LINKING PERFORMANCE & EXPERIENCE
AN ANALYSIS OF GREEN SCHOOLS
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We would also like to thank DLR Group for its partnership and financial support of this research project. DLR Group acted as an essential gatekeeper, providing the sample, access and connection to the administration in sample schools, and technical data about each school.

About DLR Group

DLR Group, an integrated design firm with offices across the United States, is recognized for its design of innovative, sustainable educational facilities. As a firm, DLR Group’s baseline for sustainable design is the defined standards of Architecture 2030.

The firm designs K-12 schools to meet, or exceed, standards and programs from a multitude of national and state sustainability organizations including the American College and University Presidents’ Climate Commitment; American Society of Heating, Refrigerating and Air Conditioning Engineers; Collaborative for High Performance Schools (CHPS); Energy Star (and is an Energy Star Partner); Green Globes; U.S. Green Building Council; and the Washington Sustainable Schools Protocol (WSSP).

DLR Group believes sustainability is best judged by disciplined evaluation of high performance building metrics (energy, air quality, day-lighting, water, maintenance costs, wellness, productivity, etc.) to measure the effectiveness of design. The execution of this study is part of its effort to evaluate and advance the performance of its designs.

About The Institute for the Built Environment at Colorado State University

The Institute for the Built Environment (IBE), founded in 1994 at Colorado State University, is a multidisciplinary research institute whose mission is to foster stewardship and sustainability of the built and natural environments through interdisciplinary educational forums. IBE’s vision is to be a premier forum for integrating research and practice toward environmentally, socially and economically regenerative places. IBE pursues this vision by engaging diverse partners to elevate the conversation and build and equip leaders to shift the marketplace.

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The design of schools has seen a significant shift in the last decade due to an increased awareness of the effects of building design on student learning and the long-term impact on district operating budgets. National trends illustrate that green school design is not a fad and is taking firm hold of the education sector, accounting for more than a third of new education construction in 2010 (McGraw-Hill Construction, 2010). Proponents of green building practices believe these buildings improve the health and performance of students, result in lower operating costs, and do not require higher capital construction costs. However, the extent to which green building affects occupants, operations, and construction costs is often difficult to quantify, which makes green building difficult to justify in the marketplace.

Therefore, the purpose of this study was to analyze costs, performance, and human impact of a sample of green school buildings in order to define benchmarks and to better understand the often intangible impacts of green building decisions. We sought to 1) Survey a breadth of variables critical in the K-12 schools sector; 2) Compare data to local, regional, or national medians; 3) Report on the performance of sample, summarizing both conclusive and inconclusive findings.

Research Question: What effect does green school design have on occupants and long-term building performance?

This study was initiated by an architecture firm, DLR Group, which is committed to benchmarking and evaluating past projects in order to inform its future work. Allowing the results of this study to be public is an illustration of the growing market trend toward transparency. We see this through the growing number of corporate sustainability reports, in the development of environmental product data sheets, and in the ongoing monitoring of building performance. Architecture 2030 has been a catalyst for these practices in the field of architecture, requiring committed firms to meet yearly conservation thresholds for projects and report annual performance to Architecture 2030. As a professional community seeking to meet common sustainability goals, we realize transparency and ongoing organizational learning through analysis and benchmarking is not only beneficial but critical to our collective success.

Literature

The costs of designing, constructing and operating schools are substantial burdens for school districts. A school district, on average, spends 18% of its annual budget on operations. Improving the efficiency of district operations can have a significant impact on the budget and allow the allocation of more financial resources to classrooms. In many cases, high performing green schools can use up to 70% less energy than same-sized conventional schools. Therefore, decisions to pursue high-performance building design and operation are critical but often difficult to justify as access to capital funding in school districts is limited to voter approved mill levies, government grants, and other sporadic funding sources.

A handful of significant research studies on the cost of green building have been completed. The 2007 Davis Langdon study, The Cost of Green Revisited, illustrates through a random distribution of costs that there is no significant difference between the cost per square foot of green and non-green buildings of the same building type (Matthiessen, 2007).

Using cost data and perceptions of increased costs of project architects, the 2006 Cost and Benefits study by Greg Kats showed a 1-2% cost increase of green buildings (Kats, 2006). If there is an average increased first cost for green buildings, many building professionals will counter the debate by stating the increased investment is quickly returned through energy savings. A 2008 study by the New Building Institute concluded LEED buildings perform on average 25-30% better than the national median (Turner & Frankel, 2008).

