet have some type of BEMCS. Another potentially profitable route is to sell to chains and owners with many buildings.
- Systems need to be installed properly and maintained properly for optimum results. This requires well-trained contractors and businesses who can efficiently provide follow-up services.
- For control manufacturers, some large companies may fear that simple control systems designed for small buildings could cannibalize sales of their larger, more expensive systems.
- New, smaller control companies have entered the small building controls market, but building owners often do not know or trust these firms to both have good products and service and to be around in the future to address any problems that arise.
- Owners may have cybersecurity concerns about making building HVAC systems and data available through the Internet.

Several program models can help address these challenges.

Program examples

We are aware of four programs that explicitly target the installation and use of BEMCS systems in small and medium commercial buildings, one each operated by a national government, state agency, university, and utility company. In addition, we discuss the role of building energy performance standards and potential new business models to help sell these controls.

DOE/Berkeley Lab Smarter Small Buildings Campaign

The Smarter Small Buildings Campaign is sponsored by DOE, and managed by Berkeley Lab. The Campaign offers technical assistance and recognition opportunities for improved HVAC controls that can save 10–20% in energy costs for small and medium-sized buildings. They work directly with building owners and managers to reduce energy costs, improve occupant comfort, and meet sustainability goals. They also partner with technology vendors/manufacturers, HVAC contractors, utilities, and other organizations to help lower market barriers to improved building performance.

The campaign includes:

- Downloadable webinars
- Guidance documents and other educational materials
- Technical assistance

The campaign seeks to move building owners along a "stairway to better buildings" as illustrated in figure 5.

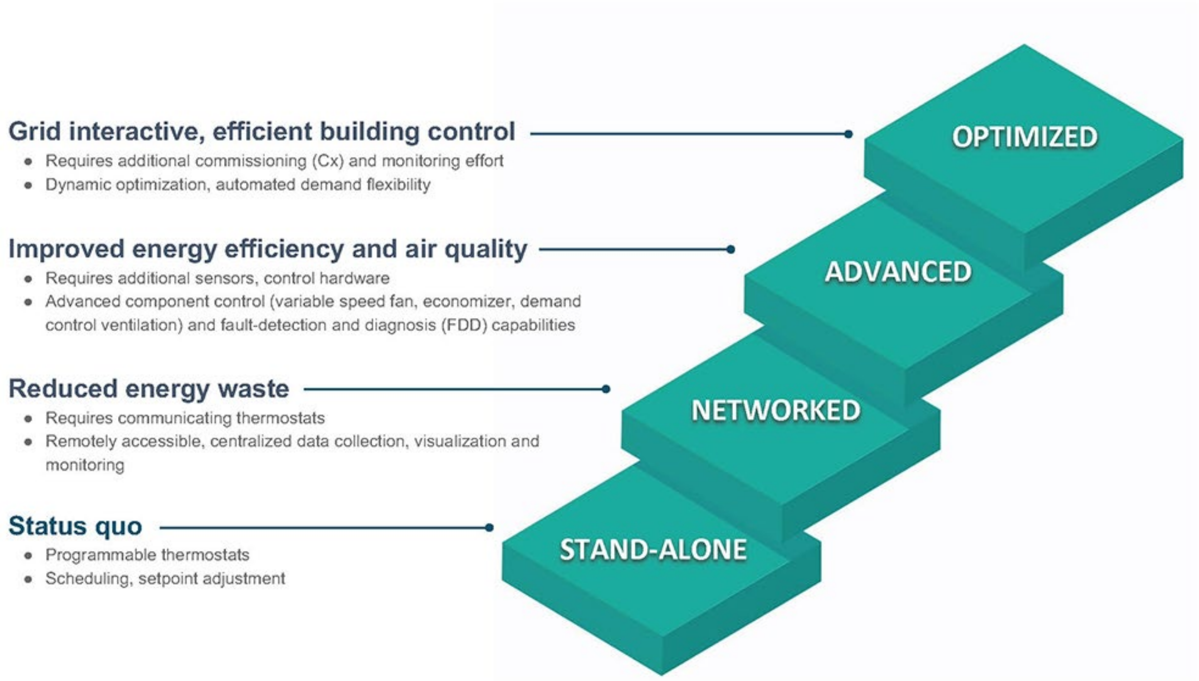

Figure 5. Stairway to better buildings. Source: Smarter Small Buildings Campaign, www.smartersmallbuildings.lbl.gov/about.

