U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Good daylighting, as shown in the second-floor hallway at L.B. Landry High School, can have numerous benefits, including improving student performance on math and reading tests. *Photo by Joe Ryan, NREL/PIX 19720*

Building Energy-Efficient Schools in New Orleans

Lessons Learned

Hurricane Katrina was the largest natural disaster in the United States, striking the Gulf Coast on August 29, 2005, and flooding 80% of New Orleans; to make matters worse, the city was flooded again only three weeks later by the effects of Hurricane Rita. Many of the buildings, including schools, were heavily damaged. The devastation of schools in New Orleans from the hurricanes was exacerbated by many years of deferred school maintenance.

In 2007, the U.S. Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL), began providing technical assistance to New Orleans' schools to improve energy efficiency and reduce school operating costs. Initial technical assistance included energy audits of open and operating school facilities and consultation on energy-efficient design strategies, energy modeling, and pre-design and design reviews for new schools. 30% energy savings over code requirements were recommended based on strategies described in the Advanced Energy Design Guide (AEDG) for K-12 School Buildings, published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

The experiences of incorporating energy efficiency after Hurricanes Katrina Rita in four new schools— Langston Hughes Elementary School, Andrew H. Wilson Elementary School (which was 50% new construction and 50% major renovation), L.B. Landry High School, and Lake Area High School—and one major renovation, Joseph A. Craig Elementary School—are described here to help other school districts and design teams with their in-progress and future school building projects in hot-humid climates.

The majority of classrooms at Lake Area High School utilize daylighting thanks to the use of exterior shading and semi-transparent daylight glazing on the upper half of south-facing windows. *Photo by Joe Ryan, NREL/PIX 19627*

More details about New Orleans Public Schools rebuilding efforts, as well as information on how school districts can incorporate energy efficiency into construction or renovation planning, can be found in Building Energy-Efficient Schools in New Orleans: Lesson Learned at *www.eere.energy.gov/deployment/pdfs/51639.pdf*.

■ Langston Hughes Elementary School

Langston Hughes Elementary School was the first school to open after Hurricane Katrina. As a result, valuable feedback and data were gathered about the school's mechanical system and daylighting that offered numerous lessons learned for future school building projects. *Photo by Joe Ryan, NREL/PIX 19526*

Langston Hughes Elementary School (Hughes) was the first new school to open in New Orleans after Hurricane Katrina. During the first 2 years, its design and operation provided useful feedback to the district for other projects. For more than one year, energy monitoring for the school was performed; the findings, particularly in regard to daylighting and mechanical system operations, offer many lessons learned for ongoing and future school building projects.

Daylighting

The layout of the Hughes site provided a unique opportunity for designers to implement progressive daylighting strategies. The property is 200-feet-deep, and more than one quarter mile wide with a long east-west axis. The new building was oriented along the length of this site with minimal east- and west-facing glass, which is a good strategy for minimizing glare in the classrooms and solar heat gains in the morning and afternoon. Unfortunately the designers did not concentrate on daylighting until very late in the design process and, because the building's structural members had already been designed, daylight glazing placement and size was limited. The second floor classrooms have sufficiently large windows, and the north-facing classrooms receive pleasant, diffuse lighting. However, the south-facing classrooms lack light shelves or exterior shading devices, which increase both glare and solar heat gains. A more comprehensive daylighting design may have addressed some of these issues and at times eliminated the need for electric lighting in the classrooms.

"A Building Automation System (BAS) that is not monitored to validate how a building is performing is like setting an automobile on cruise control and thinking the driver is allowed to sleep." – Louisiana Recovery School District

Mechanical Systems Operation

In order to achieve the goal of 31.5% energy cost savings, the Hughes design incorporated an efficient, packaged, water-cooled chiller plant and condensing boiler. The design uses variable air volume air handlers throughout the school and fan-powered boxes with electric reheat in classrooms and other small spaces. Unfortunately the sequence of operations is very conservative and, although it provides very comfortable conditions throughout the year, the heating, ventilation, and air conditioning (HVAC) energy use was found to be 50% higher than the energy model predicted. This elevated use was largely due to excessive amounts of reheat caused by the air handlers delivering air at 55°F, regardless of the heating or cooling load in the building.*

Energy Monitoring Findings

Because Hughes was the first new school opened after Katrina and their utility bills were higher than anticipated, DOE/NREL and representatives from New Orleans Public Schools performed detailed energy monitoring at the school. Energy monitoring equipment was installed and a walk-through was performed to identify under-utilized energy-efficient strategies. Findings from the walk-through ranged from excessive activation of hot water coils (in the heat of the summer) and low indoor temperature setpoints, to classroom lights remaining on when no one was present. Over the following four quarters, additional issues were also identified that contributed to Hughes' high utility bills (summarized in Figures 1 and 2, along with solutions and potential savings). As solutions to high energy use are implemented, the energy use at Hughes moves closer to the expected performance.

