GREEN, HIGH PERFORMANCE SCHOOLS

Air Quality Sciences, Inc.
2211 Newmarket Parkway
Marietta, GA 30067
(770) 933-0638
www.aqs.com

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GREEN, HIGH PERFORMANCE SCHOOLS:

"POSTER CHILD" FOR SUSTAINABLE BUILDING

Sustainable (green) educational institutions, particularly K-12 schools, are becoming the "poster child" for the positive effects high performance buildings can have on students, teachers and staff members, while at the same time saving energy and minimizing the buildings' impact on the outdoor environment. These buildings also demonstrate that it is possible to balance energy conservation and good indoor air quality (IAQ) with excellent outcomes. This white paper provides an overview of green schools, while addressing common obstacles and dispelling the myth that green schools are not good investments. It also explains how green building principles promote healthier indoor environments and includes information demonstrating the positive impact of high performance schools on student learning, comprehension and test scores; improved student health; greater productivity; and impressive financial rewards.

GREEN, HIGH PERFORMANCE SCHOOLS: AN OVERVIEW

According to the US Department of Education nearly 73 million people in the US, including 68.5 million children (6 million of whom have asthma) spend a significant amount of time each day in more than 120,000 public and private schools (Common Core Data 2002). Many of the school buildings are in poor condition, which accounts for the US Environmental Protection Agency's estimate that 50 percent of US schools have IAQ problems. *See Improving Student Health and Productivity by Improving IAQ* and *Getting There From Here: Improving IAQ in Green Schools* below for more information about the types of IAQ problems found in schools and strategies for addressing and preventing them.

As a part of its review and assessment of the health and productivity benefits of green schools, the National Research Council found "a robust body of evidence indicating that the health of children and adults can be affected by air quality in a school," and "a growing body of evidence [suggesting] that teacher productivity and student learning, as measured by absenteeism, may be affected by indoor air quality as well" (National Research Council 2006). The California Air Resource Board (CARB) reached a similar conclusion in its report to the California Legislature on the quality of indoor air in that state (CARB 2005).

DEFINING GREEN SCHOOLS

Simply stated green schools are "a school building or facility that creates a healthy environment that is conducive to learning while saving energy, resources and money" (USGBC 2008). Green schools are specifically designed to provide good IAQ, lighting and acoutistics; be energy and water efficient; wisely use natural resources; and have a minimal impact on the outdoor environment. When compared with traditional schools, green schools:

- Perform better, improve the community's image and make it easier to secure government approvals to build or renovate a school facility.

- Enhance the ability to attract and retain teachers and students.
- Reduce student absenteeism.
- Improve student health, performance and test scores (Turner Construction Company 2005). See *High Performance (Green) Schools = High Performance Student and Teachers* below for a review of the results from a number of studies that demonstrate the benefits of green schools on improving student health, performance and test scores.

One of the challenges of green schools is different people and organizations have different impressions of what "green" is as it relates to schools. The following are features of green schools as defined by the US Green Building Council (USGBC):

- **LEED® certification.** Confirms the school has been built to the highest performance standards.
- **Energy efficient lighting.** Adequate levels of the right kind of light can save energy and enhance learning conditions. Adding remote sensors, individual controls and task lighting can greatly reduce electricity costs.
- **Thermal comfort.** Comfortable indoor temperatures enhance productivity and keep students more alert. Fresher, cleaner air can be achieved with windows that open or ventilation systems that provide a constant supply of air.
- **Low-emitting materials.** Using paint, carpet adhesives, ceiling tiles, wall systems, flooring and furniture that do not emit toxic gases will improve air quality in the classroom and throughout the school. Good IAQ keeps students and faculty healthier and reduces absences related to respiratory conditions and other environmental illnesses.
- **Mold prevention.** Providing adequate ventilation and keeping relative humidity below 60 percent inhibits indoor mold growth. The presence of mold can lead to serious health concerns, especially in children.
- **Daylighting.** Skylights and large windows allow daylight to stream in, reducing energy costs and improving student concentration and performance. Adjustable blinds and shades help reduce glare. Lightshelves bounce sunlight deep into the room and provide even light distribution.
- **Acoustics.** Improved acoustics can be achieved with acoustical ceiling tiles, lined ductwork and quiet heating, ventilating and air-conditioning (HVAC) systems with appropriately placed vents. Classrooms with improved acoustics create a more productive learning environment for children and allow teachers to be heard without straining their voices.
- **Water efficiency.** Low-flow sinks, waterless urinals and dual-flush toilets reduce total water use by as much as 50 percent. Toilets that use harvested rainwater instead of potable water help ease the strain on municipal water systems. Students get a first-hand lesson on conserving water use.
- **Green roofs.** Green roofs are cooler, save energy and provide a filter for storm water run off. The natural habitat that green roofs afford for birds and butterflies creates an interactive learning environment for students.

- **Solar panels.** Roof-mounted solar panels turn sunlight into an alternative energy source for the school and provide excellent opportunities for hands-on learning.

- **Recycling.** Engaging students in recycling programs teaches them responsible environmental habits that they can apply at home. Diverting solid waste from landfills reduces impacts on municipal services.

- **Alternative transportation options.** Alternative fuel buses reduce carbon dioxide emissions, smog and ground level ozone. Bike racks and safe bike paths and sidewalks encourage an active lifestyle and decrease emissions.

- **Joint use of facilities.** By making school spaces available for use by the larger community, the need for additional facilities decreases, saving costs community-wide and decreasing the environmental impact of the community as a whole (GreenSource 2009)

GREEN SCHOOLS AMONG PRESIDENT OBAMA'S TOP PRIORITIES

In response to these concerns, there has been a dramatic move towards "greening America's schools." Green education buildings (K-12 and higher education) presently are estimated at 15 percent to 20 percent of the new construction market by value in 2008 and are expected to grow to as much as 30 percent of market share by 2013. Architects and engineers interviewed for the *2009 McGraw-Hill Construction Green Building SmartMarket Reports* expect that K-12 schools will have 20 percent of the green building market share and will surpass green office projects by 2013 (McGraw-Hill Construction 2009a, b).

