13 Tips From ENERGY STAR® Schools

How Some Schools in Indiana Earn ENERGY STAR

By Bill Wiseheart and **Thomas H. Durkin, P.E.,** Member ASHRAE

The EPA's ENERGY STAR designation for schools (www.energystar.gov) recognizes schools that are doing an exceptional job of managing the energy used in their buildings. The motivation is to reduce the demand for energy, with all the benefits that entails. According to EPA statistics, ENERGY STAR buildings use 40% less energy than average buildings. With salaries usually between 88% and 90% of a school's total operating costs and the balance (±10%) being the utility bill, schools that save 40% on their utility bills have an extra 4% to spend on educating students.

The Program

To qualify as an ENERGY STAR building, a school must be entered into the ENERGY STAR program and achieve values in the top 25% of entered schools in terms of energy use, normalized for heating and cooling degree days. Cost (in dollars) is tracked, but it is not a factor in determining ENERGY STAR certification because of the geographic variances in the cost of energy. A full year's worth of fuel and electricity consumption records are required, along with the school's operating parameters, such as building size, number of students and staff, hours of operation, school calendar, etc. To set up a school building for ENERGY STAR monitoring takes about a half hour and require basic knowledge of the building and utility bills (see the Portfolio Manager at http://tinyurl.com/2o96hn).

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Once a building has been entered into the Portfolio Manager, data upkeep only takes about 10 minutes per month.

If a building is statistically eligible for certification, i.e., a score of 75 or above (0 to 100 scale), the results must be audited by a registered professional engineer experienced in school design. The audit must show that the building meets standards for indoor air quality (ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*), thermal comfort (ANSI/ASHRAE Standard 55, *Thermal Environmental Conditions for Human Occupancy*) and lighting adequacy (IESNA's *IES Lighting Handbook*). The auditor also certifies accurate reporting of the metrics (occupants, operating hours, etc.). A Statement of Energy Performance is sent to the program managers at the EPA for a final review of the data prior to issuing the plaque and certificate. All the requirements, along with the definitions and calculations that the program uses to score a building, can be found in the "Professional Engineer's Guide to the ENERGY STAR® Label for Buildings" (http://tinyurl.com/2j2wh7).

Age Old Two-Pipe Problems	Modern Two-Pipe Solutions
Schools may need heat in the morning and cooling in the afternoon.	Design a system that can change over quickly and as often as the building or weather dictates.
It takes too long (12 to 24 hours) to change over.	Control operating parameters and changeover can be done in less than 20 minutes (*Figure 1*).
Hard to handle load variations, i.e., north side needs heat, south side needs cooling.	Air-side economizers are required and they must work.
Hard to know when to change over.	BAS monitors all spaces and it decides when to change over.
Boilers cannot tolerate cold water.	Select boiler styles that can tolerate low temperatures, i.e., condensing boilers.
Chillers cannot tolerate hot water.	Control heating water temperatures so they're never so high that chiller could be damaged.
Too many valves associated with changeover, hard to coordinate and maintain.	Design a schematic with only one changeover valve (*Figure 2*).
Cannot control humidity without reheat.	Face/bypass, single zone VAV, and outside air management schemes will control humidity even in high wet bulb parts of the country.[4,5]

Table 1: Equipment innovations and DDC address age-old concerns.

Tip 1: Becoming an ENERGY STAR school requires taking ownership. Someone must be in charge, and everyone must care about energy conservation. Although ENERGY STAR has been around for many years, the number of ENERGY STAR schools is relatively small. As of March 2008, only 884 schools have achieved it. Four states lead the way with almost 60% achieving ENERGY STAR: California has 214; Texas 108; Colorado 87 and Wisconsin 94. Several districts in other states have embraced the program; Davenport (Iowa), and Nash-Rocky Mount (North Carolina), among others, have multiple ENERGY STAR schools.

