Bells and Whistles, or Just Plain Effective?
The New Generation of Wireless Controls in Existing Commercial Buildings.

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ABSTRACT

Wireless controls are a key feature for improving the energy efficiency of existing commercial buildings. But what impact do they really have on building performance? This paper provides three case studies to explore the costs, benefits, and relevance of this technology in the existing building market.

Many of the nation's millions of small to medium-sized commercial buildings do not have building automation systems. The reluctance to install controls has historically been linked to the high cost of wiring buildings for such systems. However, new wireless technology is relatively simple and more affordable, allowing owners to reduce maintenance costs, save energy, and improve occupant comfort.

Wireless systems enable the facility manager to monitor and control multiple buildings from almost any location via a smartphone or computer. Not only do these new controls allow optimal scheduling and locate potential problems, they also enable a resolution to issues before a complaint is received.

EXISTING MEDIUM-SIZE COMMERCIAL BUILDING MARKET

Buildings in the United States account for approximately 40% of energy consumption and greenhouse gas emissions.[1] There are more than 4.8 million commercial buildings in the United States.[2] 10% to 15% of these buildings have energy management control systems serving 30% to 40% of the building area. Most of the buildings served by building automation systems are over 100,000 square feet in size.[3]

In Vermont, less than one third of existing buildings have whole-building control systems, and less than 1% of buildings have wireless controls.[4] This represents a huge regional and national opportunity for the small to medium –size existing commercial building sector to save energy by installing and optimizing energy management systems. Wireless controls with lower installation costs, minimal impact on existing building structure, and the ease of location change if building space changes, are one way to help get an energy control system into these existing buildings.

IMPACT OF BUILDING AUTOMATION SYSTEMS

Controlling buildings without existing building automation systems is a challenge for commercial property owners. It is hard to manage something you can't see. According to an ASHRAE Journal article by Jim Plourde, up to 2% of the annual energy consumed by a building can be saved by monitoring energy consumption, if building occupants know the energy use is being studied. He refers to this as the Hawthorne Effect.[5]

Running new wires in existing buildings so that HVAC equipment and lighting can be controlled is expensive, however. In many building types—including historic ones—running new wiring might not even be a viable option. The new generation of wireless controls has expanded well beyond simple lighting controls to include HVAC with ZigBee, Wi-Fi, or other communication protocol options and are one solution to this uncontrolled existing building challenge. How effective are they proving to be, and at what cost?

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[1] ICEBO 2001. DOE EERE 2009.

[2] DOE Energy Information Administration 2003.

[3] Srinivas Katipamula, Ph.D., *Low Cost Building Automation System for Small-and Medium-Sized Commercial Buildings.* November 2011.Pacific Northwest National Laboratory. CBECS

[4] Navigant Consulting, Inc. 2012. *2011Vermont Energy Management Systems (EMS) – Market Actor Report – Business Sector (Commercial and Industrial)*

[5] Plourde, Jim. 2011. *Making the Case for Energy Metering. ASHRAE Journal* April 2011 pp. 20-27.

CASE STUDY 1:
14,000 SF COMMERCIAL BUILDING

Figure 1. Vermont Public Radio

Listener-supported Vermont Public Radio (VPR) has been serving the people of Vermont and the surrounding region since 1977. As Vermont's only statewide public radio network, VPR provides an essential and trusted independent voice for news, information, music and cultural exploration for the people of our region. For the past decade, the station has consistently ranked as one of the most-listened-to-public radio stations in the country per capita, with more than 200,000 listeners each week.

The radio station is headquartered in Colchester, Vermont, near the state's largest city, Burlington. The VPR building is a late nineteenth-century historic structure that has been expanded. It is now a mix of one and two stories totaling 14,000 square feet.

It was renovated between 1992 and 1995, at which time custom HVAC systems were installed. Before a controls upgrade began in 2011, mechanical contractors recommended a replacement of the HVAC system to help resolve lingering problems from the renovation: extremely uncomfortable working environment in some areas of the building, high HVAC energy costs, high maintenance costs, and early HVAC equipment failure.

Existing HVAC systems involved DX cooled split systems, air handlers, and a natural gas-fired hot water boiler. Propane is also used on site at some of the small split-system furnaces. Laurie Kigonya, Vermont Public Radio's Human Resources Supervisor, said that she and her colleagues occupied spaces throughout the building, each of which was on a different system, and all of which were controlled by wall thermostats. On any given day, some parts of the building were cold, while other parts were too hot. Staff complaints were frequent, and there appeared to be no easy solution to the problem. As soon as one area of the building was adjusted for comfort, another would become uncomfortable.

