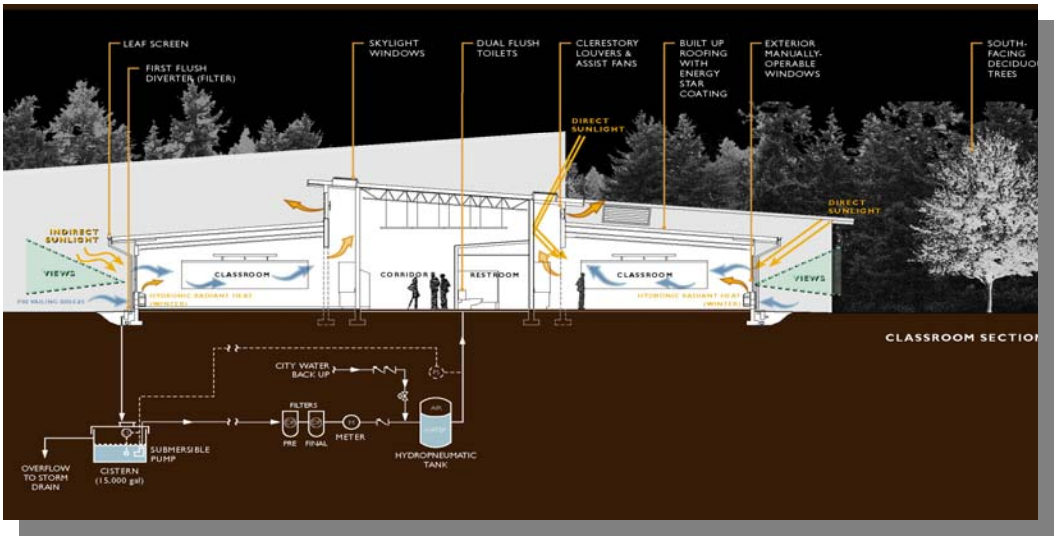

WASHINGTON HIGH PERFORMANCE SCHOOL BUILDINGS:

Report to the Legislature

(A Report on the Washington Sustainable Schools Project)

JANUARY 31, 2005

WASHINGTON STATE BOARD OF EDUCATION

AND

OFFICE OF THE SUPERINTENDENT OF PUBLIC INSTRUCTION

Prepared by Paladino and Company

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Table of Contents

Washington High Performance School Buildings: Report to the Legislature

1. EXECUTIVE SUMMARY

This Report to the Legislature is the final outcome of the Washington Sustainable Schools Project, incorporating information from the Washington Sustainable Schools Project Phase 2 Pilot Project Report (Pilot Project Report, O'Brien, 2004) and national research to extrapolate the potential impact of the Washington Sustainable Schools Protocol across all new school construction in Washington State.

This report demonstrates that high performance school buildings can deliver significant savings and increased performance including potentials for:

A+chieving Higher Standards

- **5% increase in student test scores**
- **5% reduction in teacher turnover**
- **15% reduction in absenteeism**

$aving Money

- **25% reduction in energy use**
- **38% reduction in potable water use**
- **150% Return on Investment (ROI)**

Conserving Natural Resources

- **38% reduction in waste water production**
- **22% reduction in construction waste to the landfill**
- **>1.5 million pounds reduction in CO_2 emissions**

The savings noted above represent the lower end of the savings and performance improvements that are documented in the research studies cited in this report. Many of the studies demonstrate savings significantly higher than this as noted in the sections below. Projections of potential savings for all new construction in Washington State schools in the following sections are based on conservative expectations from the cited research. The calculations and assumptions for each category of savings are documented in this report and in Appendix A.

1.1 BACKGROUND

The Washington State Legislature, State Board of Education and the Office of Superintendent of Public Instruction (OSPI) have taken an aggressive stand to encourage the development of high performance school buildings with the goals of improving achievement, reducing costs and preserving environmental resources. To provide order and consistency in pursuing these important goals, several tools have been created by OSPI. The Washington Sustainable Schools Protocol (WSSP) for High Performance School Facilities describes a voluntary pass/fail rating system to evaluate a school's progress toward sustainability. Since this Protocol is relatively new, OSPI secured and directed funding to five school districts to test the WSSP, implementing a wide range of sustainability measures and gathering data on their value and cost effectiveness. This Pilot Project is the first step towards refining what a sustainable school is and how a district would procure it.

Along with the physical improvements put in place at the five Pilot schools two other important outputs will be gained from the Project. First, the Pilot Project Report (O'Brien, 2004) describes the results of individual measures by school. Second, this Report to the Legislature takes the initial information from the individual Pilot Project schools and compares it with national data, in order to extrapolate the findings to school districts across Washington State. The intent is to provide a potential order of magnitude for costs, benefits and procedural impacts for incorporating sustainable building strategies into school design. This critical information can be used to help legislators and school district personnel make the best decisions about investing in high performance school buildings.

Washington schools reap the benefits of sustainable design at multiple levels. From a global perspective, sustainable schools reduce costs and lower demand on the tax base; from a regional perspective they reduce impacts on habitat and watersheds, from a personal perspective, they can help a single student with an attention disorder concentrate better in class.

This report looks at all of these impacts and evaluates them versus the costs of the sustainability measures. For ease of categorizing and understanding the impacts, the report considers the issues from three different perspectives: A+chieving Higher Standards, $aving Money, and Conserving Resources. These three aspects reflect the school districts' responsibilities to its students, its taxpayer base and the larger community.

1.2 A+CHIEVING HIGHER STANDARDS

High performance schools affect student learning because they create more comfortable, healthy and productive learning environments. Research into the link between high performance school buildings and student achievement demonstrates that good sustainable design is associated with potential increases of 5-26% in performance on standardized tests. The research also shows that sustainable school design is associated with a potential 15% decrease in absenteeism with the attendant increase in average daily attendance and with a potential 5% decrease in teacher turnover rates.

1.3 $AVING MONEY

High performance school buildings also show potential savings in operating expenses over the lifetime of the building. The Pilot Project and literature research show ongoing savings of 30% in energy use, over 38% in potable water use, and 38% in wastewater production. In addition they show a one-time reduction of 56% in construction waste that goes to the landfill.

For the average annual new construction building area in Washington school districts (1.5 million square feet), these percentage savings would represent the following dollar savings:

- Stormwater reduction: $ 27,522 /year

- Waste Water Reduction $ 23,050 /year
- Potable Water Reduction $ 14,077 /year
- Energy Savings $504,190 /year
- Construction Waste Savings $ 37,190 (one time savings during construction)

These potential savings are dependent on an integrated design approach that balances the needs of the heating, cooling, ventilation, lighting, potable water, and irrigation systems. The integrated design approach requires better-informed design decisions that may include expertise from design specialists and/or computer simulations to predict the performance of a new building system or the interaction among several building systems and building commissioning to ensure that the integrated systems are working as designed. The increased up-front costs or program support for this high performance design approach needs to be anticipated and funded to achieve the full benefits of sustainable design.

1.3.1 Life Cycle Cost

High performance buildings can incur increased first costs because of the investment in better performing equipment and materials and because of the additional design time and design tools (computer simulations, etc) necessary for an integrated design approach. Several research studies have suggested a 2% increase in construction costs to achieve a reasonable level of high performance design (equivalent to a LEED Silver rating). Using this 2% increase in first cost and the savings shown above, if all of Washington State's annual new school construction had high performance design, the potential savings would include:

- Positive net present value of $7,653,070
- 150% Return On Investment (ROI)
- 250% Benefit to Cost Ratio (BCR)

1.4 CONSERVING NATURAL RESOURCES

The potential savings noted above result in savings in natural resources for high performance school buildings. For the 1.5 million square feet of annual new school construction in Washington State, these potential savings amount to:

- Waste Water Reduction 4,037,817 gallons/yr
- Potable Water Savings 7,799,544 gallons/yr
- Energy savings 10,290 MWhr/yr
- Construction Waste (diverted from landfills) 930 tons
- CO_2 Emissions Reduction 1,543,439 pounds

These potential savings represent a substantial reduction of the impact of our school buildings on the environment and can provide valuable education resources for our school children.

2. INTRODUCTION

The Washington State Board of Education and Office of Superintendent of Public Instruction (OSPI) has taken an aggressive stand to encourage the development of high performance school buildings with the goals of improving student achievement, reducing costs and preserving environmental resources. Secondary objectives that can be reached with this approach include retaining our best teachers, increasing average daily attendance, reducing ongoing maintenance costs, strengthening the local community and economy, minimizing the disruption to water flows and natural processes at the site, and educating students on the values of sustainability.

To provide order and consistency in pursuing these important goals, several tools have been created by OSPI. The Washington Sustainable Schools Protocol (WSSP) for High Performance School Facilities describes a voluntary pass/fail rating system to evaluate a school's progress toward sustainability. This rating system is comprised of a number of prerequisites and optional sustainability measures. Each school participating in this protocol chooses from among the list of optional measures to chart a path toward sustainability specific to the site and goals of the district.

The Washington Sustainable Schools (WSS) Planning Workbook outlines a wide range of the benefits that students, teachers and communities derive from these recommended sustainable building practices. The workbook provides valuable how-to knowledge to districts and their design teams before they begin new capital projects.

2.1 THE WASHINGTON SUSTAINABLE SCHOOLS PILOT PROJECT

As the tools created by OSPI are relatively new, it secured and directed funding to five school districts (shown in the table below) to test the WSSP, implementing a wide range of sustainability measures and gathering data on their value and cost effectiveness. This Pilot Project is the first step towards refining what a sustainable school is and how a district would procure it.

Along with the physical improvements put in place at the five Pilot schools two other important outputs will be gained from the Project. First, the Pilot Project Report describes the results of individual measures by school. This Report to the Legislature takes this initial information from the individual Pilot Project schools and compares it with national research, in order to extrapolate the findings to school districts across Washington State. The intent is to provide an order of magnitude for the costs, benefits and procedural impacts for incorporating sustainable building strategies into school design. This critical information can be used to help legislators and school district personnel make the best decisions about investing in high performance school buildings.

	Olympia	Northshore	Spokane	Bethel			Tacoma
Pilot School	Washington	Cottage Lake	Lincoln Heights	Kapowsin	North Star	Thompson	Lincoln
Grade Level	Middle	Elem.	Elem.	Elem.	Elem.	Elem.	High School
Project Type	New/ Modernization	New	New	Existing	Existing	New	Mod'n

2.2 Relation to Governor's Priorities of Government (POG)

The #1 priority in the Governor's Priorities of Government in 2004 was to, "Improve student achievement in elementary, middle and high schools." The movement toward sustainable school design aligns closely with this goal. The school building is the physical learning environment and Washington's 2005-07 Capital Budget Request and 2005-2015 Capital Plan acknowledges that, "In recent years, substantial research has shown that the built environment has a direct impact on student and teacher performance … students working in day-lighted classrooms, for instance, have been found to progress 20 percent faster on math tests and 26 percent faster on reading tests than those students with the minimal amounts of day-lighting."

2.3 A School Based Framework for Sustainability

Washington schools could reap the benefits of sustainable design at multiple levels. From a national perspective, sustainable schools reduce costs and lower demand on the tax base; from a regional perspective they reduce impacts on habitat and watersheds, from a personal perspective, they can help a single student with an attention disorder concentrate better in class.

This report looks at all of these impacts and evaluates them versus the costs of the sustainability measures. For ease of categorizing and understanding the impacts, the report considers the issues from three different perspectives:

- ***A⁺chieving Higher Standards***

  There is a growing body of research that links high performance building features to improvements in student performance. If the appropriate measures for Washington schools can be identified, capital budgets can be optimized towards improved academic achievement.

- ***$aving Money***

  High performance buildings are by definition designed to create less environmental impact, which can save districts the cost of mitigation during development. Also, long-term utility demand reduction and simplified building systems lower the total cost of ownership of capital assets.

- ***Conserving Natural Resources***

  In Washington State a portion of school funding is provided by timber dollars, much of our electricity is produced through hydropower, and there is a growing pool of eco-friendly product manufacturers in state. By making smarter choices for building systems, schools can help maintain the natural abundance of our state resource base.

Performance in these three categories is interdependent – making a change in one area causes secondary effects in the other two. The challenge for sustainable schools is to maximize performance in all three.

3. A+ CHIEVING HIGHER STANDARDS

Students in classrooms with sustainable design features perform better on standardized tests – up to 26% better than other students.

photo: NREL PIX 00529 David Parsons

Schools open the world of learning to our children, and school buildings play a critical role in creating an optimum setting for this learning to occur. Research is just beginning to quantify the relationship between design characteristics of the buildings themselves and the health and performance of the students and teachers who inhabit them.

In recent years some pivotal research has documented the magnitude of this link between classroom characteristics and student performance. Improvements of over 20% on standardized tests have been substantiated with approaches like incorporating good daylighting in classrooms. Most of the measures that impact learning are found in the WSSP section on Indoor Environmental Quality, because these are the building performance issues that directly affect occupant comfort.

3.1 ENVIRONMENTAL CONDITIONS AND LEARNING

Children spend more time in the classroom than in any other indoor environment outside the home. Adverse environmental conditions in the school can have long-term negative impacts on student health and learning, which translate to lifelong effects for the students and society as a whole. But one recent literature review found disturbing evidence for the health of our school buildings: “Schools, relative to other kinds of buildings are seen as particularly likely to have environmental deficiencies that could lead to poor indoor environmental quality (IEQ).

Physical characteristics of school facilities affect the learning process because of their impact on student health and absenteeism, attention spans and distractions, ability to see and hear the tasks, stress, mood, teacher retention, etc. A recent review of the research on school condition and student achievement identified human comfort, air quality, lighting and acoustics as the top four out of 31 building-related factors affecting student achievement in our schools. (Earthman, 2004) All four of these are a major focus of sustainable school design.

Research has documented increases in test scores, student attention spans, health symptoms and comfort levels and decreases in absenteeism, teacher turnover rates and comfort complaints in well-designed schools. The overall impact is toward a healthier and more productive learning environment.

This section reviews the available research, identifies the magnitude of each effect on student performance and teacher preferences, and substantiates the research on these effects with data from the Washington schools participating in the WSSP Pilot Project.

