

Advantages of Implementing Sustainable Principles in School Building Projects

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Abstract— Because of the terms and conditions of human survival are closely related with sustainability, an increasing attention on sustainable development should be considered. Notably, buildings are responsible for one-third of global greenhouse gas emissions as they consume 40% of the energy use worldwide. A considerable overall amount of energy consumption in public buildings is highly contributed by the energy consumption of school buildings due to their high number in the country. Therefore, it is widely advised that alternative solutions should be investigated in order to reduce the energy consumption in school buildings. To do so, this research aims to investigate and discuss the advantages of implementing sustainable principles in school building projects through conducting a comprehensive literature review.

To fulfill this purpose, twelve advantages have been identified. These advantages can be broadly classified into two branches, firstly, advantages related to sustainable learning, such as higher student test scores, increased student attendance, enhanced teacher performance and satisfaction, changing attitudes, insurance and risk related benefits, safety and security. Secondly, advantages relating to sustainable building, for instance lower operating costs, energy efficiency, increased building life, lower environmental impact, waste diversion, increased use of renewable energy.

By considering these advantages, the decision making process in implementing sustainability in school building projects might be improved as this review places the basis for the development of a decision support tool. This might, ultimately, increase school quality and competitiveness.

Keywords— *Sustainability Principles; School Buildings; Sustainability.*

I. INTRODUCTION

It is widely acknowledged that Architecture, Engineering and Construction (AEC) industry consumes 40% of energy, 50% of natural material resources and is responsible for 50% of total waste. Therefore, it is classified as a massive consumer of natural resources. Consequently, an attention has been raised to adapt sustainability principles into AEC industry processes [1]. This is because benefits of sustainability are diverse and potentially very significant [2]. According to Gelfand [3], in 2007 in the USA, school construction comprising approximately 5% of all construction because it is a large market on its own. Boeri and Longo [4] added that school buildings have a significant importance due to its social value and relevant quantity. Therefore, a measurable impact on resource and energy consumption for community as a whole can be achieved by applying sustainable practices in schools. Such practices have benefits extend beyond the school to the outside world [3]. Further,

schools can be transformed into spaces that make an active contribution to educate on sustainability. Therefore, they are no longer just functional housing [4]. To fulfill the criteria of sustainable design, buildings such as school must ensure adequate morphological and technical standards to all spaces used by the students [5]. Based on Brkovic, Pons [6], a new sustainable schools should be developed if we want sustainable schools to be a strategy for leading us towards a better tomorrow locally and globally and for renovating the educational process. By looking at the advantages of the sustainable school, the value of sustainability in design, construction, and operation can be supported. Further, both sustainable lifestyles and sustainable learning can be deeply influenced by the quality of environment delivered by a school building. Moreover, in order to grasp the opportunity to provide real change in the sustainability of the schools, school leaders must be equipped with the skills and knowledge. Such knowledge and skills are required to deliver sustainable buildings through current procurement processes and systems [7]. According to Alshamrani, Galal [5], most of the existing school buildings, unfortunately, suffer from a low level of performance and architectural quality leading to an indoor microclimate below comfort level and to a high consumption of energy. Despite the fact that in the USA and Canada, nearly 80 million students and teachers spend at least eight hours daily in schools that might be unhealthy, there is lack of adopting sustainability principles in school buildings. Such schools might restrict their ability to learn [5]. For that reason, an exploration of the advantages of implementing sustainable principles in school building projects was required to enhance decision making process to implement sustainability in school building projects. Towards achieving this aim, literature review was employed. Thus, this paper compliments current research in the domain of sustainability by adding different advantages for such domain in order to improve the sustainable strategies in school buildings sector.

II. ADVANTAGES OF IMPLEMENTING SUSTAINABLE PRINCIPLES IN SCHOOL BUILDING PROJECTS

It is widely acknowledged that benefits of sustainability are diverse and potentially very significant [2]. According to Gelfand [3], in 2007 in the USA, school construction comprising approximately 5% of all construction because it is a large market on its own. Therefore, a measurable impact on resource and energy consumption for community as a whole can be achieved by applying sustainable practices in schools.