Beyond cost and energy savings, an additional benefit of green schools is said to be improved occupant experience. Specific variables within the built environment such as ventilation rates, filtration, materials toxicity, and daylighting influence the quality of indoor space and can have positive effects on occupant health. If student health is improved, it follows that absenteeism would be reduced and achievement would increase. To evaluate this supposition, several studies have evaluated the effect of indoor air quality, fresh air rates, and CO2 levels, and found a connection to improved attendance (Berry, 2002; Shendell, 2004; Smedje, 2000). Connecting the quality of school facilities to academic achievement, a study of D.C. public schools showed that students in school facilities with poor conditions scored 11% below students in schools with excellent conditions (Edwards, 1991), and in the daylight study by the Heschong Mahone Group (1999) student performance increased by 15-26% in classrooms with daylighting and views.
This research design limits investigation to a sample of 10 sites, with a total of 12 green schools. The sample of schools was defined in collaboration with DLR Group to include P-8 schools which are third party certified or align with criteria for certification, and have been in operation for at least 12 months. School representatives were invited to be a part of the study and once consent was gained, data were collected from the appropriate parties. Schools were given the freedom to opt out of certain components of the study; therefore, not every school is represented in each data point.

The schools participating in this research are detailed on the following pages. The variables which were evaluated in this study included occupant experience, first cost, energy use, and building operation practices.

A sample of occupants comprised of teachers and administrative staff, were surveyed using an online questionnaire which gathered their perceptions on how the building affected students, the value of the green building attributes of their facility, and how the building has affected them personally.

Construction costs (per ft²), total project square footage, and student capacity for each school in the sample were provided by DLR Group. The Annual School Construction Report was used to compare project costs to regional cost means (Abramson, 2012). In this report, regional school construction costs are indexed by school type (elementary, middle, high school) and by region.

ENERGY STAR Portfolio Manager and Target Finder were utilized to evaluate energy use. A full calendar year of utility data was provided by school representatives. Additional information was collected about the schools including the school’s utility company, the number of computers, the number of walk-in freezer units, if cooking facilities are provided, the percent of area that is heated and cooled, and if the building is open on weekends. Finally, the 2003 Commercial Buildings Energy Consumption Survey (CBECS) was utilized to evaluate the sample’s energy use compared to national means (Energy Information Administration, 2004).

Maintenance practices were evaluated by interviewing a facilities or maintenance representative for each school. The interviews were done by telephone or if requested by the contact, via an emailed questionnaire. Interview questions were designed to gather the perceptions of the maintenance staff regarding the ease and efficiency of maintaining a green school, the interface between occupants and the building, and lessons learned over time.
Oak Crest ES | Belle Plaine, MN
Completed: 2007 | Size: 91,000 ft²

Petersen ES | Scappoose, OR
Completed: 2010 | Size: 72,019 ft² | LEED Gold Certified

West Dodge Station ES | Elkhorn, NE
Completed: 2010 | Size: 62,500 ft²

Westwood ES | Zimmerman, MN
Completed: 2003 | Size: 75,000 ft² | LEED Certified

Panther Lake ES | Federal Way, WA
Completed: 2009 | Size: 91,000 ft² | WSSP

Pioneer MS | Steilacoom, WA
Completed: 2008 | Size: 107,889 ft² | WSSP
Perspectives from Occupants

The survey conducted with building occupants captured their perceptions about their green school building. When asked about motivators for building green, the key motivators cited by respondents were to 1) Save money through reduced energy costs; 2) Be environmentally responsible; and, 3) Be a model for the community and for students.

A motivator to improve student health was only mentioned by a handful of respondents. However, when asked specifically about student health, 87% of respondents reported that they perceived a positive impact on student health, with most respondents specifically describing the positive impact of daylighting.

71% of respondents perceived that the building has a positive effect on student achievement. Similarly, 71% perceived a positive effect on student behavior. For those that who did not share this perspective, many stated that it is very hard for them to identify the effect because of the many other variables which influence student achievement and behavior.

Finally, on a personal level, 85% of respondents reported that their health and productivity were positively affected by the building.

Cost

Out of the 10 sites in this sample, six were built for below the regional median cost for schools built in the same year, while four were built for costs greater than the regional median. As illustrated in Figure 1, the sample mean was $180.48 per square foot and the regional mean was $190.72, a difference of $10, or 6%. From this comparison, we cannot conclude that green building practices equate to higher project costs. Green design processes, materials, and building systems are only a portion of the factors influencing cost. In order to understand the impact of green building practices on cost, a more detailed analysis of all factors is needed. For example, we know some green building practices like integrated design can reduce costs, while others like advanced mechanical systems can increase costs. A detailed cost analysis could demonstrate the relative impact of these various factors.
Project Value
How does construction cost align with overall project value? One indicator used to evaluate project value is the total square foot per student provided by the project. Figure 2 illustrates that out of the 10 sites, eight provided more square feet per student when compared to the regional median. Overall, the sample mean square foot per student was 152 ft² while the regional mean was 126 ft². This additional 26 feet is equal to 14%.