3.2 AIR QUALITY

Pollutant sources in schools arise from a variety of different sources: organic microbes (molds, bacteria, virus, etc), formaldehyde (offgassing from composite wood products, furniture, etc), volatile organic compounds (offgassing from paints, sealants, carpets and other construction products), particulates (from copiers, foot traffic, etc), chemicals used in maintenance and laboratory procedures, and byproducts of combustion such as solid particles, carbon monoxide (CO) and nitrogen oxides. Without careful design, these accumulate in the air, jeopardizing student health and reducing performance.

Photo: NREL PIX 05452 Warren Gretz

A reduction in concentration and perceived mental performance is associated with increased indoor pollutant concentrations and lower ventilation rates.

Air quality is of particular concern in schools because children breathe higher volumes of air relative to their body weights and are actively growing; so they are more susceptible to air borne pollutants. .

High ventilation rates and the availability of fresh outdoor air are integrally linked to air quality because they act to remove or dilute volatile organic compounds and other pollutants that tend to accumulate in the building air. CO_2 concentration is often used as an indicator of air quality because people generate CO_2 as a natural part of the breathing process and if air quality and ventilation are low, interior CO_2 levels rise above normal outdoor levels. A good ventilation scheme minimizes levels of both CO_2 and other indoor pollutants. Poor ventilation and recirculation of unfiltered air in school buildings allow concentrations of CO_2 and other contaminants to increase above acceptable levels.

High CO_2 levels contribute to lethargy and reduced attention and signal the potential accumulation of other contaminants that contribute to a range of other sick building syndrome symptoms, like asthma. Asthma attacks are one of the leading causes of school absenteeism and account for over 10 million missed school days per year. [Eley, et.al., 2002, Dougan et al, 2003] Milder asthma symptoms also decrease the performance of students and teachers who remain in the school setting. [EPA, 2003]

Build-up of microorganisms and bacteria in air can also contribute to increased incidents of air-borne infections. It is difficult to differentiate the separate impacts of these individual symptoms of poor indoor air quality, but taken together they substantially increase absenteeism and decrease the effectiveness of the learning process.

There are two approaches to optimizing air quality: 1) reduce the production of interior contaminants, and 2) dilute interior contaminants by increasing the ventilation effectiveness.

These two approaches are addressed by several credits in the WSSP. **WSSP IEQ Prerequisite 2 and Credits 3, 4 and 5** all address the reduction of contaminants in building air and **WSSP Energy Credit 2** recommends using operable windows for natural ventilation to give teachers and students control over their air quality.

Several different schools in the Pilot Project are investigating measures that address these credits and thus impact air quality. Some of the impacts are measured as increases or decreases in absenteeism rates (or conversely in average daily attendance). Others are documented as changes in performance on standardized tests. These two parameters are linked because when students are absent from school, they miss valuable lessons and can be expected to have poorer test performance.

3.2.1 Ventilation Effectiveness

Increases in ventilation dilute pollutants in the air and reduce their impact on occupants. The American Society of Heating, Refrigerating and Air -Conditioning Engineers (ASHRAE) sets standards for minimum acceptable ventilation rates for various building types, including schools. Meeting or exceeding their minimum standards increases health and performance for students and teachers. As noted above, CO_2 levels are frequently used as an indicator of the ventilation effectiveness and the associated indoor air quality. When CO_2 levels reach 1000 parts per million (about three times normal atmospheric levels) headaches, drowsiness, and the inability to concentrate ensue (Schneider, 2002). This 1000 ppm level is frequently cited as an upper maximum allowable level.

3.2.1.1 What the Research Says

A study of 22 Washington and Idaho schools measured CO_2 levels in 409 traditional and 25 portable classrooms and evaluated these measurements relative to the corresponding absentee rates for the schools. After controlling for other factors that might influence attendance (socioeconomic status, ethnicity, gender, etc.) this study showed that 45% of the classrooms had CO_2 concentrations above 1000 ppm., and 4.5% were above 2000 ppm. In addition, it demonstrated that a 1000 ppm increase in CO_2 concentration was correlated with a 10-20% increase in student absenteeism (equating to a 0.5 –0.9% decrease in average daily attendance) (Shendell et al, 2004).

An EPA compilation of information on indoor air quality and student performance notes studies showing that, "A statistically significant reduction in perceived mental performance among students was associated with increased indoor pollutant concentrations and lower ventilation rates." (EPA, 2002) Studies in Norway of 800 students from 8 schools also found that high CO_2 levels in classrooms correlated with reduced performance on standardized tests (the Swedish Performance Evaluation System) and self-reported student health symptoms (Myhrvold et al, 1996).

Reductions in sick building syndrome symptoms are associated with 5.3% improvement in student test scores.

Computational Fluid Dynamics (CFD) modeling at the Northshore Pilot Project demonstrated that natural ventilation provides superior air flow (25 CFM/person) and better ventilation effectiveness than the code minimum (15 CFM/person). Northshore also showed that in order to match the performance of a natural ventilation system, a mechanical system would incur a 42% increase in first costs and increased annual energy costs of 17%. (O'Brien, 2004)

3.2.1.2 What It Means to Washington Schools

WSSP IEQ Prerequisites 21 and 2.2 require that participating schools meet a minimum ventilation standard to ensure minimum air quality standards.

In 2001, a walk-through assessment of 156 schools in Washington State indicated that 66% of portable classrooms had CO_2 levels greater than 1000 ppm and 88% of permanent buildings had at least one classroom exceeding this threshold (some ranging as high as 4000 ppm) (Prill 2001) Clearly there is much room for improvement in ventilation effectiveness in Washington's schools.

3.2.2 Natural Ventilation

The previous section notes the effectiveness of natural ventilation in exceeding minimum ventilation standards. In addition, operable windows give occupants a measure of direct control over the ventilation and air quality in their environment. "Operable windows are perhaps the single most desired feature building occupants request in the programming phase of a project." (USGBC 2003)

Photo: NREL PIX11890 Warren Gretz

Test scores increase 7% in schools with operable windows.

3.2.2.1 What the Research Says

A compelling research study by the Heschong-Mahone Group identified a 7-8% increase in standardized test scores for students in classrooms with natural ventilation and a follow-on survey of the teachers involved identified operable windows as a desirable classroom feature (HMG, 1999).

3.2.2.2 What It Means to Washington Schools

WSSP Energy Credit 2 gives one point for classrooms with operable windows and **WSSP IEQ Credit 8** gives three points for using natural ventilation instead of air conditioning.

Based upon thermal computational fluid dynamics (CFD) modeling results, both Olympia and Northshore demonstrated that natural ventilation strategies can be effective approaches to provide good ventilation and indoor air quality as compared to conventional mechanical systems. The cost of incorporating natural ventilation is relatively low (The Spokane Pilot reported an incremental cost of $14 - $70 per classroom for storefront or punched operable windows respectively). However the cost to perform computational fluid dynamics (CFD) analysis to ensure that natural ventilation will supply all the ventilation and cooling needs for the building can be a significant first cost. The Olympia Pilot calculated CFD simulation costs at $7500 per classroom or $20,000 for a typical school.

3.2.3 Reduced indoor air pollutants

The other approach to reducing the accumulation of unhealthy indoor contaminants is to reduce or eliminate the materials and situations that produce them. This includes protecting materials and duct work during the construction process, flushing out the building prior to occupancy, specifying low emitting construction materials, using the least hazardous cleaning products, and minimizing standing water and wet materials in the building.

HVAC CO_2 monitoring: Student absences escalate 10-20% with 1000 ppm increase in CO_2.

3.2.3.1 What the Research Says

Indoor air pollutants may irritate the skin, eyes and respiratory system, causing reduced health and performance and increased absenteeism. These symptoms are frequently combined, along with thermal comfort under the general heading of sick building syndrome.

Evidence from office workers suggests that when people experience just two symptoms of discomfort (e.g. dry, itchy or watery eyes, dry throat, lethargy, headache, chest tightness), they begin to perceive a reduction in their performance. That perception increases as the number of symptoms increases, ranging from 3% performance loss with 3 symptoms up to 8% performance loss with 5 symptoms (EPA 2003). Studies of performance verify these perceptions. A research group in Norway identified a 5.3% improvement in time-tests associated with reductions in sick building syndrome symptoms (Myhrvold et al, 1997).

3.2.3.2 What It Means to Washington Schools

Many new products and procedures are available to minimize the introduction of these pollutants to our school buildings: Low VOC paints, sealants, and carpets reduce exposure to construction workers and long-term off gassing; elimination of formaldehyde-based composite wood products eliminates offgassing of formaldehyde; integrated pest management minimizes the use of pesticides; green cleaning products reduce chemical exposure; separate ventilation of copy rooms and maintenance closets keeps their pollutants from contaminating adjacent work and classroom spaces. Several prerequisites and credits in the WSSP reward these practices and the use of these low polluting materials (**WSSP IEQ Prerequisite 2.3, and Credits 2.4, 2.5, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2**).

3.2.4 Thermal Comfort

Air quality and heating, cooling and ventilation (HVAC) systems are integrally related and are frequently lumped together into a descriptor of "sick building syndrome" (SBS). The temperature and relative humidity of indoor spaces affect the perception of comfort and can impact the performance of students and teachers. Extensive building comfort research in the 1970's identified a zone of temperatures and relative humidity within which the majority of people are comfortable. This "comfort zone" was adopted by ASHRAE and used to set the limits on the control of building heating and cooling (HVAC) systems. When temperatures drift outside the comfort zone, performance may decrease.

The best teachers in the country emphasize their ability to control classroom temperature as central to performance.

3.2.4.1 What the Research Says

Research in schools with traditional HVAC systems has shown that warmer temperatures tend to reduce alertness and performance while cooler temperatures reduce manual dexterity and speed of performing tasks (EPA, 2003). Harner found that the best temperature range of learning reading and math is 68-74^{0}F and that the ability to learn these subjects reduces at temperatures above 74^{0}F. As temperatures and humidity increase, students report greater discomfort and attention spans decrease (Schneider, 2002).

However, research into buildings with operable windows shows that occupants of these buildings, "demonstrate a preference for a wider range of thermal conditions, perhaps due to their ability to exert control over their environment or because their expectations match the more variable conditions they are used to experiencing in such buildings." (Brager, 2000) This has led to an "expanded" range of allowed temperatures in naturally ventilated buildings. In the adaptive standard for naturally ventilated buildings, the comfort range is expanded up to 79-86 ^{0}F on the hottest days and down to 62-72^{0}F on the coldest. It is assumed that occupants of these spaces are comfortable at higher temperatures than the original comfort zone indicated because they have control over their environment.

Control over the environment in schools is especially important. One teacher survey (Lowe, 1990) found that the best teachers in the country emphasized their ability to control classroom temperature as central to the performance of teachers and students (Schneider, 2002).

3.2.4.2 What It Means to Washington Schools

The WSSP stipulates that buildings meet the thermal control requirements of ASHRAE 55 as a prerequisite for participating in the Protocol. It also gives credits for providing operable windows, eliminating air conditioning and providing individual classroom controls for temperature and lighting, all of which provide the comfort and control levels for optimum performance.

The Northshore Pilot calculated costs of $1895/classroom and increased operations and maintenance (O&M) costs of $20/year for occupant controlled ceiling fans and computer modeled their effect on air temperature and ventilation. They concluded that the addition of occupant controlled ceiling fans is a reasonably cost effective method to increase the comfort rage of a passive cooling design and that it should be considered in the Western Washington climate zone. (O'Brien, 2004)

3.3 LIGHTING

The ability of good quality lighting to increase student performance by making tasks easier to see has long been appreciated by the design community. But recent research is expanding our understanding of how lighting affects the learning experience. Lighting is now being connected with seasonal depression, stress, physiological disorders (headaches, eyestrain, etc.), attention span, growth, development, behavior, and attitudes, all of which again impact absenteeism and learning rates.

Students in daylit classrooms exhibit 15-26% higher performance on standardized tests.

During the daytime, lighting is provided by both daylight and electric lights and these will be discussed separately below.

3.3.1 Daylight

Over the last century, school design has both embraced and shunned daylight and views in classrooms. Early 1900 classrooms were predominantly daylit. The 1940's saw the emergence of innovative daylighting designs fine-tuned to deliver balanced daylight across the entire classroom. But school design in the 1970's consciously turned its back on daylight, responding to concerns about the "energy crisis" and distractions from window views. Recent improvements in the thermal qualities of windows and new evidence about the value of views in classrooms have reversed this trend.

3.3.1.1 What the Research Says

New research is discovering clues to the effect of light on our biological systems that expands our understanding of its importance. One report indicates far reaching effects, suggesting that, "Work in classrooms without daylight may upset the basic hormone pattern, and this in turn may influence the children's ability to concentrate or cooperate, and also eventually have an impact on annual body growth and sick leave." (Kuller et al, 1992)

Numerous research projects have documented the correlation between daylight in the classroom and increases in student learning. Perhaps the most statistically rigorous, the Heschong Mahone Group (HMG) study in Washington State, Colorado and California, showed increases of up to 20% in math and 26% in reading performance when comparing scores on standardized tests from students in daylit versus non-daylit classrooms.

These highest increases were seen in California where beginning and end of the year testing provided the most stringent control over the research protocol. But even in Washington State, where only end-of-year test results were available, 9-15% increases in test scores were documented (Heschong et al, 2002, HMG, 1999). This study also confirmed the importance of the daylight quality. Most of the skylit classrooms in the study had diffusing glazing that spread daylight in the space without glare. But some skylit classrooms had clear skylights with glare from direct sun. In these classrooms with direct sun, student performance was reduced by 21%. (HMG, 1999).


Source: NREL PIX 08834 credit Robert Flynn

Researchers examining the effect of daylight in three North Carolina schools also found correlations between daylight and increased performance. The study by Nicklas and Bailey, showed that children moving to daylit schools showed an increase in performance of 5 to 14%, with an overall average increase of 5.5% (Nicklas et al, 1997).

In addition to bringing daylight into classrooms, windows also contribute views that help to relax eye muscles, minimizing eyestrain, reducing the number of vision-related headaches and decreasing stress and monotony. A follow-on HMG research project in the Fresno School District documented the importance of window views in the classroom setting, showing that views also have a positive correlation with higher student test performance. (HMG, 2003)

3.3.1.2 What It Means to Washington Schools

The WSSP acknowledges the importance of daylighting in several credits. **WSSP IEQ Daylighting Prerequisite 1** requires daylight levels to exceed a minimum recommended level in 50% of the critical task areas. **WSSP IEQ Daylighting Credits 1.1 and 1.2** give one point each for extending this requirement to 75% and 100% respectively. **Daylighting Credit 1.3** gives an additional point for providing a direct line of sight through a view window for 90% of classrooms.

