Multifamily

THE FUTURE OF ENERGY MANAGEMENT

Computers, wireless technology, and the Internet bring advanced energy management to multifamily buildings built more than 30 years ago.

by DANIEL HARRIS AND MICHAEL BOBKER

The integration of information technology, building controls, and property management has already been well established in expensive commercial buildings. Residential applications may seem further away, but early pilots suggest that there is great potential. Wireless and Web-based technologies have made possible verifiable nighttime temperature setbacks, gradual temperature reductions, customized scheduling, peak-demand limiting, and peak-demand response, with historical documentation and good resident acceptance.

The organization that we work for, the Association for Energy Affordability (AEA), recently completed a demonstration project using a new wireless energy management system. The system brings information technology concepts to energy management and offers community weatherization agencies a role as project sponsors and providers of energy monitoring and reporting services. This is AEA's second pilot of the control system for electric baseboard heating. Two more pilots are ongoing in other multifamily buildings using a similar technology platform for decentralized A/C control.


MARGERT COMMUNITY CORP.

The Ocean Village is located near the beach in Far Rockaway, New York. Energy management technology was installed in half of the 1,100 apartments at the complex.

The Project

The demonstration project reviewed in this article is a large, low-income multifamily complex in Far Rockaway, New York, called Ocean Village. Built in the 1970s, the complex of 1,100 apartments is outfitted with baseboard electric heat. Most of the heaters are original and are nearly 35 years old, and the thermostat function, which was limited before, is now almost completely gone in most apartments. In many cases, the thermostat knobs were missing.

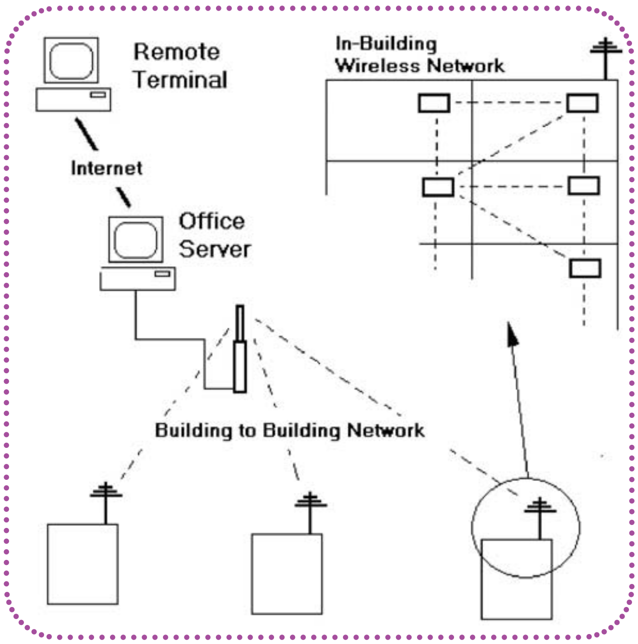
So what was the heating solution for many residents? Use the circuit breakers to turn on the heat in the winter and try to maintain a constant temperature using the windows. Needless to say, this was wasting a lot of energy. No detailed temperature data were available, but anecdotal evidence and sample measurements indicated that average apartment temperatures were well over 80°F in the winter. Sometimes heaters were left on through the summer, and often the heaters were accidentally left on in vacant apartments.

An energy audit of the site, conducted under the New York State Weatherization Assistance program (WAP) in 2003, predicted electrical savings of 1.7 million kWh per year from a combination of window replacement and a 5°F night setback through energy management system control. Of the total, 1 million kWh per year, or 59% of the savings, were calculated as attributable to the energy management system. The two measures are intricately tied together.

Replacing the single-glazed aluminum windows with double-glazed, thermally

AEA

The apartment control panels were installed above the circuit breaker panels. The thermostat meter device is partially shown at the right of the picture.



AEA

Figure 1. The wireless network infrastructure includes an in-building wireless mesh layer and a Wi-Fi building-to-building layer.

broken units seemed attractive—especially as the price of electricity steadily increased—but savings from new windows would be compromised if residents continued to use them as part of their temperature control system. Thermostats could be installed in each apartment, but with no way for anyone to keep track of thermostat function throughout the building. With residents who are not submetered and who tend to keep the temperature in their apartment in the high 80s°F, replacing the thermostats seemed costly and unlikely to be effective. To solve this dilemma, the owner decided to try something new—something that would introduce better information as a part of the solution.