Lesson Learned

Hughes was on a tight timeline for completion; however, an integrated design with the involvement of an energy modeler and daylighting consultant from the beginning would have likely resulted in a more energy-efficient design without increasing first costs or slowing the project.

*This low discharge air temperature prevents high humidity conditions in the school, but other, more energy-efficient strategies can be just as effective.

Quarter 1 Energy Monitoring Findings at Langston Hughes Elementary School

Elevated energy use was discovered when reviewing energy data weekly and utility bills monthly for six months.

- **Projected HVAC energy use was exceeded by 50%.**
- **Projected energy cost was exceeded by an average of 15%.**

Causes	Q2 Solutions	Q3 Results and Recommendations	Potential Savings
Extended hours of operation	Reduce hours of operation for HVAC, lights, and plugs	HVAC energy use down by 50% Minimal lighting evenings and weekends Computers and copiers "sleep" after set period of inactivity and turn off after school hours	$4,000/month ~ $500/month ~ $300/month
Incorrect temperature and humidity setpoints	Avoid simultaneous heating and cooling	Disable chiller plant below 50°F and disable boiler above 80°F Use separate heating and cooling setpoints (heating setpoint ≤ 5°F lower than cooling setpoint)	Contributes to $4,000/month HVAC savings shown above
BAS controls not optimized	Reprogram BAS for efficient operation	BAS operates more efficiently	Contributes to $4,000/month HVAC savings shown above

Langston Hughes Annual Energy and Cost Savings

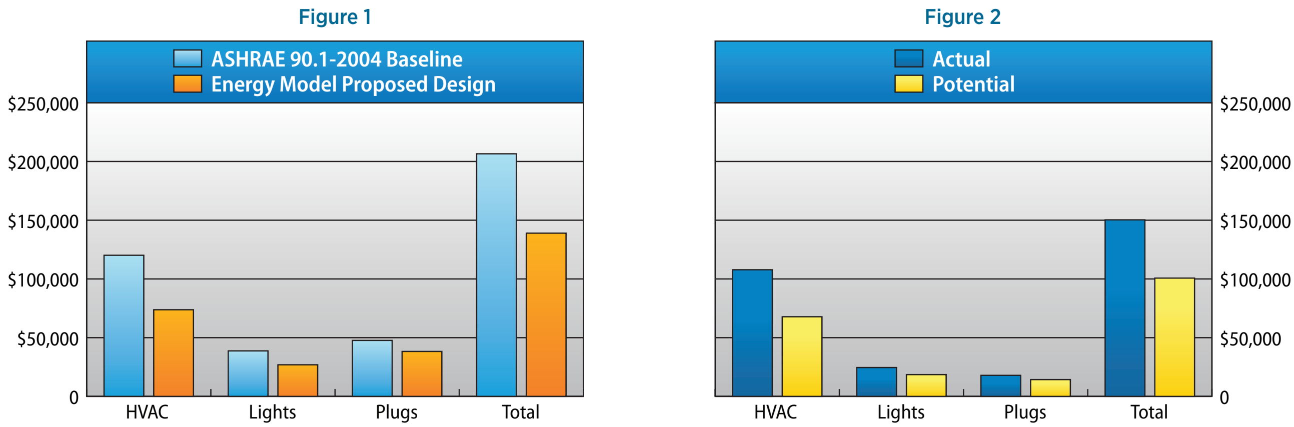

Figure 1 shows the ASHRAE 90.1 baseline and energy use predicted by the energy model. Figure 2 shows the actual energy use as of Q3 2011, and the potential energy savings if all recommendations resulting from energy monitoring are implemented.

Energy Monitoring

In its most basic form, energy monitoring is the process of comparing a building's actual utility bills to expectations (based on experience with other schools or an energy model). More detailed energy monitoring measures the energy used by the HVAC, lights, and plugs on a continual basis to identify trends in a school's energy use and to note findings. Energy monitoring provides information on a school's energy operations and if they are functioning as they were designed. Data that doesn't match expectations is a good indicator of a system problem to address.

The results of energy monitoring provide valuable data to help schools use less energy and save money. In addition to uncovering problems in existing systems and/or operations issues, the results provide important lessons learned for future designs of new and renovated schools.