Indiana has nine ENERGY STAR schools. Eight are part of New Albany–Floyd County Consolidated School Corporation (NAFCCSC or New Albany). This article chronicles New Albany's path to elite status among America's schools. New Albany's most important lesson learned is, no doubt, the same as Davenport's or Rocky Mount's: someone made a commitment (*Table 1*).

Good Design

All of New Albany's ENERGY STAR schools are heated and cooled with modern two-pipe systems,[1] as is the ninth Indiana ENERGY STAR school. The concept had its origins in New Albany in the late 1980s and early 1990s. During that period NAFCCSC operated 18 buildings serving about 10,800 students in grades K–12. Eight of the buildings were air conditioned in 1993, which is generally considered an educational necessity in the hot, humid Ohio River Valley. With school starting in mid-August and temperatures reaching into the 90s, a shortened school day for students in non-air-conditioned buildings was an unfortunate necessity. This practice created inequities in educational delivery as some students attended full days and others half days. In 1993 the School Board resolved to seek environmental equity in all NAFCCSC schools. Funding generated for the project was insufficient to install traditional four-pipe systems. NAFCCSC had already integrated building automation systems (BAS) in all their schools, including an existing older two-pipe building. The owner found that a properly programmed BAS could deal with changeover effectively and thought that two-pipe system would be an acceptable solution, as long as comfort and humidity control questions could be addressed.

Tip 2: With the right mechanical system, you can deliver consistent comfort and control humidity without running the boilers. In the years since the environmental equity project, the modern two-pipe system has become the system of choice for New Albany and many other schools in Indiana. Of the 20 schools that NAFCCSC now operates, 19 are modern two-pipe. The 20th is a four-pipe fan coil building with dedicated outdoor air system (DOAS). It is New Albany's most expensive school, costing 50% more to operate than the ENERGY STAR two-pipe buildings.

The fact that the two-pipe solution worked is not surprising. What is surprising is the dramatic improvement in energy consumption. In all cases, modern two-pipe buildings cost less to heat and cool than the conventional design cost to operate as a heat-only building.

Tip 3: It doesn't have to cost more to get a more efficient system. The modern two-pipe buildings typically cost \$3 to \$4 less per/ft^2 (\$32 to \$43 per/m^2) to build than other HVAC designs, because the mechanical system would have only half the piping of a four-pipe design, and a DOAS and associated ductwork is not necessary.

Tip 4: Low-temperature heat from condensing boilers. A significant portion of New Albany's energy savings is on the heating side. An *ASHRAE Journal* article[2] discusses the significant economic benefits (50% to 60% reduction in gas use) of low-temperature heating. Low-temperature heating (130°F [54°C] maximum temperature, reset with outdoor air temperature) is a natural for two-pipe systems, because all of the air-handling coils were selected for cooling duty. All are three, four, and five rows, which means that the heating water doesn't need to be very hot, and there doesn't need to be much of it. In the Midwest, heating is 50% to 60% of the energy used in a school, and 40% of the cost.[3] Low-temperature heat as an energy conservation measure offers a reasonable payback regardless of the building system, two- or four-pipe.