Xcel Energy Management System (EMS) program

Xcel Colorado is a large electric and gas utility serving a large portion of Colorado. Xcel's EMS program offers incentives proportional to the volume of energy saved. It is a custom energy efficiency program available to all commercial and industrial customers, but is largely targeted at commercial customers with a demand of 500 kW or greater. Xcel markets the program through trade allies, as well as directly to customers through account managers. In 2015, Xcel expanded the program to include software programs that allow customers to see and analyze real-time energy data. The program covers the entire range of EMS ranging from simple energy information and fault detection systems to more complex systems that enable operators to visualize data and identify low- or no-cost behavioral measures customers can take to reduce their energy usage (ACEEE 2018).

As an example, Xcel provided the operator of a large office building in Denver an incentive of more than $180,000 to purchase EMS equipment including a main server, software, and licenses to control the building's heating, ventilation, and air-conditioning (HVAC) system. The building saw a 20% reduction in overall electricity use (1,116 MWh saved) and a 25% reduction in overall district steam energy use in just six months (Xcel Energy 2015).

The program targets both electric and natural gas customers. From 2012–2016, the program included 316 electric customers and 176 gas customers; this includes some customers who participated as users of both fuels. Expenditures over this period averaged just over $1 million per year (ACEEE 2018). Over the 2017–2021 period an additional 231 projects were undertaken (N. Minderman, DSM policy and strategy consultant, Xcel Energy, pers. comm., June 2023).

In recent years, participation has slowed down as more than half the projects that vendors proposed did not meet cost-effectiveness criteria and could not move forward. After having several projects declined, some vendors stopped submitting projects or submitted in other categories not subject to cost-effectiveness testing at the individual project level. The likelihood that many of the most cost-effective projects have already been implemented probably contributed to these challenges.

An independent evaluation conducted in 2022 (TRC 2023) found that cost effectiveness was being too tightly evaluated and did not account for the fact that customers invest in EMS for multiple reasons, not just cost effectiveness. The evaluation recommended charging only half of the incremental cost against energy and demand savings. The evaluation also recommended adding prescriptive rebates and increased training for trade partners on peak load shifting. Xcel agrees with these recommendations and has proposed to make these changes, while also supporting efforts to bring their controls/EMS and demand response program more closely together.

Xcel Energy has recently found more success with an energy information system offering, which focuses on leveraging the systems that customers already have in place to provide performance-based incentives for improved operations (Xcel Energy 2023; N. Minderman, DSM policy and strategy consultant, Xcel Energy, pers. comm., June 2023).

NYSERDA scaled deployment of advanced rooftop controls program

The New York State Energy Research and Development Authority (NYSERDA) has a history of funding innovative programs selected through a request for proposal process. One program selected this way was a project to promote and install advanced rooftop unit controls on single-speed rooftop systems. This program was implemented from 2015–2018 by the firm Energy Solutions and sought to demonstrate and validate the savings opportunity. Information on this program comes from the project final report (Energy Solutions 2019).

The program installed a specific type of control and variable speed drive that converted the supply fan from single speed to variable speed operation. The program included "Intelligent Controls 101" webinar training sessions for contractors, end users, and utility staff and "Contractor and Customer Engagement Webinars" for the targeted contractor network on the specific control selected, its deployment, and benefits. The program offered a $2,400 incentive to contractors for each control installed.

Over the course of the program 186 controls were installed at 24 sites. Monitoring found 35% average electricity savings and 5% natural gas savings across these sites. They found that the controls were particularly well suited to buildings with long operating hours, large capacity units, and/or sites with proportionately large HVAC loads and variable occupant loads such as restaurants and retail. Another key finding from the program was that successful implementation of advanced controls requires a focus on workforce education and training.

