Energy Efficiency and Indoor Air Quality in Schools

Overview

Indoor Air Quality
Tools for Schools

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In the 1998-99 school year, U.S. K-12 public schools provided instruction to over 46 million students. An estimated 70% of all school buildings have indoor air quality (IAQ) problems, leading to an unhealthy environment.[1] Because children breathe a greater volume of air relative to their body weight compared to adults, they may be more sensitive to indoor air pollution. Additionally, occupants of school buildings are close together, with approximately four times the occupant density in schools compared to office buildings. A 1995 GAO study[2] reports that ventilation, indoor air quality, temperature (heating and cooling), and lighting are among the leading unsatisfactory environmental conditions in school buildings. Because mounting evidence indicates that the quality of a school's physical environment affects educational achievement, increased attention to both energy efficiency upgrades and indoor air quality in schools could provide significant benefits.

Many energy efficiency upgrades can improve the quality of schools' indoor environment, protecting and even enhancing IAQ without sacrificing energy performance. However, if certain energy upgrades are not done correctly, they may adversely impact indoor air quality. Increased energy efficiency in building construction, for example, has resulted in tighter building shells and reduced ventilation rates.

This document describes how to protect and enhance both indoor air quality and energy efficiency. For further information on improving school energy performance, please refer to the ENERGY STAR® *Building Manual*, available for download in the Tools & Resources section at www.energystar.gov/buildings. For guidance on indoor air quality, consult the *Indoor Air Quality Tools for Schools* Kit (see page 5 for contact information).

Common IAQ Culprits

Many factors interact to create an unhealthy indoor environment. The most important include indoor pollutants, outdoor pollutants near the building, pollution transport through the ventilation system, air cleaning or filtration, and indoor climate (temperature and relative humidity). Many building materials, the furnishings and equipment, and the occupants and their activities are sources of indoor pollution. Following is a list of some of the more common pollutants and their sources.

- **Environmental Tobacco Smoke (ETS):** Lighted cigarettes, cigars, pipes.
- **Biological Contaminants (mold, bacteria, viruses):** Wet or damp materials, cooling towers, humidifiers, cooling coils or drain pans, damp duct insulation or filters, condensation, wet carpet or ceiling tiles, sanitary exhausts, bird droppings, cockroaches or rodents, people with contagious viruses.

[1] *Productivity Benefits Due to Improved Air Quality,* Dorgan Associates (1995), p.3.7.

[2] *School Facilities: Condition of America's Schools,* United States General Accounting Office, February 1995.

- **Volatile Organic Compounds (VOCs):** Paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, fuels, plastics, copy machines, printers, tobacco products, perfumes, dry cleaned clothing, marking pens, art supplies.
- **Formaldehyde:** Particle board, plywood, cabinetry, furniture, carpets, fabrics.
- **Soil gases (radon, VOCs, sewer gas, methane):** Soil and rock (radon), sewer drain leaks, dry drain traps, leaking underground storage tanks, land fills.
- **Pesticides:** Termiticides, insecticides, rodenticides, fungicides, disinfectants, herbicides.
- **Particles (tiny solid particles or dust particles in the air):** Printing, paper handling, smoking and other combustion sources, outdoor sources of air pollution, deterioration of materials, vacuuming, construction/renovation, chalk.

Pollution transport through ventilation. Outside air also contains contaminants that can be brought inside through the ventilation system. Indoor air quality problems caused by outdoor pollutant sources can stem from idling school buses, local traffic or vehicles at loading docks, cooling towers for the air conditioning system, sanitary or kitchen exhausts, trash and landscaping chemicals storage.

Air cleaning or filtration. Some contaminants are removed from the air through natural processes, when chemicals react with other substances or settle onto surfaces. Removal processes may also be deliberately incorporated into the building through air filtration devices. Standard filters protect HVAC equipment from large particles, while high-efficiency filters may collect some breathable particles. Upgrading the filtration system is commonly recommended as good indoor air quality practice. However, ozone generators sold as air purifiers can create special problems and are not recommended.