Green schools also have become a main concern of President Barack Obama, who has identified three investment priorities for restoring our nation's economic vitality and putting Americans back to work: energy, education and healthcare. According to the US Green Building Council, green schools are at the intersection of these goals. For example, President Obama's commitment to greening thousands of schools will not only have the potential to provide students and teachers with healthier facilities but will possibly save school districts millions of dollars while dramatically decreasing the impact these buildings have on energy consumption and the environment. With reduced operating costs, green schools can put the money saved directly back into the classroom. Green schools also are healthy places to learn, work and play, which could lead to significant savings and relief to the country's over-burdened healthcare system. To that end, President Obama has dedicated almost $100 billion to energy, education and healthcare in his proposed 2010 federal budget (USGBC 2009a).

The American Recovery and Reinvestment Act (ARRA) signed by President Obama on February 17, 2009, provides significant funding and financing opportunities to modernize, renovate and repair public schools. Under the "State Fiscal Stabilization Fund" up to $53.6 billion can be allocated to schools, including higher education and K-12 schools. Nearly $40 billion is targeted to school districts "for the support of elementary, secondary and postsecondary education and, as applicable, early childhood education programs and services" [pages 165 and 166, Sec. 14002(b)]. School districts may use the funds they receive for "any activity authorized by the Elementary and Secondary Education Act of 1965, the Individuals with Disabilities Education Act, the Adult and Family Literacy Act, and the Carl D. Perkins Career and Technical Education Act, or for modernization, renovation and repairs of public school facilities (including charter schools), which may include modernization, renovation and repairs consistent with a recognized green building rating system" (NCEF 2009).

The states are set to receive about $8.8 billion "for public safety and other government services, which may include assistance for elementary and secondary education, and for modernization, renovation or repair of public school facilities and institutions of higher education facilities, including modernization, renovation and repairs that are consistent with a recognized green building rating system [page 166, Sec. 14002(b)]." The states appear to have wide discretion in distributing this money, making it difficult to predict how and on what it actually will be spent (NCEF 2009). An additional $24.8 billion in eligible bonds also have been authorized for renovation, repairs and school construction.

An important note: The ARRA allocates no money specifically for school modernization, and while eligible for funding, modernization projects in some states may prove to be a low priority compared with other critical educational needs (NCEF 2009).

COMMON OBSTACLES TO GREEN SCHOOLS

Despite these well-documented benefits, there is still reluctance to employ green building principles. *The Turner Construction Company 2005 Green Building Market Barometer*, for example, assessed the views of 667 senior executives involved with educational facilities both green and traditional. Even though nearly three-fourths (73 percent) of the executives involved with K-12 schools thought the total costs of green schools over a 20-year period would be lower than traditional schools, only one-half (50 percent) said that school districts typically consider the total lifecycle costs of a project over time. Emphasis instead is on initial project costs.

What is intriguing about these findings is more than one-half of US K-12 schools were built more than 45 years ago, with 30 percent built before 1950 and another 21 percent built between 1950 and 1959. The average time lapse between renovations of a K-12 school is 42 years. In other words, a strong case can be made for green schools given their project costs saving over 20 years, less than one-half the time schools typically are in service. The executives also noted that the greatest obstacles to green construction were higher construction costs (74 percent) and a lack of awareness of the benefits green schools offer (67 percent) (Turner Construction Company 2005).

The 2008 Turner Construction Company Green Building Market Barometer interviewed 754 senior executives involved in green buildings (not just education). Among those interviewed were developers, owners, real estate brokers and service providers, architectural, engineering and construction firms, and owners. They rated the significance of eight obstacles to green building (see Table 1). At the top of the list was the amount of documentation and additional cost to earn a LEED certification, even though most of the executives acknowledged that LEED provides value. Higher construction costs and payback taking too long were also among the top three reasons for not building green. The executives said that owners often focus on short-term budget issues and do not take a long view when considering whether or not to embrace green building principles. With respect to indoor environments, a notable finding is 43 percent of the executives said that difficulty in quantifying benefits is a significant obstacle (Turner Construction Company 2008).

Table 1. Obstacles to Green Building Construction (percent of respondents who rated each obstacle as extremely or very significant)*

Cost and documentation for LEED certification	54%
Higher construction costs	50%
Payback too long	50%
Lack of awareness of benefits	48%
Difficulty in quantifying benefits	43%
Short-term budget horizons	41%
More complex construction	28%
Increased operating costs	23%

* Turner Construction Company 2008 Green Building Market Barometer

GREEN SCHOOLS COST MORE: DISPELLING THE MYTH

In contrast with green schools, traditional schools are designed and built to meet building codes, which minimizes capital costs. This approach may not provide comfortable, productive and healthy work environments for students and teachers – the primary purpose of any school. Green schools are built to higher standards for higher performance. Key programs defining green construction include the US Green Building Council's LEED for Schools and the national Collaborative for High Performance Schools. They also are specifically designed for high performance. See *Green School Building Programs* below for more about IAQ guidance in these standards and state laws addressing green schools.

A national review of 30 green schools built in 10 states, conducted from 2001 to 2006, demonstrated that green schools cost less than two percent (2%) more than traditional schools, or about $3 per square foot, but provide financial benefits that are 20 times as large ($71 per square foot). Lower energy and water costs, improved teacher retention and lower health care costs save green schools about $12 per square foot (see Table 2 for a summary of financial benefits of green schools derived from this review).

This review also found that green schools are cost effective to maintain and can save an average $100,000 each year in operating costs, which is enough to hire two additional teachers, purchase 250 computers or 5,000 new text books. In addition, the researchers concluded that the “financial savings to the broader community are significantly larger and include reduced cost of public infrastructure, lower air and water pollution, and a better educated and compensated workforce” (Kats 2006).

Table 2. Summary of Financial Benefits of Green Schools ($/ft^2) Derived From a National Review of 30 Green Schools Built in 10 States (Kats 2006)*

Energy	$9	Teacher retention	$4
Outdoor air pollutant emissions	$1	Employment impact	$2
Water and wastewater	$1	**Total**	**$74**
Increased earnings	$49	**Cost of greening**	**($3)**
Asthma reduction	$3	**Net financial benefits**	**$71**
Cold and flu reduction	$5		

* A detailed discussion of the financial benefits associated with the reductions in energy, carbon and outdoor air pollutant emissions, water and wastewater is beyond the scope of this white paper. Readers are encouraged to review the Kats report for more information on these topics.