Several districts in the Pilot Project estimated the cost of incorporating daylight in school design. Initial construction costs varied from nominal to significant depending upon the strategies employed. Olympia and Northshore considered daylighting as elements in an integrated design combining light wells with natural ventilation and thermal chimneys at the interior classroom walls. This approach incurred incremental costs of up to $11,968 per classroom in the Northshore Pilot (O'Brien, 2004). These integrated designs make it difficult to isolate the costs for daylighting alone. However, several districts in the Pilot study noted the evidence of improved performance by students and staff as sufficient reasons to incorporate daylighting strategies.

3.3.2 Electric Light

Like daylight, electric lighting has impacts on both vision and psychological/physiological processes in the classroom environment. A good electric lighting design provides targeted task light as needed and provides ambient lighting to supplement daylight in the space for all hours of the day. Direct/indirect pendant electric lighting is an excellent way to deliver this light in a balanced, glare-free way. When combined with the new, narrower T8 and T5 fluorescent lamps and electronic ballasts these pendants have better color quality and energy efficiency to deliver the light with minimum energy use. Their energy impacts are discussed in Section 4.4.2.


Photo credit: Finelite

Direct/Indirect pendant electric lights deliver balanced, glare-free lighting.

3.3.2.1 What the Research Says

Direct/indirect pendant lighting delivers light to the ceiling and walls, making spaces appear brighter and improving overall visibility. A research study by the Light Right Consortium compared three office environments with different electric lighting strategies – a regular array of recessed parabolic luminaires, a direct/indirect pendant scheme with wall washing and a direct/indirect scheme with individual control of a desk task lamp. This study demonstrated that the lighting designs that provided direct/indirect lighting and wallwashing were rated as comfortable by 81%–85% of participants. By comparison, the design that provided only downlight (2x4 troffers) were rated as comfortable by only 69–71% of participants. In addition to occupant preferences, the study also found that the presence of personal control had a measurable impact on the motivation of office workers to perform tasks. (Light Right Consortium, 2004)

The Northshore and Spokane Districts evaluated the use of direct/indirect pendant mounted electric lighting in comparison to standard 2x4 parabolic fixtures. They determined that the pendant fixtures have an initial construction cost premium of up to $800per classroom and slightly higher energy and maintenance costs, but they provide an improvement in lighting quality, including glare reduction, contrast and color rendition. (O'Brien, 2004)

3.3.2.2 What It Means to Washington Schools

The **WSSP Lighting Quality Credit 2** provides one point for designing with pendant mounted indirect/direct or semi-indirect luminaires with high-lumen T8 or T5 lamps.

Pendant fixtures require 9-10 foot ceiling heights that may require a design change that carries a cost premium in school construction. But optimum daylighting strategies and stack driven natural ventilation schemes also require higher ceiling elevations. An integrated design with natural ventilation, daylighting and pendant direct/indirect electric lighting can share the cost premium of increased ceiling heights.

3.4 ACOUSTICS

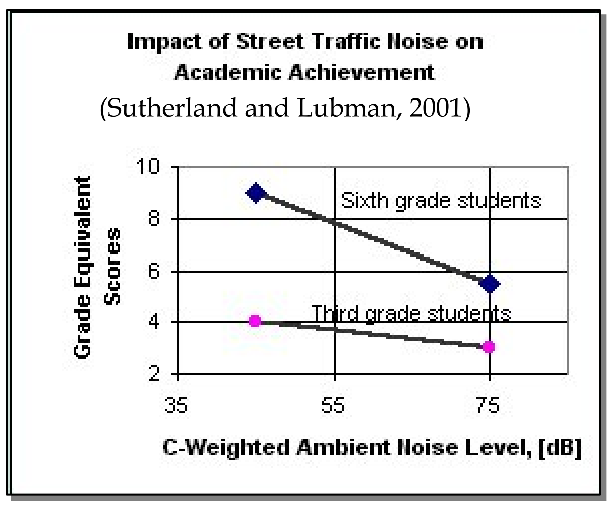
3.4.1 Improved Acoustic Performance

Photo: Nrel Pix 09406 Warren Gretz

Reading and math scores increase 2 grade equivalents in quiet 6th grade classrooms.

Research studies show that learning depends on the ability to communicate with spoken language and that perception of language is the foundation for the ability to read and write. Up to 60% of classroom activities involve listening to and participating in spoken communications. Excessive noise can only be partially ameliorated by a teacher raising his or her voice level and then only at the potential cost of voice fatigue. Experts believe that as many as one-third of all students miss up to 33% of the oral communication that occurs in the classroom. In addition, there is evidence of a reduced number of verbal interactions between teachers and students in noisy classrooms. (Sutherland and Lubman, 2001)

Noisy and reverberant classrooms may act as a barrier to learning and as a barrier to educational access for students with hearing disabilities and students for whom English is a second language.



3.4.1.1 What the Research Says

A classic study into the effects of noise on scholastic achievement was carried out by Lukas, et al in a group of California schools located at different distances from freeways, and thus experiencing different levels of background noise. This study demonstrated that the higher background noise levels correlated with reduced grade equivalent reading and math test scores. The reading scores are shown in the figure to the right as a function of the C-weighted background noise level in the classroom. (Sutherland and Lubman, 2001)

In another study, two Cornell researchers compared first- and second-graders at two New York City schools and found that students attending the quieter school scored as much as 20% higher on a word recognition test than students in the second school with noisy airplanes flying overhead. (Lyons, 2001)

3.4.1.2 What It Means to Washington Schools

WSSP IEQ Prerequisite 3 requires a maximum unoccupied background noise level of 50 NC and **IEQCredit 6** gives one point for achieving improved acoustical performance of 35 NC maximum.

In the Pilot Project, the Spokane district investigated the costs of achieving **WSSP IEQ Credit 6**, limiting background classroom noise levels to a maximum of 35 NC. They evaluated the cost for 25 classrooms plus media center and gym at $65,891 for ceiling tiles, plus $5,580 for TECTUM™ wall panels. However, they also noted that this credit is easy to achieve in their school district because their district already has a more stringent requirement for classrooms to achieve 25-30 NC.

The Northshore and Olympia Districts investigated the classroom noise due to fan operation from the HVAC systems. Northshore noted that their passive ventilation scheme met the 30 NC required to meet credit IEQ Credit 6, except at times when filters and fans are added to improve indoor air quality. They calculated a cost of $6,412, or $400 per classroom for providing sound lining in the ductwork and isolation mounting for the fans to reduce classroom noise from 50 to 45 decibels (db). Olympia also noted that when fans were operating in a cooling mode (more than what was needed for ventilation), the target classroom noise levels may be exceeded and the Protocol noise criteria may not be met.

The Spokane Pilot noted that due to the added costs for acoustical separations it is preferred if noise generating equipment is located away from classroom spaces. If this is unavoidable it's critical that acoustic isolation methods are considered early in the design as they can have a major impact on other systems. One of the more effective ways to dampen noise from mechanical systems is through utilization of a concrete pad that can add significantly to the structural requirements of a roof top unit or penthouse. Similarly, acoustic treatments in classrooms should be integrated into the design, rather than tacked on later. Spokane recommended using tackable acoustic wall panels that can address acoustic needs while allowing for flexibility in ceiling finishes and providing larger areas for display.

3.5 TEACHER RETENTION

As noted in many of the sections above, these building improvements also impact the teachers' health, comfort and satisfaction with their work environment This can lead to increased teacher retention, increasing the quality of education and reducing costs to the school district.

3.5.1.1 What the Research Says

Recent research has documented the potential for lower turnover rates for urban teachers in schools with better buildings. A study of teachers in Washington, D.C., and Chicago demonstrated that poor facilities affect the health and productivity of teachers. "More than one-quarter of Chicago teachers and about one-third of Washington [DC] teachers reported suffering health problems rooted in poor environmental conditions in their schools. … These problems translated into reduced teacher effectiveness, with almost 20 percent of Chicago teachers and one-third of Washington [DC] teachers reporting lost teaching time." (Schneider, 2003) Moreover, for teachers who experienced health effects related to poor facilities, about 50%-65%considered changing schools and about 40% thought about leaving the profession entirely. To test the extent to which the quality of the building affects teacher retention, this study asked teachers to rank their school facilities with a grade of A to F (A = highest; F = lowest) and then rank their probability of remaining at their current school for another year. Factoring out the other common influences such as pay, satisfaction with administration, community, years at current school, etc, the study found that there was a 5% increase in the probability of remaining at the same school for teachers who ranked their school facilities with an A versus those with an F. Further, the quality of the facilities had a higher influence on teacher retention than pay! (Buckley, 2004)

Photo: NREL Pix 09577 Warren Gretz

Studies show that the quality of facilities has a higher influence on teacher retention than pay!

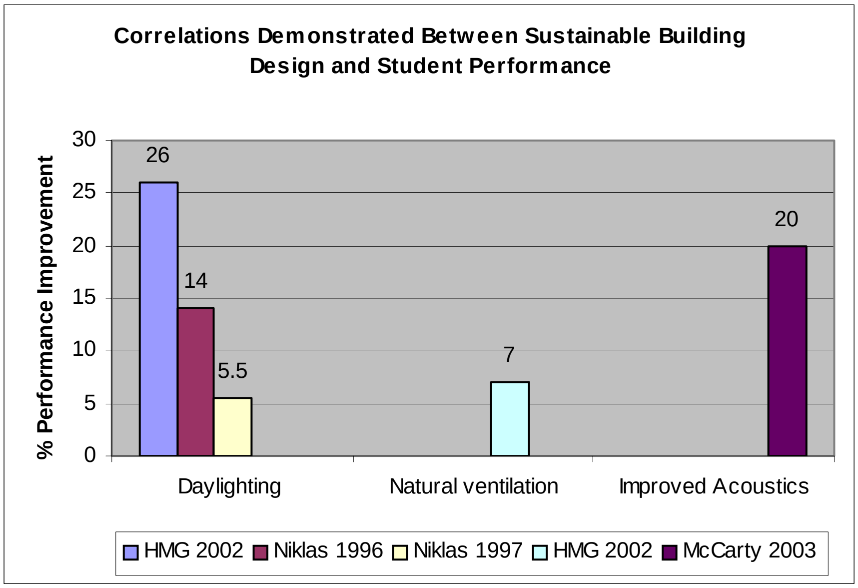
An earlier study of over 1,000 schools in Alabama established the significance of reduced turnover rates to student performance by noting that, "when socioeconomic factors are taken into account, increased faculty stability from year to year enables a school to achieve a substantially higher success rate in student performance on the SAT" (PARCA, 2002).

3.5.1.2 What It Means to Washington Schools

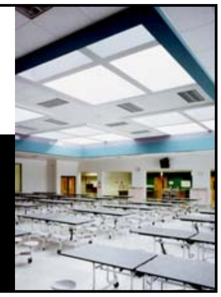
Higher teacher retention rates and improved teacher health are most likely some of the factors contributing to the increased performance noted in the research above. The impact of teacher effectiveness cannot be separated out from the direct effect of the facility on students.

3.6 Total Impact on Achievement

The research cited above demonstrates that sustainable school design is associated with better student and teacher performance, showing higher standardized test scores of up to 26%. The results from some of this research are summarized in the graph below. Individual studies identify the effects of specific measures; the interaction among the measures is difficult to assess. However, the magnitude of the impact of even a single measure can be dramatic when its potential impact on standardized test scores is extrapolated to the entire student population.



4. $AVING MONEY



Good economic decisions about a strategy's cost effectiveness must take into consideration the total cost over the full lifetime of the building..

photo: NREL PIX 8835 Robert Flynn

Although most of the high performance building design approaches to increase productivity potentially increase the initial capital cost of the school building, they are also frequently linked with operating savings that offset the incremental capital cost increase. The ongoing building operation and maintenance savings for schools taking a sustainable building approach are summarized in this section. Annual savings in energy, water use and capital savings during construction of new buildings (including construction waste removal) add money back into school district budgets that can be diverted toward operations, maintenance, teachers, staff and learning materials.

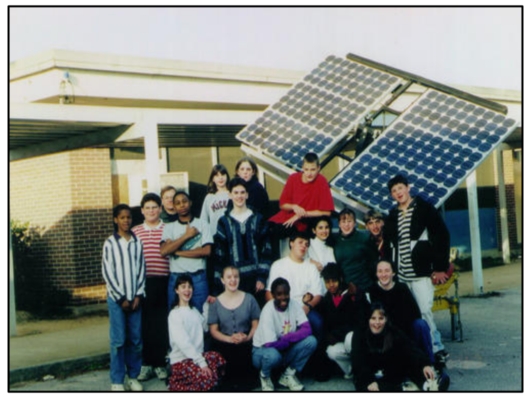


Photo: NREL PIX #10901 Solar Electric Power Assoc.

Wise decisions in the design and construction of resource efficient, high performance school buildings accomplish three key goals:

- Investment in education
- Fiscal responsibility to the community
- Long term value enhancement of capital assets

4.1 DIRECT $AVINGS

Direct savings arise from reductions in first costs for building construction or from reductions in ongoing operating costs, such as energy and water bills. However, some measures that provide long-term savings in operating expenses come with an incremental first cost. Over the life of the building, the operating savings may more than make up for the increased first cost, and a Life Cycle Cost Analysis (LCCA, see section 4.3) will determine whether this is so for a particular set of measures. These analyses require an evaluation of the costs and projected savings and may involve computer simulations of building performance.

4.2 INDIRECT $AVINGS

Indirect savings can come from increased performance, risk reduction, increased average daily attendance (and its associated federal/state funding), etc. Although these sources of savings are difficult to quantify, it is important to understand the potential scope of their impact on the financial equation for each school district. Some of these sources of indirect savings are presented below.

4.2.1 Performance

One way of valuing the increased performance of students in high performance school buildings is to quantify it relative to the amount of money spent on educating a student for a year. For this analysis, we will use the conservative value of 5% performance improvement that was used at the end of Section 3. In the 2002/2003 school year, Washington schools invested $7,436 per year from the General Fund for the education of each student (OSPI website, 2004). Using this as the "value" for educating each student, a 5% increase in performance translates to an increased value of $372 per student per year. With a population of a million students, the total value of a 5% increase in student performance over all schools in the state calculates to an increased educational value of over $372 million. Clearly, performance improvements are an overwhelming driver in the equation for cost effectiveness.

