A Review on Sustainable Building (Green Building)

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ABSTRACT

Nowadays, the world faces many challenges and problems from climate change and global warming. Many scientific studies reported that different industries have huge roles to generate this condition. Specially, the construction industry has the most responsibility about these challenges on the earth. Doubtlessly, the utilization of inappropriate technologies, appliances, and materials in buildings have threatened the environment and human health today. So, there is a significant question, what is the appropriate way to solve these problems in construction industry? The engineers and technologists have realized the environmental problems are from using some technologies and materials in construction industry since over the past few decades. Scientists suggested the best way to overcome the aforementioned threats is to consider "sustainable" or "green" design for buildings. So, the main intention of sustainable building is to shift from harm to harmless technologies and materials in buildings. Thus, one of the main purposes of this study is to explore generally regarding sustainable technologies, standards, and materials, which help the buildings reduce consuming energy and resources, in order to generate the positive influences on people, nature, and society. Accordingly, "sustainable" buildings can be more friendly with environment and human, and use key resources, such as, energy, water, and materials more optimal than the conventional buildings. Furthermore, the study was to address the benefits of developing sustainability in buildings on different perspectives, based on the review and points out future directions of study.

KEYWORDS: Sustainability, Sustainable (Green) Building, Green Technologies/Materials, and LEED.

INTRODUCTION

The history of sustainability traces human-dominated ecological systems from the earliest civilizations to the present [17]. The ancient Chinese used concentrated solar power for heat energy, Native Americans used hot springs as renewable geothermal sources for cooking and healing, and some speculate the Egyptians used wind power to help build their pyramids [3]. But the Western Industrial Revolution tapped into the vast growth potential of the energy in fossil fuel. Coal was used to power ever more efficient engines and later to generate electricity. Modern sanitation systems and advances in medicine protected large populations from disease [4]. The results of Industrial Revolution increased the population and pollution from 17th to 20th Century. So, "Luddites" were emerged in the 19th in Britain, who smashed the factory machinery in opposition with the new factory systems and technologies. Similarly, after World War II, the "green movement or ecology movement" was appeared, its members were criticized the most new technologies generating environmental pollution, and advocated using green technologies [2].

During the energy crisis of the 1970's, sustainable issues moved from research and laboratories to reality in construction industry. Builders and designers were exceedingly looking for a way to reduce the reliance of buildings and homes on fossil fuels [3]. Moreover, they were considered that "sustainable buildings" consuming energy optimally for heating and cooling systems, and likewise using renewable energy (solar panels or wind power). With the turn of the new millennium, global competition has increased. This competitive pressure motivates the companies' management to verify their methods and practices [9]. One of the effective strategy for being more competitive in construction industry, is sustainability issues. Nowadays, "the green building trend has increased rapidly worldwide in recent decades as a means of addressing growing concerns over climate change and global warming, and to reduce the impact of the building industry on the environment" [17, p. 302]. Thus, developing new

technologies based on renewable energy in building can be very essential for energy conservation, environmental protection, and even future of the earth. According to USEPA [12], new technologies and materials are constantly developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by efficiently using energy, water, and other resources; protecting occupant health and improving employee productivity, and lastly reducing waste, pollution and environmental degradation.

