North Carolina Department of Public Instruction

Energy Guidelines

For K-12 Public Schools

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Public Schools of North Carolina
State Board of Education
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Division of School Support – School Planning
6319 Mail Service Center
Raleigh, NC 27699-6319

http://www:schoolclearinghouse.org

School Planning Staff

Mr. Steven M. Taynton, Section Chief
Mr. Roger Ballard, Architect
Mr. Greg Flynn, Architect
Mr. Ken Phelps, Architect
Mr. Long Chang, Structural Engineer
Mr. Johnny Clark, Mechanical Engineer
Mr. Robert Bryan, Electrical Engineer
Mrs. Pam Ray, Administrative Assistant.
Ms. Mary Gruebnau, Statistical Research Assistant

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the Office of Curriculum and School Reform Services
6307 Mail Service Center
Raleigh, NC 27699-6307
Telephone (919) 807-3761; fax (919) 807-3767

Foreword

The responsibility for providing public school facilities in North Carolina rests with the counties and the special chartered school districts within them. State support for school construction has been provided through state bond issues in 1949, 1953, 1963, 1973, and 1996 when it became apparent that local resources could not keep pace with growing facility needs. In 1983 and 1987 portions of local half cent sales taxes were earmarked for school construction and in 1987, the Public School Building Capital Fund was created to fund capital projects from a portion of the Corporate Income Tax. Additional funds were provided, starting in 2006, by the North Carolina Education Lottery. Local boards of education, which are the legal owners of school facilities, are responsible for planning and erecting appropriate facilities to support instructional programs.

House Bill 102 of the 1993 General Assembly Session established “An Act to Require the Local Boards of Education to Use the Energy Guidelines for School Design and Construction and to Require Energy-Use Goals and Standards in Order to Assure the Construction of Energy-Efficient New Schools and School Renovations.” This bill included the following language in 115C-521 “Erection of School Buildings:” “In the design and construction of new school buildings and in the renovation of existing school buildings that are required to be designed by an architect or engineer under G.S. 133-1.1, the local board of education shall participate in the planning and review process of the Energy Guidelines for School Design and Construction that are developed and maintained by the Department of Public Instruction and shall adopt local energy-use goals for building design and operation that take into account local conditions in an effort to reduce the impact of operation costs on local and State budgets.”

The North Carolina Public Schools Energy Guidelines have been developed to provide school systems and designers with useful and reliable design information to use as a basis for new schools, additions and renovations. We believe that these guidelines will enhance the ability of local school systems to plan economical and energy-efficient facilities that maximize value to their communities and provide healthy, comfortable and inviting environments for learning. It is our hope that these guidelines provide strong direction for school design, while maintaining local control of that process.

William C. Harrison, Chairman and
Chief Executive Officer
State Board of Education

June St. Clair Atkinson, State Superintendent
NC Department of Public Instruction

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- Steve Taynton, AIA, Section Chief, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Roger Ballard, Architect, Consulting Architect, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Greg Flynn, NCARB, Consulting Architect, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Ken Phelps, Architect, School Planning Consultant, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Long Chang, PE, Consulting Structural Engineer, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Johnny Clark, PE, Consulting Mechanical Engineer, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Bob Bryan, PE, Consulting Electrical Engineer, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Pam Ray, Program Assistant, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Mary Greubnau, Statistical Research Assistant, School Planning Section, N.C. Department of Public Instruction, Raleigh, N.C.
- Len Hoey, Program Manager, N.C. State Energy Office, Raleigh, N.C.
- Robert L. Talley, Jr., PE, Electrical Engineer, State Construction Office, N.C. Department of Administration, Raleigh, N.C.

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INTRODUCTION

These energy guidelines have been prepared to give the design team, consisting of architects, engineers and owner representatives, assistance as they make decisions that have an impact on the use of energy and result in the construction of energy efficient facilities.

Efficient facilities are buildings that operate with less energy, and have reduced maintenance while providing healthy and comfortable interior environments. Building efficient facilities may have a higher initial cost, but with high efficiency systems and proper maintenance, will experience lower operating cost throughout the life of the building. Any increase in initial cost related to energy efficiency will potentially be saved many times over.