4.2.2 Risk Reduction

Performance value is not the only value that high performance buildings deliver. Beyond the impacts associated with student learning, there are 5 identifiable economic impacts from poor indoor environmental quality: 1) lost revenue due to reduced student average daily attendance, 2) time and money spent handling complaints and their associated monitoring and mitigation efforts, 3) increased staff turnover rates, 4) increased energy use to mitigate complaints/problems (ex: increased ventilation to reduce odors or stuffiness, etc) and 5) the long term liability from health impacts.

Examples of the cost of indoor air quality (IAQ) problems abound. The Janvier Elementary School in New Jersey spent nearly $100,000 to correct mold and flooding problems; and Yuma High School in Arizona spent over $5 million to clean up its mold problem. A survey of air quality problems by the EPA noted that, "School districts have spent from $200,000 to $13.1 million to remediate a school with a severe mold problem." (EPA 2002) These costs included repairs to the schools and relocation of students during the repairs, but did not include liability for student health which can escalate costs even higher. In response to this, the EPA established an "IAQ Tools for Schools Program" to help school districts identify and remediate air quality problems. Since implementing an IAQ program in 1998, the Hillsborough County Public School District in Florida has spent only $400 on IAQ consultants as compared to an estimated $250,000 prior to 1997. (EPA, 2002).

Furthermore, schools that fail to take actions consistent with existing IAQ guidelines and other environmental health standards run the risk that they will be found liable for negligence. The risk is significant because, under negligence theory, a school board's liability is not limited to the costs of remedying the IAQ problem; the board also faces the threat of actual and punitive damages. (Singer et al, 1997)

4.2.3 Attendance Based Funding

Student attendance in our public schools is a critical factor in securing limited operational funding. Changes in ventilation or in any other factor affecting student attendance will influence the funding provided to many school districts, because funding is linked to annual average daily attendance. For example, "in California, the most currently available (2001-2002) funding rate is $12.08 per student-day not absent . For a classroom of 20 children with a 185-day school year (3700 student-days), a 1% decrease in annual average daily attendance (or 20% relative increase in absence) is $450 per classroom in funding lost to the school district." (Shendell, 2004)

4.3 First Costs vs Life Cycle Costs

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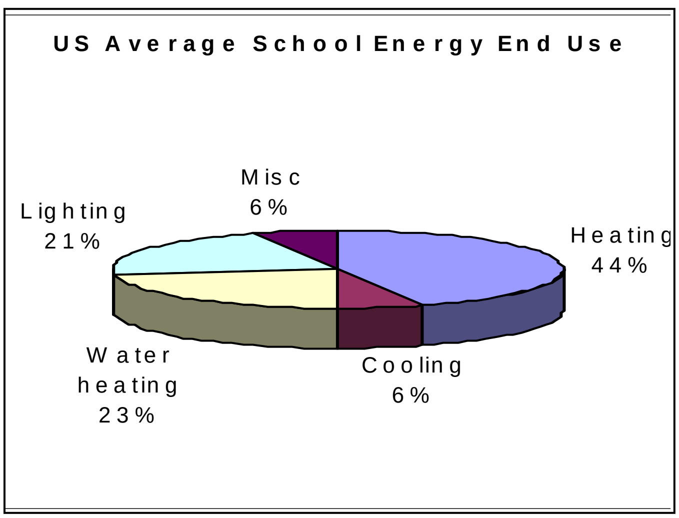
First cost increases may be incurred because the sustainable building features include technologies that are higher quality or are relatively new to the market and thus have higher initial costs or require more specialized labor for installation. Costs may also be increased to pay for the additional time, simulation tools and resources required in a truly integrated design process. However, it can be argued that if an integrated design approach is used, higher expenses in one area can be offset by savings in other areas for a zero net increase (or potential decrease) in capital costs. For example, a smaller air conditioning system may potentially be specified if a "cool roof" approach minimizes the building's cooling loads. The net change in first costs can thus be partially or fully offset (and may even be lower than the less efficient design).Within the sustainable design industry, however, the rule of thumb for LEED Silver Rated projects is that their initial capital costs will on average be about 2% higher than a non-LEED rated building.

But good economic decisions about the cost effectiveness of a strategy or integrated group of high performance building strategies must also take into consideration the total cost implications of each strategy over the full lifetime of the building, including operating, maintenance and replacement costs (and potentially the value of indirect benefits that come with the strategy). The Pilot Project schools analyzed each sustainable strategy to determine its life cycle cost (LCCA) over a 30-year building life. Taking this LCCA approach, allowed them to make wise decisions about when to make an up-front investment in a high performance design option to guaranty a positive return over the life of the building. The following section describes some of the strategies investigated and their associated life cycle costs and savings.

4.4 Energy $avings

School buildings represent about 12% of the energy used for commercial buildings in the United States; and the typical US school building consumes about 75,000 Btu per sq.ft. per year for all of its energy needs. Heating and cooling take about half of this energy, while lighting and water heating each consume about a fifth to a quarter, as shown in the pie chart to the right. (USDOE, 2004) A significant amount of this energy can be saved with an integrated, energy efficient design approach.



4.4.1 Building Envelope, HVAC & Water Heating $avings

The building skin or "envelope" regulates the flow of heat into and out of a building and has major impacts on the amount of energy required to thermally condition the interior. Combined with energy efficient heating, ventilation and air conditioning (HVAC) equipment, an efficient building envelope can provide significant energy and cost savings over the life of a school building.

4.4.1.1 What the Research Says

As noted above, a school building's HVAC equipment can typically consume 50%of its total energy use and 40% or more of this can be saved with energy efficient envelope and mechanical system design. A wide range of strategies are available to achieve these savings, including high insulation levels in windows, walls and roofs, reduced solar gains, preconditioned ventilation air, efficient heating/cooling strategies and equipment, efficient fans and distribution systems, and efficient setbacks and system controls. The exact strategies selected ultimately depend on the climate and internal loads of the school building proposed.

In the WSSP Pilot, all districts conducted research into a range of envelope and HVAC strategies. Bethel District investigated the actual costs of an energy efficient ground source heat pump compared to a more conventional boiler and cooling tower system for two schools constructed within the last 5 years. The ground source heat pump had a very small incremental cost (repaid within the first year of savings), but was projected to save about 30% in energy costs. Spokane estimated similar savings (23%), but at a 17% increase in system cost. This increase in system cost caused negative life cycle savings for Spokane, but the district opted to pursue the ground source heat pump system because of the effect of its additional filtration on air quality and the expectations that rising energy costs will eventually offset the first costs.

Olympia evaluated hydronic radiant heating with heat recovery ventilators as compared to conventional fin-tube radiant heating systems and found that the efficient hydronic system demonstrates a $3500 annual energy cost savings and 83% reduction in maintenance costs at a comparable (or lower) first cost. The overall estimated life cycle cost savings of the radiant floor hydronic system is $196,000. (O'Brien, 2004) They also noted that in nearly all K-12 installations of radiant heating in the Northwest, occupants report increased levels of thermal comfort. In spite of this, they acknowledge that there is overall lack of knowledge of these systems and their advantages and suggest early client education and more investigation of this technique by WSSP.

For ventilation technologies, both Olympia and Spokane evaluated the costs and energy efficiency of displacement ventilation systems compared to conventional systems. Olympia determined that displacement ventilation would provide a first cost savings of $20,000 compared to 20 tons of air conditioning and would provide annual maintenance and energy savings of $1,200 for an overall life cycle cost savings of $76,000. Spokane calculated similar life cycle savings ($53,000) but with a small 3% increase in first costs.

On the other hand, some envelope and HVAC measures evaluated in the Pilot were not cost effective. Tacoma, for example, elected not to increase roof insulation to the NREC requirements for the historic portions of Lincoln High School after they determined that the estimated annual energy savings of $520 would not offset the $30,759 first cost over the lifetime of the building. (O'Brien, 2004)

4.4.1.2 What It Means to Washington Schools

WSSP Energy Prerequisite 1 requires schools to meet the minimum efficiency standards of Washington State's Non-Residential Energy Code (NREC). **WSSP Energy Credit 1** provides points for exceeding this code. High performance building envelope materials, HVAC and water heating equipment provide energy savings that contribute to these credits.

Clearly the right choice of strategies for HVAC and envelope can result in substantial economic savings for schools, along with improvements in thermal comfort to promote higher achievement noted in Section 3.2.4. Some of the strategies come at no incremental first cost (or even a lower first cost) but other strategies that yield attractive lifecycle savings or other environmental benefits come with an increased first cost. In addition, the whole building computer simulations that may be required to evaluate the different system options add cost to the design/engineering fees. Funding for these increased first costs is important to ensure both that the best integrated system is specified and that the best life cycle cost is achieved. See Section 4.4.3 for an analysis of both costs and savings in a whole-building, integrated energy savings approach.

4.4.2 Lighting $avings

In addition to the large increases in student performance that accompany good lighting design noted in Section 3.3, high performance lighting can reduce annual operating costs and generate significant savings over the lifetime of the building. Electric lighting accounts for 35- 50% of a school's electrical energy consumption (Eley, et.al., 2002), or about 20% of the total energy use. Energy efficient electric lighting design can easily achieve 30-50% savings with a combination of strategies. Savings may come from specifying more efficient electric lighting or from turning off or dimming electric lights in response to occupancy or daylight. As an added benefit of these strategies, when lights are turned off, waste heat from the lighting system is reduced, lowering demands on the school's cooling equipment. The savings can be as much as 10% to 20% of a school's cooling energy (Eley, et. al 2002)

These savings may, however, also incur increased first-costs due to the additional cost of daylighting devices (windows, shading elements, lightshelves, etc), electric lighting upgrades (more efficient lamps, ballasts and luminaires), electric lighting controls, and model studies or lighting computer simulations to predict the performance of the integrated system. Again, a life cycle cost analysis is necessary to fully evaluate the balance of savings and costs over the life of the building.

4.4.2.1 What the Research Says

The easiest energy savings accrue from specifying energy efficient electric lighting, especially in retrofit situations where lighting installed at up to 2 watts/sq.ft. or more can be replaced with efficient lamps, ballasts and luminaires that use a total of less than 1 watt/sq.ft. This can save over 50% of the electric lighting energy use while increasing the lighting quality. In a lighting retrofit at the State University of New York at Buffalo, the energy officer noted that in many of the university's buildings lighting upgrades, "saved 30 to 40 percent in wattage... There were a couple of buildings where we saved as much as 70 percent and maintained lighting or improved it." (Kennedy 2000)

Further energy savings can come from the addition of automated controls. The CHPS case study on Georgina Balch Intermediate School estimated savings overall energy savings of 15% from daylight controls alone after efficient lights were installed. Demonstrated lighting savings from switching or dimming lights in response to daylight can reach up to 22%, as shown in a North Carolina school designed by Nicklas and Bailey (Nicklas and Bailey,1997) In the

Washington State Pilot Project, the Bethel District calculated the potential for a reduction of 10% in the total school energy use with a well-integrated daylighting and controls design. (O'Brien, 2004).

Occupancy sensors that turn off lights when spaces are unoccupied can provide additional savings, especially if staff and maintenance personnel don't routinely turn lights off. A survey of occupancy sensors in schools by the Lighting Research Center found that, "For shared scheduled spaces, in particular classrooms, it is often difficult to ascertain the hours of use. Classrooms are used not only for teaching during the day, but also for community activities during the night. Often more than one teacher uses the space, but does not 'own' the classroom. Since these spaces are sporadically used and do not have a clear 'owner' occupancy sensors are a good choice for reducing wasted lighting energy. The average energy savings [for electric lighting] was 31.7%." (LRC, 2003) However, savings can be lower, or even negative if staff are rigorous about turning lights off in their classrooms. Thus, lighting savings from occupancy sensors can range from 0% (where staff are rigorous in turning lights off) to over 30% when staff is less diligent.

Schools installing both daylighting controls and occupancy sensors reap the benefits of both. The Design Lights Consortium estimates that photocells plus occupancy sensors have the potential to save 45% on electric lighting use (which translates to about 10% of overall building energy use) in a school building designed to a lighting code of 1.2 watts per square foot. (NEEP, 2002) A study of an efficient, integrated lighting system at Heritage Oakes School demonstrated savings on electric lighting energy averaging over 50% for a seven-month monitoring period (PIER, 2004). And because both daylighting and occupancy sensors reduce the heat from electric lights, they can accrue additional savings from reductions in cooling energy use.

4.4.2.2 What It Means to Washington Schools

WSSP Energy Prerequisite 1 requires schools to meet the minimum efficiency standards of Washington State's Non-Residential Energy Code (NREC). **WSSP Energy Credit 1** provides points for exceeding this code. High performance lamps, ballasts, luminaires and lighting controls contribute savings to achieve these credits.

The costs for these advanced lighting systems can range from slightly less than a conventional system with no automatic controls to over 35% more (PIER, 2004). Efficient lamps and ballasts (T-5 or T-8 with electronic ballasts) are always a cost effective investment. High performance luminaires may cost slightly more but payback indirectly in lighting quality. Although some research suggests that high quality pendant-mounted direct/indirect luminaires can be less costly than conventional fixtures (PIER, 2004), the Spokane and Northshore Pilot Projects determined that they cost approximately $700-800 more per classroom.

Since Northwest electricity rates are low, the WSSP Pilot Project data show that automatic controls must be carefully designed to achieve good life cycle cost effectiveness. Tacoma, Spokane and Northshore districts analyzed the predicted savings and costs for daylight responsive lighting controls and noted relatively long payback time periods (independent of reductions in building cooling costs). However, Northshore noted that even with these long paybacks, their contributions to overall energy savings can help a project qualify for utility rebate programs which can thus offset their first cost increases. Some utilities – Seattle City Light, for example - even give a specific rebate for each photocell controller. (O'Brien, 2004)

Thus it is important to have an integrated lighting approach to minimize incremental first costs and reap the energy and quality benefits of high performance lighting designs. The best approach is to use an integrated daylighting and electric lighting design that maximizes the use of natural lighting during daylight hours and uses electric lighting to supplement daylight when needed. The electric lighting design should include energy efficient lamps and electronic ballasts. Direct/indirect luminaires should be evaluated for their potential to deliver high quality lighting with minimal glare (incremental cost of up to $800 per classroom). Manual switching should be designed to turn lights off in unoccupied or daylit zones. Automatic occupancy controls and daylight dimming controls can be added to ensure energy savings when the budget allows or utility rebates are available.