Something New

AEA worked with the local weatherization agency, Margert Community Development Corporation, with the support of the Downstate WAP office of the New York State Division of Housing and Community Renewal (DHCR) and the Long Island Power Authority, to apply a system developed in partnership with Intech21, a wireless mesh control systems developer from Glen Cove, New York. The designers saw the opportunity to create a system that would perform a thermostat function in each apartment but with all the individual units linked together in an energy management system so that all data would be available through a central server and all the thermostats could be controlled together. This "fleet management" would make possible control strategies such as night setback, outside-temperature cutoff, global setpoint changes, and active demand management.

An integrated control panel installed above the apartment circuit breaker panel controls the baseboard heaters. It also performs a temperature sensor function, sending out temperature readings, and a submeter function, recording electrical usage and demand. A solid-state relay for each electric baseboard circuit is actuated by a dry-contact closure from the solid-state, communications-enabled power meter.

Each meter device communicates in a wireless mesh network within each building. Wireless mesh networks are self-organizing, self-healing communication networks that transmit at a very low data rate and thus are useful for scientific applications where high bandwidth is not necessary. A single electrical master meter serves the entire complex. This meter was also upgraded to a fully digital interval meter and equipped with pulse outputs to interface with the in-building network.

Because the housing complex consists of many separate buildings without connecting tunnels, another set of signal interfaces and radio frequency transceivers using wireless protocols is installed for building-to-central office communication. A server that is installed in the central management office receives and stores data and transmits control instructions using this network. The office server is connected to the Internet (see Figure 1). An off-site server provides third-party managed data storage and management via an SQL database.

The graphic user interface (GUI) is the front end of the on-site office server. It is also programmed into a Web browser to allow remote access to data and control-setting parameters by individuals with the correct identity and password. A user on a remote terminal sees the same GUI as the on-site personnel and may use the GUI to monitor data and control operations with the same convenience as on-site personnel.

All data monitored by each meter device are sent to the server through the two layers of network every 15 minutes. Control changes made using the GUI travel through the networks to the appropriate meter device or group of devices.

Initial Results

In order to compare energy use with the new control system with historical energy use, we created a model using historical usage and heating degree-day

(HDD) data. We normalized the data by plotting the average kWh per day for a particular bill against the corresponding HDD per day for that billing period. Using two years of historical data, we created a series of data points and derived an equation for typical performance (see Figure 2). The average HDD per day for each billing period was entered into the derived equation and solved to yield a projected kWh per day, which is then multiplied by the number of days in the period.

Early results indicate substantial success. Weather-normalized savings in the first three winter months of 2005 (October, November, and December) show that the building overall has saved 24% of energy over the historical projections, or around 480,000 kWh (see Table 1).

While these results are tracking somewhat below the savings projected by the energy audit, they are encouraging. Introductory use of the energy management system has been conservative, as temperature limit settings have been approached very cautiously. It is important to remember the comfort of the residents and the importance of resident acclimatization and acceptance in a context where residents cannot override the remotely set high limit. Currently, the winter daytime setpoint is 81°F with an eight-hour night setback to 75°F. Energy management savings for the first few months are attributable primarily to the night setback function, and secondarily to the fact that the high limit prevents extreme overheating and accidental overheating during warm weather. These setpoints are still rather high, and greater savings will result from gradual setpoint reductions over time. There is an important interaction with the window upgrading: As drafts are reduced, there is less perceived need for higher space temperatures.

With respect to cost-effectiveness, the project was calculated with an average cost of $0.10/ kWh and a very modest inflation rate (2% per year). The current average cost is $0.16/kWh. The actual price structure includes a monthly demand component that must be considered. Uncontrolled cycling can result in unnecessary peaks. Although it was not implemented in the first quarter of operation, AEA's programming provides for peak demand limiting by intelligent cycling, informed by overall building demands that will further contribute to the system's economic performance.