Based on their program experience, Energy Solutions recommends that utilities incorporate advanced controls in their programs including large pilot programs or as a regular program measure and further recommends that programs incorporate contractor education and training.

University of California, Davis

The University of California, Davis campus is the second largest campus in terms of student enrollment in the University of California system. There are more than 1,000 buildings on campus including many small ones with less than 5,000 sq. ft. (about 500 sq. meters) of floor area. To help better manage energy use in these small buildings, the university's engineering department set up a system of networked thermostats to monitor and control many of the small buildings. Specifically, simple networked thermostats were selected and installed to replace the original single-building thermostats. These networked thermostats were connected to a web-based portal for monitoring and control. They found that with small customizations, these platforms can be integrated into facility management workflows. The resulting system reduced energy use by 28% (electricity and gas), improved scheduling, and allowed closer management of these systems, and provided significant advantages for maintenance crews since these systems can now be monitored on smartphones or tablets. A grid-responsive load-shedding program was also implemented for additional cost savings. They note that the networked thermostats can also be connected to additional systems such as economizer controls for improved ventilation management and energy savings. Furthermore, with data from these systems integrated centrally, the networked system can also be used for improved analytics and fault detection. A toolkit has been developed to share the program with other campuses, whether for energy savings, improved management of ventilation, or a more proactive maintenance approach (Fauchier-Magnan, Morejohn, and Pritoni 2022).

The possible role of building performance standards

Building performance standards (BPS) set targets for maximum energy use and/or carbon dioxide emissions. They regulate overall building performance, with BEMCS being just one approach for helping to meet these standards. In the United States, 15 states and cities have enacted these standards, as summarized in table 1. These standards typically require building owners to reduce the energy use and/or emissions of their buildings over several cycles. Energy consumption and compliance with BPS are generally monitored via annual energy use benchmarking reports filed by building owners each year using energy consumption data from utilities and fuel vendors. The first tier of required savings typically takes place in the late 2020s as shown in table 1, although for smaller buildings and multifamily buildings, the effective date for the first tier may be delayed until the early 2030s. As shown in table 1, these standards often apply to buildings with floor areas over about 20,000–30,000 sq. ft. (1,858–2,787 sq. meters) and thus often include medium-sized buildings but usually not small buildings. While specific standards vary extensively between jurisdictions, the first tier typically requires 10–20% energy savings. Since BEMCS on average reduce energy use by 10–20%, BEMCS can be an important strategy for meeting initial BPS standards. The jurisdictions with BPS standards would be good locations to target for BEMCS programs.

Table 1. Building performance standards enacted in the United States

Jurisdiction	Year enacted	Building types included	Minimum building size covered (sq. ft.)	Initial year of performance requirements
Reno	2019	C, MF	30,000	2026
Washington, DC	2019	C, MF	10,000	2026
New York City	2019	C, many MF	25,000	2024
Washington State	2019	C, MF	20,000	2026
St. Louis	2020	C, MF	50,000	2025
Chula Vista	2021	C, MF	20,000	2028
Colorado	2021	C, MF	50,000	2028
Boston	2021	C, MF	20,000	2024
Denver	2021	C, MF	25,000	2024
Maryland	2022	C, MF	35,000	2030
Montgomery County, MD	2022	C, MF	25,000	2028
Seattle	2023	C, MF	20,000	2027
Cambridge, MA	2023	C, MF	25,000	2026
Oregon	2023	C, MF	20,000 for C 35,000 for MF	2028
Newton, MA	2024	C	20,000	2030
Evanston, IL	2025	C, MF	20,000	TBD

Note: C = commercial; MF = multifamily. Effective dates shown are for the largest buildings; often smaller buildings and multifamily buildings are given additional time to comply. Source: Nadel and Hinge 2023, supplemented with recent additions.

New business models?