See Section 4.4.3 below for an analysis of both costs and savings in a whole-building, integrated energy savings approach.

4.4.3 Integrated Design & Commissioning $avings

In an integrated design, the HVAC, water and lighting systems are designed together along with the building form and envelope details to maximize performance, and minimize overall cost. These integrated designs must also take into consideration the climate and context for the building – different solutions will arise from different building locations, schedules (winter and summer use), scale and cultural expectations (acceptability of user interaction and new technologies like composting toilets, etc). Savings in one area may partially (or fully) offset higher costs in another area thus achieving high performance and multiple benefits at a lower cost than the total for all the components combined. For example, a school with well-designed windows incorporating high performance glazing will have reduced solar gains. This leads to reduced air conditioning loads and the potential to downsize (or eliminate) the air conditioning system (freeing up money that can then be used to pay the higher first cost for the glazing). The overall goal of most integrated design approaches is to select the best group of strategies to deliver the most productive, efficient school building with a positive savings over the life of the building – i.e.: to use intelligent design to get the most for the dollars spent.

A key to successful integrated building design is the participation of people from different specialties of design: architecture, HVAC, lighting and electrical, interior design, and landscape design. By working together early in the design process, these participants identify highly attractive solutions to design needs that would otherwise not be found. The mechanical engineer calculates energy use and cost at key times during the process, informing designers of the energy-use implications of building orientation, configuration, fenestration, mechanical systems, and lighting options. The inclusion of an energy management system can also help to guaranty the proper functioning of interacting systems and can provide access to information about their status.

The integrated design approach requires better-informed design decisions that may include expertise from design specialists and/or specialized analysis techniques (computer simulations, model studies, etc.) to predict the performance of a new building system or the interaction among several building systems. The increased up-front cost or program support for this high performance design approach needs to be anticipated and funded to achieve the full benefits of sustainable design.

These savings are also only achievable if the integrated systems are *commissioned* – reviewed by a third party early in the design process and after construction to ensure that the interactive systems are designed well and are performing as they were designed. Frequently the design process is also initiated with a facilitated design charrette to provide design clarity and consensus on project goals. Several Pilot Projects noted the importance of the design charrette and independent commissioning agent for ensuring quality control. (O'Brien, 2004)

4.4.3.1 What the Research Says

Aggregating savings from multiple measures, a Department of Energy analysis of the potential for reducing energy use and operating costs in schools calculated potential reductions of energy costs from $.90/sq.ft. to $.45-.68/sq.ft. (representing reductions of 25-50% in energy costs). This estimate is borne out by several research studies:

- In the 1990's the Portland School District embarked on a seven-year energy efficiency plan in 90 different school buildings, including heating and cooling system upgrades, better insulation, lighting improvements, and digital controls to ensure that building systems functioned optimally. These measures are saving the district over 33.7 million Btu's annually (Alban and Drabick, 2003).
- In addition to it's lighting controls, the Georgina Blach Intermediate School, mentioned earlier, incorporated a range of energy efficiency measures including improved insulation, white roof and walls, natural ventilation efficient fan operation and an increased cooling setpoint. These measures in total are projected to deliver energy savings greater than 35% compared to the base case building.
- An experiment conducted at the Iowa Resource Station compared energy consumption for an envelope/lighting integrated design in one set of rooms with standard construction practices in an identical set of rooms. In this study, all rooms were the same size and were oriented identically, and the HVAC system remained the same. Energy monitoring during three seasons in 2003 demonstrated a 32% reduction in lighting energy, 25% reduction in cooling energy and 28% reduction in demand charges. (Energy Center of Wisc., 2005)

Although many of the Pilot measures were evaluated individually and didn't achieve the synergistic effect of an integrated design, several Pilot projects estimated savings using an integrated design process in their projects. Bethel School District simulated the overall energy use in their proposed design for Thompson Elementary School with its integrated design for energy efficient lighting, heating, cooling building envelope and controls compared to a building that just meets the NREC standards. They demonstrated energy savings of 30.7% for the integrated design.

The Northshore Pilot was also able to estimate the costs and savings of an integrated energy design by comparing their current project, Phase II, with conventionally designed Phase I. Phase II has an integrated natural, passive ventilation system using operable windows, louvered wall cabinets, thermal chimneys (also functioning as light shafts) and assist fans to reduce total net energy use and improve indoor air quality. This integrated system yields a 9% reduction in construction costs, a $25,000 annualized energy cost reduction, and an estimated 30-year life cycle cost savings of $356,000. (O'Brien, 2004)

As noted above, an energy management system is often provided to ensure the smooth functioning and energy savings of these integrated approaches. One research study indicates that continuously monitoring a building's energy systems can lead to reductions of 10-15% in annual energy bills. Savings typically come from resetting existing controls to reduce HVAC waste while maintaining or increasing occupant comfort levels. (Platts, 2002) In the Pilot Project, the Olympia team found similar results in their evaluation of an integrated energy management system to manage building energy use at Washington Middle School. The team noted that with most contemporary HVAC systems using Direct Digital Controls, the enhancement to an EMS provides about 10% annual savings with significant 30-year life cycle savings at a marginal increase in first costs. (O'Brien, 2004)

4.4.3.2 What It Means to Washington Schools

WSSP Energy Prerequisite 1 requires schools to meet the minimum efficiency standards of Washington State's Non-Residential Energy Code (NREC). **WSSP Energy Credit 1** provides points for exceeding this code. The Protocol provides 4 to 12 points for achieving energy savings of 10% to 50%. Integrated design including improvements to building envelope, HVAC efficiency, lighting, and water heating efficiency directly benefit these credits.

Savings. The research on integrated design solutions noted above shows annual energy savings ranging from 25-50%, indicating that new school buildings in Washington State should be able to achieve 30% savings with integrated design approaches that include building location and massing, envelope design, HVAC, and lighting.

Costs. These savings may incur increased first costs and additional costs for commissioning and extra design services, including energy simulations. For commissioning, Spokane estimated the cost of an independent commissioning agent to meet current OSPI requirements at $34,770. The costs to meet LEED Energy and Atmosphere credit 3 is an incremental $8,740, and another $6,270 to meet credit 5. From this data, the total commissioning cost would be $49,780, or about 0.6% of the construction costs for a *typical* 55,000 square foot school with 450 students and a construction budget of $8.7 million. Extra design services may also increase first costs. In the Pilot study, the Olympia District determined a cost of about $20,000 to run a Computational Fluid Dynamics (CFD) simulation of a typical school to determine ventilation performance. The cost of a building energy simulation is about the same for an elementary school (and higher for a large high school). Each of these represents less than 0.25% of the construction cost for the typical school described above. Incremental A&E costs for an integrated design approach are difficult to assess; some of this interaction will be subsumed within a changing professional dynamic, but some incremental expense should also be budgeted.

4.5 WATER $AVINGS

In the United States, about 340 billion gallons of fresh water are withdrawn every day from rivers, streams and reservoirs for commercial, residential and agricultural use. This accounts for about a quarter of the nation's total supply of renewable fresh water. The LEED Reference Guide estimates that, "water efficiency measures in commercial buildings can easily reduce water usage by 30% or more." (USGBC, 2003) Schools are excellent organizations to implement water conservation strategies because the measures both save money on the school's operating expenses, and also teach students important lessons about conserving water that can be taken home with them for continued savings there. The savings can be substantial. "In Seattle, a single school lost 2.5 million gallons of water to a few toilets that flushed constantly for two months. The culprit? Large pieces of rust that broke loose inside pipes after water was turned off for the summer. … [The school district] found the problem by comparing utility bills at different schools of the same size. Plumbers fixed the problem, but not before the toilets had flushed away $17,000 in additional water/sewer costs." (Harrigan, 1999)

School facilities that use water efficiently can reduce costs through lower water use fees, lower sewage volumes to treat, and energy and chemical use reductions. Efficient water strategies may involve specifying energy conserving water use fixtures (toilets, showers, etc), reducing or eliminating the amount of water needed for irrigation or replacing the use of potable water with gray water for secondary uses (toilet flushing, irrigation, etc.).

4.5.1.1 What the Research Says

When low-flow fixtures replace older inefficient fixtures the savings can be extremely high. In a Canadian study of dual flush toilets, "significant water savings was achieved in this project by replacing existing toilets with dual-flush toilets. Flush volumes were reduced by 68 percent in single-family dwellings, 56 percent in office washrooms, and 52 percent in the participating restaurant. Total water savings will vary depending on frequency of use." (CMHC, 2002) In the UK, monitoring results demonstrated a 38% reduction in water for flushing toilets when low flush toilets were installed at an existing middle school. (Keating and Styles, 2004)

But even in new construction high performance fixtures can provide substantial savings compared to the minimum fixtures required by code. In the Pilot Project, the Olympia District demonstrated a 32% reduction in life cycle cost (not including a water efficiency grant they also obtained) and a 46% reduction in water and sewer flows associated with the use of water–conserving toilets, urinals and commercial dishwashers compared to the code minimum fixtures for Washington State (O'Brien, 2004).

Photo: Christine Frankovitch; NREL PIX 10816

Shoreline School District used a weather-based control system to reduce their district's water costs by up to 50%.

Irrigation presents another large opportunity for water savings. A rigorous water saving landscaping plan including climate-adapted native plantings can potentially eliminate the need for irrigation on all areas except playfields. In Washington State, the Shoreline School District instituted a comprehensive program to reduce the amount of water used for irrigation at the District's schools. Using a weather–based control system reduced their district's water costs by up to 50%. Rising water costs during the 1990's increased the value of these conservation efforts to over $50,000 per year. (Water Smart Technology, 2002)

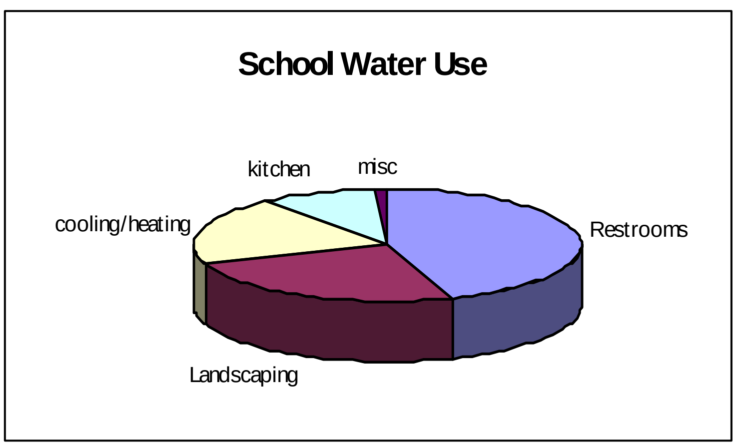
The Pilot Project data for the use of rainwater harvesting systems for irrigation and toilet flushing is not so encouraging. Two school districts, Olympia and Tacoma, studied the costs and benefits of using rainwater for toilet flushing. Designs for the two systems were very different, driven by the conditions of the site and building. But in both studies the first costs and life cycle costs associated with the rainwater collection and distribution system were cost prohibitive. Although the strategy yields significant savings in potable water, they determined that this approach is only economically viable under specific conditions, such as 1) in districts where water is scarce and rates are very high (Eastern WA and some island communities), 2) where the first cost of the cistern can be shared with the storm water management system, 3) where the capacity of the system can be minimized through the use of efficient fixtures or high precipitation locations or 4) when grant funding is available. (O'Brien, 2004)

Sometimes water savings come as a secondary benefit with other sustainable design strategies. For example, the Bethel School District determined that using a ground-coupled heat pump system eliminates the boiler and cooling tower associated with a conventional heat pump system and also gives a 20% reduction in potable water usage. In addition, this approach eliminated the use and cost of boiler treatment chemicals.

4.5.1.2 What It Means to Washington Schools

The WSSP Water Prerequisite 1 requires projects to develop and design to a landscape and ornamental water use budget. **WSSP Water Credit 1** (Reduce Potable Water for Landscaping) allows up to 3 points for reducing potable water use for irrigation by 50% or 100% and for creating an irrigation commissioning plan. **WSSP Water Credit 2** (Water Use Reduction) provides up to 3 points for 1) reducing use of potable water for building sewage conveyance by at least 45%, 2) reducing total potable water use in the building by at least 20% and 3) reducing total potable water use by an additional 10%. A total of 6 points are available for water use reduction.

Water use in schools varies widely by site because of differences in irrigation needs. One study (New Mexico 1999) estimated the following water end-uses for schools: restrooms = 45%, landscaping = 25%, Cooling/heating = 20%, kitchen = 10%, and miscellaneous = 1%, as shown in the chart to the right. Using this data and the demonstrated savings noted above, we can calculate the potential savings on potable water for a typical school. The research above indicates the opportunity for about 50% savings in irrigation for existing buildings. New building construction would not be expected to achieve savings quite as high, so a value of 30% savings will be used for this analysis. The Olympia Pilot Project showed the potential to reduce restroom and kitchen water use by 46%. The Bethel Pilot Project showed the potential to essentially eliminate the cooling and heating water use by employing a ground-coupled heat pump, but not all schools will be able to adopt this strategy, so this analysis will assume that these ground coupled heat pump water savins are available to only 20%



of the new schools. Applying all of these estimated savings to their respective end-use percentage, we calculate an overall total potential savings of about 38% in potable water use for a high performance new school.

At this point in time, it appears that further investigations into cost effective rainwater harvesting systems are necessary to economically justify them for Washington State schools, so these systems will not be factored into the expected potential water savings. However, rainwater harvesting systems provide excellent opportunities for student experiments and explorations about water flows and conservation and may still be justified for new school projects based on these amenities in addition to their water savings.

4.6 WASTE $AVINGS

Photo: David Parsons; NREL PIX 05291

For projects involving deconstruction of an existing building, construction waste can reach 288 lbs/sq.ft of new building.