Recovery from night setback also requires special programming to avoid establishing unnecessary peaks. This is a tricky problem. Essentially, we would customize to resident schedules, optimize the start of heat-up based on outdoor temperature and apartment temperature response, and cycle units to avoid exceeding a preset demand limit. Eventually we might like to get at bedrooms and bathrooms separate from living rooms, but we're not up to that yet.

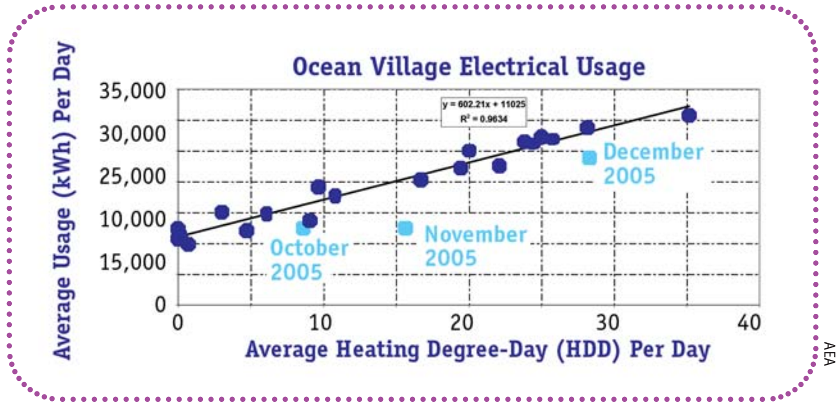


Figure 2. HDD analysis of the data from the first three winter months of 2005. (The light blue squares indicate the billing data for the three winter months of 2005, and the dark blue circles are historical billing data.)

Table 1. Initial Results for the Ocean Village Energy Savings in 2005

	Actual Billing Data	Projection of Energy Use by Weather Normalization	Savings		
Year 2005	**kWh**	**kWh**	**kWh**	**$**	**%**
October	361,800	470,280	108,480	17,030	23
November	349,200	572,470	223,270	35,280	39
December	835,200	982,660	147,460	23,650	15
Total	**1,546,200**	**2,025,410**	**479,210**	**75,960**	**24**
Window savings (41%)			**196,480**	**30,720**	**10**
EMS savings (59%)			**282,730**	**45,240**	**14**

Operator and Resident Acceptance

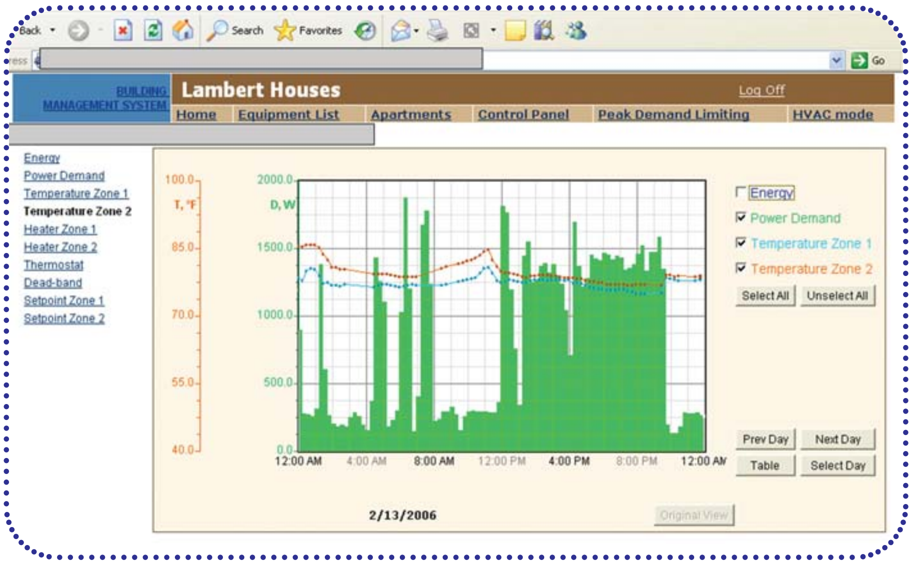
What was also encouraging was the ease with which the on-site maintenance staff learned the system. Every maintenance staff person is familiar with a Web browser and can navigate the GUI just like any other Web site. AEA serves as the energy monitor for the site, to help the maintenance staff to operate the energy management system and analyze the data. But now for the first time the maintenance staff can see what is happening in each apartment. The energy management system saves them an incalculable amount of labor in heating-related complaints and investigations.