■ Joseph A. Craig Elementary School

Joseph A. Craig Elementary School opened in 1927 and was renovated following Hurricane Katrina to primarily bring the electrical, mechanical, and plumbing systems up to current codes and standards. *Photo by Joe Ryan, NREL/PIX 19718*

Joseph A. Craig Elementary School (Craig), located in the historic Treme neighborhood, opened in 1927 as the first new school in New Orleans built for African American children. In 2007, an environmental assessment identified a leaking roof and extensive mold. Since Craig was not a Quick Start School, its renovation was put on a fast track and planners didn't include any energy efficiency goals in their renovation plans.

However, Craig was a school in the Solar Schools Initiative (funded by Entergy, the Entergy Charitable Foundation, and Nike) and had a 25 kilowatt (kW) photovoltaic (PV) system installed. The Craig renovation included a small addition for the cafeteria and kitchen, but primarily made repairs and brought the electrical, mechanical, and plumbing systems up to current codes and standards.

HVAC Design and Fan-Coil Unit

Although the design of the Craig renovation didn't include any specific energy goals, the conservative and simple design of the school's HVAC system was a good choice for New Orleans' hot-humid climate.

To keep the classroom temperature comfortable, Craig uses energy-efficient fan-coil units (FCU), which provide individual temperature control of each classroom and other spaces. The four-pipe FCUs in each classroom add the right amount of heating or cooling to keep the classroom at comfortable conditions, minimizing the potential for simultaneous heating and cooling in a given space.

In a hot-humid climate like New Orleans, conditioning the outdoor air necessary to bring into the building represents a substantial load on the HVAC system (typically about 1/3 of the building's HVAC load). At Craig, outdoor air is conditioned by a dedicated outdoor air system (DOAS) and ducted to the classrooms and other spaces in the building. In colder weather, the high-efficiency condensing boilers send hot water to the DOAS units to pre-heat the outdoor air to space neutral conditions (65°F, 50% relative humidity). In warm-humid weather, the DOAS units use direct expansion cooling and hot-gas reheat to again supply air to the school at space neutral conditions.

Unfortunately, the DOAS units at Craig are constant volume, meaning they have two settings: on and off. This makes it difficult to implement the energy saving demand-controlled ventilation strategy, varying the amount of outdoor air introduced to the building relative to the number of occupants. With constant volume outdoor air units, it's important to operate them only when the school is substantially occupied.

Energy Monitoring Findings

Although Craig was renovated prior to the district setting energy efficiency goals, the district recognized the importance of validating energy performance in a renovated school. Through this energy monitoring effort, it was discovered that Craig's HVAC system wasn't shut off at the end of the day—it was on 24/7. Energy monitoring also indicated various electric loads operating 24/7. A walk-through of the building identified electric, freeze-protection heaters were improperly set and operating at warm temperatures, as well as exhaust fans operating continuously. These issues highlight how easily automated systems can be programmed improperly without the building occupants' knowledge. Because of the energy monitoring effort, simple solutions were identified to address the issues and reduce energy consumption at Craig.

Lesson Learned

Craig has a relatively straightforward HVAC system; however, seemingly benign changes to the BAS programming can have a dramatic, negative effect on the school's operation. Technology can provide a convenient means of operating sophisticated systems in modern buildings; however, automation can create unnoticed issues if sufficient training and monitoring are not provided. Training operations staff early and often on complex energy systems will ensure appropriate system use and energy savings.

Andrew H. Wilson Elementary School

Andrew H. Wilson Elementary School, built in 1909, underwent a major renovation following Hurricane Katrina after suffering major flooding and wind damage. In addition to renovating the existing building, the school doubled its square footage and added both photovoltaic and solar hot water systems. *Photo by Joe Ryan, NREL/PIX 19648*

Andrew H. Wilson Elementary School (Wilson) was originally designed by renowned New Orleans architect E. A. Christy and built in 1909. Hurricane Katrina's winds damaged the roof, flooding the school from above, while the failure of the floodwalls in the aftermath of Katrina flooded the school from below. After many months of sitting in disrepair, Wilson was chosen as a Quick Start School. The project included a major renovation of the existing building and an addition that doubled the square footage of the school by adding a gym, cafeteria, media center, and administrative spaces.