Savings on waste come during both initial building construction and ongoing building operations. Building construction can save waste by reusing a building (or portions of a building), using salvaged materials or recycling "waste" portions of building materials. These savings reduce overall cost of the building, conserve natural resources, reduce the impact of the saved material's "embodied" energy (and associated emissions) and reduce the effect of building practices on the environment (landfills, etc). Throughout the building's lifetime, environmentally responsible purchasing and recycling efforts also contribute toward reducing waste and provide ongoing savings to the school district. This section discusses the dollar savings of avoided waste.

4.6.1.1 What the Research Says

The LEED Reference Guide (USGBC, 2003) estimates that about 2 to 2.5 lbs of waste are generated for every square foot of commercial building space constructed. When a new building replaces an existing building, the waste generated (and savings potential) can be significantly higher. Paladino and Company conducted an informal survey of 6 LEED buildings showing that for projects involving deconstruction of an existing building, construction waste ranged from 8 to 288 lbs per square foot of new building and that 22-90% of this waste was recycled for these projects.

Many school districts are initiating recycling programs to also reduce waste generated throughout the year, providing operating savings year-round:

- Oak Grove Elementary School in California started a recycling program in 1992, not to save the Earth, but rather to save the school district money. The program has been wildly successful, achieving an 80% diversion rate. Oak Grove has gone from generating 32 to 4 cubic yards per month of landfill trash. The school's recycling program has had an impact on not just students and staff, but on the community as well. Parents report they didn't recycle much before but now they do. Oak Grove School is exceeding its own waste reduction goals and helping the community in the process.
- Another award winning recycling program at Mount Baker School District in Deming, Washington, involves intensive student participation and is totally self-supporting. In a recent year, the students saved $18,000 through recycling and reuse of a variety of

different materials and an additional $7,000 from avoided disposal fees. (Innovative Design, 2002)

4.6.1.2 What It Means to Washington Schools

The **WSSP Materials Prerequisite 1** requires schools to have accessible spaces dedicated to recycling. **WSSP Materials Credit 1** (Site Waste Management) provides up to two points for recycling jobsite waste during building construction. **WSSP Materials Credit 2** (Building Reuse) provides up to 3 credits for reusing part or all of an existing building rather than building new. **WSSP Materials Credit 3** (Resource Reuse) provides up to 3 credits for using salvaged or refurbished materials during construction and **WSSP Materials Credit 4 (**Recycled Content) gives an additional 2 credits for specifying recycled content materials.

The Paladino analysis of LEED buildings noted earlier indicates large opportunities for recycling construction waste (22-90%). Using an average of these numbers yields a value of 56% of school construction waste that can be recycled. The dollar value of these savings can be significant. Current City of Seattle tipping fees are $90 per ton (Freemont Transfer Station) and approximately $40 of this can be saved by recycling the material waste.

5. CONSERVING NATURAL RESOURCES & THE ENVIRONMENT

Rain gardens at one Pilot School are projected to reduce first costs by 32% and handle 4.5 million gallons of stormwater runoff.

Photo: NREL Pix 01791 SMUD

High performance school buildings contribute to a healthy environment by reducing the demand on natural resources, minimizing (or eliminating) the generation of polluting substances that accumulate on the earth's surface, and restoring/maintaining local habitats and water tables. These buildings are responsible citizens in the local (and global) environment. They teach by example to the students and staff who inhabit them – long-term lessons that continue to influence future generations.

5.1 ECO SYSTEM HEALTH – SITE & STORMWATER

Standard development and construction practices are frequently destructive to the local ecology. They contribute to urban sprawl, encroach on agricultural land and open space, increase transportation infrastructure, and disrupt the natural balance of water tables and thermal and lighting conditions. Sustainable site development minimizes these environmental impacts by avoiding development of sensitive sites and following good construction practices. Some of these practices involve repairing and connecting habitats, creating native landscaping that mimics natural approaches to irrigation and pest management and constructing natural features to stabilize topography and retain and filter stormwater runoff at the site.

Appropriate site selection is covered in the **WSSP Site Prerequisite 1 and Credit 1** (Sustainable Site Selection). These credits require school facilities to comply with all siting and environmental impact study requirements in the WA State OSPI School Facilities Manual and provide points for avoiding development on inappropriate sites (greenfields, wetlands, floodplains, farmland, or threatened or endangered species habitat). Other credits in the WSSP Site Category give points for minimizing the building footprint, providing joint use of facilities and parks, providing opportunities for low-polluting transportation and incorporating the sustainable construction practices outlined below.

5.1.1 Stormwater Retention & Water Tables

In natural settings most rainwater infiltrates into the ground; only a small portion runs off the surface into receiving waters. Most developed school sites, however, have large areas of impervious paving and roofing which can generate large amounts of runoff that drain into the municipal stormwater system and are not available to replenish the local aquifer. This stormwater runoff contains sediment and other contaminants that negatively impact the water quality of local ecosystems. Careful construction practices can minimize runoff during construction and after the building is built, thus limiting the negative impacts of the overall development.

5.1.1.1 What the Research Says

A desire to purify stormwater led to the design of bioswales at the Oregon Museum of Science and Industry (OMSI) in Portland. Seven bioswales were incorporated into the parking lot in lieu of raised medians between the rows of parking. The boiswales are sufficient to infiltrate 75% of all the rains at the site and will filter 60-90% of the suspended solids in the runoff. This system also saved $78,000 in first costs compared to a conventional lot with its expensive catch basins and drainage system. (Thompson and Sorvig, 2000) The Thompson and Sorvig study also determined that every gallon of water properly managed on-site saves more than $2 in engineering costs downstream.

Using a similar approach, the Northshore Pilot evaluated the environmental and financial benefits and costs for applying low impact development (LID) strategies to a school site, including "rain gardens" for retaining and treating the site stormwater. Rain gardens are constructed systems designed to mimic natural systems to perform stormwater retention, treatment and infiltration functions while serving as integral landscaping elements. The rain gardens designed in the Northshore Pilot Project were estimated to handle almost 4.5 million gallons of stormwater runoff per year with first costs that were 32% less than a conventional stormwater system. However, the additional design and permitting fees calculated for this new technology increased the initial costs so that they were comparable to the conventional system. The project team expects that as permitting jurisdictions become more familiar with LID methods, the additional design costs should become negligible. The LID stormwater design approach also reduces the burden on municipal treatment systems and provides long-term maintenance savings by using natural landscape features in lieu of conventional underground pipes and vaults. (O'Brien, 2004)

The Spokane Schools Pilot Project evaluated the on-site infiltration of stormwater runoff that is treated by swales overflowing into drywells. This approach cost $17,500, but treatment of stormwater on-site is required by local municipal codes, so the team concluded that this was not an added first cost above a baseline system. This system is estimated to retain 1,275,864 gallons of run-off on the site, which would save the City approximately $1275 per year if it were routed instead through the municipal sewer/stormwater system. (O'Brien, 2004)

5.1.1.2 What It Means to Washington Schools

WSSP Site Credit 3 provides one point for promoting onsite infiltration and an additional point for reducing site runoff to zero or treating it to substantially remove suspended solids and phosphorus before it leaves the site.

The Pilot Projects have demonstrated that where soil conditions are appropriate (pervious) and where there is sufficient room on the site for the needed natural treatment systems (bioswales, rain gardens, etc) low impact development strategies should incur no incremental costs (and potentially large first-cost savings) to school districts and should provide substantial ongoing savings for local stormwater treatment facilities. Local permitting jurisdictions can accelerate the adoption of these approaches by improving their permitting processes.

The opportunity for minimizing and purifying stormwater runoff is high for new school construction in Washington State. But not every site will have soil and site conditions appropriate for these strategies; suburban/rural sites usually have larger areas to incorporate bioswales and rain gardens and thus may find it easier to achieve these stormwater retention goals. For the environmental analysis in Section 6, we assume that 75% of the school sites are suburban/rural and will be able to significantly increase their onsite stormwater retention by the use of strategies similar to those noted above. This change in stormwater retention should be enough to reduce the utility rate schedule for these schools from a "moderate" to a "very light" site coverage classification, thereby reducing their annual stormwater utility bills.

5.1.2 Reducing Heat Islands & Light Pollution

Conventional development impacts the temperature and lighting conditions of a region, creating microclimates that disrupt local wildlife populations and affect energy use and comfort. The use of exterior electric lighting at night brightens the night sky, causing an unnatural environment that may attract, repulse or disorient wildlife and disrupt natural biorhythms (including humans). In addition, excess lighting at night wastes energy and can create safety hazards.

Our buildings and their infrastructure also affect temperatures in urban areas. On warm summer days with calm winds, urban temperatures may be 2 to 8 °F higher than the surrounding countryside (Thompson and Sorvig, 2000); this increase in temperature is termed the "urban heat island" effect. Higher temperatures are created when natural vegetation is replaced by heat absorbing surfaces, as is common in urban developments. Increases in urban air temperature by just a few degrees could cost consumers millions of dollars on their cooling energy bills each year, while at the same time increasing harmful air emissions. These artificial heat islands can be reduced by minimizing the amount of dark paving and roof areas, and shading or increasing the reflectance of the areas that remain.

5.1.2.1 What the Research Says

To minimize light pollution and save energy, some schools are experimenting with using occupancy sensors on exterior lighting at night so that lights are off when school property should be unoccupied. As a side benefit, some of these schools have also experienced a decrease in vandalism. After implementing a "dark campus" approach like this the Livermore Joint School District in California reported energy savings of about 10% along with a slight decrease in vandalism; and Cupertino Union School District reported that vandalism dropped 29% while energy savings totaled $8,190 during the 1981/82 school year. Other schools reduce the impact of night lighting by using special "cutoff" light fixtures that direct all the light downward instead of wasting it to the night sky.

To investigate urban heat island effects on site temperatures, The Heat Island Group measured the temperature of three different paving materials on a sunny day. Dark, fresh asphalt had a temperature of 123°F; lighter, aged asphalt was 115°F and asphalt with a white coating was only 88°F! (LBL, 2000)

One of the school design decisions that affects urban heat islands is the decision for two-story versus one-story construction, because one story construction can double the amount of roof area (which is frequently dark in color). Taking this into consideration, two schools in the WSSP Pilot Project researched the costs of two-story building construction relative to one-story, with the goal of reducing the roofing surface, which reduces both the heat island effect and the amount of impervious site area (helping to minimize stormwater runoff). The Northshore District determined that the first cost for two-story construction was $84,988 more than one-story because of the additional vertical circulation elements needed. This was partially offset by an estimated savings of $5,120 for reduced stormwater drainage requirements (with ongoing savings in stormwater system maintenance costs of $15 per year). The Spokane School District similarly found increased costs of $168,642 or $2.92 per square foot for two-story construction. (O'Brien, 2004)

5.1.2.2 What It Means to Washington Schools

WSSP Site Credit 4 provides up to two credits for landscaping and roofing strategies to reduce heat islands; and **WSSP Site Credit 5** provides one point for lighting strategies to reduce exterior light pollution.

As noted above, the two Pilot Projects calculated that two-story construction costs more than one-story in Washington State. But in spite of the increased costs, both Pilot Project schools opted for the two-story construction because of other amenities that it brings, like increased outdoor space and better opportunities for interaction among teachers and programs. The Spokane team noted that some school building code requirements increase construction costs for two-story construction for K-2 graders by requiring sprinklers and extra egress in second floor spaces. Because of this they recommend an analysis of stacking layout and code requirements early in the design process to identify potential cost implications. (O'Brien, 2004). Careful attention to specification of exterior light fixtures and surface reflectances should reduce these impacts in Washington schools and make these credits relatively easy to achieve even for one-story construction.

5.2 Resource Efficiency and Pollution Prevention

Schools in Washington consume valuable natural resources during their construction and during their operations throughout the life of the building. Along with the monetary savings noted in Section 4.6, when schools use materials more wisely by using less materials, using recycled content and salvaged materials or using local, renewable or low impact materials, they conserve both the material itself and the energy (and associated emissions) used to produce and transport it. Both of these represent significant environmental savings.

The monetary savings from efficient materials,energy and water use were quantified in Section 4 of this report. This section deals with the environmental implications of these savings.

5.2.1 Reduced Resource Use

One of the most effective strategies for minimizing the environmental impacts of material use in the construction of schools is to reuse existing school buildings. This reduces the total new material needed while minimizing the environmental impacts associated with the production and delivery of new building products and reducing solid waste volumes and habitat disturbance. In new buildings, the use of salvaged and recycled materials has similar impacts at a smaller scale and helps to stimulate the local recycling market.

5.2.1.1 What the Research Says

Reuse of the "Old Main" Lincoln High School in the Tacoma Pilot kept about 7,732 tons of concrete, limestone and brick out of the landfill, along with large amounts of wood, clay-tile roofing and plaster. In addition to saving on materials, the reuse of this school building preserved some of the history and identity of its neighborhood and saved the school district nearly $3 million compared to constructing an entirely new building (O'Brien, 2004).

Reuse of "Old Main" in Tacoma kept about 7,732 tons of concrete, limestone & brick out of the landfill.

Although Section 4 noted that economic savings motivate many school districts to employ recycling and reuse programs, environmental stewardship and reducing stress on community landfills are also significant factors. The Boulder County School District (Colorado) has an exemplary program that recycles almost six hundred tons of office/classroom paper, cardboard, newspaper, aluminum, tin, plastic and glass from its schools each year. This compares to 14.7 tons recycled in 1988 - a 4000% increase. As the collections have expanded, many schools have been able to cut their trash service by one third to one half. This aggressive program represents savings of over ½ million trees each year. To publicize this program each school has a recycling contact who receives monthly feedback on both the quantity and quality of materials recycled. The number of trees "saved" by their paper recycling is posted on their tree banner, an impressive 3.5 x 7 foot "trees saved" thermometer (Eco-cycle, 2002)

Schools in Madison County, Illinois, also have a comprehensive recycling program that includes a focused intent on completing the loop by purchasing recycled content materials. The materials they purchase include recycled paper, pencils, pens, playground benches, and recycled tire running tracks. (Madison, 2005)

5.2.1.2 What It Means to Washington Schools

WSSP Protocol Materials Credit 2 gives up to 3 points for reuse of a building's shell, structure and interior walls/finishes. In addition, **WSSP Materials Credit 3** gives up to 3 points for using salvaged materials in a new building.