The following guidelines are recommendations intended to be used in the design, construction and operation of new and renovated school buildings. Building design should use an integrated approach where all building systems and components are considered from conception to completion. The goal of the design team should be to provide a healthy and functional facility meeting the requirements of the school system, while giving the best overall cost performance over the life of the facility.

BUILDING ENERGY PERFORMANCE

In 1993, the North Carolina General Assembly passed a bill requiring all Local Education Authorities to establish an energy budget as a minimum efficiency requirement or maximum energy usage for all schools built in their jurisdiction. This budget can be established by assistance from DPI School Planning, State Energy Office and through analysis by consultants. The base line energy budget must be used by the design team as a minimum performance for the building and should be used to confirm performance of the facility following occupancy.

The 2009 North Carolina State Building Code has set forth ASHRAE 90.1 as the standard for building energy usage. It is the recommendation of School Planning that each school facility be designed to operate with at least 30% less energy than the base building described in the 90.1-2004 standard.

The design team must plan from the very beginning of the design process for a low energy consumption facility by:

- Minimizing east and west facing glazing.
- Control south facing glazing to take advantage of natural lighting while preventing glare conditions.
- Planning for heat-rejecting envelope finishes.
- Committing to energy efficient building construction materials and systems.
- Committing to a properly sized high efficiency HVAC system.
- Carefully considering an effective ventilation system.
- Specifying energy recovery systems.
- Reducing building energy loads.
- Committing to a low-consumption/high-efficiency lighting strategy (daylighting, etc.).

For further guidance in the design of energy efficient schools, please review ASHRAE's "Advanced Energy Design Guide for K-12 School Buildings" and the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy "Energy Smart Schools".

Life Cycle Costing and Building Modeling

Each Facility must have a comprehensive analysis performed to ensure the design of an efficiently operating facility.

Many different facets of a building affect the operating efficiency and each should be carefully evaluated. These include the building orientation, building shape, envelope (walls, roof, glazing), domestic water heating, the HVAC system, and electrical systems (lighting and power). Evaluation of the different alternatives possible should include a life cycle cost analysis of each. The analysis process should be applied as early in the design process as possible and be a continuous evaluation throughout the design phase.

Examples of energy control measures that should be evaluated:

- Day lighting design
- Solar domestic hot water heating
- High insulation values
- Highly efficient low maintenance HVAC systems
- Energy reclaim systems for HVAC
- Computer control of all building systems

While comparing alternative measures, it is important that each measure use fair and accurate data. Data, including construction cost for labor and materials, energy cost, cost of bonds or loan interest where applicable, certified energy efficiency factors, service life, and maintenance cost should be determined through the gathering of certified published data. Assumptions must be limited as much as possible. When necessary, assumptions must be made equally between alternatives using the best architectural and engineering judgment. These analyses are only as good as the data used in the calculations.

To confirm that energy savings goals are met, a whole building evaluation (modeling) should be performed using computer simulation software.

More detailed information about specific building aspects and systems that effect energy usage are discussed later in this document.

Performance Verification

Following construction completion of the facility, proper maintenance and continuous monitoring of all building systems that impact energy usage must be performed. This work is necessary to ensure the building performs as intended for the life of the facility.

ARCHITECTURE

Building siting and shape are important aspects of a new facility which have a significant impact on energy efficiency. Site selection and building envelope construction must be the result of verified cost effective measures. Local sources of potential pollutants should be examined during the site selection process for impact on indoor air quality control.

Decisions in selection of construction materials, assemblies and systems, especially those that influence energy usage and other energy control measures, must be properly evaluated by computer analysis to provide the best overall energy performance that meets or exceeds the energy budget established by the local education authority.

Building Orientation

Maximize daylighting potential by orienting major glazing areas to face south and north, while minimizing solar heat gains by having as little wall area and glazing as possible facing east and west. In the summer, east and west-facing walls and windows receive direct solar radiation for a longer period each day than south-facing walls. North and south facades receive diffused and reflected solar radiation for longer periods than the east- and west-facing walls. Diffused and reflected solar radiation causes less glare and contains less infrared radiation, or heat. Additionally, the shallow sun angles in the eastern and western skies are very difficult to shade. In general, an elongation of the building along the east/west axis should be the goal of the owner and designer.