Gregory Kats notes in his 2006 report, *Greening American’s Schools: Costs and Benefits*, that there is a learning curve associated with designing and building green schools, which has a direct impact on associated costs. For both private and public owners and developers of green buildings, the first green building project generally costs more than subsequent buildings. The state of Pennsylvania and the cities of Portland, Oregon and Seattle, Washington have experienced this trend; for example, Portland’s first three reported LEED Silver buildings incurred cost premiums of two percent, one percent and zero, respectively, and Seattle found the cost premium of LEED Silver buildings declined from three to four percent to one to two percent (Athens 2002, Kats 2006).

High Performance (Green) Schools = High Performance Students and Teachers

Several high profile reviews of the scientific literature underscore the dramatic health gains from improving indoor environments in schools, a key goal of green schools. The Center for Building Performance at Carnegie Mellon University’s Building Investment Decision Support (BIDS) program, for example, reviewed more than 1,500 studies that relate technical characteristics of buildings, such as lighting, ventilation and thermal comfort to tenant responses, such as productivity or health. The researchers concluded that “collectively, these studies demonstrate that better building design correlates with increases in tenant / worker well being and productivity… Seventeen separate studies all found positive health impacts (reduction in reported prevalence of symptoms) from improved IAQ, ranging from 13.5 percent to 87 percent improvements, with an average improvement of 41 percent" (Kats 2006). Even though these studies focused on offices and adult building occupants, the results can be extended in concept to green schools.

Kats (2006) notes that results from a number of school specific studies also showed significant positive impacts from improving the indoor environment; for example:

- "An analysis of two school districts in Illinois found that student attendance rose by 5 percent after incorporating cost-effective indoor air quality improvements" (Illinois Healthy Schools Campaign 2000).

- "A study of Chicago and Washington, DC schools found that better school facilities can add three to four percentage points to a school's standardized test scores, even after controlling for demographic factors" (Schneider 2002).

- "A recent study of the cost and benefits of green schools for Washington State estimated a 15 percent reduction in absenteeism and a 5 percent increase in student test scores" (Paladino & Company 2005).

Three green schools highlighted in the Kats report demonstrate similar improvements in performance:

- "Students moving into the Ash Creek Intermediate School in Oregon experienced a 15 percent reduction in absenteeism" (Rudolf 2005).

- "Students moving from a conventional school into the new green Clearview Elementary School…experienced substantial improvements in health and test scores. A PhD thesis on the school found a 19 percent increase in average Student Oral Reading Fluency Scores (DIBEL) when compared with the prior conventional school" (Boecker 2005).

- "The Third Creek Elementary School in Statesville, NC [is] the country's first LEED gold K-12 school…Documented student test scores before and after the move [to the new school] provide compelling evidence that learning and test scores improve in greener, healthier buildings…Students and teachers improved from less than 60 percent of students on grade level in reading and math to 80 percent of students on grade level in reading and math" (Moseley Architects).

The National Research Council's interim report offers an excellent discussion on the challenges of establishing a direct causal link between the quality of indoor air and changes in building occupant health, learning achievements and teacher productivity. The report concludes: "The body of available research is suggestive of an association between the condition of a school building and student achievement. All of the studies analyzed by the committee found that student test scores improved as the physical condition of school buildings improved. The degree of improvement of students' test scores varied across the studies, but in all cases students in buildings in better condition scored higher than students in buildings in poor condition" (National Research Council 2006).

From a review of available research, the CARB report to the California Legislature also concluded that: "Epidemiological studies have often found significantly lower prevalence of respiratory illness or surrogates for respiratory illness (sick leave, total absence from school) in buildings with higher ventilation rates, reduced office sharing, and less crowding" (Fisk 2000, Myatt et al 2004, Shendell et al 2004).

The responses from executives involved with green buildings interviewed for *The Turner Construction Company 2005 Green Building Market Barometer* offer anecdotal evidence backing up these studies. Nearly three-fourths (74 percent) said that green schools increased their ability to attract and retain teachers, 72 percent said that green schools reduced student absenteeism and 71 percent noted that student performance improved in green schools as compared with traditional schools (Turner Construction Company 2005).

IMPROVING STUDENT HEALTH AND PERFORMANCE BY IMPROVING IAQ

Before discussing strategies for using green building principles to improve IAQ and student health and performance (see *Getting There From Here: Improving IAQ in Green Schools* below), it may be helpful to review what makes poor IAQ potentially so dangerous to children, including a review of poor IAQ as a link to childhood asthma and autism.

INDOOR AIR: COMPLEX MIXTURE OF VISIBLE, INVISIBLE CONTAMINANTS

Indoor air is an intriguing, complex environment that contains a myriad of visible and invisible contaminants. Airborne pollutants, including potential carcinogens, reproductive toxins and human irritants, are 2 to 10 times higher indoors when compared with outdoor levels and can be as much as 1,000 times higher in newly constructed and renovated indoor spaces. These visible and invisible contaminants generally fall in one of two categories: (1) particulates or (2) gases, vapors and odors. The following provides a brief description of each category and the health problems associated with them. For more detailed information about these indoor air contaminants, see the AQS research report, *Clearing the Air on Indoor Air Cleaners / Purifiers*, which is available at no cost under the White Paper tab of the premium content section in the AQS Aerias IAQ Resource Center website (www.aerias.org).

PARTICULATES: SIZE IS EVERYTHING

Particulates are particles that are small enough to suspend in the air. Suspended inorganic particles, such as metals (lead, mercury); dust; pollen; asbestos and other fibers; car, bus and truck exhaust; or environment tobacco smoke (ETS) and other types of smoke are often referred to as aerosols. Suspended organic compounds and small living organisms, such as bacteria and viruses; mold spores and pieces of mold colonies; dust mite feces and body fragments; cockroach body parts; and dander from cats, dogs and other mammals, are called bioaerosols (McDonald and Ouyang 2000). Allergens, associated with grasses, pollen, dogs, cats, dust mites, cockroaches and mice to name a few common examples, also fall into this category. Particles can range in size from very small (0.001 μm to 10 μm), which can remain in the air for a long time, up to relatively large (100 μm), which quickly settle out of calm air (ALA Special Report on Air Cleaners).