Washington's K-12 inventory of permanent space is about 138 million square feet. Buildings built before 1980 account for 72% of the inventory and of that amount over 56 million square feet is over 20 years old and has not yet been modernized. In recent years, modernization has averaged over 2 million square feet per year (OSPI, 2004). Many of these buildings hold historic value for their neighborhoods; all of them represent valuable materials with large impacts for their continued use. Careful evaluations of opportunities for building and material reuse should accompany each new construction decision.

5.2.2 Renewable and Local Materials

Specifying locally harvested and manufactured materials both supports the local economy and reduces the transportation required to bring materials to the site. Using rapidly renewable materials rather than non-renewables, which include fossil fuel-based plastics or slowly regenerating resources such as old-growth lumber, reduces the environmental impact of the school building by lowering its impact on the climate and by avoiding contributions to deforestation. Rapidly renewable materials are products that regenerate quicker than the demand for the products. Many rapidly renewable materials, such as agricultural waste products converted into pressed agri-board products, bamboo, cork flooring, and others perform as well as their non-renewable counterparts.

In many cases, wood is the best material for school building construction, but the way in which it is grown and harvested greatly affects its impact on the environment. Changing the way we use wood in construction can alter the course of forest destruction, allowing us to save some forests from being turned into tree farms and preserving forest ecosystems for future generations. Irresponsible forestry practices such as clear cutting and herbicide use have the potential to undermine ecosystems. The environmental impacts as a result of these conventional forest practices include soil erosion, stream sedimentation, habitat destruction, water and air pollution and waste generation. Sustainable forestry practices eliminate these problems and preserve forest ecosystems. To ensure that wood purchased by schools has a minimum impact on the environment, it is important to specify the use of certified, sustainably harvested wood products.

NREL PIX 10857 Robb Williamson

In this school auditorium, chair fabric is biodegradable, carpet squares can be recycled back into carpet as they wear out, all wood is FSC-certified, and acoustical panels are made of agricultural waste.

5.2.2.1 What the Research Says

Three Pilot school projects investigated the costs and opportunities for using certified wood products. At an initial cost premium between 0-15%, there appears to be no immediate financial or operational benefits to the owner for the use of certified wood. The studies also pointed out fluctuating and unpredictable costs of certified wood and the critical role that the general contractor plays in ensuring certified products are actually purchased, installed and documented. (O'Brien, 2004)

5.2.2.2 What It Means to Washington Schools

WSSP Materials Credit 5 gives one point for the use of rapidly renewable materials and **WSSP Materials Credit 8** gives up to 2 points for specifying regional or local materials. In addition,

WSSP Materials Credit 6 provides up to 3 points for using wood-based products from a sustainable forest certified by a third party - one point if the certified wood represents 20% of the cost of all wood-based materials, one additional point for 30%, and one point if the third-party certification offers chain of custody verification.

Though certified wood may be more expensive, it promotes sustainable forestry practices and sends an important message to students and the community about the school's commitment to the environment and the future. However, at this time there is a financial disincentive for its inclusion in school projects in Washington State. This credit will therefore be a relatively difficult one to achieve unless budgetary incentives are provided.

5.2.3 Reduced Emissions: (CO_2, CFC's & other greenhouse & ozone-depleting gases)

Scientists agree that global climate change is happening already and that the most likely cause of the changes are man-made emissions of the so-called "*Greenhouse Gases*" that can trap heat in the earth's atmosphere. Although there are six major groups of gases that contribute to global climate change, the most common is carbon dioxide (CO_2). Carbon dioxide is a global problem, but the countries that produce the greatest amount per person are in North America, Europe and Australasia. Most CO_2 in these countries comes from burning fossil fuels, such as coal, gas and oil to heat buildings and provide transportation. All living things also give off CO_2, but in general, plants capture as much as animals and microorganisms generate. In contrast, the large amount of CO_2 that we now produce by burning fuel cannot be fully offset by plants and adds to the gases in the atmosphere.

Carbon dioxide emissions from fossil fuels are an indicator of the Northwest's contribution to global environmental degradation; these emissions constituted 66% of the Northwest's climate-altering pollution in 1990. (Ryan and Haws, 1995) The best way of reducing emissions is by using less energy both for operating our school buildings and transporting students and staff to the buildings. Generating energy from solar and wind resources on site also reduces fossil fuel emissions. Indirectly, the reuse of buildings and salvaged materials provides additional savings in CO_2 because of the inherent value of CO_2 in the "embodied" energy of the material use avoided.

Other building system-related gases contribute to changes in the earth's atmosphere. Old refrigeration equipment uses chlorofluorocarbons (CFCs), which fall into a larger category of ozone-depleting substances. These substances react with ozone molecules in the earth's stratosphere, destroying the ozone and reducing the stratosphere's ability to absorb ultraviolet radiation. This can lead to increases in skin cancers, cataracts and weakened immune systems. CFC production in the US was completely phased-out in 1995; specification of non-CFC building equipment is now standard. Hydrochlorofluorocarbons (HCFCs) and Halons have replaced the use of CFCs, but they also have detrimental effects on ozone and are scheduled for phase-out.

5.2.3.1 What the Research Says

Every time energy is saved, the savings can be restated in the reduction of CO_2 emissions, with conversion factors depending on the fuel mix avoided. When the St. Louis Public School District retrofitted 42 school buildings with a variety of energy efficiency measures, they saved nearly $450,000 a year, and reduced carbon-dioxide emissions by more than 8 million pounds. (Missouri, 2000)

Currently there are over 2,500 alternative fuel school buses in the U.S. –Displacing 4-5 million gallons of petroleum each year. The State of New York Clean Fuel Bus Program has provided $25 million to purchase clean-fuel buses. In one district, twenty of the district's buses are new, low-emission vehicles and 18 are diesel buses that now use an oxidation catalyst to reduce pollutants. Over the life of these vehicles, it is estimated that about 4.3 million pounds of carbon dioxide (CO_2), 430,000 pounds of carbon monoxide (CO), 483 pounds of particulate matter (PM), and 48,620 pounds of oxides of nitrogen (NOx) will be avoided. (NYSDEC, 2004)

5.2.3.2 What It Means to Washington Schools

No credits in the WSSP specifically call for reduction of CO_2 emissions, but a number of them contribute to reduced emissions. **WSSP Energy Credit 1** provides 4-12 points for energy savings beyond code, all of which contribute to reduced emissions. The potential 30% energy savings noted in Section 4.4.3.2 can be converted to the equivalent savings in CO_2 emissions based on a typical fuel mix for the State of Washington. Additional emissions savings will be accrued from reductions in transportation fuel (and use of cleaner fuels) and embodied energy for salvaged buildings and materials.

WSSP Site Credit 2 provides up to 3 points for transportation alternatives that reduce use of private cars and their associated emissions and **WSSP Site Credit 1** provides 1 point for locating schools within close proximity to their student population.

WSSP Materials Credit 7 provides 1 point for ensuring that all new base building equipment is free of HCFCs and halons.

5.2.4 Sustainable Operations & Maintenance

The ongoing operations of school buildings utilize numerous chemicals and processes that affect the health of occupants and the environmental health of the site. High performance school buildings employ sustainable operations and maintenance procedures that minimize the use of toxic chemicals or that isolate the impacts of contaminants like copy machine emissions that cannot be fully eliminated. Green housekeeping practices involve using non-toxic cleaning materials with low VOC's, strategically placing walk-off mats to minimize dirt and particles entering the school and employing practices that reduce or eliminate pesticides. They stress products and practices that promote health, not just good appearances.

5.2.4.1 What the Research Says

School programs to reduce chemicals in school operations can have extensive impacts. The West Des Moines Community School District in Iowa has more than 8,675 students and 1,200 staff. The district was the first in Iowa to implement Integrated Pest Management systems that focus on preventative measures instead of chemical use and has cut chemical pesticide use by

50 percent. West Des Moines was also part of Metro Waste Authority's Rehab the Lab program to identify and remove potentially hazardous materials from the school, resulting in the removal of more than 2,000 pounds of chemicals. To reduce the amount of waste generated, the district also introduced resource management contracting that has reduced solid waste hauling services by 45%. (Iowa 2003)

5.2.4.2 What It Means to Washington Schools

WSSP Extra Credit 1 provides the opportunity for extra points for district-wide policies that promote green housekeeping, integrated pest management, and low environmental impact disposable product purchasing programs that are implemented across the entire district. Although these policies may require changes in standard operating procedures, these green practices are high priorities for Washington schools because they improve the health of students and staff while minimizing the impacts on site ecology.

Photo: NREL PIX 00464 David

Schools with environmental education programs consistently have higher test scores on state standardized tests.

5.3 Environmental Education and the Surrounding Community

Schools often serve as central gathering places for the community and have an important role in conveying environmental values to both their students and the surrounding neighborhood. Sharing the use of school facilities and using the school building as an example of sustainable principles are just two of the ways a school building can convey a sustainable message.

5.3.1 Shared facility use

Sharing the use of the building and grounds with the surrounding community opens up school amenities like libraries, gymnasia, playfields, and meeting rooms to the surrounding neighborhood, leverages the State's investment in building construction, and allows the school to create a true community of learning. From a sustainable building point of view, it reduces the need for constructing other new buildings to duplicate these functions in the neighborhood and allows a wider audience for its message of sustainable building construction and operation.

WSSP Sites Credit 1 provides up to two points for the joint use of school facilities with the community and 1 point for joint use of grounds with local parks.

5.3.2 The School As "Community T eacher"

School buildings are silent teachers of what to value in the world. High performance school buildings that conserve water and energy, are in tune with the seasons and local climate, and use materials wisely teach by example to the students and staff that occupy them. If an environmental education curriculum is developed around the school facility, students can study the performance of their building, saving money for the district and learning valuable lessons at the same time – lessons that they carry with them throughout their lives.

5.3.2.1 What the Research Says

Environmental education saves schools money by getting students involved in research that the school and district can use. A group of students in Soquel, California, studied the energy usage at their school and made recommendations for savings to the electrical and building systems that reduced their school's energy costs by 40%, resulting in savings of about $24,000 per year to their school and ultimately over $160,000 for the entire district. This prevented the dumping of over 300,000 lbs of pollution into the environment, representing the equivalent of taking about 200 cars off the road. The students also wrote a primer for green school design that outlines a process for other students to follow. Most of the students involved said it was the most meaningful learning experience of their lives. (Christopher, 2002)

Photo: NREL PIX 10676, Scott Milder

Exposed HVAC components at Roy Lee Walker School help students monitor energy savings and learn about buildings systems.

These environmental learning experiences seem to translate to higher performance in other areas of learning. "Schools with environmental education programs consistently have higher test scores on state standardized tests and have more support from parents, community and administration." (Audubon, et. al, 2004) According to the Environmental Education Association of Washington, "Not only do kids in environmental education frequently do better on standardized tests, they also tend to have higher overall grade averages, stay in school longer, and behave better in their classes. We're seeing such results in both Washington State and across the country." (DNR, 2004)

5.3.2.2 What It Means to Washington Schools

WSSP Extra Credit 2 provides 1 point for developing an environmental education program that highlights the environmentally sensitive aspects of the building structure and site through exposed systems, lesson plans, teaching aids and signage.

The "Environmental Education Status Report 2004" for the Governor's Council on Environmental Education recommends that the State, "Incorporate environmentally sound principles, materials and policies for school facilities and school operations (such as recycling and energy conservation) that model best practices and offer relevant learning opportunities to students." (Governor's Council, 2004) There appears to be broad general interest among Washington's schools. Fifty-three percent of Washington schools have at least one classroom involved in community or statewide environmental education and 87% of Washington's schools responded that they want an environmental education program. (Audubon, et. al, 2004) Clearly the desire, opportunities, and benefits for environmental education are strong.

6. CONCLUSIONS & AGGREGATE IMPACT

High performance building design maximizes Washington State schools' responsibilities to their students, their taxpayer base and the environment.

Photo: NREL Pix 04557 David Parsons

6.1 SUMMARY OF BENEFITS

This report has documented research studies that demonstrate a range of savings and performance improvements possible in high performance school buildings. The range of increased performance demonstrated by the research includes the potential for:

- 5-26% increase in student performance
- 5% reduction in teacher turnover
- 15% reduction in absenteeism
- 25-50% reduction in energy use
- 38% reduction in potable water use
- 38% reduction in waste water production
- 22-90% reduction in construction waste to the landfill

The following sections make assumptions about these potential savings and apply them to the 1.5 million square feet of new school buildings constructed each year in Washington State. These projections are based on conservative expectations from the cited research. Some of them assume performance at the low end of the range demonstrated by the research and others at the average expected range. The calculations and assumptions for each category of savings are documented in the following sections and in Appendix A.

6.2 AGGREGATE IMPACT OF A+CHIEVEMENT

As noted in Section 3.6, students in high performance school buildings show increased performance over other students – with potentially increases of over 5% on standardized test scores. The 1.5 million square feet of new school construction each year in Washington State accommodates approximately 11,350 students (based on an average of 130 sq.ft./student). All of these students would benefit from the better lighting, ventilation, thermal comfort, air quality and acoustics that can accompany high performance school building designs.

6.3 AGGREGATE IMPACT OF $AVINGS

In order to calculate the life cycle cost of high performance school design, we must have values for the savings that accrue to the buildings because of their sustainable features (both one-time savings and annual operating savings, or costs) and the expected changes in = first costs for design and construction. In addition, an analysis of the impact on Washington schools must make numerous assumptions about the buildings, staff and students affected, utility rates, cost of money, etc. The following two sections outline the assumptions made about these input values and the expected change in first costs. The following sections detail the results for the life cycle cost analysis and the associated environmental affects. .

6.3.1 Economic Analysis Assumptions

To appreciate the impact that high performance school buildings could have for Washington State, this analysis takes the savings noted in earlier sectins and applies them to the square footage of new buildings that are constructed in Washington State each year. The projected new building square footage was obtained from the document, "Total School Construction Projects Funded by Year and Type of Construction 1985-2003," provided by the Office of the Superintendent of Public Instruction. Values from this document were averaged over the 11 years from 1993-2003. The total includes both new construction and new-in-lieu construction, since these are the building projects that are able to fully benefit from high performance building design. This document shows an average of 1,475,810 square feet (about 1.5 million square feet) of space added each year. This document also shows that the average cost for new construction in 2003/2004 was $172/square foot.

The economic analysis in this section includes assumptions about occupancy, cost of money, construction costs, days of operation, utility rates, etc, as shown in the table below. These values are average values for the State of Washington; their derivation and reference data are documented in Appendix A.