Daylighting is a very low-cost strategy when planned for from the beginning. By making the decision to orient most windows to face north and south, half of the daylighting challenge is met and costs for window shading are largely minimized.

Building Configuration

A compact building form is more energy efficient. Spaces that will benefit most from daylighting on the north and south perimeters of buildings should be positioned where they can make the best use of north- and south-facing glazing. These spaces include classrooms, offices, media centers, and meeting rooms. Large floor plans may require daylight monitors and other solar devices to deliver daylight to building interiors. Building spaces should be grouped by use to allow for selective use of HVAC systems.

Insulation

Insulation in the building envelope is important to the overall comfort and energy efficiency of the building. Attention should be given to thermal bridging such as in buildings that have outside walls that are framed with steel studs and provide a parallel path for heat flow between the insulation batts. According to Table A3.3 in ASHRAE Standard 90.1-2007, a six-inch metal stud wall with R-19 insulation can have an effective overall R-value of only R-7.1.

In general, insulation has a positive effect on air conditioning and heating loads and results in energy savings up to a certain point, but additional insulation beyond required insulation levels have strong diminishing returns. The most effective place to apply additional insulation is in the roof assembly, where a larger proportion of heat gain or loss occurs.

Attention should also be given to sealing the building envelope to prevent unwanted air infiltration and moisture intrusion. Control of air and moisture is an essential element of HVAC systems and indoor air quality.

Radiant barriers, as part of building envelope assemblies, may help reduce heat gain if properly installed with airspaces and subject to cost benefit analysis. Thermal mass can help minimize temperature swings and should be considered when comparing construction types. Light colored exterior walls can help reduce solar gain.

Glazing

Selection of appropriate glazing represents a good opportunity for significant energy savings. Two important issues are pertinent: radiant (as opposed to conductive) heat gain and visible light gain. Ideally, windows would have a minimal thermal penalty and assist with lighting requirements. To accomplish this dual role, the infrared or heat portion of solar radiation must be rejected, while the visible or light portion is transmitted.

U-Factor - U-factor measures how well a product prevents heat flow from one area to another. The rate of heat transfer is indicated in terms of the U-factor (U-value) of a window assembly. U-Factor ratings generally fall between 0.10 and 1.20. The insulating value is indicated by the R-value which is the inverse of the U-value. The lower the U-value, the greater a windows resistance to heat flow and the better its insulating value.

Solar Heat Gain Coefficient - Solar heat gain coefficient (SHGC) measures how well a product blocks the heat that is caused by sunlight. The SHGC is the fraction of incident solar radiation admitted through a window and directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a windows solar heat gain coefficient, the less solar heat it transmits.

Visible Transmittance - Visible transmittance (VT) measures how much light comes through a product. VT is expressed as a number between 0 and 1. The higher the VT, the more light is transmitted.

Air Leakage- Air leakage (AL) is indicated by an air leakage rating expressed as the equivalent cubic feet of air passing through a square foot of window area (cfm/sq ft). Heat loss and gain occur by infiltration through cracks in the window assembly. The lower the AL, the less air passes through these cracks.

Roof Construction

Roof construction can have a significant impact on energy usage. Roof slope, insulation type and thickness, and color of the finished surface should all be carefully considered and analyzed to ensure as efficient a roof system as economically feasible.

Window Shading

For existing conditions or where it is necessary to darken a space for films or overhead project, light colored interior blinds should be provided.

Horizontal window shades should be properly sized and provided on the south side of the building to prevent glare and localized overheating.

Horizontal or vertical shades should be used for any large areas of east and west glazing.

Where a daylighting system is incorporated, control of artificial lighting should be controlled relative to blind position as described under the Daylighting paragraph below.

Wall Shading

Roof overhangs are commonly considered energy savers because they block solar radiation during the summer from reaching part of the wall.

Daylighting

A well thought out and planned daylighting system will both reduce energy consumption and improve the visual environment of a space. Lighting can account for a large percentage of the building's energy consumption and a daylighting system will help to minimize that energy consumption and its resultant cost.

