SEDAC CASE STUDY

Building Automation Systems

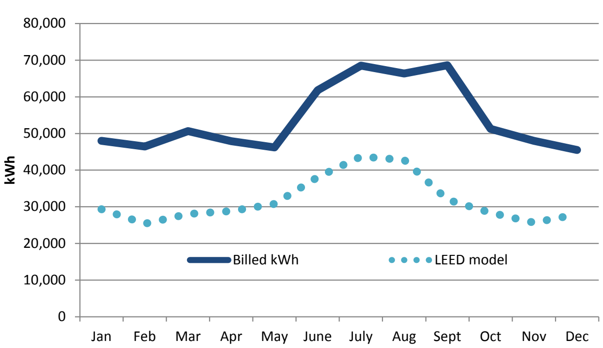
Why was this building using so much energy?

AN ENERGY WHODUNIT

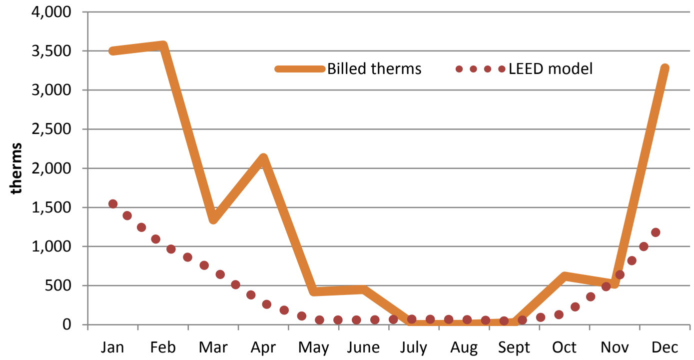
It was a building energy mystery - a beautiful new 34,000 square foot museum facility that was using twice as much energy as it should. Built in 2004 at a cost of $5.3 million, it was designed with energy efficiency in mind. But for reasons that building operators could not explain, the utility bills were one and a half times the expected electricity usage, and more than twice the expected natural gas usage.

UNEXPECTEDLY COSTLY BILLS

The owners paid $49,000 for utilities in 2005, the first year the building was open. The second year they paid $52,000. Energy prices climbed, and by 2008 they were paying almost $79,000 for gas and electricity, or $2.38 per square foot per year. This amount was much more than the museum expected, especially since the computer energy model built for LEED certification predicted energy bills would be about half this number, or $45,000 per year at 2008 energy prices.



Electricity use: Expected (LEED) vs Actual



Natural gas use: Expected (LEED) vs Actual

THE TROUBLE WITH ESTIMATES

How can you know the energy usage of a building before it is built? The simple answer is...You can't. You can *estimate* the energy usage, based on the design and assumptions about how the building will be used. Differences between the design and the actual building, in terms of construction quality and human behavior, will almost always result in variations from the estimate.

In the case of this museum, however, it was obvious something was not working correctly. Staff were often uncomfortable in the building and reported spaces were either too hot or too cold. Adjusting the thermostat did not fix the problem. After five years of climbing expenses and comfort complaints, the building management turned to the Smart Energy Design Assistance Center (SEDAC) for help.

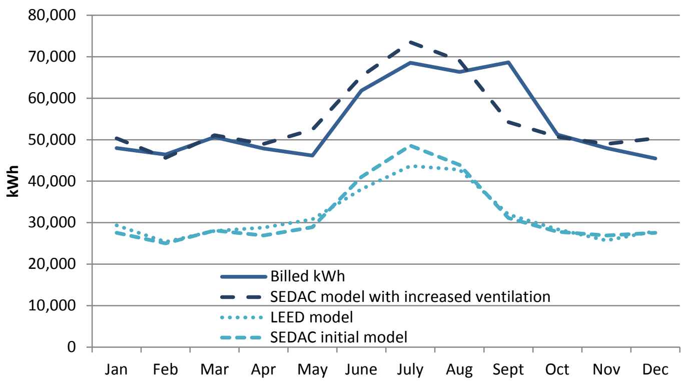
LEARNING FROM ENERGY MODELS

SEDAC provides free building energy assessments to public facilities and private companies throughout Illinois. A SEDAC Building Energy Specialist visited the museum and met with managers and staff. After observing the building and examining its construction and systems, the SEDAC engineer built an energy model of the building to compare to the model built for the LEED certification process. Interestingly, SEDAC's model very closely matched the energy use predicted by the LEED model. The large gap between the modeled and actual energy use remained unsolved.