Indoor climate/temperature and relative humidity. Inadequate temperature and humidity conditions affect indoor air quality for several reasons. As temperature and relative humidity increase, so does the rate at which chemicals are released. Mold and dust mite populations also increase with humidity levels. In addition, students, teachers, or school staff who are thermally uncomfortable may have a lower tolerance to pollution exposures.

ASHRAE Standard 55-1992, Thermal Environmental Conditions for Human Occupancy, identifies many factors that influence thermal comfort and conditions. In most cases, maintaining a school within the appropriate ranges of temperature and relative humidity will meet thermal comfort requirements.

How Energy Efficiency Projects Affect IAQ

Many energy upgrades, such as those related to fans, motors, drives, and chiller/boiler systems, generally have little impact on IAQ. Other energy efficiency measures are usually very compatible with IAQ. Examples include energy recovery (explained in a later section of this document), which may reduce the energy burden of outdoor air, especially in extreme climates or when high outdoor air volumes may be required (e.g., in schools, auditoriums). Tune up/maintenance of the HVAC system (e.g., clean coils/drain pans) can at times improve IAQ by removing contaminant sources. Finally, testing, adjusting, and balancing the HVAC system can improve ventilation effectiveness. The

Proportional Balancing Method reduces static pressure and energy requirements better than conventional balancing methods.

Some energy projects have the potential to degrade IAQ, but can be made compatible with appropriate adjustments. For example, variable air volume (VAV) systems with fixed outdoor air dampers tend to degrade IAQ unless proper steps are taken.

Table 1 outlines the cautions and practical steps that may be needed to avoid IAQ problems for each energy efficiency measure.

The Energy Cost of Outdoor Air Ventilation

The IAQ control most often associated with high energy cost is the 15 cubic feet per minute (cfm) per occupant outdoor air requirement of ASHRAE Standard 62-1989. An EPA study[3] modeled a comprehensive energy retrofit program and compared two retrofitted buildings, one operating at 5 cfm per occupant and one at 15 cfm per occupant. Humidity was controlled in both cases. Energy savings foregone to achieve adequate ventilation ranged from 3 to 9% of the pre-retrofit energy cost. Post-retrofit results showed total energy savings of 22 to 41% at 5 cfm per occupant and between 19 and 37% at 15 cfm per occupant.

The study showed that relatively high energy penalties during extreme weather conditions were counterbalanced by energy savings during milder weather, where the additional outdoor air provided some “free cooling” benefits. Free cooling is especially significant in schools where high occupant densities result in large internal heat gains, requiring cooling even during cool weather.

Energy Recovery Ventilation

The high occupant densities of schools and classrooms challenge building designers to incorporate ventilation systems that provide adequate outdoor fresh air. While maintaining compliance with ASHRAE Standard 62-1989, designers are also interested in minimizing capital and operational costs. Because increased outdoor air ventilation rates can result in higher heating and air-conditioning costs and more indoor moisture problems in some geographic locations, there is increased interest in energy recovery ventilation (ERV) technology. ERV systems transfer energy between the inlet and exhaust streams as the building is being ventilated. Some systems transfer only heat energy, while others also transfer latent (moisture) energy through a desiccant coating or other means. Significant energy reductions can be achieved by reducing the energy requirements of conditioning the outdoor air, particularly during extreme weather conditions.

The total economic viability of ERV technology depends on its impact on total costs. ERV technology can lower capital costs by reducing the peak loads, which in turn makes it

[3] Hall, John D., Mudarri, David H., and Werling, Eric. Energy Savings in Relation to Indoor Environmental Quality. In *Proceedings of ACEEE 1998 Summer Study on Energy Efficiency in Buildings*. 1998. American Council for an Energy-Efficient Economy. Vol. 8, pp 99-110.