Daylighting

Wilson made excellent use of daylighting with creative design. The school's national partner in the building project was a leader in the United States in daylighting. Wilson's innovative shading devices are especially effective in saving energy and bringing diffuse daylight into the building. While windows in schools are typically covered by blinds and shades, the designers of Wilson's daylighting systems used a combination of interior and exterior light shelves, overhangs, and fabric baffles to prevent glare and diffuse the bright sunshine coming through the windows and roof monitors. Natural daylight provides sufficient light to most classrooms and teaching spaces for approximately 50% of the occupied time. A high-efficiency electric lighting system is coupled with the engineered daylighting system to augment it when needed. Using two rows of high-efficiency light fixtures in the classrooms instead of three, dimmable T-5 lamps and daylighting/occupancy sensors, the school's lighting power density was reduced by 37% from ASHRAE 90.1 standards. Additionally, as a result of using less electric light in the building less heat was introduced, lowering cooling costs.

Renewable Energy

In addition to the energy-efficient design and the use of the sun to provide daylighting throughout the school, the sun is used to generate both electricity and hot water, lowering Wilson's operating costs.

A 4.8-kW PV system was installed to feed into the school's electrical system while a solar hot water system supplies 80% of the kitchen's hot water needs.

Use of renewable energy systems in a school setting, like Wilson's PV system, can be used as a teaching tool. Setting up an interactive monitoring system and control panel for students can provide both a hands-on learning tool about renewable energy and a means to alert the school operators if the systems are not performing to their potential.

Design and Energy Use

The design team for Wilson went to great lengths to develop a very energy-efficient design, achieving Leadership in Energy and Environmental Design (LEED) Gold certification and 35% energy cost savings when compared to ASHRAE 90.1-04. The design includes an efficient envelope (high-performance windows and well-insulated wall/roof assemblies) and efficient chiller and boiler plants.

Although Wilson's design is very good, a review of utility bills indicated its energy use was significantly higher than the energy model predicted. The exceptionally high gas use, even during warm months, indicated that the VAV system was likely overcooling and then reheating the air with the hot water coils. This simultaneous heating and cooling can double the HVAC system energy use if it is not monitored and minimized through proper selection of heating/cooling setpoints and energy-efficient strategies for preventing high humidity.

Lesson Learned

Wilson had the most energy-efficient design of any of the Quick Start Schools, but their utility bills have been the highest on a dollar per square foot (ft^2) basis with annual gas usage per square foot at least twice that of any of the Quick Start Schools. For a high-performance design to be effective, proper BAS control settings must be programmed, monitored, and maintained.

■ L.B. Landry High School

At approximately 236,000 ft^2, L.B. Landry High School is one of the largest new schools in New Orleans, providing a new performance gym, practice gym, and band and choir rooms for its students. *Photo by Joe Ryan, NREL/PIX 19730*

L.B. Landry High School (Landry) is one of two new high schools built with the initial funding from the FEMA settlement. Landry is a large school, with about 236,000 ft^2 of conditioned space. The new building has an auditorium, two gymnasiums, and a community health clinic and replaces a school facility that suffered more from years of neglect than the winds of Katrina. Landry uses a modern design with a conservative HVAC system and good daylighting to achieve its energy efficiency goals.

Mechanical Design

Since Landry is larger than 150,000 ft^2, the baseline cooling system according to LEED energy modeling requirements was a water-cooled chiller, but the engineers had chosen a less-efficient air-cooled chiller for the HVAC design. This decision made their goal of achieving 31.5% energy cost savings over the ASHRAE 90.1-04 baseline more difficult. However, by improving the building envelope and eliminating the complexities of water-cooled chillers, the designers were able to approach their goal by achieving 27% energy cost savings. The air-cooled chiller system has also been easier to maintain, resulting in more predictable and sustainable levels of energy consumption.

> **"Installation of high-efficiency HVAC systems does not guarantee energy savings. Systems must be integrated in a manner that allows for efficient operations."**
> **– Louisiana Recovery School District**

Daylighting and Acoustics

Landry's performance gym, practice gym, band room, and choir room use tubular daylight devices and the 3rd floor corridors use north-facing clerestory windows to provide effective daylighting. Most of Landry's classrooms have sufficient glazing and overhangs that, when combined with the photo/occupancy sensors and dimmable ballasts, are able to reduce the amount of electric lighting in the spaces. The north-facing windows are flush with the exterior building skin while the south-facing windows are recessed into the building skin, reducing glare and solar gains in the warmer months.

During the design phase for Landry, engineers were challenged with long duct runs and limited space for the ductwork. As a result, keeping the air noise out of the classrooms was difficult and required bringing in an acoustics expert to help solve the problem. Sound attenuation was added to the design to keep the noise out of the classroom but also necessitated larger blower motors to move the air throughout the building. These complexities increased the initial and operating costs of the HVAC system and could have been avoided if the acoustics expert had been brought in during the design phase.