Observations made during the site visit partially explained the discrepancy. It was a normal practice, according to building staff, to prop the door open when groups of visitors arrived. Also, the building was operating under a relatively large positive pressure. Positive pressure in a building means that the HVAC system supplies more air to the space than it returns, blowing the building up like a balloon.

Slight positive pressure is normal. Excessive positive pressure creates a situation where the HVAC system works hard to pressurize the building, but is unable to do so whenever air was escaping freely out open doors. In this case the system was heating and cooling far more air than necessary, and consequently using far more energy than it should. The museum also had much more lighting use and energized exhibits than were included in the first models.

When the SEDAC energy model was adjusted to reflect a much larger intake of outside air, and increased lighting and plug loads, the model returned results that more closely matched the billed usage of the building.



Electricity: Actual Usage vs Energy Models

The result confirmed what the employees already suspected - something needed to be done about the HVAC system and its poor performance. The SEDAC engineer recommended that the building owners apply for a more in-depth SEDAC service called retro-commissioning (also known as RCx). Retro-commissioning optimizes the energy-using systems in a building using an existing Building Automation System (BAS). The aim of retro-commissioning is to tune the BAS and its control of building systems so they perform well for both for human comfort and economy of operation.

BUILDING AUTOMATION PITFALLS

Building Automation Systems are electronic controls that can be used to manage a building's heating and cooling systems. When properly set up (commissioned), a BAS is a very useful tool in keeping a building comfortable and economical to run. When they are ***not*** properly set up and maintained (an unfortunately common occurrence) the BAS can cause a building to use more energy than if there were no automatic controls in place at all.

A building automation system was installed as part of the museum's original design. Once the building construction was completed, the BAS was simply turned on and left untuned.

BAS commissioning (initial setup) should ***always*** customize the system to the unique nature of the building - not simply to maintain normal temperatures, but also to use energy in an intelligent manner. In this case, tuning did not occur and because the interface was so confusing, staff were quickly dissuaded from attempting to use it. The building automation system ran out of control for five years, until SEDAC was asked to look at the museum's energy consumption.

The building owners decided to apply for the SEDAC RCx services. SEDAC engaged a local independent retro-commissioning expert, McNally Engineers, to help troubleshoot the system.

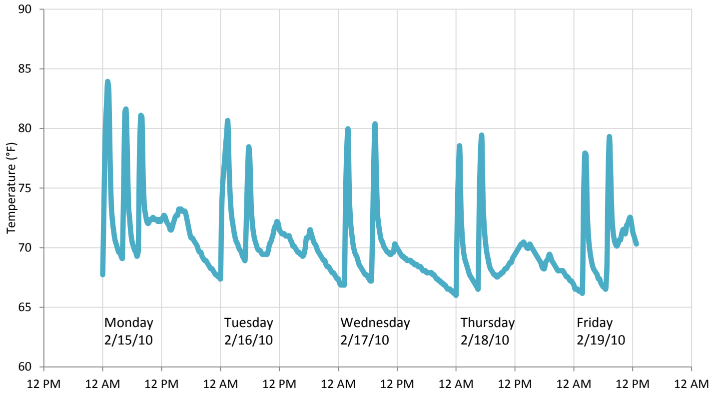
VISUALIZING THE PROBLEM

McNally began work by placing small sensors (data loggers) around the building to collect data. Utility bills generally span one month, providing total usage for the whole month. Much finer data is needed, however, to paint a picture of how a building is behaving from day to day. The data loggers tracked temperature, humidity, and light levels on ten-minute intervals for two weeks. In the meantime, McNally stopped by the building late one night to see what the museum looked like when nobody was home and found all the lights blazing. With a couple of nighttime snapshots and the data gathered by the loggers, a clearer picture of building behavior started to come together.

Nighttime waste - lights were left on 24/7
image courtesy McNally Engineers Ltd.