Inhaling particulates can cause eye, nose and throat irritation and increase the risk for respiratory infections. Health care professionals are especially concerned about the long-term effects of inhaling fine particles (less than 2.5 μm – also referred to as PM2.5 or fine PM), because they can travel deep into the lungs where they can remain embedded for years or be absorbed into the bloodstream. Inhalation of fine PM have been linked to increases in respiratory health problems such as asthma, bronchitis, pneumonia and emphysema; hospitalization for heart or lung disease; and even premature death. The results of numerous studies have demonstrated a correlation between adverse health effects and the level of fine PM. In response, the US EPA has established an aggressive program and standards to reduce fine PM levels in outdoor air. These same concerns also apply to indoor air in schools and other environments where children spend their time. For more information and a comprehensive review of these studies, see Dockery et al 1993; Moolgavkar, Dockery and Pope 1994;

Godleski et al 2000; US EPA Provisional Assessment of Recent Studies on Health Effects of Particulate Matter 2006; and the US EPA website on particulate matter, www.epa.gov/oar/particlepollution.

Larger particles (greater than 10 μm) do not cause as much concern, because they get caught in the nose and throat and are cleared from the respiratory tract by coughing or swallowing (ALA Special Report on Air Cleaners).

GASES, VAPORS AND ODORS: WHAT YOU CAN'T SEE CAN HURT YOU

The types of gases or vapors most often found in indoor environments include combustion byproducts, such as carbon monoxide, nitrogen oxides, sulfur dioxide and polycyclic aromatic hydrocarbons (PAHs); phthalates; pet, human and cooking odors; ETS; volatile organic compounds (VOCs); and microbial VOCs and mycotoxins. Many of these substances also produce odors, some of which are pleasant while others can be distracting and irritating.

Volatile Organic Compounds. Among the most prevalent of all indoor air constituents are volatile organic compounds, with as many as 100 to 1,000 different VOCs in the air where children can easily inhale them. Some VOCs can cause eye, nose and throat irritation; cough; headache; general flu-like symptoms, skin irritation and some may cause cancer. Others produce odors that may be objectionable. Complicating matters is the potential for interactions of VOCs with other chemical compounds to form additional compounds that also may be a threat. As a result, even though the concentrations of individual VOCs may be well below odor thresholds or known toxic levels, their occurrence in complex mixtures may lead to perceived poor IAQ, irritation among those exposed or effects not yet known or defined.

Air Quality Sciences, Inc. (AQS) has measured VOC levels in more than 200 US schools and found 345 different VOCs in the indoor air. Table 3 lists the 14 most common VOCs found in these schools. Other frequently found VOCs of concern in schools include perchloroethylene and methylene chloride, potential carcinogens related to spot cleaners, degreasers and art supplies.

Table 3. Common VOCs found in schools

VOC	Source(s)	VOC	Source(s)
Toluene	Cleaners, construction materials	Hexanal	Cleaners, adhesives, deodorizers
Xylenes	Cleaners, construction materials	2-Butoxyethanol	Wood cabinetry, cleaners, paints
Siloxanes	Waxes, polishes, deodorants	Ethanol	Cleaners, disinfectants
Formaldehyde	Furniture, ceiling tile, wood shelving, cabinetry	TXIB	Plastics, paints
Hexane	Markers, cleaners	Acetaldehyde	Plastics, paints
Acetone	Markers, art supplies	Longifolene	Cleaners, wood products, flooring
1,4 Dichlorobenzene	Cleaners, deodorizers	Naphthalene	Adhesives, art supplies

The AQS test results also showed that the average total VOC (TVOC) level was 276 μg/m^3, with a minimum of 1.7 μg/m^3 and a maximum of 4600 μg/m^3. Most standards and guidelines consider 200 μg/m^3 to 500 μg/m^3 TVOC as typical within existing, non-complaint buildings. Levels higher than this may result in irritation to some occupants. While TVOC is a good indicator of elevated VOCs, and complicated VOC mixtures may lead to irritation, minimizing the presence of specific chemicals with known health hazards is required.

A growing number of scientists also are concerned that exposure to very small traces of VOCs and some industrial chemicals in homes and schools may have profound impacts on fetuses, newborns and children, including disruptions to the endocrine system (hormones), gene activation and brain development. An especially striking finding is some chemicals may have health impacts at extremely low levels, which are not seen at higher levels. Minute levels of phthalates, for example, which are used to make toys, building materials, drug capsules, cosmetics and perfumes, have been linked to sperm damage in men and genital changes, asthma and allergies in children (Waldman 2005, Bornehag et al 2004).

In a 2006 review study, researchers from the Harvard School of Public Health and the Mount Sinai School of Medicine systematically examined publicly available data on chemicals with the goal of identifying industrial chemicals that are the most likely to damage developing brains. The researchers found that 202 commonly used industrial chemicals have the capacity to damage the human brain, and they concluded that chemical pollution may have harmed the brains of millions of children worldwide. About one-half of them are considered high-volume production chemicals. The authors also concluded that the toxic effects of industrial chemicals on children have generally been overlooked (Grandjean and Landrigan 2006, Grandjean and Perez).

Researchers at the University of London suspected that small amounts of some environmental chemicals might have a dramatic effect on hormone levels. They tested the hormonal strength of 11 common chemicals, known to mimic estrogen. Alone, each chemical was very weak, but when low doses were mixed with natural estrogen, the strength of estrogen doubled (Waldman 2005, Rajapakse et al 2002). High levels of estrogen are associated with some forms of cancer and developmental problems during puberty. For more information about results of studies linking environmental contaminants to illnesses, see Cohen 2006.

At this time, research in this area is still new, and as yet results do not present a clear picture. One study of particular note, the National Children's Study, sponsored by the US EPA and the Centers for

Disease Control and Prevention (CDC), is in progress with results expected in 2010. By the time the study is completed, about 100,000 children at various ages from birth to puberty will have participated. Among the primary goals is to investigate the associations between exposures to environmental pollutants, such as VOCs among others, and health problems, especially asthma, autism, attention deficit disorder and alterations at puberty caused by hormonal disruptions and other neurobehavioral and neurocognitive disorders (Özkaynak et al 2005).

Microbial VOCs and Mycotoxins. Moisture is a vapor that must be monitored as too much moisture can support indoor mold growth, particularly in schools that are not well maintained, have water or plumbing leaks, and have HVAC systems that do not keep interior humidity levels below 60 percent. Some types of mold also emit VOCs, known as microbial VOCs or MVOCs, which are responsible for the characteristic musty, earthy odors associated with mold. Children who are sensitive to MVOCs may experience eye, nose and throat irritation. Some molds can also produce mycotoxins at various times during their lifecycles. Children can experience potentially serious health problems if they are exposed to high levels of these compounds, but this is rare in most indoor environments.