Table 1: Energy Efficiency Measures Where Adjustments May Be Necessary

Measure	Comment
Improved building shell (e.g., lights, office equipment)	If infiltration is reduced, may need to increase mechanically supplied outdoor air to meet applicable ventilation standards.
Reduced internal loads	Reduced loads will reduce supply air requirements in VAV systems. May need to increase outdoor air to meet applicable ventilation standards.
Air-side economizer	Uses outdoor air to provide free cooling. Can improve IAQ when economizer is operating by helping to ensure that the outdoor air ventilation rate meets IAQ requirements. On/off set points should be calibrated to both the temperature and moisture conditions of outdoor air (for example, by using an enthalpy controller) to avoid indoor humidity problems. May need to disengage economizer during an outdoor air pollution episode.
Variable Air Volume (VAV) systems with fixed percentage outdoor air	VAV systems can yield significant energy savings over Constant Volume (CV) systems in many schools. However, many VAV systems provide a fixed percentage of outdoor air (e.g., fixed outdoor air dampers), so that during part-load conditions when the supply air is reduced, the outdoor air may also be reduced to levels below applicable standards.
Night pre-cooling	Cool evening air pre-cools the building while simultaneously exhausting accumulated pollutants. To prevent microbiological growth, controls should stop pre-cooling if the dew point of outdoor air is high enough to cause condensation on equipment.
CO_2 controlled ventilation	CO_2 controlled ventilation varies the outdoor air supply in response to the CO_2 level, which is used as an indicator of occupancy. This may reduce energy use for general meeting rooms, theaters, etc., where occupancy is highly variable. The system should incorporate a minimum outside air setting to dilute building-related contaminants during low occupancy periods.
Reducing demand (kilowatt) charges	Caution is advised when using night pre-cooling and sequential startup of equipment to eliminate demand spikes if load-shedding strategies include changing the space temperature set points or reducing outdoor air ventilation during occupancy.
Reducing outdoor air ventilation	Applicable ventilation standards usually specify a minimum continuous outdoor air flow rate per occupant, and/or per square foot, during occupied hours. Reducing outdoor air flow below applicable standards degrades IAQ, and is not recommended.
Reducing HVAC operating hours	Delayed start-up or premature shutdown of the HVAC system may create IAQ problems and lead to occupant complaints. Insufficient lead time prior to occupancy can cause thermal discomfort and pollutant-related health problems if the HVAC system cannot sufficiently deal with loads from both the nighttime setbacks and current occupancy. It may be acceptable to shut down equipment before occupants leave if fans are kept operating to ensure adequate ventilation.
Extending temperature control setpoints	Some energy managers may be tempted to allow space temperatures or humidity to go beyond the comfort range established by applicable standards. This is not recommended, as occupant health, comfort and productivity are compromised. The lack of overt occupant complaints is NOT an indication of a healthy environment.

possible to downsize equipment. In some system configurations, ERVs may further reduce costs by eliminating the need for certain exhaust fans. ERV systems, however, also entail certain inefficiencies and pressure losses that reduce the overall operating savings. In addition, some systems may require more maintenance, or may incorporate additional filtration systems beyond the ones required for the baseline system.

ERV systems are more economically viable in extreme climates, particularly in hot and humid climates where total energy recovery systems are employed to reduce moisture-related cooling loads. For example, in a sample calculation for a prototypical classroom wing of a school building with a central air handling system in Miami, Florida, a total energy recovery system achieved a simple payback of 4 years for a 9-month school year, but was reduced to less than 2 years for a 12-month operation with afternoon and evening classes.

Summary

This document, particularly Table 1, describes the precautions to take to prevent or resolve indoor air quality problems related to energy efficiency. This document was designed to help facility managers create a healthier indoor environment for students, teachers, and staff. Increasing energy performance through energy efficiency measures can not only save energy and money, but also improve the indoor air and comfort in school buildings.

Additional Resources

The Indoor Air Quality Web site at **www.epa.gov/iaq** provides information and guidance on indoor air quality in homes, schools, and commercial buildings. Many documents can be downloaded, or you can call the Indoor Air Quality Clearinghouse at 1-800-438-4318 (Fax 703-356-5386).

Information on how schools can start implementing energy efficiency upgrades can be found at the ENERGY STAR® Web site at **www.energystar.gov/buildings.** Documents are also available from the ENERGY STAR Hotline at 1-888-STAR-YES (1-888-782-7937).