Such practices have benefits extend beyond the school to the outside world. By looking at the advantages of the sustainable school, the value of sustainability in design, construction, and operation can be supported.

Much research has dealt with sustainable buildings, however, some of it reveals many advantages of the sustainable school in different aspects and in various countries. In this section, such advantages in different aspects will be discussed.

A. Higher Student Test Scores

Despite the fact that lower tests scores is the costs of poor air quality and indoor environmental in schools including lighting levels, air flow, humidity, and temperature [8], sustainable schools are best environments for education [3]. Alhaydari and Jassem [9] and Olson and Kellum [10] supported this view, stated that by providing safe, healthy and environmentally friendly environment for pupils, teachers, and staff, higher student performance can be achieved. Olson and Kellum [10] emphasizes that indoor air quality and daylighting are the two elements of sustainable building design which have direct effects on student performance. In agreement with the aforementioned views, Edwards [11] stated that greater satisfaction with the school as a place for education is reflected in improved SATS results. According to Gelfand [3], an analysis of more than 21,000 students in different states in the USA presented that higher student performance in standardized testing and reading was strongly associated with utilizing daylighting through windows and skylights. The progression of students in classrooms with the better daylighting was (19% to 20% in California and 7% to 18% in Colorado and Washington) faster than their peers in classrooms with least daylighting. Further, depending on Kats [8] report, sustainable school design offers an extremely cost-effective way to improve student learning. Kats [8] and Olson and Kellum [10] agreed that good lighting can provide test scores improvement, off task behavior reduction, and plays a significant role in student achievement. To sum up, better study and learning environment and student performance improvement can be achieved by designing schools to be healthy, and distinguished by more daylighting, less toxic materials, improved air quality and better light quality, improved ventilation and acoustics [8].

B. Lower Operating Costs

Kats [8] and Olson and Kellum [10] agreed that the operations and maintenance (O&M) benefits of greening school buildings are probably significant. They demonstrated that sustainable schools reduced operations and maintenance costs. They generally have higher design and construction costs and lower operational costs than conventional schools. Kats [8] noted that about \$70 per ft² is the financial savings compared to conventional schools. Such savings are 20 times as high as the cost of going green. Table 1 illustrates the positive financial returns from sustainable schools (\$/ft²) [8]. By saving energy and decreasing maintenance and operating costs, sustainable schools will ultimately contribute positively to better quality of life [2]. Depending on Edwards [11], using sustainable schools out of hours will probably reduce the level of vandalism and hence money spent on repairs. Therefore, in

full life-cycle costing terms, a range of community, educational and social benefits can be offered by sustainable schools. Kats [8] concluded that building high performance healthy school buildings is now far more fiscally prudent and lower risk than building traditional, unhealthy and inefficient school buildings.

TABLE 1 Green schools give positive financial returns [8]

Financial Benefits of Green Schools (\$/ft ²)	
Energy	\$9
Emissions	\$1
Water and Wastewater	\$1
Increased Earnings	\$49
Asthma Reduction	\$3
Cold and Flu Reduction	\$5
Teacher Retention	\$4
Employment Impact	\$2
Total	\$74
Cost of Greening	(\$3)
Net Financial Benefits	\$71