![Figure 2: Square Foot per Student](image)

Energy Performance
To evaluate energy performance, the ENERGY STAR metric was used. An ENERGY STAR score was chosen as a high-quality indicator of project efficiency since the score considers more than just Energy Use Intensity (EUI); it also considers operational efficiencies as indicated by building function, occupancy schedules, loads, and climate. It should be noted that the ENERGY STAR score for Evie Garrett Dennis was calculated for the whole campus using data from the individual buildings; therefore, the score for each school is the same (94).

Figure 3 illustrates the scores for each school in the sample and how they fall in relation to the national median. The sample mean ENERGY STAR score was 81. A rating of 81 indicates that a building is operating in the top 19th percentile, or better than 81% of similar buildings nationwide. Considered individually, nine out of the eleven buildings evaluated for ENERGY STAR have a score over 75 and would receive the ENERGY STAR award. This is a significant result and is consistent with previous research on green building performance and indicates that the special attention paid to energy efficiency during design results in higher performing schools (Turner & Frankel, 2008).

![Figure 3: School ENERGY STAR Scores](image)
Though site specific operational procedures, schedules, and occupancy loads have a critical influence on building efficiency, it is clear that building design plays a significant role in long-term energy performance. More analysis is needed to determine what they key drivers are for the ENERGY STAR Scores of specific schools; such as, the high score at Evie Garrett Dennis or the low score at Ashland Ridge.

In addition to the ENERGY STAR score for each building, we also evaluated site Energy Use Intensity (EUI). A low EUI is an indicator of efficiency; however, variations in building design, use, and climate within the sample make analyzing each school’s EUI difficult without the proper comparison benchmark. Therefore, we utilized ENERGY STAR’s Target Finder to evaluate the project’s alignment with Architecture 2030 reduction targets.

For the K-12 sector, Architecture 2030 recommends utilizing ENERGY STAR’s Target finder to determine the project’s goal for 50% reduction in site EUI (the 2010 Architecture 2030 target). Project information (zip code, square footage, loads, and usage patterns) was entered into Target Finder for each of the study’s schools. Target Finder utilizes this information and the 2003 CBECs regional median EUI for K-12 schools to determine the project’s EUI reduction goal.

Figure 4 illustrates each project’s site EUI and the Target Finder 50% EUI Reduction Goal. In total, eight schools are operating at or better than the 2030 Challenge 50% reduction target. In addition, by organizing the schools by the year constructed, it is clear that over time the buildings’ design has become increasingly more efficient.

Finally, to illustrate the impact of energy efficient design on the total cost of ownership for a school building, an estimation of lifetime utility costs for Evie Garrett Dennis (EGD) Campus are shown in Figure 5. Using Target Finder, annual utility costs were estimated for the campus and for a campus performing at the regional median. Costs were accrued assuming an annual 2% utility rate increase. Figure 5 illustrates that over a life of 50 years, EGD will save an estimated $7.5 million in utility costs. This estimate is most likely the minimum savings, as a 2% rate increase is very modest.

**Figure 5: Projected Lifetime Energy Cost of EGD**
Operations & Maintenance

The interviews with school facilities representatives provide diverse perspectives and together offer a representation of the operation and maintenance characteristics of green schools. Their responses provided insight into how green schools are similar or different to conventional schools, how the district has shifted practices to align with greater sustainability in operations, and how occupants have responded to or engaged with the building.

Overall, those interviewed did not consider the green school more difficult or costly to maintain. However, some stated that they must change filters more regularly, that the more efficient bulbs are more expensive to replace (though they are replaced less frequently), or that they occasionally must reach out to a technician to assist on more complex building automation changes. The general sentiment was the buildings operated efficiently, used their time efficiently, and because of the design they were able to maintain a healthy and comfortable environment for occupants.