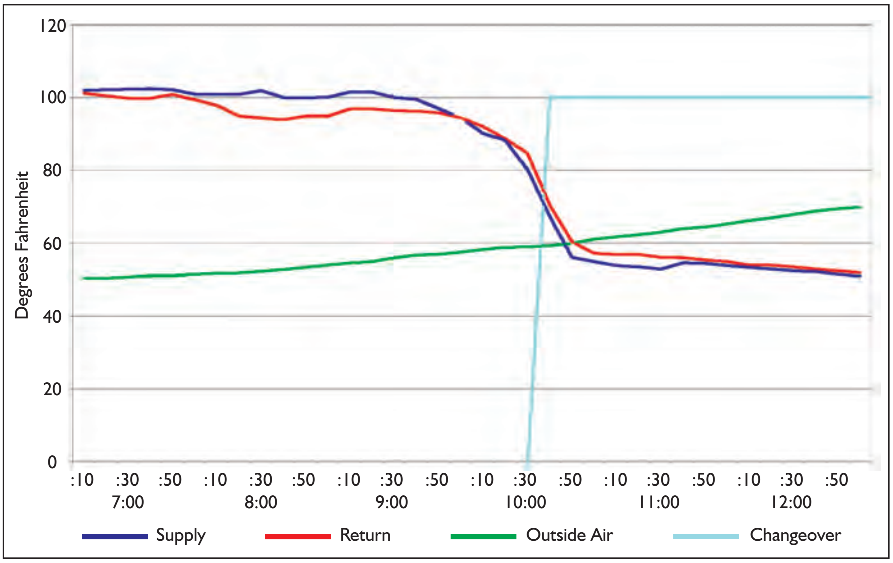

Figure 1: Slate Run Elementary changeover 11/20/2007.

Tip 5: Don't be afraid to question conventional wisdom. Conventional wisdom ties a significant energy negative to traditional (old) two-pipe systems: energy wasted during changeover. However, if someone were to use wasted energy during changeover as justification for spending additional money (estimated at $\$3/ft^2$ [$\$32/m^2$]) to install a four-pipe system in lieu of a modern two-pipe, the payback is not being considered, as follows:

A 100,000 ft^2 (9290 m^2) school with a 200 ton (703 kW)

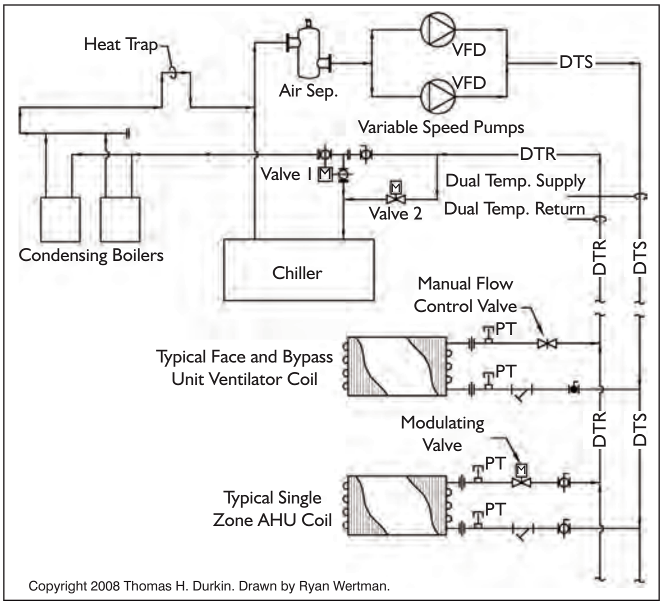

Figure 2: Two-pipe schematic.

air-cooled chiller at 1.25 kW/ton (0.36 kW/kW) at 95°F (35°C) OAT, 0.7 kW/ton (0.2 kW/kW) at 70°F (21°C) OAT (changeover temperature);

- Electricity at $0.10/kWh;
- Fifty changeovers per year (actual will be about 30);
- Changeover time of 30 minutes (actual will be about 20 minutes, *Figure 2*);
- Cost per changeover = $7 (worst case);
- Changeover cost per year = $350; and
- Payback four-pipe versus modern two-pipe = 857 years.

No combination of factors or utility rates will decrease the payback to a reasonable level. Although it is accurate that energy is wasted when a two-pipe building changes over, it isn't much. The previous example represents less than one-half of 1% of the total energy used in an efficient building. The changeover is completely automatic and does not require any operator attention.

Tip 6: Optimize distribution energy. Because two-pipe hydronics are based on the higher flows dictated by cooling (as compared to heating flows), and because smart two-pipe design dictates face/bypass control (constant speed pumping) rather than valve control (variable speed pumping) of terminal equipment,[4,5] creative hydronic design must address any potential over-pumping concerns.