A daylighting system begins with the proper orientation of the building to utilize the benefits of north and south facing glass and minimize the need for glazing on the east and west exposures. Quality glazing should be used to minimize transmission loads through the glass.

Natural light can be introduced into the building by sidelighting (vertical windows), toplighting (monitors, skylights, clerestory), or corelighting (courtyards, atriums, lightwells or solar tubes).

Light shelves on south windows should be provided for daylighting applications to project light into the building interior while blocking glare and direct solar radiation into conditioned spaces.

Ceilings are a major component in the performance of a daylighting system. Ceiling materials and configuration must be carefully considered when designing the system. Ceiling height and finish reflectance are also important factors in the design. Ceiling heights should be as low as reasonably possible to reduce the distance between the light source and the surface requiring illumination. The light reflectance rating of the ceiling should be .8 or higher.

The finish of all interior surfaces, particularly walls, should also be considered in the design of the daylighting system. Dark colors are poor reflectors of light and will increase the amount of light (and energy) required to adequately light a space.

Artificial lighting should be adjusted, based on available natural light, by using automatic controls for continuous dimming.

The following are principles that should be taken into consideration in the design of a daylighting system.

- Design daylighting for spaces with higher lighting loads such as classrooms, gyms, cafeterias, etc.
- Prevent direct sunlight penetration into glare-sensitive teaching spaces.
- Provide gentle, uniform light throughout the space.
- Avoid creating sources of glare.
- Allow teachers to control the daylight with operable louvers or blinds when it is necessary to provide low light during films or overhead projection. Provisions should be provided to require louvers or blinds to be opened before artificial lighting will operate.
- Design the lighting system to complement the daylighting design and encourage maximum energy savings through the use of automatic lighting controls.
- Plan the layout of interior spaces to take advantage of daylight conditions.
- Proper placement of automatic sensors in the space is critical.

PLUMBING

Water Heating

Solar water heating systems should be considered for some of the water heating needs such as kitchens and shower areas. This should be determined through Life cycle cost analysis.

Instantaneous (point of use) electric water heaters for remote fixtures should be considered where the cost of the piping/insulation and energy loss offset the cost of the instantaneous heater. This should be determined through Life cycle cost analysis.

Use gas-fired water heaters for kitchens, locker areas with showers and areas where large demands are congregated. Electronic ignition systems should be used. High-efficiency condensing-type water heaters should be considered. This should be determined through Life cycle cost analysis.

In buildings that are heated and cooled with hydronic heat pumps, consider using hydronic heat pump water heaters connected to the hydronic loop. Using this type of domestic water heating equipment will allow the water heaters and to extract heat from the loop that the building cooling equipment rejected into the loop. Significant energy savings can be accomplished due to the trade off of energy between the domestic water heating system and the building cooling system as well as the high efficiency of the heat pump system it-self.

Hot water should only be supplied to fixtures that are required by the local health department and deemed necessary by the local education authority. This will save construction costs by limiting the amount of hot water piping and will reduce energy costs by reducing the amount of water heated and the amount of energy lost through the piping system.

Insulation

Specify water heaters and storage tanks that provide energy efficiency and stand by performance as required in chapter 5, table 504.2.1 of the North Carolina State Building Code (Energy).

Insulate all domestic hot water distribution piping as require in chapter 5, table 504.5 of the North Carolina State Building Code (Energy).

Fixtures

Specify low-water-flow fixtures in accordance with chapter 6, table 604.4 the North Carolina State Building Code (Plumbing).

Use automatic lavatory faucets for all student-use restrooms, in accordance with chapter 6, paragraph 604.4.1 of the North Carolina State Building Code (Plumbing).

Controls

The building automation system should be used to control water heater and recirculation pump schedules. This will provide savings in pump energy and reduced system losses. A local aquastat should be used to cycle the recirculation pump during scheduled periods.

Heating Ventilating and Air Conditioning

System Selection

It is important to make the right choice when selecting the HVAC system for any school facility. HVAC systems impact the quality of the indoor environment and are a significant factor in the operating cost of the facility. Since the cost imposed on the school system over the life of a building far exceeds the initial construction investment, the operating efficiency is a major criterion on which systems are selected. This selection should be made through good engineering practices and evaluation. The systems must comply with the North Carolina State Building Code, must operate efficiently, provide proper zoning of the facility, provide and control the recommended temperature and humidity within the facility, and provide the proper indoor air quality required for a healthy learning environment.