Formaldehyde in Schools. Formaldehyde exposure is a major concern in schools, particularly in those that use portable classrooms. Formaldehyde is used widely by industry to manufacture building materials and numerous household products, and also is a by-product of combustion and certain other natural processes. Primary sources include pressed wood products such as particleboard, plywood, and medium density fiberboard (MDF); finished furniture, shelving, and cabinetry made with composite boards and certain coatings; decorative fabrics and textiles; and paper products. It also may be used as a biocide in certain paints and coatings, adhesives and personal care items.

Based on more than 300 measurements collected in residences, office buildings and schools, AQS studies have found typical concentrations range from 0.01 ppm to 0.03 ppm in office buildings and 0.05 ppm to 0.08 ppm in homes. An average level of 0.04 ppm has been found in schools, with new or recently renovated or refurbished school environments reaching 0.14 ppm. The levels found in schools are higher than the 0.027 ppm (27 ppb) limit recommended by the state of California's Environmental Protection Agency for an eight hour exposure period. Available clinical and epidemiological data indicate that individual responses to formaldehyde may vary substantially. Irritation may occur at levels of 0.08 ppm or less, and odor detection has been measured as low as 0.03 ppm. When formaldehyde is present in the air at levels exceeding 0.1 ppm, some people may experience watery eyes; burning sensations of the eyes, nose, and throat; coughing; wheezing; nausea; and skin irritation. Some people are very sensitive to formaldehyde, while others have no reaction to the same level of exposure. Other health effects include coughing, fatigue and severe allergic reactions. High concentrations may also trigger asthma attacks.

POSSIBLE ROLE OF POOR IAQ IN CHILDHOOD ASTHMA AND AUTISM

In recent years, educators, parents, physicians and pubic health officials have been very concerned about the dramatic increase in the number of children who have developed asthma and possible connections to indoor air pollution. From 1980 to 1994, for example, the proportion of Americans with asthma increased by 75 percent. In children under the age of five, the proportion grew by 160 percent (AAAAI 2005).

The reason for their concern is asthma is the leading cause of school absenteeism and hospitalizations in children under the age of 15, accounting for an estimated 14 million lost school days and $16 billion in annual health care expenditures for both children and adults. Asthma also tends to be seasonal, especially among children, with a noticeable spike in asthma-related emergency room visits and hospitalizations in September (Johnston et al 2006, Neidell 2004, AAFA 2005, AAAAI 2005). See

Table 4 for statistics illustrating the enormous toll asthma can take on children's health and the US economy.

Table 4. Asthma in the US by the numbers*

Twenty million people in the US have asthma, 9 million of whom were children. One-half of those with asthma specifically have allergic asthma.	In 2003, the prevalence of asthma in adult females was 35 percent greater than the rate in males. Approximately 40 percent of children who have one or both parents with asthma also will develop asthma.
From 1980 to 1994, the proportion of Americans with asthma increased by 75 percent. In children under the age of five, the proportion grew by 160 percent.	In 2003, there were 12.7 million physician office visits and 1.2 million outpatient department visits due to asthma. In 2002, there were 1.9 million asthma-related visits to hospital emergency rooms.
More than 70 percent of people with asthma also have allergies.	Asthma accounts for approximately 24.5 million missed workdays and 12.8 million missed school days annually.
Asthma prevalence is 39 percent higher in African Americans than in Caucasians .	Direct health care costs for asthma in the United States total more than $11.5 billion annually; indirect costs (lost productivity) add another $4.6 billion for a total of $16.1 billion. Prescription drugs represent the largest single direct medical expenditure at more than $5 billion.
There are approximately 5,000 deaths from asthma each year.	The value of reduced productivity due to death represented the largest single indirect cost related to asthma, approaching $1.7 billion.

* As reported in the Media Resources Media Kit, Asthma Statistics, AAAAI 2005.

Researchers have clear evidence that the quality of indoor air is a factor. A number of studies have found an association between VOCs and asthma in children (CARB 2005). One study of particular note demonstrated that children exposed to high levels of VOCs were four times more likely to develop asthma than adults (CARB 2005, Rumchev et al 2004). Two other studies provide the first solid evidence that damp buildings and exposure to mold bioaerosols is a risk factor for developing asthma and not just in making asthma symptoms worse. The risk for developing asthma appears higher for, but is not limited to, children who are sensitive to mold allergens or who have parents with asthma (Jaakkola et al 2005, Cox-Ganser et al 2005). For more information about these studies, see the AQS white paper *Asthma and Damp Buildings: Making the Connection*, which is available free of charge from the Aerias AQS IAQ Resource Center under the Premium Content tab at www.aerias.org.

Green schools with their improved IAQ as compared with traditional schools may offer a significant benefit in reducing the prevalence of childhood asthma. A recent review by Carnegie Mellon of five separate studies found an average reduction of 38.5 percent in asthma in buildings with good IAQ. Kats reports that a 25 percent reduction in the number of children with asthma in an average size new school with 900 students translates into 20 fewer children a year with asthma, resulting in an annual direct and indirect cost savings of $33,000 (Carnegie Mellon 2005, ALA 2006, Kats 2006).

Educators, parents, physicians and pubic health officials also are concerned about an apparent increase in the number of children diagnosed with autism spectrum disorders (ASD) – and as with asthma, question if there is a connection with exposure to indoor air contaminants. Estimates suggest that around 6 in 1,000 people in the world suffer from ASD, with more boys affected than girls. The increase in prevalence of ASD is partially due to changes in diagnostic criteria, terminology and increased reporting. Although there are as yet no conclusive links between autism and chemical exposure, a recent review of scientific literature on the causes of neurodevelopmental disorders implicated a number of industrial chemicals including lead, methylmercury, polychlorinated biphenyls, arsenic and toluene (Grandjean and Landrigan 2006).

GETTING THERE FROM HERE: IMPROVING IAQ IN GREEN SCHOOLS

Efforts to improve IAQ in schools are gaining momentum, due in part to the explosive growth in the number of children developing asthma and the increased interest in using green building methods, environmentally friendly products and green cleaning. With respect to indoor air quality, all green building programs base their guidance on three primary strategies: source control, ventilation and air cleaning. Recognizing that IAQ and energy conservation are complementary goals also is important as is ensuring that the building maintenance program includes provisions to prevent indoor mold growth. This section provides an overview of these strategies.