However, understanding the specifics of sustainable building and determining effective sustainable practices can be confusing [13]. It seems that sustainable building design may generate extra amount of costs for construction companies and buyers for applying some extra standards and expensive techniques in first step. But the results have indicated that sustainable buildings can save too much money for energy and maintenance of the buildings, and also reduce environmental problems [10], [19], [6]. In order to design and develop easily green buildings, U.S. Green Building Council (USGBC) was the first organization that founded to present effective green standard for constructing sustainable buildings in 1993. Subsequently, USGBC members quickly realized that the sustainable building industry needs a system to define and measure green buildings. For this aim, the first LEED pilot project program, which referred to LEED version 1.0 was launched at the USGBC membership summit in August 1998 [14]. After successful implementation of the first green standard (LEED 1) by USGBC, several institutes were established to generate sustainable standards for buildings, such as, the U.K. Building Research Establishment Environmental Assessment Method (BREEAM) of the EU, and the Green Building Council of Australia (GBCA) Green Star system and others [18]. However, the green design is relatively still a new concept, and the history of green building only goes back a few decades [6]. But it seems that the sustainable buildings are becoming very popular in different countries, not just because home owners want to have more environmentally-friendly, safer, cleaner homes for their families, but also societies want the different individuals to achieve the efficiency and long-term advantages of constructing green homes in saving money, energy, and reducing waste [17], [19].

Sustainability concept

The terms “sustainability” and “green” that are often used “interchangeably”, have gained recognition in the architecture, engineering, and construction issues since over the past few decades [6]. Also, the effort to formulate a definition for sustainability leads to many of the issues and problems because there are several definitions for sustainability. For example, one website lists some 27 definitions for sustainability [2]. In ecology, sustainability is how biological systems remain diverse and productive. The World Commission on Environment and Development in 1987 defined sustainability as “the project to meet present needs without compromising the ability of future generations to meet their needs” [3]. According to Dusek [2] “sustainable development” is another sustainability term that was devised prior to the notion of “sustainability” in general, the comprehensive definition of sustainability includes:

- Maintenance of resources, particularly the use of renewable resources;
- Passing on of resources, the environment, and social benefits for future generations;
- Preservation of biodiversity and the integrity of the environment;
- Maintenance of technological and economic development, enhancing the well-being of the human population, and
- Fostering and enhancing of a comfortable and fulfilling lifestyle for the human inhabitants.

However, sustainability is not just about cos, it also offers equally economic, environmental and societal benefits. In other words, the concept of the sustainability can be interpreted the overlap of environment, economy, and society [15], as depicted in Figure 1.

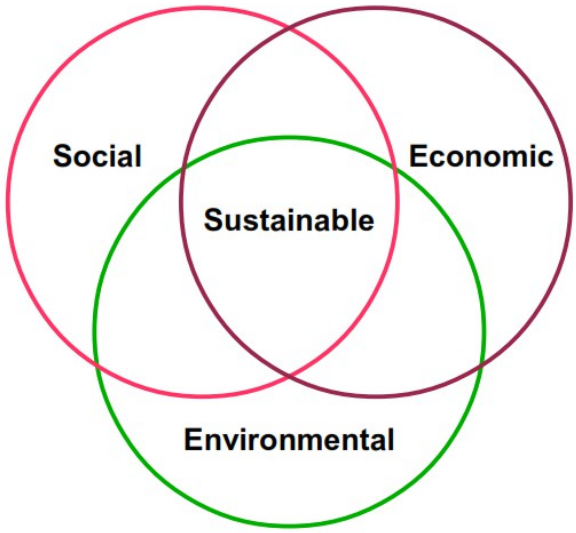

Figure 1: Concept of sustainability (Balancing economic, environmental and societal benefits)

Furthermore, sustainable development is not intrinsically the only a valuable issue, but it can also serve as excellent vehicles for launching a broader community conversation about economical, environmental, and social matters in general [11]. Significantly, the general definition of sustainability emphasizes that economical, ecological and social aspects are supposed to be given equal weight. Considering their application that is still not the case. As shown in Figure 2, the efforts have been made to bring the other two aspects back into balance, but these attempts have not yet been successfully happened in the reality [15].