Temperature, humidity and ventilation control directly relate to health issues and must always take precedence over energy issues.

The evaluation process should include a detailed computer simulation using software such as Carrier HAP or Trane Trace to compare logical alternative design options that meet the functional requirements of the facility. The simulation must consider all operating parameters including building schedules, internal and external influences on the building temperature, humidity and air quality, estimated initial construction cost, operating efficiencies, energy cost, maintenance and replacement costs for each system type.

Building schedules must be provided by the school officials and account for all school functions. These should include the normal school hours and operations after normal school hours. The HVAC system must also be designed to meet the varying annual schedules. For instance, libraries control temperature and humidity year-round. Other spaces, such as auditoriums, are only intermittently occupied, while school administration facilities often operate beyond the normal school year. It may not be the most cost efficient to operate an entire chiller plant during the summer to solely serve a media center, administrative area, chemistry storage, or data closet. Separate HVAC systems should be evaluated as a part of the alternative options simulation. Grouping these specialty areas together is advisable to reduce the number of separate HVAC systems required.

Based on availability, alternative fuel sources (electricity, fuel oil, natural gas, propane) should be evaluated and analyzed as a part of the alternative options simulation.

Maintenance cost should be determined using industry published, actual documented, historical data for each system type. Sources for this information include ASHRAE and Trane Company as well as others.

The service life of each system type must be considered. Reference the ASHRAE Handbook of HVAC Applications for the service lives of the different systems. Replacement cost must be included for systems with a shorter service life than those of the comparative systems.

The simulation must account for cost escalations for energy, maintenance and replacement over the life cycle period.

At least three logical alternative system options should be compared in the computer simulation process. The selected system should be the system, determined by the simulation, to be the most cost effective by providing the best overall life cycle cost.

For new schools, system types that potentially offer a superior life cycle cost are:

- Geothermal Heat Pump system (ground source)
- Water source Heat Pump Systems (boiler, tower)
- Four pipe chiller and boiler systems

For small additions and small buildings where the existing building or campus system does not have sufficient capacity or is not economically feasible for expansion to serve the new space, system types that potentially offer the best overall life cycle cost are:

- Air to Air Heat Pump system (split system)

System components that should be considered as offering a good life cycle cost are:

- Variable volume air flow systems
- Variable volume hydronic systems
- High efficiency boilers
- Energy reclaim equipment

These systems should be complimented with demand control ventilation, direct digital controls, etc.

HVAC Loads

HVAC loads must be determined in accordance with generally accepted engineering standards such as ASHRAE Handbook of Fundamentals.

Calculating the HVAC loads must account for all factors contributing to the heat gain and heat loss in each space. Designers should consult closely with school system staff to accurately determine all internal loads. Internally generated loads that contribute to cooling requirements are heat and moisture generated by occupants, lights, and equipment. Heat gain from external loads include heat radiated from the sun into the interior through windows, and heat conducted to the interior through exterior surfaces. Calculations must use an accurate account of all construction systems (i.e. walls, windows, roof) and their resistance factors.

Outside design temperature conditions must meet the requirements of chapter 3 of the North Carolina Building Code (Energy) and indoor design conditions should meet the North Carolina Department of Public Instructions Facility Guidelines of 75 degrees F summer and 72 degrees F winter. Modification of the conditions is not allowed as a safety factor.

Outside air introduced as ventilation must meet the quantities required in chapter 4 of the North Carolina State Building Code (Mechanical) and also be included in the heat gain and loss calculations.

Loads must be calculated for the actual building conditions. As an example, where daylighting strategies are planned, the cooling loads should account for the reduced artificial lighting levels instead of the design standard watts per square foot. This will require the Architect, the electrical engineer and the mechanical engineer to work together early in the design phase to determine all parameters. Similarly, when highly reflective surfaces such as a white roof are to be used, the cooling load calculations must take it into account also.