THREE GOALS FOR IMPROVING IAQ

Source Control. The US EPA, the American Lung Association (ALA) and other experts agree that source control is the only completely effective way to remove pollutants from indoor environments. They also agree that total eradication of indoor air contaminants often is not feasible or practical. A more realistic goal is to use building materials, furnishings, finishes, office equipment, and cleaning products and processes that emit low levels of VOCs. Surface cleaning also removes larger particles and kills bacteria and viruses on floors, furniture, walls, doorknobs, bedding and linens, and bathroom fixtures. In addition, keeping the HVAC system in good working order and air ducts and drip pans clean are important for minimizing dust and particle accumulation and indoor mold growth.

Source control also involves inspecting a building regularly inside and out for any signs of water damage, which is a good indicator that moisture levels are high enough to support indoor mold growth. If water damage or signs of mold are found, they should be corrected immediately. The best way to prevent indoor mold growth is to eliminate all sources of excess moisture, from leaks in the building envelope, improper building pressurization, an inefficient or malfunctioning HVAC system and appliances to building occupant activities.

Ventilation. Ventilation and air cleaning are invaluable for assisting with pollution reduction. They two work hand-in-hand with source control, as many types of air cleaners are an integral part of the HVAC system. A well-designed and properly operating HVAC system brings in and conditions outdoor air and circulates the air through the building. The primary benefit beyond warming, cooling and managing the humidity in the air is to dilute indoor air pollutants and to minimize their impact on the indoor environment and building occupants. In addition, the HVAC system is invaluable for maintaining appropriate building pressurization, which is critical for preventing moisture intrusion. The HVAC system may bring in outdoor air pollutants as well as pick up indoor pollutants, such as mold spores, allergens, dust and VOCs from one area of the building and transport them to another.

Air Cleaning. The goal for air cleaning is to remove indoor and outdoor pollutants by trapping them inside a mechanical device. Effective air cleaning protects HVAC systems and components, furnishings and décor of occupied spaces; reduces housekeeping and building maintenance; and protects building occupants. Experts emphasize, however, that air-cleaning devices alone cannot ensure good IAQ, particularly where ventilation itself is inadequate. As noted, air cleaning is most effective when used in conjunction with source control and ventilation (US EPA 2006, ALA Special Report on Air Cleaners).

IAQ AND ENERGY CONSERVATION: COMPETITIVE OR COMPLEMENTARY GOALS

Americans consume about 70 percent more energy per dollar of gross domestic product (GDP) than do people in most other developed countries. In 2000, Americans spent (directly or indirectly) about $600 billion on energy of all kinds. Residential energy consumption in 2000 accounted for 20 percent, commercial 17 percent, industrial 36 percent and transportation 27 percent of energy consumed in 2000, which is almost identical to that in 1990 (Joskow 2001). Also of note, a building designed since the late 1990s uses less than one-half the energy consumed on a per-square-foot basis than a building designed in 1970 (Ross 2007).

Schools in the United States spend $7.8 billion on energy each year; more than the cost of computers and textbooks combined, according to a 2003 report from the National Center for Education Statistics. The US Department of Energy (DOE) estimates that these high utility bills could be reduced as much as 25 percent if schools adopt high performance (green) design principles and technologies (Plympton et al 2004).

To achieve energy efficiency goals, ventilation rates are often reduced to the detriment of IAQ and the building occupants breathing that air, thus supporting the misconception that providing good IAQ and energy conservation are competing goals. Compounding the misconception is the energy required to operate the HVAC system is about 50 percent of a building's energy cost. Since energy efficiency can reduce operating costs, and because the burning of fossil fuels is a major source of greenhouse gases, energy conservation has become a matter of public policy. There are some indications, however, that the interdependent relationship between IAQ and energy is gaining acceptance in the public policy arena as evidenced by the increasing number of proposed IAQ-related state legislation in the past several years.

The US EPA's evaluation of energy cost and IAQ performance of ventilation systems and controls addresses this misconception by demonstrating that good IAQ and effective energy conservation can complement each other while providing significant savings and protecting the outdoor environment. According to the US EPA, many energy efficiency measures with the potential to degrade indoor air quality appear to require only minor adjustments to protect the indoor environment (US EPA 2000).

In this study, energy efficiency measures (including lighting upgrades) were adjusted to either enhance or not degrade indoor environmental quality and were combined with measures to meet the outdoor air requirements as prescribed in ANSI/ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*. As a result, total energy costs were cut by 24 percent to 43 percent for the office building and 22 percent to 37 percent for the school. Not included were savings from reduced lighting during unoccupied hours that could provide 12 percent to 22 percent savings or improved equipment operations that could provide 5 percent to 15 percent savings (US EPA 2000).

Operational measures that could degrade IAQ, such as widening the daytime temperature dead band, relaxing the nighttime temperature setback and reducing HVAC operating hours, were not included. Cumulatively, these three measures that are not compatible with IAQ would have reduced total energy costs by only 3 percent to 5 percent in the office building, and 7 percent to 10 percent in the school.

When compared with the potential savings noted above, the US EPA concluded there is a demonstrable compatibility between indoor environmental and energy efficiency goals, when energy saving measures and retrofits are applied wisely (US EPA 2000).

GREEN CLEANING FOR HEALTH, ENVIRONMENTAL PROTECTION

In large part, the significant health risks children face from exposure to cleaning products has spurred federal, state and local governments to require the creation of green cleaning programs and the use of green or environmentally preferred cleaning products, especially in schools. New York, Illinois, Maine and Missouri are the only states thus far to require green cleaning in schools by law. Other states, such as California, Connecticut, Massachusetts, Minnesota, New Jersey, Ohio, Oregon, Pennsylvania, Vermont and Washington; cities, such as Chicago, Illinois; Washington, DC; Seattle, Washington; and Santa Monica and San Francisco in California; and school districts in Chicago, Illinois; Montgomery County, Maryland; Boston, Massachusetts; Bellingham, Washington; Great Neck, New York; and Amity, Connecticut also require the use of green cleaning strategies and green cleaning products in state buildings and schools.

In addition, the federal government requires the use of environmentally preferred cleaning products for its buildings. This list is by no means exhaustive, but offers a clear indication of the extent green cleaning and the use of green cleaning products are catching on in the US. In addition, the USGBC (LEED) standard for existing buildings (LEED-EB) awards the use of green cleaning products with credits toward certification.