Lesson Learned

By not using a true integrated design approach, the Landry design team encountered challenges. If the team had included engineers, energy modelers, and acoustics experts in the early design stages, some of the hurdles encountered later could have been avoided. Additionally, the design team did not initially receive clearly stated goals (energy savings, LEED certification, etc.) from the district because of the tight turnaround time. Establishing clear goals early in the process may have also helped to avoid some of the hurdles the team encountered later.

Although a chiller system with a higher efficiency rating could have been selected for Landry, the simpler air-cooled system has produced consistent performance and energy efficiency due to its ease of operations and maintenance (O&M). This is an especially important consideration for managing future O&M and energy costs.

■ Lake Area High School

Lake Area High School's design team addressed the deep flooding experienced during Hurricane Katrina by designing the school to be above ground with a ground-level parking garage. *Photo by Joe Ryan, NREL/PIX 19646*

Lake Area High School (Lake) is a new, 170,000 ft^2 school on a small site in an area of New Orleans that saw deep flooding after Hurricane Katrina. The design team addressed flooding issues by raising much of the school off the ground and adding a ground-level parking area under part of the school.

Daylighting and HVAC

The designers were able to provide good daylighting by placing a majority of the classrooms along north- or south-facing areas of the school and using exterior shading and semi-transparent daylight glazing (upper half of window) on the south-facing classrooms. Additionally, the mechanical system installed at Lake was top-of-the-line with magnetic bearing chillers and desiccant enhanced outdoor air units. The outdoor air units were also fitted with a return duct so its gas furnace could be used in recirculation mode for morning warm-up, minimizing the use of electric heaters in the fan-powered boxes throughout the school and reducing the electric demand charge.

Elevated Energy Use

The energy model for this design indicated a 34% energy savings versus the ASHRAE 90.1-04 baseline. However, in the first year of its operation, the school consumed twice as much energy as the energy model predicted and 30% more energy than the ASHRAE 90.1-04 baseline building. Problems with the operation of these systems prevented the building from being truly energy efficient.

So how could a facility with state-of-the-art HVAC equipment not perform well in reality? The primary issue was that while highly efficient system components were specified, these components were not fully integrated during design to operate efficiently as a system. Once the building was completed, the test and balance and commissioning processes were stalled due to difficulties in getting the HVAC system operation to meet the design intent. During the extensive time it took to work out these issues, the systems at Lake were left in continuous, 24/7 operation. Regardless of how efficient the systems at Lake were, if the school (or any building) is operated for 100% more hours than the energy model assumed, then the utility bill will be approximately 100% higher than the energy model predicted. In order to keep these tasks on track, it is good practice to hold the general contractor responsible for paying the utility bills until all commissioning activities are completed to the owner's satisfaction.

Once these issues were addressed, the school began operating on a more standard schedule, dropping its energy use dramatically, using 22% less energy than the ASHRAE 90.1-04 baseline. In addition, three-way chilled water control valves have been subsequently replaced with two-way valves allowing the variable speed pumps to reduce energy consumption during part load conditions.

Missed Training Opportunities

The mechanical system at Lake is complex with high-tech water-cooled chillers and multi-purpose desiccant assisted outdoor air handlers. In order to operate smoothly and achieve and maintain its energy-efficient potential, the school will likely have to keep a full-time engineer on staff. Although this will add to the school's labor costs, the lower O&M costs will counteract this. Additional training for operations staff on the use of the systems will be necessary to keep the systems operating properly and the utility bills affordable.

Lesson Learned

Cutting edge equipment may not be the most cost-effective design for a school. The default mode for mechanical systems in schools should be "off." These systems are very large and consume large sums of energy when they are operating. Continuous operation of the Lake systems resulted in first-year utility bills $220,000 higher than expected.

Additionally, when "state-of-the-art" adds complexity that makes commissioning, testing and balancing, and O&M difficult and expensive, simpler systems that can easily be operated as efficiently as possible should be considered—the end result may be a less-efficient design, but a far more efficient and less costly operation.

L.B. Landry High School corridor. *Photo by Joe Ryan, NREL/PIX 19726*

Additional Resources

These additional resources provide information on energy-efficient schools.

ASHRAE Advanced Energy Design Guides
www.ashrae.org/technology/page/938

U.S. Green Building Council LEED Rating System
www.usgbc.org/DisplayPage.aspx?CategoryID=19

Collaborative for High Performance Schools
www.chps.net/dev/Drupal/node

DOE Building Energy Software Tools Directory
http://apps1.eere.energy.gov/buildings/tools_directory

RebuildingNolaSchools
http://rebuildingnolaschools.wordpress.com

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www.eere.energy.gov/deployment/new_orleans.html

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