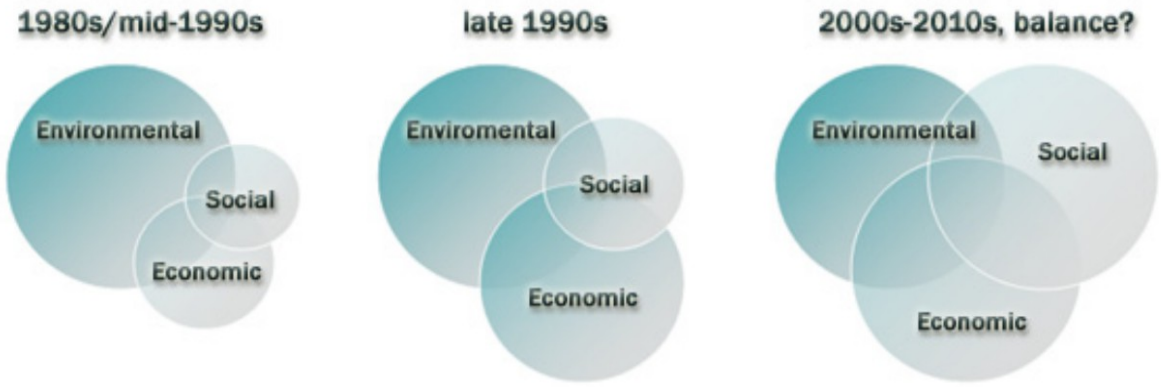

Figure 2: The Changes of balance on three main factors of sustainability since 1980s till 2010s in the world [15, p. 44]

Sustainability Building

The main target of sustainable building design is to develop "environmentally friendly construction practices" that contribute to save energy, water, and raw materials; minimizing water surplus and greenhouse gas emissions; and consuming reuse and recycle of materials, in order to create houses that are comfortable, clean, safe, and productive. Sustainability in construction engineering is a philosophy and an integrated design process, not only a building style [8], [19]. Dusek [2] stated that the metaphor and language of sustainability have increasingly become the central manner of expressing ecological concerns about the economy and technology today. Therefore, sustainable building is often referred to as "green" or "environmentally sound" building. Some interpret it as "timeless", others refer

sustainable buildings as buildings possessing high-technologies, or even "smart building" [11]. Accordingly, the synthesis work of sustainable building is formalized in the materials balance models with interrelationships between the economic system and the environment, as demonstrated in figure 3. In this framework the "economic system" is "open" and "circular", specified by a set of "extraction processes of matter and energy from the environment", then basic processing, production and consumption. Each of these processes makes at the end of its residues by now no longer usable in the environment, in its receptor bodies. Also, all these processes, productions, and consumption are based on sustainability in a building with the aim of generating a productive and economic house with minimum harmfulness on environment [1].