AN ERRATIC HEARTBEAT

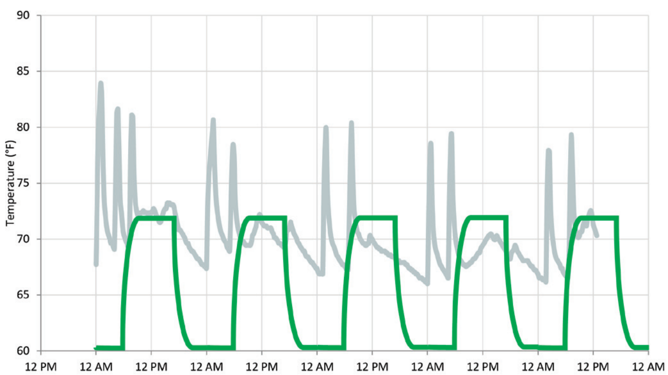
The discovery that lighting schedules were not turning lights off at night explained a part of the excess electric use. But the data collected by the loggers showed an even larger energy problem. The temperature in classroom spaces was fluctuating wildly, creating a graph that looked like a heartbeat monitor. The pattern of spikes was repeated once a day, with the first spike happening exactly at midnight.



Classroom temperature profile: major daily fluctuations

Precisely at midnight, when a new calendar day starts, the temperature was driven up as high as 83° F. Once it reached that high temperature, it was sharply driven down to around 68° F. The graph showed an increase back to the high 70's, then back down to a relatively normal indoor temperature, where it eventually stabilized.

The spiking temperature pattern made those spaces very uncomfortable and was wasting large amounts of energy by alternating between heating and cooling multiple times in a day. A proper temperature profile looks like a row of teeth, hovering flat at the set-point during open hours, and dropping back to the setback temperature in the unoccupied hours.



What a temperature profile ***should*** look like

LOCATION, LOCATION, LOCATION

Why would the temperature be fluctuating so wildly? The answer is that the thermostats controlling the open spaces and classrooms were located at the end of hallways, far away from the spaces they were trying to control. When the thermostat thought it was chilly, it would turn the furnace on, but it took so long for the warmth to arrive at the thermostat that the classrooms were massively overheated by the time the message arrived. Then when the thermostats registered the uncomfortably high temperature, the BAS would try to cool it down to normal, again overshooting the mark. The distant location of the thermostats was causing an energy-wasting information lag.

MIDNIGHT OPENING

Why would the temperature go haywire exactly at midnight? The BAS is a computer controlled system, so every time the calendar day rolls over to the next, it will start the schedule for that day. The schedule was set to start at midnight every day (the default start of a daily schedule), rather than a half-hour before opening time for the museum. With the change of a single entry in the BAS, the midnight startup problem was fixed, saving the building 10% on its energy bills.

SIMPLE SOLUTIONS

Once the problems in the system were diagnosed, most were able to be fixed with a few strokes of the keyboard and some minor physical changes. Thermostats were moved to more appropriate locations, and lighting motion sensors and temperature controls were installed in smaller rooms and basement areas. The controls contractor edited the BAS schedules to make the HVAC systems work more efficiently. The pressurization problem was eliminated by adjusting outside air intake settings. The lighting schedules were activated to turn the lights off at night . To stop the midnight HVAC startup, the scheduled start time was changed to 30 minutes before opening. Finally, overrides and custom schedules were added, and the Director and staff members received training on how to use the BAS interface.

After this handful of fixes and some educational efforts, the building was operating much closer to original expectations.

STAY ON TARGET

As a part of the retro-commissioning process, the building was set up to be monitored remotely. The monitoring website, called BudgetWorks™, gives the building operator three streams of data. These data streams can tell the building operator if the building is working correctly or if something needs to be addressed. First, the site pulls in current energy use data from the electric company and tracks usage over time. The actual energy use is then compared to two energy models: one that simulates default behavior of the building under current weather conditions (the baseline), and another that simulates the way the building should behave if everything is working correctly (the budget or target). If actual use is significantly above the target, the building operators should look for reasons for the additional energy use.