As most of the schools in the sample had been in operation for a few years, interviewees were able to discuss how the school has performed over time. Most stated that a certain amount of time was required in the beginning to “dial-in” the building systems, which they saw as an expectation of all new buildings. As well, time was required to train staff members on how to operate and problem-solve any issues in the new systems. Attention to progress energy efficiency varied among the sample. Some schools had committed personnel and systems in place to track, monitor, and improve energy efficiency while others did not. Within those that did not, siloed departments seemed to discourage fluid communication between those operating the building and those paying the utility bills. The opportunity to identify problems and adjust practices was lost in these cases. For other districts, software programs offered the best method for identifying and rectifying problems early, initiating work orders, utilizing facilities staff time efficiently, and sending timely communication to school principals.

The interviewees offered insight into how building occupants interface with the facility. In most cases, staff members worked in a conventional school before moving to a green school; therefore, occupant training and education was essential in order for occupants to understand how the building was different and the role they play in maintaining the building’s efficiency.

Maintenance-wise we have not had a lot of issues. The maintenance requests seem to be fewer, so I think the costs are going to be significantly lower than many of the district’s buildings because of how it was designed and constructed.”

“The key to a cost-effective green school is good building automated system (BAS) and maintenance/utility software.”

For staff that came from older schools with greater individual control, they often found it frustrating to not be able to adjust the temperature or open windows in their classrooms. However, overall, interviewees stated they had very few thermal complaints, that occupants were very happy in their spaces, and pleased particularly with the amount of natural daylight in their classrooms.

All interviewees stated that if their district builds another school they would prefer a green, high-performing school. They also added that they intend to gather and integrate their lessons learned into future designs in order to create progressively more efficient schools. They mentioned holding planning meetings and doing interviews with students, faculty, and facilities staff to gain insights into what works well and what does not.

“We have very few thermal complaints. We even often hear that they are less sick than when they were in the old building.”

“Overall the reaction has been very positive among the staff; though teachers do not like the fact when they cannot individually maintain their own thermostats.”

“One issue has been trying to get people and staff to understand you don’t need to open the windows, fresh air is coming in because of the system. You know, old habits, they come from schools that didn’t have air conditioning so the first thing that they do is they walk over and open a window or two. And so, those things, training users...It’s getting better and better, though every year you get new teachers so we’ll go through it again.”

“The key to a cost-effective green school is good building automated system (BAS) and maintenance/utility software.”

“Prior to the design of a new school, lessons learned sessions will be held on the previous constructions so the best strategies can be implemented in the new design.”
Our purpose in this study was to analyze a sample of green schools in order to evaluate if the results align with previous research and commonly held beliefs that green buildings are more efficient and positively impact occupants. In order to evaluate these measures, we conducted occupant surveys, collected utility usage and cost data, and interviewed building operators.

• The results of the occupant survey support the supposition that green school facilities have a positive impact on occupants. Respondents were enthusiastic about their green school with the majority perceiving positive effects on student health, achievement, and behavior.
• Our findings from this study rebut the common perception that higher design and construction costs must be incurred to build green schools. The majority of green schools in this sample were built below their regional median for schools built in the same year.
• In energy performance, the sample green schools operated above the ENERGY STAR national median, with a sample mean score of 81. A rating of 81 indicates that a building is operating in the top 19th percentile, or better than 81% of similar buildings nationwide. In addition, eight of the schools operate at or below the Architecture 2030 Challenge 2010 targets for Energy Use Intensity (EUI).
• Finally, through interviews with facility managers, we confirmed that the buildings’ efficiency is also illustrated through perceived efficiencies in the daily operation and maintenance of the facilities.

These results point to a number of strategies that should be integrated into the design and construction process of school buildings. First, initial staff training at building occupancy is critical to efficient operations. In addition, training for new staff members should be integrated into orientation. These trainings should inform occupants about the sustainability features of the building, the expected effects on occupants, and how to best interface with new or unfamiliar green features in the building (i.e., windows, occupancy sensors, dual-switched lighting, light shelves, etc.). During new project planning, district custodial and maintenance professionals should be invited to inform aspects of the building’s design; specifically, material selection and building automation system interfaces. Finally, long-term plans for energy management should be established with district facilities departments. New school projects offer an opportunity to establish energy management best practices which can be applied to existing schools and greatly impact district utility expenses.

The methodology of this study should serve as a replicable example of on-going benchmarking of design, performance, and occupant impact. Architecture firms like DLR Group with firm-wide commitments to high-performance, green building should see this report as a significant step in the field, illustrating the movement toward greater transparency of the impact of design and construction practices.

References


1 P-8 was chosen as the extents of the sample in order to achieve some consistency across school types. High schools have unique occupancy schedules, loads, and curriculum programs which make them difficult to compare to lower schools.
2 Third Party certification in the sample include the U.S. Green Building Council’s LEED Certification and the Washington Sustainable Schools Program (WSSP).