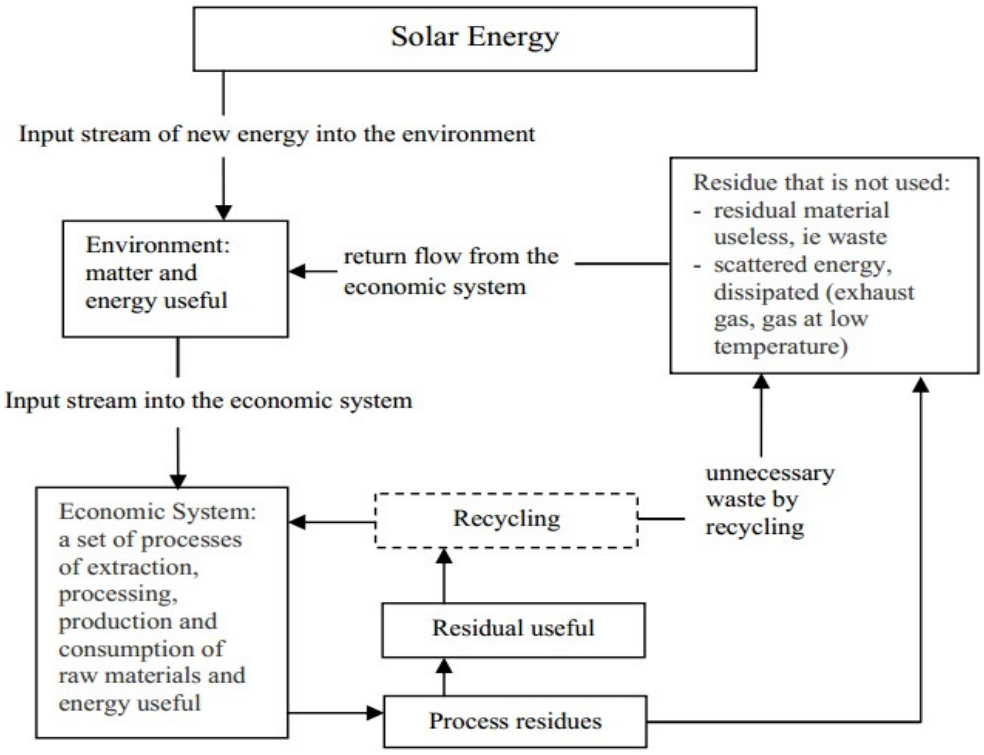

Figure 3: Interrelationships between the economic system and the environment in sustainable building [1, p. 19]

The sustainable (green) building design is the practice of creating structures and using processes that are environmentally responsible throughout a building's life cycle, such as, "site selection", "design", "construction", "operation and maintenance", "renovation", and "demolition" respectively. This practice expands and complements the classical building design concerning economy, utility, durability, and comfort [19]. Sustainable building is also known as a green or high-performance building. According to USEPA [12], the main elements of the sustainable buildings are namely:

- Harvest all their own water and energy needs on site. Be adapted specifically to site climate and evolve as conditions change;
- Operate pollution free and generate no waste that is not useful for some other process in the building or immediate environment;
- Promote the health and well-being of all inhabitants, as a healthy ecosystem does;
- It should comprise energy efficient integrated systems that maximize efficiency and comfort;
- Improve the health and diversity of the local ecosystem rather than degrade it and;
- Be beautiful and inspire us to dream.

THE MAIN ASPECTS OF SUSTAINABLE BUILDING

Sustainability Building

U.S. Department of Energy estimated that buildings in the United States accounted for 73.6% of total electricity expenditures, and 40% of the total carbon emissions in 2012 [19]. Thus, new building technologies should constantly be introduced to minimize consuming electricity and harmful impact of the building on the surrounding environment. The main specifications of these technologies (green) should be namely [5]:

- Using resources more efficiently (energy, and water);
- Enhancing and protecting the health and well-being of the occupants, and;
- Reducing negative impacts (waste, sewage, and pollution).

The implementation of the sustainable (green) building needs to utilize green technologies that are more involved in the development and utilization of products, equipment and systems that conserve the natural environment and resources. These technologies can improve the performance of the buildings on environment, people, and economy [10]. Many case studies were shown that home builders and developers have been embraced the concepts of Eco-friendly building, and emphasized on the green technologies with buildings, in order to increase ventilation control, enhance temperature control, enhance lighting control, and increase day-lighting. Thus, green technologies can significantly be correlated with high level of productivity and performance in the buildings [19]. There are many equipment and tools, which are the results of the investigation and development of the green technologies for buildings, they can be categorized into four main groups in construction industry [16], as follows:

- Energy: Passive solar, heat pumps, and solar energy;
- Water technology: Water harvesting, and aqueduct system;
- Natural lighting: Design with retractable awnings, and day-lighting design (sunlight transportation systems, energy efficient light bulbs, compact fluorescent lights (CFL), light emitting diodes (LED), and sustainable lighting, and;
- Natural ventilation.