ECONOMIC ANALYSIS ASSUMPTIONS	
Project Information	
Discount Rate	3%
Period of Analysis	25 Yr
New Construction cost	$172 /sqft.
Building Related Inputs	
New Building Square Footage	1,475,810 sqft.
Number of students housed in new construction	11,352
Number of teachers in new construction	454
Annual School Days (Students)	180
Annual Work Days (Teachers)	197
Starting Teacher Salary	$30,023/Yr
Location Related Inputs	
Location (Urban/Suburban/Rural)	75% Suburban
Cost of Landfill Tipping Fees (est.)	$90/ton
Cost of Recycling Tipping Fees (est.)	$50/ton

Stormwater Utility Rate	$542/acre
Typical Energy Use	79kBtu/sq.ft.
Typical Energy Cost (Energy Utility Rate)	$0.049/kWh
Water Utility rate	$1.35/CCF
Water Meter Charge	$ 3,193/Yr
Waste water Utility Rate	$4.27/CCF
Savings Related Inputs	
Reduction in Teacher Turnover	5%
Energy Savings	30%
Potable Water Savings	38%
Wastewater Savings	38%
Construction Waste Savings	56%

6.3.2 First Cost Assumptions

The cost data from the Pilot Projects is not comprehensive enough to allow a reasonable extrapolation for the expected change in first costs for the wide range of sustainable measures available to high performance school buildings. In lieu of more comprehensive data from the Pilot Projects, this report relies on national research information to assign appropriate expectations for first costs as outlined in this section.

A report on three city buildings (office building, police and fire) in Portland by Xenergy and SERA Architects for the Northwest Energy Efficiency Alliance analyzed the incremental cost of making them LEED rated buildings (Xenergy, 2000). The incremental cost was estimated in two different ways – first to achieve a building design that produced the lowest first cost and second to achieve a building design that produced the lowest life cycle cost. These two analyses resulted in the first cost changes shown below.

Building	**% Increase in First Cost**	
	Lowest First Cost Approach	**Lowest Life Cycle Cost Approach**
OFFICE	0.3%	1%
POLICE STATION	1.3%	2.2%
FIRE STATION	-0.3%	0%

The analysis shows that for this series of buildings, the incremental first cost for achieving a LEED rated building ranges from –0.3% to +2.2%. This report further indicates that in spite of the increased first costs for some of the buildings, the overall life cycle costs (25 year life, discount rate 5.8% nominal, 3% real) are lower for the LEED buildings (not counting gains in productivity) due to the use of salvaged materials, and reductions in energy, potable water and stormwater runoff. Note that this analysis is for a LEED *Certified*, not Silver, rated building. It is reasonable to assume that to move from a LEED Certified to a LEED Silver rating would incur somewhat higher first costs than indicated here.

Another study indicated that, "While the environmental and human health benefits of green building have been widely recognized, this comprehensive report confirms that minimal increases in upfront costs of about 2% to support green design would on average result in life cycle savings of 20% of total construction costs – more than 10 times the initial investment." (Kats, 2003)

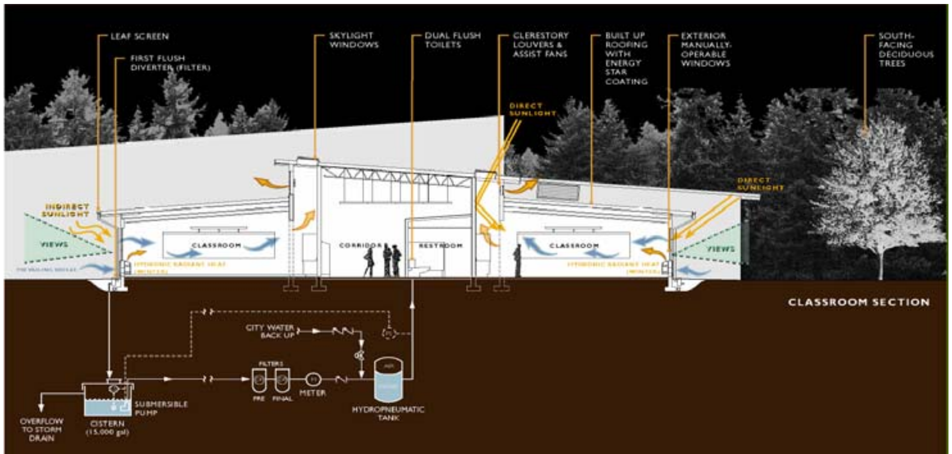
This value of 2% increased first cost is frequently quoted by the green building design community as the average incremental first cost for achieving a high performance building that could achieve a LEED Silver rating. This value is consistent with the range of values in the Portland study noted above; so this study will use the 2% incremental first cost assumption in the economic analyses below.

6.3.3 Life Cycle Cost Analysis

The life cycle cost analysis of the annual new construction for Washington State schools was performed using the savings and economic input noted in the Table of Economic Analysis Assumptions above. The results are shown in the following table, High Performance School Building Life Cycle Cost Analysis. It shows both direct savings and indirect savings. The direct savings arise from stormwater reduction, wastewater reduction, potable water use reduction, energy use reduction and construction waste diversion from landfill. Note that the construction waste diversion is a one-time savings (at the time of construction); all others are annual savings based on the percentage savings values that are derived from the research sections above. The indirect savings arise from increased teacher retention. The value for increased teacher retention is based on research showing 5% increased teacher retention in good building facilities. This calculation also uses an average turnover rate of 15.7% for Washington State (an average turnover rate for US teachers), a starting teacher salary of about $30,000, and a cost to the district of 1.5 times the teacher salary for each turnover (again, an average value from research into turnover costs). The potential for changes in student performance has not been assigned an economic value and thus is not considered in this analysis.

6.3.4 The Bottom Line

The result of this analysis with a 2% increase in first cost (noted in section 6.4.2) and the savings shown in Section 6.1 is a positive net present value for the savings of $7,653,070. This equates to a Return On Investment (ROI) of 150% and a Benefit to Cost Ratio (BCR) of 250%. The potential for results like these can improve taxpayer confidence that their money is being well managed and can improve voter confidence in proposed school bonds.



High performance school buildings are a strong investment, potentially delivering a Return on Investment of 150% and a Benefit to Cost ratio of 250%.

High Performance School Building Life Cycle Cost Analysis

Discount Rate	3%	
Period of Analysis	25 Yr	
Cost of construction	$254,237,836	based on $172/sqft
Incremental first cost	$5,084,757	assuming 2% incremental first cost

Direct Savings Measures	Environmental Savings	$/Yr Savings	Type (annual or one time)	First Cost	Present Value	Net Present Value	Sum of Gains	Sum of Costs
Stormwater Reduction		$27,522	annual	$ -	$ 479,236	$ 479,236	$ 479,236	$ -
Waste Water Reduction	4,037,817 gal/Yr	$23,050	annual	$ -	$ 401,375	$ 401,375	$ 401,375	$ -
Potable Water Use Reduction	7,799,544 gal/Yr	$14,077	annual	$ -	$ 245,120	$ 245,120	$ 245,120	$ -
Optimize Energy Performance	10,290 MWh/Yr	$504,190	annual	$ -	$ 8,779,535	$ 8,779,535	$ 8,779,535	$ -
Waste Management, Divert 50% or 75% CDL	930 tons	$37,190	one time	$ -	$ 37,190	$ 37,190	$ 37,190	$ -
Total Present Value of Direct Savings					**$9,942,456**	$ 9,942,456	$ 9,942,456	$ -
Return on Investment (ROI)	-							
Benefit Cost Ratio (BCR)	-							

Indirect Savings Measures	Environmental Savings	$/Yr Savings	Type (annual or one time)	First Cost	Present Value	Net Present Value	Sum of Gains	Sum of Costs
Teacher Retention		$160,532	annual	$ -	$ 2,795,371	$ 2,795,371	$ 2,795,371	$ -
Total Present Value of Indirect Savings					**$2,795,371**	$ 2,795,371	$ 2,795,371	$ -
Return on Investment (ROI)	-							
Benefit Cost Ratio (BCR)	-							

Savings Measures	Environmental Savings	$/Yr Savings	Type (annual or one time)	First Cost	Present Value	Net Present Value	Sum of Gains	Sum of Costs
Direct Saving Measures		$37,190	one time	$ -	$ 37,190		$ 37,190	$ -
Direct Saving Measures		$568,838	annual	$ -	$ 9,905,266		$ 9,905,266	$ -
Indirect Saving Measures		$160,532	annual	$ -	$ 2,795,371		$ 2,795,371	$ -
Total annual ongoing savings		**$729,371**	**annual**	**$ (5,084,757)**	**$ 12,700,637**	**$ 7,615,880**	**$ 12,700,637**	**$ (5,084,757)**
Total Present Value						**$ 7,653,070**	$ 12,737,827	$ (5,084,757)
Return on Investment (ROI)	150%							
Benefit Cost Ratio (BCR)	250%							

6.4 AGGREGATE IMPACT OF CONSERVING RESOURCES

The savings noted above for the annual 1.5 million square feet of new school construction can also be described in terms of their impact on the region's resources.

The table below expresses the savings for these 1.5 million square feet of new construction in terms of the resources they save and the equivalent household use. The CO_2 emissions are expressed as the equivalent number of trees required to mitigate the effect of the emissions.

Aggregate Savings from 1.5 million sq.ft. New Construction		
	Savings	Equivalent Use
Wastewater	4,037,817 gal/yr	42 Houses
Potable Water	7,799,544 gal/yr	77 Houses
Energy	10,290 MWh	3,230 Houses
Construction Waste	930 tons	289 Houses
CO_2 Emissions	1,543,439 pounds	23,152 Trees

6.5 CONCLUSIONS

Washington State has taken the first step in developing the Washington Sustainable Schools Protocol and has funded five school districts to test its ease of use and the impact of its measures. This study has demonstrated that:

- High performance school buildings can potentially have significant positive impacts on student performance, school district budgets and Washington State's natural resources.
- These benefits can be attained with minimal (<2%) incremental capital costs.
- This combination of costs and savings show strong positive savings over the building life (ROI =150% and Benefit to Cost Ratio, BC, = 250%).
- The overall savings and success of these sustainable measures depends on an integrated design approach involving the participation of all design team members early in the design process and supplemented by sophisticated technical evaluations/simulations of building system interactions, both of which are likely to incur additional design costs.

The benefits and savings potential for high performance school buildings is great. The State has the opportunity to reap these benefits for all future years if it can establish the incentive for

School Districts to invest in the extra first costs for integrated design work and high performance construction techniques and materials. This high performance building design approach delivers strong positive results to the "triple bottom line," maximizing Washington State schools' responsibilities to their students, their taxpayer base and the environment.

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APPENDIX A

References and assumptions for savings calculations

8.1 STORMWATER

Stormwater savings are based on the change in the stormwater utility rates for the % of impervious surface area on site.

Assumptions are:

- 25% of projects are urban and have no rate change.
- Of the 75% suburban/rural the rate change assumes that high performance design allows a school project to change from moderate to very light site coverage as defined by the Issaquah stormwater utility rate schedule available at: http://www.ci.issaquah.wa.us/page.asp?navid=603
- The total site area has been assumed to be 10 times the building area.

8.2 WASTEWATER

- Savings are calculated based on the metered potable water use in the building (since wastewater rates are based on potable water use, not actual wastewater production).

- The reduction in wastewater generated is equivalent to potable water savings and has been assumed to be 38% based on the range of potential water savings noted in the research data for schools prorated over the various water end uses typical for schools.
- The savings from gallons of wastewater reduction achieved in high performance school buildings is calculated at a $4.27/ CCF wastewater utility rate (average of Seattle Public Utilities wastewater rate for 2002 and Tacoma Public Utilities rate).

8.3 POTABLE WATER

- Savings are calculated based on the metered potable water use in the building.
- The potable water use reduction has been assumed to be 38% based on the range of potential water savings noted in the research data for schools prorated over the various water end uses typical for schools.
-
- The economic savings are calculated at a $1.35 /CCF water utility rate (based on average commercial water rates for Seattle, Tacoma and Olympia).

8.4 CONSTRUCTION WASTE DIVERTED

- The savings are calculated based on the total construction waste diverted as per the industry standard of 2.25 pounds/ sq ft. (assumes that new construction does not replace an existing building).
- The construction waste diverted is assumed to be 56% based on the average of the 22% to 90% range as suggested by research data for schools.
- The economic savings are based on the difference between the cost of landfill tipping fee ($90/ton) and cost of recycling tipping fee ($50/ton). (Source: $/ton at Freemont Transfer Station, Seattle, Washington)

8.5 ENERGY SAVINGS

- Energy savings are calculated over an assumed typical school energy consumption of 79.3 KBtu/ sq ft. Based on Building Energy Databook: Energy End-Use Intensities and Consumption of Education Facilities (USDOE, 2004)
- The energy savings has been assumed to be 30% based on the range of savings from 25% to 50% as suggested by research data for schools.
- The economic savings are calculated based on the energy cost of $.049/kWh. (WA State average)

8.6 CO_2 EMISSIONS

- Reduction in CO_2 emissions has been calculated based on the energy savings in kWh and the corresponding CO_2 emissions avoided.
- Rate of CO_2 emissions has been assumed as 0.15 pounds/kWh based on the information available at http://www.americanforests.org/resources/ccc/

8.7 TEACHER RETENTION SAVINGS

- Cost of teacher turnover has been calculated based on the information in a Texas study on teacher turnover (SBEC, 2000). This study lists three levels of teacher turnover costs. For the purpose of this report 1.5 * Teacher's annual salary has been used as the turnover cost of a teacher. (This estimate was considered the "pragmatic estimate" in the Texas study).
- Average annual teacher turnover rate is assumed to be 15.7% based on the US averages mentioned in the reference: http://www.nctaf.org/documents/nctaf/CTT_grahic.pdf

  The potential increased teacher retention rates in high performance school buildings are based on research documenting teacher's evaluations of their school buildings and their self reports on their intentions to leave the school or school system. (Buckley, 2004) The study estimates a 5% probability of teacher retention with increasing levels of school facility quality.
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 Roy Lee Walker Elem School classroom

NREL PIX 10674 Scott Milder

NREL PIX #00975 Warren Gretz   Minturn Middle School