Although there is no set legal or regulatory definition as to what is “green” or “green cleaning,” the concept itself is straightforward. An overall green cleaning program applies a holistic approach to cleaning and focuses on cleaning effectively to create healthier buildings and reduce outdoor environmental impacts. Both factors must be considered in making decisions about green cleaning products and services. An effective green cleaning program also requires shared responsibility between manufacturers, distributors, cleaning personnel, building owners and managers, and building occupants, with the overall goal of getting everyone involved in caring for school buildings (Ashkin and Holly 2007).

To assist commercial users and consumers in making informed decisions, several green cleaning standards from Green Seal, the Environmental Choice Program (ECP) and the GREENGUARD Environmental Institute have been developed. Both Green Seal and the ECP focus primarily on VOC content, while GREENGUARD Certification focuses exclusively on VOC emissions from cleaning products and their impact on human exposure. Manufacturers are also encouraged to create safer, lower emitting products.

GREENGUARD Certification requires that products undergo VOC emission performance testing for more than 10,000 individual chemicals. All individual VOCs detected must not exceed acceptable risk levels established by key global public health organizations and programs including the American Conference of Government Industrial Hygienists (ACGIH); the International Agency on Research of Cancer; National Toxicology Program; California’s Proposition 65 (CA Prop 65) and Section 01350 environmental requirements; and the US EPA.

The revised Green Seal Standard GS-37 for institutional cleaners includes the GREENGUARD Children & Schools Certification for Cleaners and Cleaning Maintenance Products and Systems inhalation criteria and dynamic chamber test method as one of two options for assuring low VOC emissions for Green Seal certification. For more information, see the white paper, *Cleaning Chemicals* *and Their Impact on Indoor Environments and Health*, which is available free from the AQS-Aerias Indoor Air Quality Resource Center website, Premium Content tab (www.aerias.org).

MOLD PREVENTION STRATEGIES

As a living organism, mold needs warmth, moisture and a food source to grow. Today's buildings, including schools fulfill these needs with no trouble. Among the numerous nutritional sources commonly available are materials that contain cellulose and organic binders, such as some wallcoverings, gypsum wallboard, paint, wood paneling, plywood, oriented strand board (OSB), ceiling tiles, textiles, upholstered furniture, insulation, and other porous materials where mold breaks down the material itself or uses organic debris that has collected. Some adhesives used with wallcoverings also may contain starch, which may provide a potential food source for mold.

Mold also needs warmth. Indoor environments typically are maintained at a temperature of 65 degrees F to 75 degrees F (18 degrees C to 24 degrees C), which is hospitable to many molds. Some varieties of mold can survive at temperatures below 50 degrees F (10 degrees C) or above 122 degrees F (50 degrees C). At relatively low temperatures (50 degrees F to 60 degrees F), mold spores take longer to germinate and growth is slower. In addition, mold requires adequate amounts of moisture for a long enough period of time in order to grow. Water requirements vary over a broad range, depending on the species of mold. Sufficiently high humidity levels at the surface of the substrate must be maintained long enough for the mold to become established.

When mold takes hold of building materials, it not only can cause deterioration, which can be expensive and inconvenient to replace, but it also can become a source of indoor pollutants, which can lead to serious health problems. For example, mold and its byproducts, including microbial VOCs and mycotoxins, can cause allergic reactions, which also can trigger asthma attacks as noted above.

The golden rule of any mold prevention plan is to eliminate the source of moisture and keep building materials dry before and after installation. One effective strategy for controlling condensation is to select materials and finishes that allow air and moisture to move freely through a wall system. Using highly permeable materials on the cold side and low permeability materials on the warm side of a wall system maximizes the ability of water vapor inside the wall system to migrate from the wall cavity into the interior space where it can evaporate. Innovative products that resist indoor mold growth are now in the marketplace.

Another powerful tool is to use mold-resistant products that inhibit or reduce indoor mold growth. A significant challenge for architects and specifiers, however, is determining which mold-resistant products are the best choices for specific applications. Air Quality Sciences, in conjunction with the GREENGUARD Environmental Institute, has created and validated a test method that provides reliable, quantitative and reproducible results across a wide variety of building materials, within a reasonable amount of time and under realistic and reproducible conditions favorable for mold.

The results were used to construct an easy-to-use rating system that ranks a product's ability to resist mold growth (see Table 5). Results are reported on a scale of one to four, with one being least resistant (highly susceptible to mold growth) and four being most resistant to mold growth, based on a quantitative count of mold colonies. This rating system can greatly assists architects and specifiers find the best building materials for their needs as well as support product manufacturers in their efforts to provide products that meet this critical requirement.

Table 5. Rating system for microbial resistance of building materials

Rating	Name	Definition
1	Highly Susceptible to Mold Growth	Growth comparable to highly susceptible materials. Log(CFU) > 7.5 at 3 weeks.
2	Susceptible to Mold Growth	Growth comparable to susceptible materials. Log(CFU) < 7.5 and > 5.5 at 3 weeks.
3	Resistant to Mold Growth	Growth comparable to resistant materials. Log (CFU) < 5.5 and > 2.5 at 3 weeks.
4	Highly Resistant to Mold Growth	Growth comparable with highly resistant materials. Log (CFU) < 2.5 at 3 weeks.

GREEN SCHOOLS BUILDING PROGRAMS

US EPA IAQ Tools for Schools. At the federal level, the US EPA's Indoor Air Quality Tools for Schools (IAQ TfS) program continues to lead the way in providing resources and programs for school districts, administrators, facility managers and teachers to improve the air quality in schools. The IAQ Tools for Schools Kit, which the US EPA provides to schools at no cost, includes easy-to-follow checklists, videos, sample memos and policies, a recommended management plan, and a unique problem-solving wheel. Using the tools in the Kit, school officials can educate staff, students, and parents about the importance of good IAQ and their roles in ensuring a healthy, comfortable learning environment. The IAQ Tools for Schools Awards Program provides incentives and public recognition to schools and school districts that are implementing the Kit. Three award categories are offered: Great Start, Leadership and Excellence, each of which honors schools and school districts as they progress through the various stages of the IAQ TfS Kit.

For more information, visit the IAS TfS website at www.epa.gov/iaq/schools.