Fresh-Air Ventilation

Fresh air may be introduced into the occupied space by ducting the fresh air and introducing it into the return air of the air handling unit or it may be delivered directly into the space by a separate ducted system and air-handling unit.

Fresh air introduced into the return air system may be untreated or may need to be dehumidified in more humid climates. Fresh air systems that deliver the fresh air directly to the classrooms must always be cooled and heated.

Either system may be able to use exhaust air to temper the fresh air (and save energy) with an air-to-air heat exchanger.

Adequate fresh air must be provided to avoid indoor air quality problems. Refer to chapter 4 of the North Carolina State Building Code (Mechanical) for minimum requirements. Over-ventilation or “dilution ventilation” is not recommended and will potentially result in high humidity problems unless costly steps are taken to control the humidity level and will result in both higher first costs and higher operating costs.

Refer to United States Environmental Protection Agency, “IAQ Design Tools for Schools” for recommendations on indoor air quality.

Filtration

Good filtration (minimum MERV 8) must be provided to remove airborne contaminants and reduce the need for dilution effects of high ventilation rates. Maintaining clean filters will result in reduced fan horse power and improved air flow, both of which will save energy.

HVAC General Guidelines

- Verify that the mechanical systems serving each area of the school have been zoned by orientation and use patterns.
- Avoid over sizing heating and cooling equipment. In daylit spaces, downsize cooling equipment to reflect daylighting benefits associated with the lights being off during peak load periods (when the sun is the brightest, the daylighting is at its peak usage and heat-producing lights will be turned off).
- Install a high-efficiency air filtration system to remove particles of airborne dust.

This will also help in maintaining good indoor air quality.

- Design HVAC system installations to ensure adequate access for inspections, regular housekeeping, service and maintenance.

- Design ventilation/exhaust systems such that the overall building will operate under an acceptable level of positive pressure.

- Incorporate energy reclaim systems that, where evaluated by a life cycle cost analysis, prove to be feasible. Energy reclaim system should result in a reduction in size of primary systems. This must be taken into account during modeling.

- Provide proper air distribution to deliver conditioned air to all occupied areas. The selection and location of diffusers are important to space comfort, saving energy and operation of the HVAC system. Select diffusers with high induction ratios, low pressure drop, and good partial-flow performance. The location of diffusers should be determined on the basis of proper airflows, rather than for the purpose of a simplistic or symmetrical pattern.

- Ductwork must not be located outside of the insulated envelope of the building.

- Specify sealing of ductwork seams, joints, and connections with permanently pliable water-based mastics or sealants. Refer to ASHRAE Standard 90.1 for guidance.

- Minimize long duct runs and unnecessary turns to limit static pressure losses. Duct work fittings should follow SMACNA design and construction recommendations to ensure the highest in airflow efficiency.

- Incorporate variable-speed, high-efficiency motors for pumps and fans, where feasible. This should be a part of the initial HVAC system simulation.

- Include in project specifications the requirement for a building commissioning program. Commissioning should be performed, as a minimum, during construction and verification periods of the project.

Controls

School buildings should be provided with computer based building automation systems (BAS) to efficiently control all aspects of the HVAC system. Control of plumbing and lighting systems as well as monitoring equipment status and energy usage should also be incorporated into the BAS.

Building Automation Systems

Optimal start saves energy by reducing the system operation to the minimum time necessary to provide comfort conditions. Optimal start should be used such that at the beginning of the day, the BAS determines the time at which the cooling or heating system should be activated to bring the building to comfort conditions by the time it is occupied. The time that chillers, boilers and fans are activated is based on a calculation within the BAS based on outside and inside temperatures and historic data to determine the best time to activate the HVAC systems.

Thermostats specified for educational facilities should be of the electronic type. These respond much more rapidly to changes in temperature than bi-metallic thermostats and provide finer comfort control with less variation in interior conditions. The location of control thermostats should be given careful consideration. In general, the devices should be located on interior walls away from direct air movement from diffusers.

Electronic temperature sensors should be provided with an override button on the face plate that allows the occupant to signal the BAS that a space is occupied and needs conditioning during periods when the space is normally unoccupied for a programmed period of time.