VPR asked Kilawatt Technologies, Inc., a local energy management company, to help them with a solution. Kilawatt Technologies provides data-driven statistical analysis of energy and environmental management options. Gregory Johnson, PE, the company's President, and Steven "Rocco" Antinozzi, its Vice-President, proposed wireless thermostats with a Wi-Fi communication protocol option. These worked well in this application because they offered a web based remote control, continuous close interval trending, HVAC reports, alerts, and reminders, free mobile apps, and a web portal without annual or monthly fees.

The client and the vendor clearly defined their respective roles. Kilawatt first specified a reconfiguration of the control structure to allow for energy and environment optimization. Kilawatt Technologies then took responsibility for specifying all necessary wireless control equipment to meet this new control plan. Finally, Kilawatt directly supervised the installation and verified operation.

VPR retained their electrician to install the components and their engineering staff assisted in providing Wi-Fi through an existing system.

The final project scope:

1. Capability for automatic start and stop of the boiler, and all related circulation pumps from multiple HVAC control modules.
2. Automatically start and stop AHU #1, #2, and #3, as required.
3. Integrated control of three studios from a single command module.
4. Integrated control of two air handlers and two perimeter heat loops, two air handler heating coils, and separate cooling coil and multiple location temperature sensing.

Project costs were $14,000 for hardware.

Building comfort improved, and complaints essentially stopped.

No unscheduled maintenance on HVAC equipment was necessary during the ten months between July 2011 and April 2012, thus keeping down maintenance costs.

Using a 3-year average baseline, electric energy consumption dropped by 16% from the baseline data collected one year after the installation of the wireless controls. Natural gas consumption was reduced by 29%, and propane was reported to have decreased by 27% in the first six months after installation of the controls.

CASE STUDY 2:
40,000 SF COMMERCIAL BUILDING

Figure 2. NorthCountry Federal Credit Union

NorthCountry Federal Credit Union (NCFCU) is a Vermont financial co-operative serving more than 22,000 member-owners.

NCFCU owns a 4-story, 40,000 square foot building in South Burlington, Vermont, built in 1998. The building contains the credit union's main branch and offices. The balance of the space is leased to a single long-term tenant.

Heating and cooling occur via water-source closed loop heat pumps, high-efficiency condensing heating hot water boiler, and a cooling tower. Heat recovery ventilation provides fresh air throughout the building year round.

No central building automation system existed until Sandra Benoit, Facility Manager for NCFCU, hired Kilawatt Technologies to design and manage the installation of 47 energy management nodes with 106 external sensors and a wireless data connection.

Project cost was $70,800 for wireless controls and sensors. The cost included optimization of the new controls for the current building operation, with a new, simplified and automated sequence of operation. Sensors were installed at the water source heat pumps and at all major HVAC equipment.

Despite the significant investment, NCFCU recognized that getting the building under control would improve comfort for staff and building tenants. Although the company expected both maintenance savings and reductions in energy use, occupant comfort was the primary driving factor for the owner in pursuing whole-building controls upgrades.

Were their goals reached with the installation of these wireless controls? Ms. Benoit states "In the past, I would receive numerous calls daily complaining about the temps in the office. This summer I would say I have had a total of 5 comments, not even complaints. Those were minor and really just human nature, the temp was 72, had been all spring, but once it hit 80 outside, 72 was just a little warm." Savings on maintenance costs and reductions in energy use have been significant as well.

Electric energy savings have been 9% of the building's total annual electric energy consumption; natural gas savings are an estimated 23% of the total building's natural gas annual use. The building's energy use index (EUI) decreased by almost 10 kBtu / sf / yr after the controls were installed. EUI went from 68.3 to 59.9 kBtu / sf / yr, or nearly 12% total energy savings. This is 39% better than the average EUI for a building located in New England.[6]

CASE STUDY 3:
21,200 SF COMMERCIAL BUILDING

Figure 3. Vermont Public Television

Conference attendees and residents of Montreal who turn on their televisions this week might see programming from a Vermont station that installed wireless controls. Vermont Public Television's Colchester facility is a 1960s-era, single-story building with 22,000 square feet.