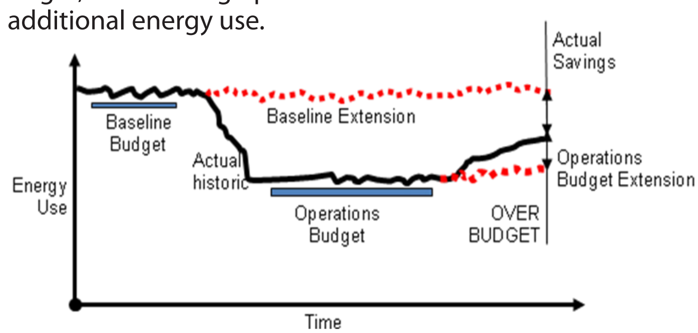


image courtesy McNally Engineers Ltd.

A CAUTIONARY TALE

Despite the success of the retro-commissioning (RCx) process in identifying and fixing major energy wastes in the museum, building owners and operators should take careful note of what happened next. Just a few months after completing the RCx process, McNally logged into the BudgetWorks website to see how the museum was performing. Imagine the surprise when the website showed the building was now using even more energy than before the retro-commissioning process began!

After making a phone call to the building operators, and some additional detective work, it was discovered that the entire Building Automation System had somehow been overridden. Everything in the building was running constantly, and as a result it was using more energy than when the museum staff had first contacted SEDAC. While the override was easy to fix, the incident highlights the value of continuous monitoring of building systems.

The ability to monitor real-time building energy use is not standard BAS functionality. BAS systems typically just report which building elements are currently running. Savvy building owners and operators know that real-time energy data is available from utility companies on 15 or 30 minute intervals. That interval data can be incorporated into the BAS or a separate online monitoring tool.

VISUALIZATION

In order to optimize energy conservation and energy cost savings, it is important to visualize the energy use over time. Graphing makes historical energy use patterns clear. New problems are much easier to detect. Tracking usage patterns over time can also prevent a new energy problem from continuing for months or years without being identified, and save a company from an unnecessary drain on resources.

The final piece of this puzzle - that is, making efficient building operation a reality - is to have a knowledgeable employee working with the data on a regular basis.

Some facilities have even installed an accessible display in a public area of the building, so all building users can see how the building uses energy throughout the day and week. This helps to create user interest in energy conservation.

PROJECT REWARDS

The utility bills for the museum for the year of 2011-12 showed huge savings: electric use was down by 16%, and natural gas use decreased by 67%.

Total energy cost for the 2011-12 year was $41,000, a reduction of 48% over the 2008 utility costs. Adjusting for the steep drop in natural gas pricing since 2008, the savings after retro-commissioning are still 27% over the 2008 costs.

GOING FORWARD

When the Museum was built, the plans included mounting brackets for solar panels on the roof. The intent was to add solar panels when funding became available. In 2010, the museum secured funding for the solar panels, and an 8.46 kW array was installed, providing an on-site and renewable energy source.

SAVE ENERGY WITH SEDAC SERVICES

ENERGY ASSESSMENTS

SEDAC performs energy assessments for both existing buildings and new construction. SEDAC has four levels of service. Level 1 offers helps identify areas for general energy-savings. Level 2 and Level 3 identify specific energy-saving opportunities and involve bill analysis; Level 3 further includes energy modeling and life cycle cost analysis. Level 4 provides technical support for implementation of much more detailed recommendations based on the owner's specific criteria.

All services from SEDAC are funded through the Illinois Energy Efficiency Portfolio Standard (EEPS) and are free of charge for customers in the Ameren Illinois, ComEd, Nicor Gas, North Shore Gas, and Peoples Gas service areas.

RETRO-COMMISSIONING

SEDAC performs retro-commissioning (RCx) services for public sector buildings in Illinois. This program identifies measures to improve the control, scheduling, and operation of energy consuming systems to match the current functional requirements of a building. The end result is energy and demand savings, and in many cases, improved occupant comfort and productivity.

ABOUT SEDAC

SEDAC is sponsored by the Illinois Department of Commerce and Economic Opportunity in partnership with ComEd and Ameren Illinois Utilities. SEDAC is managed by the University of Illinois at Urbana-Champaign and supported by the 360 Energy Group.

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