"We love it," says Darrin Azar, the lead superintendent at the site. "We are very pleased with the system and how it works. We can see everything that is going on in the facility day-to-day. There is no more guesswork. We hope that they will install it in the other 550 apartments."

Site staff worked effectively with AEA and readily adapted to being able to communicate on an ongoing basis with an outside entity armed with information about its heating energy management. Third-party energy monitoring offers a significant opportunity for energy efficiency agencies and service providers. The potential lies in the value of data provided by so many monitoring and measuring points, but the difficulty is in mining it. Analyzing all these data is a specialty, and no one in the property management chain, from maintenance to director, has the responsibility, skill, or time to do it. They'd be happy with summary progress and action reports. An energy monitoring and service bureau can provide this service on a large number of buildings, using its expertise with energy metrics and data visualization tools to make recommendations and document savings and persistence. The monitoring agent can quickly see if there is a problem with a thermostat. Data can be updated every 15 minutes, and if a thermostat stops reporting, it can be spotted and scheduled for a visit to find out why. It is natural for the energy consultant to progress from the initial analysis and recommendation of a new energy measure to assume the role of energy monitor. In this way, the energy consultant can remain tied to the project and can continue to make recommendations that will preserve the savings that were achieved when the system was first installed.

How do residents react? At Ocean Village, the introduction of the energy management system has been quite smooth, and acceptance has been high. In a previous pilot—perhaps significantly one not accompanied by window replacement—reaction has been more varied. Some residents find it a welcome addition, some dislike it but tolerate it, and some find a way around it, or even tamper with the system. How to account for, predict, and mitigate negative reactions has been a topic of some discussion within AEA. Some of us are proponents of preinstallation education. Others, as suggested below, think that the introduction strategy is very important. But one key feature of the IT-based approach is that the data can be a window onto resident behaviors that would otherwise be invisible.

With electrical usage and temperature reported every 15 minutes to the server, behavioral patterns become apparent. The stories of ice bags on locked thermostats are almost legendary in the trade. But, perhaps for the first time, we have been able to document the event—visible as a sudden drop in temperature with increase in electrical use. Another common reaction to perceived underheating is the unsafe use of space heaters and gas stoves, which we have also been able to pinpoint using the same identification method (see Figure 3). Identifying these behaviors makes it possible to follow up with a specific, targeted response. Perhaps a combination of customized setpoint adjustment and resident consultation and education is required. Based on this experience, AEA is developing pattern recognition programs and, for outright tampering, even game theory-based response algorithms.



AEA

Figure 3. A screen shot of the GUI from an apartment that is using a gas stove (or other nonelectric heater) for additional heat shows a temperature increase with the electric heating off.

Implementation Implications

The new technology makes a big difference in how implementers can approach the introduction of temperature control projects. Much of our energy efficiency menu tries to avoid the effect of occupant behavior, by using high-efficiency appliances and other high-performance equipment that provides the same service with lower energy use. Temperature control projects don't work this way—and by definition, we are changing felt conditions. This poses a challenge for occupant acceptance, without which a project may be doomed to failure.

Improving temperature control is, of course, not new to the field. Night setbacks appear in the earliest energy conservation handbooks. Zone control, the use of nonelectric thermostatic radiator valves (TRVs), and system balancing are other familiar temperature-related techniques—techniques that most practitioners have used and that are now embodied in ASHRAE 90.1. These techniques make possible local control based on local temperatures. Feedback stays local, except, of course, in the case of a complaint to the superintendent when the resulting temperature is unsatisfactory.