The HVAC systems are electric heating and cooling. There are electric heat coils in the air handlers, electric perimeter baseboard heat, and air conditioning in the studios. Controls were originally pneumatic. Until 2012, there had not been building-wide control in the past 35 years.

[6] DOE Energy Information Administration 2003.

Figure 4. Control Room at Vermont Public Television. Photo courtesy of Vermont Public Television.

Joseph Tymecki, CPBE, Vermont Public Television's Chief Technology Officer and Chair of the Public Broadcasting Service's Enterprise Technology Advisory Committee, also teamed up with Kilawatt Technologies to better control the building's HVAC systems and reduce energy consumption.

They installed 24 current transformers, gateways, and telecommunication interfaces, along with seven internet building control nodes, seven sensor boards, four duct sensors, outside air temperature sensors, and relative humidity sensors. The new wireless controls reduced total electric consumption by 15%, and reduced peak demand by 24%. Total project costs were $39,600, which included the cost of bringing the existing heating system under precision control. They also included an economizer program for the existing air handling system, which will supplement future air conditioning. With annual cost savings of approximately $11,600 and with incentives provided by the statewide energy efficiency program, Efficiency Vermont, project payback is estimated to be 2.9 years.

CONCLUSION

Wireless controls are a viable option for existing buildings that do not have a building automation system. In order to go beyond equipment replacement measures to capturing energy savings from HVAC and lighting systems optimization, energy management control systems are required.

In order to get the significant savings seen in these three case studies, it is imperative that the controls be optimized. Kilawatt Technologies maintains that it is the analytics that produce the results. Steven Antinozzi states: "Modern control systems, and other hardware items, by themselves, whether wireless or wired, cannot be depended upon to produce savings, and in fact, if not intelligently managed, can be expected to produce negative results."

Are they cost-effective from an energy savings perspective, even when commissioned with extraordinary care? Not in every case, although product costs continue to decline, making these controls more cost-effective with time. Maintenance savings and demand-limiting capability can also be a driving factor for their installation.

Less tangible benefits should also be considered: increased tenant comfort can result in a higher rate of lease renewals, and staff comfort can lead to longer periods of employee and/or tenant retention. Taken together, these results—energy savings, stable workplace environments, and low maintenance costs—can lead to substantial long-term savings for companies.

Table 1. Energy Savings Summary

Case Study Number	Property	Building Area	Design, Installation, and Optimization Cost	Total Annual Energy Savings	Electric Savings	Natural Gas Savings	Electric Savings	Natural Gas Savings	EUI Improvement	EUI Improvement
		(square feet)	($)	($/yr)	(kWh/yr)	(CCF/yr)	(%)	(%)	(kBtu/sf/yr)	(%)
1	Vermont Public Radio[1]	14,000	$14,000	$8,870	48,996	1,772	16%	29%	24.60	21%
2	North Country Federal Credit Union	40,000	$70,800	$9,300	56,163	1,456	9%	23%	8.43	12%
3	Vermont Public Television[2]	21,200	$39,600	$14,113	102,418	N/A	15%	N/A	16.49	15%

[1]EUI calculations exclude propane consumption, which decreased 29%.
[2]Peak electric demand was reduced by 24%.
[3]Electric rate based on statewide blended rate of $0.1378/kWh. Natural gas cost savings based on G1 rate for VPR of $1.1957 per CCF including distribution charge and G3 rate for NCFCU of $1.0720 per CCF including distribution charge.

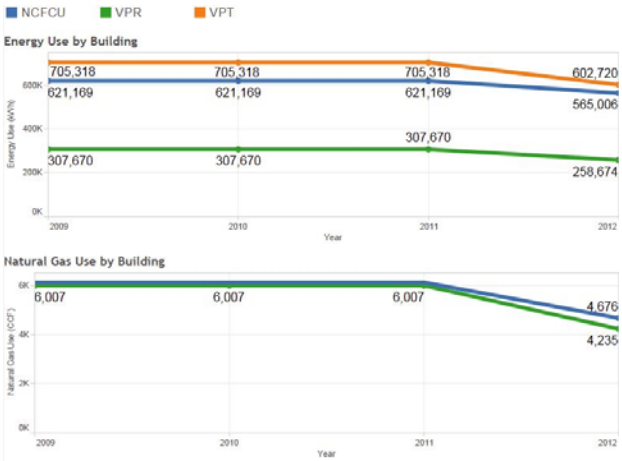

Figure 5. Energy Use by Building with average baseline use shown in years 2009 through 2011

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