Select cooling coils for 12°F to 14°F (6.6°C to 7.7°C) ΔT rather than 10°F (5.5°C), equaling 17% to 30% smaller pumps and piping versus a 10°F (5.5°C) design.

Because no control valves are in the two-pipe terminal piping, the pump head should be about 10% less than the pump head in a valve controlled system (8 ft or 3.5 psi [24.13 kPa]) (24 m) less (±10%) than the head in a valve controlled system control valve differential). Ten percent less pump head for the same flow equals 21% less pump energy.

Significant pump savings occur when a modern two-pipe building is running in heating mode. Again, because all coils are selected for cooling, they will be significantly oversized when used in heating, even with low-temperature heating water. By lowering the heating flow, either by variable speed motors, two-speed motors, or by big-pump/little-pump arrangement, significant pump energy can be saved in heating, to the point where a two-pipe system typically will use less pump energy in heating than any other hydronic system. Heating flow is typically 60% of cooling flow, or 21% of theoretical cooling horsepower (power being a cubed function of speed, not including drive losses). To realize this savings, it will require a piping design that is proportionally balanced, so that as the pumps turn down, all units will see the same relative flow reduction.

Fan power is another area where modern two-pipe systems have an energy advantage. Typical fan size for air distribution via unit ventilator (two- or four-pipe) is 0.33 hp per 1,000 cfm (0.5 kW per 1000 L/s). This compares to 1.2 hp per 1,000 cfm (1.9 kW per 1000 L/s) for a VAV system, up to 1.4 hp (2.2 kW per 1000 L/s) for fan-powered VAV, and 1.5 hp per 1,000 cfm (2.4 kW per 1000 L/s) for buildings with DOAS air designs.

Tip 7: Manage outside air well. Ventilate appropriately, but only when students are in the building. An appropriate amount of properly conditioned fresh air is essential for a healthy and effective learning environment. But, outside air is at least 30% of the cooling load, at least 70% of the heating load, and about 95% of potential humidity problems (Indiana data). From an energy standpoint, it is essential to build into the controls the ability to manage outside air. Although traditional operating modes are limited to "occupied" (defined as day temperatures and normal ventilation) and "unoccupied" (defined as temperatures set back and outside air dampers closed), all of the two-pipe buildings have control systems that allow a "day-unoccupied" setting (defined as normal space temperatures with OA dampers closed). Day-unoccupied is used to warm up or cool off the buildings after weekend or night setback, and other times throughout the day when the students may be at lunch or recess. Occupancy sensors that close OA dampers, in addition to turning off the lights, also play a role. Large assembly spaces such as gyms, auditoriums, and cafeterias have CO_2 monitoring for OA control.

Good Operation

The NAFCCSC began developing their operational strategies in the mid-1980s as part of a corporation-wide energy management initiative. The key first step was integrating a BAS into each of its schools. It was done in three phases beginning with six buildings in 1984 and completed in 1991. The first efforts were simple on/off control of a few major pieces, evolving today into direct control of all HVAC equipment.

Tip 8: Ownership. From the inception of New Albany's conservation efforts, ownership has been critical. They had

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seen well-intended programs in neighboring districts falter due to lack of attention, and NAFCCSC vowed it would ensure its investment in BAS would realize its potential return. It was obvious that conservation programs would take constant effort and that nothing would happen on its own. It would take work and oversight. NAFCCSC has always had an energy manager specifically responsible for their conservation efforts. Primary duties are to monitor the systems; to diagnose problems and dispatch maintenance; to interact with school staff; and, by evaluating strategies and results, to find ways to improve.

Tip 9: Create a corporate energy culture. One of the biggest challenges to any conservation program is culture change. In New Albany, one of the first initiatives was to take scheduling control away from the individual schools and to centralize it. A form was created, and every event that fell outside of regular school hours had to be requested and scheduled. The "if-you-don't-tell-us-it-won't-be-on" did not go smoothly at first, but with a commitment from the superintendent and the school board, it is now accepted practice.