As implementers, we well know that a complaint usually trumps energy savings, no matter how dramatic. Moreover, the time spent responding to complaints can easily destroy the economics of a project. And we also know that people generally dislike change, especially when it is imposed from the outside. The parable of the boiling frog provides important insight here:

If you put a frog into very hot water he will struggle to get out. But if you put him into room temperature water and very gradually heat it, he will quite happily boil to death. (This is a metaphor, not a recommended experiment.)

This parable suggests where new technology with Web-based data communication can make a huge difference in our practice.

Ideally, new temperature regimes would be introduced very gradually, with small change increments, so that people would acclimate to the new conditions, rather than responding to drastic changes. This has not been possible with conventional technologies. Each setpoint change requires access into an apartment. This is time-consuming at best and is often not easy to arrange and schedule. So temperature setpoints are established based on the assumption that establishing the setpoint is a one-shot deal. If our initial space temperature is 80ºF (which we commonly find in New York City apartments under heating conditions), and if we have only one adjustment opportunity, we will probably choose a setting of 73ºF or 74ºF—a pretty big change. Research has found that "about a 5.4ºF change in temperature…is necessary to change a thermal sensation category by one unit or temperature category" (ASHRAE Fundamentals 2005, 8.12).

With conventional technologies, there is also often a debate as to whether to lock the setpoint or to give the occupant access for adjustment. The former approach—exemplified by the locking cover over a wall thermostat—often leads to resentment, frustration, and vandalism. The latter approach begs for the setpoints to be pushed as high as they will go, probably approximating the original temperature condition. In electrically heated buildings, we often find the thermostat built into the baseboard element turned clockwise to its maximum temperature setting and all the windows open (note that tenants don't pay for their electricity). Without external feedback, it is impossible to know if the control is set appropriately, well calibrated, and functioning properly.

The new generation of communicating, Web-based controls overcomes many of these barriers and enables building operators and energy managers to introduce new temperature regimes more effectively. Consider the following:

• Communicating temperatures, even before using controls, provides baseline data that can be used to inform new settings and expectations.

• Remote access makes possible repeated setpoint changes at minimal expense. Changes can be made universally across the set of points, or they can be customized to individual cases or by preset rules.

• Digital control allows setpoint changes in fractions of degrees.

• Feedback data make it possible to observe control calibration and to identify malfunctions, tampering, and the use of auxiliary heating sources.

• Complaints can be addressed by remote reset, so an uncomfortable resident can, without too much trouble, receive customized attention.

• Individual controls can be programmed for special needs. This adds an element of resident "friendliness" that can promote acceptance.

• Temperature results are fully documented and easy to review.

These capabilities suggest that the new technology really can have an impact on the way we work on temperature control projects, and on the way we think about getting them accepted by a building's residents.

MARGERT COMMUNITY CORP.

Lead Superintendents Darrin Azar (seated) and Julio Menendez (left) of Ocean Village work with Wayne Murchison of Margert Community Corporation to change settings on the GUI.

The Future Is Now

The Ocean Village project has demonstrated that energy management systems can make sense for the owner, the site maintenance staff, the residents, and the energy efficiency consultant in multifamily housing.

Enhanced temperature control in multifamily properties can produce significant savings. Utilization of new IT-based networking technology can help overcome barriers to occupant acceptance while adding savings functionalities unavailable from purely localized control—functionalities such as demand limiting and demand response—that can also be applied to decentralized air conditioning. The capability of remote monitoring also increases the reliability of persistence and suggests avenues for local economic development. While system costs at this phase of development are too high for market commercialization—probably by a factor of about two—cost-effectiveness has been shown to be sufficient, in the right circumstances, to meet the test for application under publicly supported programs.

The intelligent application of new technologies allows for advanced control and monitoring options, and the increased availability and decreasing prices of these converging technologies will bring more and more opportunity to save energy.

Michael Bobker, CEM is director of strategic technology and Daniel Harris, P.E. is a controls development manager for AEA in New York City. AEA is a not-for-profit training and technical services organization that serves community-based housing organizations that are local subgrantees of New York State's Weatherization Assistance program.

FOR MORE INFORMATION:

Association for Energy Affordability, Incorporated
505 Eighth Ave., Ste. 1801
New York, NY 10018
Tel: (212)279-3902
Web site: www.aeanyc.org