C. Energy Efficiency

It is widely acknowledged that conventional school buildings are not comfortable and consume excessively both in terms of the environmental point of view and economic impact. Such buildings consume too much energy because of low insulation, low environmental quality, presence of thermal bridges, obsolete equipment, and use of no performed windows [4]. Therefore, Ahn, Pearce [12] and Hydes and Creech [13] demonstrated that the concept of sustainable building saves energy. Kats [8] agreed with the aforementioned view and added sustainable schools uses one-third less energy than conventional schools. This reduction in energy is due to using more energy efficiency equipment, including better design, and installation of energy efficiency procedures such as increased insulation. Depending on Gelfand [3], energy costs come out of schools general fund. This will compete with instruction costs such as student supplies, books, and teachers. \$8 billion a year or 2% to 4% of school budgets was a school energy spending amounts in the USA, which it is more than schools spend on textbooks. By adopting sustainable schools design, an average of 33% less energy was used than conventionally designed schools. The enhancements in energy performance comprise greater use of daylighting and sensors, more efficient lighting, better insulated walls and roofs, and more efficient cooling and heating systems [8, 10]. To sum up, Kats [8] emphasized that shifting to more energy efficiency such as system design and installation labor for insulation, better windows, in-state manufacturing, renewable energy systems, etc., would have significant positive economic, employment and security impacts. Because of most energy consumed in schools obtain from burning fossil fuels, some of which is imported from countries that fund terrorism.

D. Increased Student Attendance

Sick days can give a general “hidden” idea about higher absenteeism and increased respiratory ailments due to poor air quality and indoor environmental in schools [8]. There is

considerable evidence indicated that indoor environmental quality can be improved by utilizing sustainable design and construction [10-12]. Such improvement results in healthier faculty and students, which in turn results in lower absenteeism [10]. Gelfand [3] stated that there was a clear reflection of a healthy environment in reducing sick days for both students and employees. Edwards [11] agreed with the aforementioned views and added greater satisfaction with the school as a place for education can cause lower level of pupil absenteeism (approved and unapproved). In sustainable schools, the decrease of absentee rates is directly linked with displacement ventilation, which is one of the (HVAC) strategies (heating, ventilating, and air-conditioning). In New Jersey, after installing displacement ventilation, 60% of absentee rates were declined. Further, the average daily attendance, in Washington, was increased from 89% to 93% by changing the operations methods. In addition to that, Kats [8] gave a concrete evidence in his report from those involved with sustainable schools that such kinds of schools reduced student absenteeism. He stated that an average reduction of 38.5% in asthma and of 51% in colds and influenza can be obtained in buildings with improved indoor air quality. Therefore, shifting from an unhealthy, conventional school to a healthy school has a high impact in reducing asthma incidence of 25% and in reducing colds and flu of 9-20%.

E. Enhanced Teacher Performance and Satisfaction

Sustainable schools are designed precisely to deliver productive, comfortable, and healthy work environments for faculty and students. Teachers believe that both teaching quality and student achievement can be affected by temperature comfort [8, 10]. Pettifer [2] supported this view and added sustainable buildings will contribute positively to healthy work environment, work efficiency, and better quality of life. So it would contribute positively to school districts retain and recruit teachers [10, 11]. Edwards [11] and Kats [8] agreed that by adopting green design approaches, which is enhanced the quality of the classroom environment, stress in teachers will be reduced leading to lower rates of staff turnover or absenteeism, and this in turn leads to enhanced productivity. Kats [8] reported that a reduction of 5% in teacher turnover can be obtained from sustainable schools. Such reduction can raise teacher retention of 3%. Gelfand [3] emphasizes that both operating and quality costs of education can be affected by teacher retention. In green design, the benefits of teacher retention alone surpass the cost of greening. Kats [8] support this view indicated that an additional full-time teacher payment can be saved by adopting such design. He emphasized that school's ability to retain and attract teachers can be improved by being green. In addition to that reduction in sick days of 7% in sustainable schools has been experienced by teachers. This means one day a year less due to a better work environment and healthy air. Alhaydari and Jassem [9] added that sustainable schools represent a living tool for learning that enables the teacher to introduce the student to many natural and new good technical matters. Olson and Kellum [10] added that sustainable school features can be combined into teachers' curriculum to provide students with practical learning chances.

F. Increased Building Life

It is widely acknowledged that the real challenge facing the building sector is making existing building more sustainable. Sustainability can be contributed by extending the service life of existing buildings. Similarly when a new building is constructed in order to achieve permanence goal [3]. Kats [8] reported that reflective roofs or green, planted roofs, which are known as "cool roofs", contributes to a significant expansion of the roof life. Such types of roofs are significantly reduced city or local temperature as heat /light is reflected back into space rather than absorbed and radiated locally. Usually, highly reflective roofs last 20% longer than classical roofs, while green roofs are expected to last 30-50 years or longer.