Use carbon dioxide sensors to reduce ventilation rate below the code required minimum when a space is unoccupied as determined by the carbon dioxide levels.

Economizers should be included in all large (3000 cfm and above) air handling systems, except those located in extremely high humidity climates. Control of the economizer should be by a dry bulb sensor in dryer climates and by an enthalpy sensor in more humid climates.

Turn off all outside air intake during unoccupied periods.

Monitor pressure drop across filters and replace as necessary to save fan energy.

Energy monitoring

Energy sources must be monitored for verification of actual energy usage for operation of the facility.

Electrical energy should be monitored 24 hours a day 365 days a year. The building automation system should be used to constantly monitor, archive data and totalize the electrical energy usage.

Natural gas or propane systems usage should be monitored. Measurement of this fuel should be by measurement of actual fuel flow by a gas flow sensor. The building automation system should be used to constantly monitor, archive data and totalize usage of this fuel.

Fuel oil systems usage should be monitored. Measurement of this fuel should be by measurement of actual fuel flow by a fluid flow sensor. The building automation system should be used to constantly monitor, archive data and totalize usage of this fuel.

LIGHTING AND POWER SYSTEMS

General

Lighting and electrical systems have a major impact on energy usage for any school facility. Lighting and power equipment are also a significant part of internal heat gain. The design team must work together to provide an efficient lighting system while ensuring proper lighting levels that provide a good visual environment. As a part of the design, special consideration should be given where persons with visual or emotional exceptionalities, that are sensitive to light intensity and glare, will occupy a space. See School Planning publication: Facilities for Exceptional Children.

Providing adequate lighting must always remain a top priority when considering innovative lighting systems, since the quality and quantity of light directly impacts the comfort and productivity of the students and instructors.

Lighting Systems

As previously discussed in this document, daylighting must be considered for all applicable areas. This should be accomplished through cooperation between the architect and the lighting engineer to take full advantage of natural lighting. Artificial lighting should be designed as a supplement, secondary to natural lighting.

Lighting systems must be the result of careful consideration of all types of lighting equipment and components including energy efficient fixtures, ballast, lamps and controls. Careful selection of the fixture type, including the proper application of the lens type, is important. The designer should strive to achieve the highest lumen output per watt input, or efficacy, for the fixture as a unit.

The following lamp types are considered viable options when properly applied:

> Fluorescent – T8 lamps with electronic ballasts are to be considered as a baseline in efficiency. T5 lamps should be considered by life cycle cost analysis.
>
> High Intensity Discharge – Careful consideration must be made to select the correct lamp that will provide the correct lighting level and quality (color).
>
> Light Emitting Diode – These lamp types offer the best efficiency, however, may not be cost effective. These fixture types are continually improving and their cost continue to become more competitive. Designers should monitor the status of this option and evaluate their viability through life cycle cost analysis.

Task lighting should be considered where the application of this type of lighting can reduce the level of general lighting that is required. This should be evaluated by life cycle cost analysis to determine if the cost and operation of the task lighting system will be offset by the cost savings in reducing the general lighting system cost.

Different areas of the facility with different usages, lighting level requirements and ceiling arrangements must be evaluated separately. The final selection for each lighting system should be determined through a life cycle cost analysis.

Controls for Lighting

All lights and lighting systems require either manual or automatic controls. Controls and how they are used are important to limiting the energy used for lighting systems. Lights should be turned off whenever the space is not occupied or levels reduced when the function of the space will allow.

Manual controlled systems are controlled with on/off switches or dimmer switches. Multiple switching is required by the North Carolina State Building Code (energy). This arrangement allows for switching two or more levels of lighting. Multiple switching should be incorporated in all areas when the space functions will allow. Different levels of lighting a space can be accomplished by switching banks of fixtures or the preferred option would be to use multiple ballasts in each fixture. Multiple ballasts allow an even level of lighting throughout the space.

Automatically controlled systems are controlled with photo electric sensors, occupancy sensors and/or automatic timing equipment. The building automation system should be used to enable the building lighting systems on a time of day schedule. Occupancy sensors should be installed in classrooms and larger spaces to turn off the lights automatically when the space is unoccupied. The occupancy sensor must be wired in series with the wall switch.