Tip 10: Do not compromise comfort. This has been New Albany's mantra since the inception of its energy management efforts. However, the way it is interpreted has changed through the years. Early on, all classrooms were maintained at 72°F (22°C). It became apparent that one size does not fit all, as maintenance was constantly receiving complaints and having to adjust individual classrooms. One maintenance technician told complainants (tongue in cheek) that there was a "warm 72 degrees" and a "cold 72 degrees." The temperature of walls and window glass in a classroom affected how comfort was perceived due to radiant losses or gains. Now, teachers have limited control of temperatures in their rooms, usually plus or minus three degrees from a nominal 72°F (22°C). The range is further individualized through programming, and comfort complaints have been virtually eliminated.

Tip 11: Do not compromise the educational environment. In the early days of the program, it was found that poor practices had been implemented by well-meaning service contractors or school personnel in the name of energy conservation. Many outside air dampers had been rendered inoperable. Obviously, these had to be repaired. As NAFCCSC moved toward modern two-pipe systems, outside air economizers became a critical part of their comfort strategy. Today, with the latest generation of BAS controls, New Albany is able to fine-tune outside air, ensuring that when students are present, proper amounts of outside air is delivered. When students aren't there, i.e., morning warm-up or teacher-only occupancy, outside air is closed.

Tip 12: Look beyond the HVAC systems. In 2005, NAFCCSC elected to step up conservation efforts and go beyond the HVAC systems approach that had served them well since 1984. Recognizing that a great deal of equipment in schools is not connected to the BAS, the school board created an energy auditor position. This auditor, working under the energy manager, meets with school staff to reinforce the importance of energy conservation, to give them tips on how to save energy, to audit facilities, and to do after-hours inspections looking for equipment that may be running unnecessarily. Computers have been a major focus as thousands were left running at the end of the school day.

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Tip 13: Choose your battles. Recognizing they had to have the cooperation of the building staff, NAFCCSC elected not to pursue prohibiting coffeemakers and personal refrigerators. The energy saved would not justify the political capital spent. And, a valuable lesson was learned when they turned off the soft drink machines during unoccupied hours via internal timers. The backlash from the buildings was impressive, as folks were receiving warm product early in the morning. NAFCCSC started monitoring energy use on the machines and determined that turning off the vending machine lights made more sense and saved more energy than cycling the compressors.

Conclusion

The New Albany–Floyd County Schools' philosophies have meshed well with ENERGY STAR, because ENERGY STAR has goals for efficiency and optimized student environment. The benefit for the school corporation has been significant energy savings with no compromises in indoor air quality, occupant comfort, or humidity control. From 1985 to present, total utility savings has exceeded $5 million, with $1.2 million of that occurring in the last three years. The energy savings ultimately and directly benefit the students, as all of those dollars have been redirected from utilities to enriching classroom programs. Along with the energy savings, a significant reduction has occurred in greenhouse gas emissions.

In addition to energy (operating) savings, New Albany's selection of simpler, less costly systems (the modern two-pipe) has saved capital dollars that have been redirected for other building needs such as roofs, windows and infrastructure improvements. This combination of both saved capital and energy dollars has produced outstanding facilities.

Finally, ENERGY STAR provides external validation of conservation efforts. Many purported conservation success stories boast of large energy savings, but these savings may be based on the participant's starting inefficiency. Essentially, the more inefficient a building is, the more the potential savings will be. The ENERGY STAR program bases efficiency on national averages, not on where a school started in the efficiency continuum.

How does ENERGY STAR match with ASHRAE's *Advanced Energy Design Guide for K–12 Schools*, CHiPS (Consortium for High Performance Schools), EnergySmart Schools, USGBC LEED® for Schools Rating System, etc.? The answer is well, because ENERGY STAR is a performance benchmark, while the others are design guides.

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