G. Lower Environmental Impact

Environmental/resource conservation is deemed one of the most important driving factors of sustainable design and construction [9, 12]. Environmental benefits through reduced pollution can be provided by sustainable schools [10]. Gelfand [3] stated that schools are considered a large sector of the building market. They, therefore, have a large contribution to people impact on the planet. Depending on Kats [8], each year one sustainable school could save:

- 1,200 pounds of nitrogen oxides- a principal component of smog
- 1,300 pounds of sulfur dioxide- a principal cause of acid rain
- 585,000 pounds of carbon dioxide- the principal greenhouse gas and the principal product of combustion
- 150 pounds of coarse particulate matter- a principal cause of respiratory illness and an important contributor to smog

In fact, the public benefits of sustainable schools are greater than those that work straight to the fiscal advantage of schools. These comprise improved environmental quality, reductions in water pollution, and raised productivity of education in an enhanced school environment [8]. Sekki, Airaksinen [14] reported that, in UK schools, energy costs could be reduced by around £44 million per year. Such reduction would prevent 625,000 tonnes of CO₂ from entering the atmosphere. By using sustainable school design, an average water use reduction of 32% have been achieved, as stated in Kats [8] report. Direct savings for the building can be accomplished by this reduction. Not only that but substantial societal benefits can be reached by decreasing pollution, reducing infrastructure costs to transport and treat wastewater and to carry water. Sustainable building experts, in Kats [8] report, assumed that wastewater and water costs for schools average 5% of the cost of energy. By reducing water and sewer cost, large savings can be obtained in addition to the cost savings from increased groundwater recharging and reduced water pollution. In addition to that, Kats [8] noted that an environmental total benefits of waste recycling was calculated \$151-\$331. Edwards [11] agreed with above discussion and added that green schools offer investment advantages by maximizing children's exposure to daylight. Such investment can reduce the environmental

footprint of the school in terms purely of energy consumption.

H. Changing Attitudes

It is widely recognized that community can be influenced by its schools. Edwards [11] emphasized that green schools can contribute positively to the pupils' learning experience and possibly also to the wider community. He stressed that greater integration can be introduced between community and school life which is reflected in improvement in educational standards. It can be extended beyond the education task occurring inside the classroom. Both sustainable school and its community can work together to demonstrate energy saving behavior, change eating habits, and reduce driving. Such influences will have a strong impact on students' behavior which will ultimately enhance community behavior towards sustainability [3]. According to Edwards [11] the level of vandalism can be reduced by using cherished sustainable school out of hours, which will ultimately reduce money spent on repairs. In addition to that, greater satisfaction with the school as a place for learning is reflected in the observed reduction in the incidence of bullying [11]. Kats [8] added that as spiritual, moral, and religious values are important, such values are related for school design choices. Alhaydari and Jassem [9] stated that sustainable schools are a successful social environment, as they are designed to provide spaces suitable for setting up various activities in the community and bring them closer to the people of the same neighborhood and the region. Therefore, the role of the school in the community can be enhanced. Henderson and Tilbury [15] agreed with the aforementioned view and added active partnerships and participation for sustainability are not only occurring within the school but between the school and the community. Brkovic, Pons [6] emphasized that experiential learning about plants growing and healthy nutrition can be gained by raised beds in sustainable schools. By engaging pupils through various activities within these features, they can learn from those engagements. Further, based on Alhaydari and Jassem [9] sustainable schools adopt the principle of transforming the school building into a living educational tool in which the school becomes a whole, interacting with students and educational owners on the one hand, and a sustainable building that reduces the environmental impact on society and the environment on the other hand. In summary, a range of community, educational and social benefits can be offered by sustainable schools in full life-cycle costing terms [11].