Collaborative for High Performance Schools. At the state level, California has taken the lead in raising awareness about the negative impacts of poor IAQ in schools and protecting students from indoor air pollution through its Collaborative for High Performance Schools (CHPS) program. The CHPS mission is to facilitate the design, construction and operation of high performance schools; environments that are not only energy and resource efficient, but also healthy, comfortable, well lit and contain the amenities for a quality education.

The CHPS program has now become national. More than 40 school districts in 16 states have joined CHPS, including Arizona, California, Colorado, Georgia, Minnesota, New York, North Carolina, Oklahoma, Pennsylvania, North Carolina, Oregon, Rhode Island, Texas Vermont and Washington. In the Summer 2008, CHPS National was launched and these states are now referred to as CHPS National states (CHPS 2007).

The CHPS program features five Best Practices Manuals (BPM), which focus on design, construction, operation and maintenance. With respect to children's health in green schools, the *BPM Volume III: Criteria* and the *BPM Volume II: Design* cover the design issues relevant to ensuring good indoor air quality in these buildings.

The CHPS program offers two types of CHPS recognition for schools: CHPS Verified and CHPS Designed. CHPS Verified is a third-party verification and project management tool, which is ideal for projects seeking incentive funding such as California's Proposition 1D incentive grants. The CHPS Designed is less stringent and is a free Self-Certification System. Programs are now available in the 2009 Edition.

In addition, CHPS encourages the use of products that emit low levels of VOCs, including formaldehyde. The CHPS website features a table, which lists products that have been certified by its manufacturer and an independent laboratory to meet the CHPS Low-Emitting Materials criteria (California Section 01350) for use in a typical classroom as described in a CA Department of Health Services (CDHS) Standard Practice. A school that specifies and installs the materials listed below qualifies for points under Indoor Environmental Quality Credit EQ2.2.

For more information, please visit the CHPS website at www.chps.net.

LEED for Schools. The USGBC's LEED for Schools Rating System recognizes the unique nature of the design and construction of K-12 schools. Based on LEED for New Construction, it addresses issues such as classroom acoustics, master planning, indoor air quality, mold prevention and environmental site assessment. By addressing the uniqueness of school spaces and children's health, LEED for Schools provides a comprehensive tool for schools that wish to build green, with measurable results. The LEED for Schools Rating System is most applicable to new construction and major renovation projects in K-12 educational spaces. Other projects, such as university educational buildings, K-12 athletic facilities or interpretive centers, may also choose to use LEED for Schools. Nearly 20 states and school districts have mandated that new schools must be designed and built to achieve a certain level (depending on state) of LEED for Schools (USGBC 2009b).

Specifying adhesives, flooring systems, paints and coatings, ceiling and wall systems, furniture and composite wood products with low levels of chemical emissions can result in higher quality indoor air and increased protection of children's health. The USGBC has approved GREENGUARD Children & Schools℠ Certification as an acceptable compliance path for all low-emitting flooring credits in LEED® Rating Systems, including LEED for Schools where it was originally recognized. Products are tested to meet the requirements of GREENGUARD or for small products, the California Department of Health Services "Standard Practice for the Testing of Volatile Emissions from Various Sources Using Small-Scale Environmental Chambers."

Other states and local jurisdictions are following suit, as are private education organizations. Among the guidance offered by these programs is to use environmentally friendly construction materials, furnishings, finishes, office equipment, and cleaning products and processes. To date, however, none of the available product standards and protocols that ensure low emission levels of VOCs has taken children's special needs into account – until now.

GREENGUARD Certification for Children & Schools. The GREENGUARD Environmental Institute (GEI) has created a standard and product certification for low-emitting products and materials for use in daycare and school facilities. The stringent GREENGUARD Certification for Children & Schools is an extension of the established GREENGUARD Indoor Air Quality Certification Program.

This standard takes the sensitive nature of school populations and the unique building characteristics and maintenance conditions found in schools into consideration and presents the most rigorous product emissions criteria to date. The following summarizes key provisions in the standard, requiring that all construction and furnishing products meet these emission levels within seven days of unpackaging and installation in the school. This standard limits acute (irritation and odor) and long-term chronic exposure effects (Table 5).

Products certified under this program are recognized as CHPs approved products (CHPS recognizes those products meeting the CA 1350 criteria for chronic CRELS and does not recognize GREENGUARD's additional requirements for particles and phthalates). They are also recognized for various LEED IEQ credits (see www.greenguard.org for listing of available credits).

Table 5. GREENGUARD Emission Standard for Educational Environments (see bullets following the table for important notes)

Chemical	**Allowed Emission Contributions**
TVOC	< 22 µg/m3
Formaldehyde	< 0.0135 ppm
Total Aldehydes	< 0.043 ppm
Individual VOCs	< 1/100 TLV or • ½ CA Chronic REL (whichever is less)
Total Phthalates	< 10 µg/m3
Total Particles (< 10µm)	< 22 µg/m3

Notes:

- Total phthalates include dibutyl (DBP), diethylhexyl (DEHD), diethyl phthalate (DEP), dibenzyl phthalate, (DBzP), diisobutyl phthalate (DIBP), and diethyl (DEP), common material related phthalates.
- Identified VOCs measured in mass spectrometric scan of C6 - C16 hydrocarbon range, evaluated for presence on ACGIH/TLV list and CA CREL list. TVOC includes all measured VOCs in scan range calibrated to toluene.
- Total aldehydes include 2-Butenal, Acetaldehyde, Benzaldehyde, Benzaldehyde 2,5-dimethyl, Benzaldehyde 2-methyl, Benzaldehyde 3- and/or 4-methyl, Butanal, Butanal 3-methyl, Formaldehyde, Hexanal, Pentanal, and Propanal.
- Particles applicable to fibrous, particle-releasing products with exposed surface area.

PARTNERING FOR GREENER HEALTHIER SCHOOLS

AQS stands ready to partner with the school districts to create and maintain healthy indoor environments. In addition to supporting the GREENGUARD product certification programs, the firm also employs building consulting experts who can advise you on how to improve IAQ in schools as well as diagnose and resolve IAQ problems.

Visit us at www.aqs.com to learn more about how the AQS Building Consulting Group and Product Evaluations team can help you, or call us at (770) 933-0638. Also visit the GREEENGUARD Environmental Institute at www.greenguard.org and the AQS Aerias IAQ Resource Center to learn more about particulates, VOCs and other indoor contaminants. Aerias may be accessed from the AQS website or at www.aerias.org.

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