Saving Energy One Small Building at a Time

BACnet® for a City

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Groucho Marx once complained that he lost more than $200,000 in the stock market crash of 1929. "But I was lucky," he added. "Some people lost millions. I would have lost more, but that was all I had."

Energy journals today are filled with articles about huge skyscrapers that saved astronomical amounts of energy by using the latest energy-saving technologies. These stories are impressive, but it's easy to forget that within a stone's throw of that skyscraper is a 10,000 ft^2 (929 m^2) fire station. Or a small community center. Or a single-story office building. As with Groucho Marx's $200,000, these buildings don't seem small to the people who work there—or to the people who maintain them. And if you look at how many small buildings there are in a typical city, you soon realize the energy they consume represents a significant opportunity for conservation.

The City of Orlando didn't overlook its small buildings. In addition to its large public facilities the city owns dozens of small neighborhood centers, fire stations, and administrative buildings. Most of these have stand-alone HVAC systems. They also have domestic water heaters, exhaust fans, and lights that stay on until somebody remembers to turn them off. Last year, they upgraded 26 of these buildings as part of an American Recovery and Reinvestment Act (ARRA) funded energy project. The buildings may have been small, but the annual utility bill for these buildings topped $525,000.

Deciding how to achieve these savings was a daunting task. The buildings ranged from a relatively new (2007) fire station to a senior center that was built in 1945. Within these buildings were 82 air-handling units (AHUs), 76 of which were older variable volume and temperature (VVT) systems. In general, these AHUs supplied air at a constant temperature with no reset. Most of the AHUs were 5 to 15 ton (18 to 53 kW) rooftop direct expansion (DX) systems, although three had chilled water coils supplied by small chillers. Many buildings operated on regular weekly schedules. Some neighborhood centers were occupied "as needed," and fire stations operated 24/7. A few buildings included vehicle maintenance bays with outdated lighting systems, but none of the buildings had energy meters that could be monitored remotely.

That was the task that confronted Nate Boyd, energy project manager for the City of Orlando. Working with David Miller of TLC Engineering they performed a comprehensive energy survey on all the facilities. They then designed a $1.75 million retrofit project to install supervisory controls and remote metering. They submetered major pieces of equipment and installed current sensors at key points so they could keep track of what was happening. The project also installed variable frequency drive (VFD) control in all the VVT systems; replaced 43 of the worst DX systems with new, high-efficiency units; installed light emitting diode (LED) lighting in vehicle service bays and some fire stations, installed heat pump hot water systems in 10 fire stations, installed new lighting control systems in four buildings, and implemented more efficient control algo-

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rithms throughout all the buildings. And, of course, they tied the entire system together with BACnet.

"BACnet allows facility managers to integrate multiple building systems into a common front end," said Boyd. "It's an open standard supported by multiple vendors, so I don't have to worry about it becoming obsolete or not being supported in the future."

He added that specifying compliance with ASHRAE Standard 135 and requiring BACnet Testing Lab (BTL) listed equipment reduced the risk of getting stuck with equipment that required third-party gateways to integrate into the control network.

Miller had worked with both BACnet and non-BACnet control systems on past projects, and he enthusiastically supported the decision to use BACnet. He also recommended using a single vendor to install the control systems and integrate everything into a single front end.

"I didn't want this to become a 'science fair project' to demonstrate interoperability among multiple vendors. That's been proven many times over. I wanted a single point of contact for the controls work. BACnet guaranteed us that if we weren't happy with that vendor's performance we could choose a different vendor for future work."

Figure 1: BAS summary graphic of Primrose Plaza, one of the larger buildings in this project. The gray areas indicate unoccupied rooms where sensors have turned off the HVAC to save energy.

Fortunately, they were very happy with the way this project turned out. Based on approximately nine months of operation, the first year's energy savings will be $124,000, nearly 25% below the previous year's use. In general, the most cost-effective upgrade was the controls retrofit. Some buildings realized a reduction in utility costs of more than 50% due solely to the controls upgrade. The control strategies used did not require experimental, high-risk algorithms.

Dramatic savings resulted from simple measures such as turning the equipment off when the building was unoccupied, adjusting setpoints based upon the demand for heating and cooling, using occupancy sensors to relax setpoints when rooms were temporarily unoccupied, and using CO_2 sensors to control the amount of ventilation air brought into the system. In addition to the savings in the total amount of energy consumed, the new controls leveled out the peak energy demands of many buildings. This saved money on the utility bills and also reduced the strain on the local utility systems.

Perhaps even more important than the energy savings, the feedback from the people who use these buildings has been positive. This is particularly impressive when you realize that before the retrofit, the buildings were operating as stand-alone entities, with thermostats that allowed the occupants to set whatever temperature they wanted, and with equipment that often ran 24/7 to ensure the buildings were comfortable whenever anyone happened to use them.

The retrofit project changed these procedures in a very public way, and it could easily have been misinterpreted as replacing local control by an autocratic "big brother" operation. Boyd and Miller made sure that didn't happen.

"Anytime you go in and start to mess with the systems and environment surrounding a person's place of business, or in the case of fire stations, a person's residence, you are going to receive feedback both positive and negative," said Boyd. "Once the systems were installed and commissioned, and the managers at those locations received training on how to access and view the controls, the feedback has been mostly positive."