I. Waste Diversion

It is worth noting that sustainable design and construction caused waste reduction [12]. Olson and Kellum [10] stated that environmental benefits through reduced landfill waste can be provided by sustainable schools. Such reduction can be achieved by diverting waste. Sustainable school can increase employment by diverting waste from landfills to more labor intensive activities such as sorting and recycling. Kats [8] agree with this view and noted that, over 20 years, 20,000 more jobs would be a result of creating a minimum energy consuming target for Pennsylvania of 10% from

renewables. It is worth noting that, for every 1,000 tons of waste disposed, only 2.5 jobs are generated, however 4.7 jobs are generated for 1,000 tons of waste diverted. Therefore, comparing with conventional non-green buildings, increased employment will be added to green design features such as renewable energy, efficiency, and waste diversion. Not only that but recycle most construction and demolition waste is cost less than dispose of it by at least 35% as stated in Kats [8] report. Construction and demolition (C&D) waste is estimated about 25% of the solid waste discarded nationally. In sustainable schools, the financial benefits of increased (C&D) waste diversion of 74% are appeared significant.

J. Increased Use of Renewable Energy

It is widely known, by using renewable energy, less labor intensive and more contaminating energy sources, for example imported heating oil, gas, and coal burned in power factories to produce electricity, will be displaced. To be more sustainable, such energy, both on site and off site, is generally used [8]. Depending on Olson and Kellum [10], to develop student interest in alternative energy sources, onsite renewable energy sources, for example photovoltaics, can be utilized as a teaching tool. In sustainable schools, increased use of renewable energy has a positive employment benefit. Increasing employment is likely due to a shift to more renewable energy. By 2020, about 100,000 net new jobs in USA would be created, if renewable energy use will expand to 20% [8].

K. Insurance and Risk Related Benefits

Sustainable schools can offer health related benefits which have significant risk and insurance impacts [8]. He noted in his report that, in 2002, most insurers reported a tripling of mold-related claims. Therefore, greater commissioning and improved ventilation in sustainable buildings decreases the probability of mold and associated liability problems.

L. Safety and Security

Children should feel secure, calm and safe to be able to learn. So it is necessary to tackle safety and security problems through architectural design of a sustainable school [6, 9]. Brkovic, Pons [6] noted that there are indirect contributions to the quality of the learning atmosphere within sustainable school by considering a variety of security and safety issues in its design. Not only that, Olson and Kellum [10] emphasized on using green materials and supplies to minimize or eliminate possible sources of allergens, toxins, and other dangerous pollutants such as formaldehyde or volatile organic compounds (VOCs). Lung ailments such as asthma will be reduced by using green materials and supplies. Fig. 1 summarizes the two main advantages of implementing sustainable principles in school building projects, namely, advantages related to sustainable learning and advantages related to sustainable building. Each one includes other different advantages.