Among the challenges facing BEMCS in small and medium buildings is that customers lack the time and expertise to understand, install, and manage BEMCS. A potential business model is for entrepreneurial firms to provide these services in exchange for a substantial share of the energy savings as well as utility payments for demand response. This cash flow could pay for staff, financing, remote monitoring of controls they install, and troubleshooting when needed. Such a firm would quickly develop expertise in the best controls for different types of buildings and many “tricks of the trade” for installing and troubleshooting these systems. Of course there are substantial challenges. Such a firm would need initial financing and would need to quickly gain a reputation for quality work. Marketing costs could be substantial, necessitating an initial focus on chains and at least medium-sized buildings. Good baselines would need to be established in order to compute savings and clear lines established for maintenance—delineating what is the owner’s responsibility and what is the control vendor’s responsibility.

We have heard about a few instances that incorporate some elements of this potential model. For example, Bank of America had an internal team offering some of these services to bank branches. And GridPoint, an energy management and sustainability services provider, offers remote monitoring for a subscription fee. Further experiments with new business models could be useful.

Conclusions and recommendations

As illustrated by data from the United States, on the order of 70% of medium-sized commercial buildings and 85% of small-commercial buildings lack BEMCS. In the United States, such systems can typically reduce energy use by 10–20%. Such systems can also help to manage peak electrical demand, which provides additional value given the costs of expanding electric grids to serve rapidly growing power demand.

Small- and medium-sized building owners face time, expertise, and financial constraints that hinder adoption of BEMCS. Education, training, and technical assistance programs, along the lines of the DOE Smart Small Business Campaign, can help, as can financial incentives, such as those provided by Xcel and NYSERDA, and building performance standards. Ultimately new business models could be helpful to apply creative approaches for financing and maintaining systems while sharing in the economic value BEMCS can provide. Chains offer a good starting place for these efforts as chains have many similar buildings and projects can often be sold to central management in lieu of building by building marketing.

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Appendix—Energy savings studies

Table 1. Example studies on energy savings from small building control improvements

Title / Date	**Summary Results**
Improving Operating Efficiency of Packaged Air Conditioners and Heat Pumps (PNNL 2014)	EnergyPlus simulation study of advanced control strategies for packaged rooftop HVAC units (RTUs) found that multispeed supply fan control combined with DCV resulted in HVAC energy savings (fan electricity energy consumption, cooling electricity energy consumption, and heating gas energy consumption) of 24% to 35% across four building types and 16 locations.
A Low-cost Centralized HVAC Control System Solution for Energy Savings, Load Shedding, and Improved Maintenance (UC Davis 2022)	Implementation of SWARM at UC Davis has resulted in whole building energy savings ranging from -2% to 52 %, with a median savings of 28%.
Small- and Medium-Sized Commercial Building Monitoring and Controls Needs: A Scoping Study (PNNL 2012)	Case study of a controls upgrade for a 20,000 sq.ft. building. Whole-building energy savings of approximately 22% were estimated using empirical models of pre- and post-upgrade building energy use.
Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction (PNNL 2017)	A simulation study was performed using Energy Plus to evaluate the energy savings that could be achieved through various energy efficiency measures (EEMs) implemented in the control system. National savings of 11% ("efficient") to 48% ("inefficient") were found for stand-alone retail buildings, and 4% ("efficient") to 31% ("inefficient") for strip mall retail buildings.
Deep Savings for Small Commercial Direct Install: A Replicable Model for High Volume, Cost Effective Energy Savings (NBI 2016)	By installing highly efficient equipment, addressing multiple measure types, and identifying as many energy savings opportunities as possible, SMUD's Complete Energy Solutions (CES) program was able to reduce customers' total electrical kWh consumption by 19% over baseline.
Small Commercial EMS Scaled Field Placement (kW Engineering 2015)	The study presents the results of the energy performance of small commercial buildings after the installation of a new energy management system (EMS). The mean HVAC energy savings achieved was 18% based on 9 buildings, primarily due to scheduling changes (more unoccupied hours) and setpoint adjustments (higher cooling setpoints and lower heating setpoints).
Scaled Deployment of Advanced Rooftop Unit (RTU) Controls in New York State (Final Report)(Energy Solutions 2019)	Report describes the energy savings achieved through the field deployment of the CATALYST advanced rooftop controller. Average RTU electricity savings of 35% were achieved across 186 units at 24 sites, and 75% of all units achieved at least 30% electricity savings per RTU.

Source: Crowe, Hart, and House 2022