Facilities with daylighting systems should control the level of artificial lighting based on a photoelectric sensor located in each space using this system. These sensors must adjust the level of artificial lighting as the natural lighting varies to maintain a constant level of lighting in the space. The photoelectric sensor must be wired in series with the wall switch.

Exit Signs

Fixture types must be selected that offer low energy consumption and low maintenance.

The following fixture types are considered viable options when properly applied:

LED exit signs – These fixtures offer large savings with little maintenance.

Fluorescent exit signs – These fixtures offer large savings with little maintenance.

Electroluminescent exit signs – These fixtures use no power thus no wiring and virtually no maintenance. Life expectancy for these fixtures is 20 years.

The final selection for the type of exit sign to be used should be determined through a life cycle cost analysis.

Lumen Maintenance

In some spaces a lumens maintenance system has the potential to save energy over the life of the lighting system. The output of certain types of lamps decreases over its life due to internal degradation, as well as dust and pollutant buildup on its surface. Recognizing this fact, designers do their calculations using the assumed light output of a partially-aged lamp, usually assuming about 70 to 75 percent of the output of a new lamp/ballast/housing combination. This results in overlighting near the beginning (although lamp deterioration is more rapid at early stages than later).

The strategy of lumen maintenance is to create a desired end condition of consistent and proper light levels at the workplace by varying power levels to the ballast. Photosensor controls adjust power output to provide a constant light level, reducing power to new lamps, and increasing power later in the lifespan of the lamp. This results in lower overall power levels and corresponding energy savings over much of the life of the lamp.

The decision to implement this type system should be determined through a life cycle cost analysis.

Power Systems

Careful consideration must be given to the design of the electrical distribution system. Proper selection of voltages and distribution methods are important in limiting system energy losses. The goal in this evaluation is to reduce resistance line losses. An analysis comparing increase system costs with expected energy savings by reducing line losses should be performed.

A detailed evaluation of electrical loads must be made in the process of sizing dry type transformers used in school facilities. Transformers must be properly sized for normal operation to be above 50% of their rated capacity to ensure maximum efficiency. Specify high efficiency transformers as described in the U.S. Department of Energy standard for energy efficient transformers.

Energy efficient motors should be used on all new equipment and when existing motors are replaced. Efficient motors, especially large motors, can provide significant savings.

Commissioning

Total building commissioning is required to accomplish an efficiently operating building. Commissioning of the building envelope, plumbing systems, HVAC systems and electrical systems confirms that these systems are constructed/installed in the intended manner necessary to accomplish the required efficiency levels.

A commissioning contractor should be a registered engineering firm, experienced in the commissioning of school facilities. This contractor should be a third party agent contracted directly with the school system.

The following is a list of responsibilities that should be required of the commissioning contractor:

- Review final construction documents for coordination among trades and completion of necessary information and accuracy.
- Provide a commissioning specification to be included along with the construction specifications. This document must include testing and balancing requirements for the project.
- Review construction contractor’s equipment submittals.
- Supervise and validate all final construction testing and balancing functions and review and approve all final contractor report documentation.
- Supervise and validate all seasonal testing and balancing functions and review and approve all final contractor report documentation.
- Following one year occupancy, perform all testing and data acquisition necessary to verify system and building performance. This measurement and verification process will determine how the facility is actually performing as compared to the original designer prepared analysis.

Operation and Maintenance

Operation and maintenance is paramount in maintaining the efficient performance of the facility. Each school system must provide skilled staff to operate the building systems, controlling and maintaining them to perform as originally intended throughout the life of the facility.

Proper training of school system maintenance staff must be performed following completion of construction. This training must include operational, service and repair training for all equipment and building control systems in the facility. The cost of all training should be a part of the construction project.

References

- ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, Georgia

- ASHRAE Handbook of HVAC Applications, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, Georgia

- ASHRAE Standard 90.1, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, Georgia

- Advanced Energy Design Guide for K-12 School Buildings, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, Georgia

- Energy-Smart Schools, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

- IAQ Design Tools for Schools, United States Environmental Protection Agency

- North Carolina State Building Code, Energy

- North Carolina State Building Code, Plumbing

- North Carolina State Building Code, Mechanical