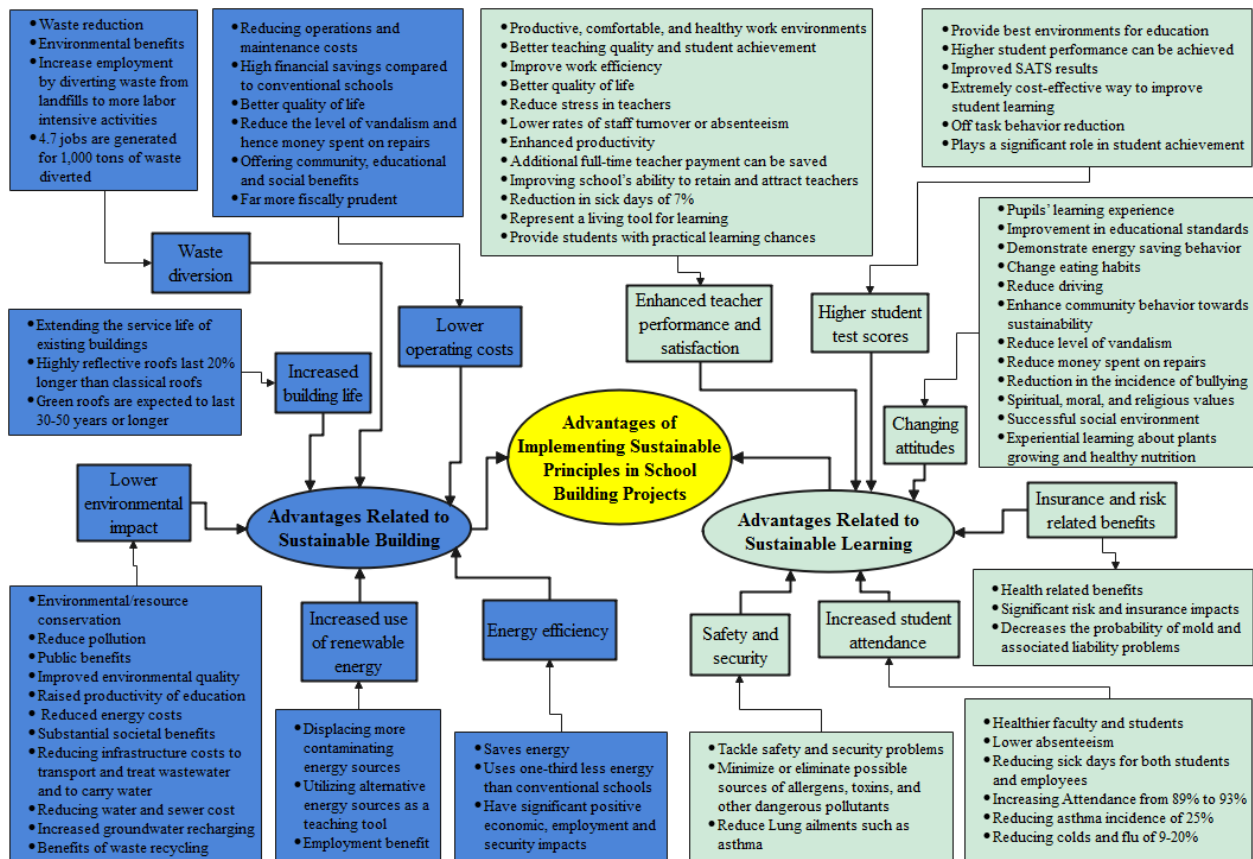


Fig. 1 Advantages of Implementing Sustainable Principles in School Building Projects

To sum up, better study and learning environment and student performance improvement can be achieved by designing schools to be healthy, and distinguished by more daylighting, less toxic materials, improved air quality and better light quality, improved ventilation and acoustics. Further, building high performance healthy school buildings is now far more fiscally prudent and lower risk than building traditional, unhealthy and inefficient school buildings. Therefore, a range of community, educational and social benefits can be offered by sustainable schools in full life-cycle costing terms.

III. CONCLUSIONS

This paper has focused on the sustainable principles in school building projects, with attention being focused on the advantages of implementing such principles. To have an overall picture about the sustainable principles in school building projects, an overview for literature has been conducted to highlight the advantages of implementing such principles around the world. Twelve advantages have been extracted from the related literature. Such advantages have been categorized within two branches, firstly, advantages related to sustainable learning, namely, higher student test scores, increased student attendance, enhanced teacher performance and satisfaction, changing attitudes, insurance and risk related benefits, safety and security. Secondly, advantages relating to sustainable building, such as, lower operating costs, energy efficiency, increased building life,

lower environmental impact, waste diversion, increased use of renewable energy.

It can be concluded that by adapting sustainable schools energy, money, and resources will be saved as well as healthy, well-lit, comfortable environment conducive to learning and student achievement can be provided. Therefore, it is widely advised that school buildings' designers and architects needs to change. By doing so, better choices will be made for not only their clients but for the society as well as the environment.

The paper reveals that new models of sustainable schools should be developed if we want such schools to be a strategy for leading us towards a better tomorrow locally and globally and for renovating the educational process. As school buildings have a considerable importance because of its social value and relevant quantity.

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