They specifically did not establish strict rules for setpoint control. "The firefighters seemed to like to keep their sleeping quarters very cool," said Miller. "This is where they live. We gave them what they wanted."

They also could not gain efficiencies through occupancy scheduling or demand control, since the fire stations were occupied 24/7. The savings in fire stations came from replacing worn-out DX systems with more efficient units, and in using

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Figure 2: An energy reporting package screenshot of Primrose Plaza showing the energy savings resulting from a controls upgrade. The image has been annotated to include energy data from before the upgrade, as electronic metering was installed as part of the project. Occupant comfort is maintained even in the hottest months, as indicated by the average environmental index of 93%.

reset control strategies. That was enough to reduce energy use in most fire stations from 17% to 26%, without any adverse effect on the firefighters who live and work in these facilities.

There was no way to measure comfort before the controls retrofit, but the new system includes an environmental index[1] to track occupant comfort. This shows the average comfort level across all facilities has consistently scored in the low- to mid-90s (100 is ideal). Obviously, comfort is not being sacrificed to save energy, which is important to the morale and productivity of the people in these buildings. This score is particularly impressive when you realize that comfort is, as it should be, based on what the building occupants want. More than 300 independently controlled zones are in these buildings, with cooling setpoints that range from 70°F (21°C) (fire station dormitory area) to 80°F (27°C) (recreation center). Local setpoint controls allow occupants to adjust these ±2°F (±1°C) throughout the day.

The people who maintain these buildings also appreciate the new central supervisory controls.

"By reading pertinent information through the BACnet interface to our chillers and electrical service sub-meters, along with the hardware points from the control system, our facilities management crews are beside themselves with the remote troubleshooting capabilities of the controls system," said Boyd. "This saves them untold hours in the field and reduces the quantity of replacement components they need to bring with them. Our building managers are also thrilled with the retrofits. We give the fire station admin lieutenants and management personnel at other buildings "view-only" access to the controls at their sites, allowing them to 'see what we see.' This drastically reduces the number of nuisance hot/cold calls, and greatly enhances their ability to report real equipment issues or outages."

As with any new system, there are still a few "teething problems" to work out. This is especially true in buildings where the original HVAC equipment was grossly oversized. Over time the capacity of this equipment deteriorated to the point where it was now "right sized," although woefully inefficient. Not realizing how much the old equipment had declined, replacement equipment was selected to match the nameplate capacity of the worn out machinery. This initially resulted in short-cycling, excessive airflow noise through the diffusers, and comfort complaints.

The new system allows technicians to adjust the operating parameters and tune the controls to find an appropriate balance of indoor environmental quality characteristics, including noise, but that takes time. A lesson learned is that equipment deteriorates over time, and if an old and decrepit piece of equipment is meeting the load today it was probably oversized when it was new. It would be a good idea to run some load calculations before ordering a replacement.

From a financial standpoint, one of the interesting features of this project is that it became the basis for a revolving loan fund (RLF) for in-house energy projects. The initial ARRA funding was used as seed money. All projects include energy meters, and the energy use is carefully monitored. Utility costs after each energy project are compared to the preceding utility bills and the savings are credited to the RLF. Then, the RLF can be used to fund additional energy projects.

The improvements to these initial 26 buildings have been in place for less than a year, and they've already contributed more than $88,000 in utility savings to this fund, plus an additional $40,000 in anticipated rebates. Projections are that the fund will equal the original $1.75 million seed money in seven years. While a seven-year return on investment (ROI) is not particularly spectacular, Boyd points out that a simple ROI is not the best measure of success for a project like this.

Most of the mechanical systems upgraded were in dire need of replacement. The cost of the new mechanical equipment significantly increased the ROI, but the city would have had to buy new equipment anyway, even without the energy initiative. The energy initiative only meant they were buying equipment with, say, a seasonal energy efficiency ratio (SEER) of 16 rather than a SEER of 13. Buildings that didn't need new equipment and could get by with a simple control system upgrade saw ROIs as low as 1.5 years.

Regardless of how you do the accounting, the project has been a success. Orlando has buildings that are performing better, are providing a more comfortable place for people to live and work, and are saving energy. The energy savings translate into dollar savings, and those dollars will be used to fund more projects. Boyd is tracking these buildings through the EPA's ENERGY STAR program, and although the initial projects have not yet been in operation for a full year the energy performance has already improved their ENERGY STAR ratings

Photo 1: Miller (left) and Boyd analyze the performance of a building in the project.

by up to 30 points. Some may soon qualify as ENERGY STAR facilities.

Probably the biggest lesson learned from this experience is "Don't ignore small projects or small buildings!" The savings from these small projects keep growing over time, and this money can be used to fund more small projects and perhaps a few big projects in the future. Small or large, these projects can use BACnet. All future projects that include new HVAC equipment, electric meters, renewable energy components, and lighting systems will be required to use BACnet. That was another lesson learned. To no one's surprise, BACnet successfully integrated the widely scattered buildings into a unified, energy-saving system. BACnet worked as advertised.

References

1. Tom, S.T. 2008. "Managing energy and comfort." *ASHRAE Journal* 50(6). ■