Green Materials

Another main aspect of sustainable buildings is green materials. It is very important to know that construction industry uses large quantities of natural resources today. In fact, construction activities utilize 60 percent of the raw materials, and similarly 60 percent of the nation's surplus and non-hazardous solid waste are belonged to construction industry in the USA [11]. There are some materials that can be used in constructing buildings, as widely known green materials. These materials are recyclable, reusable and to prevent wasting energy in the houses [16]. Likewise, salvaging building materials and reusing them can save energy and reduce greenhouse gas emissions by minimizing the need to extract and process raw materials and ship new materials from long distances to construction projects. In addition, the green materials reduce the economic and environmental impact from waste disposal [11]. As stated by Milani [7], a green material is one that simultaneously does the most with the least, fits most harmoniously within ecosystem processes, helps eliminate the use of other materials and energy, and contributes to the attainment of a service-based economy. Torgal and Jalali [11] asserted the majority of materials in construction industry are not green, and the green materials can be specified in the following groups:

- Resource efficiency: It can be performed by utilizing materials that meet the following criteria:
  a) Recycled content,
  b) Natural plentiful or renewable,
  c) Resource efficient manufacturing process,
  d) Locally available,
  e) Salvaged, refurbished, or re-manufactured,
  f) Reusable or recyclable, and
  g) Recycled or recyclable product packaging.
- Indoor air quality (IAQ): It can be enhanced by using materials that meet the following criteria:

a) Low or non-toxic,
b) Minimal chemical emissions,
c) Low-Voc assembly,
d) Moisture resistant, and
e) Healthfully maintained.

- Energy efficiency: It can be maximized by utilizing materials prevent wasting energy (insulating materials), and;
- Water conservation: It can be obtained by using materials that conserve and restore water (water harvesting and natural refinery for water).

Green Building Standards

Several countries including the U.S., U.K., Australia, Canada, Japan, Korea and India have either already presented the green building guidelines, or are in the process of developing them [6]. Doubtlessly, green standards have the essential roles to design and develop sustainability in construction industry. The main aim of a green standard (checklist) is to ensure that the sustainable issues are comprehensively implemented in all stages of green housing project. Thus, using an established green building rating system is recommended [16]. There are variety standards related to green building rating system, or green standards, such as, the American Leadership in Energy and Environmental Design (LEED), the U.K. Building Research Establishment Environmental Assessment Method (BREEAM), and the Green Building Council of Australia (GBCA) Green Star system, have been presented to assist the construction industry in implementing green building projects by providing guidelines for green buildings [18]. Amongst these green standards, LEED or US green building standard is the best green building rating system.

The Leadership in Energy and Environmental Design (LEED) was created by the U.S. Green Building Council in 1998 [6]. The main targets of LEED are to promote healthful, durable, affordable, and environmentally sound practices in building design and construction within 7 topics: 1) Sustainable sites; 2) Water efficiency; 3) Energy and atmosphere; 4) Materials and resources; 5) Indoor environmental quality; 6) Innovation in design, and; 7) Regional priority. The findings were revealed that the LEED certified buildings contributed toward the tenants' health and productivity because of "improvements in indoor environmental quality" [18]. This standard has a rating system with different checklists for new construction and major renovations based on sustainable development, it is also a set of performance standards for certifying the design and construction of commercial, or high-rise residential buildings of all sizes for both public and private, meet the sustainable criteria. Thus, the inspectors have important role to evaluate the building, and give a certain score for each stage of a building from first to the end step. Consequently, the buildings can achieve awards ranging, if they met LEED guidelines in four levels [14]. Meanwhile, LEED certificates can be granted to the green buildings based on the following scales [5]:

- LEED Certified 40–49 points;
- LEED Silver 50–59 points;
- LEED Gold 60–79 points;
- LEED Platinum 80 points and above.

BENEFITS OF SUSTAINABLE BUILDING

Benefits of sustainable building on social perspective (Quality of life, health, and safety)

Acceptance of the green building guidelines in various societies can be attributed to comparatively a long history of this movement [6]. Nowadays, the factor of "feel-good" is a social motivation to construct green buildings, especially in huge cities [8]. The social benefits of sustainable design for buildings are more related to improve the quality of life, health, and well-being. High-performing sustainable buildings provide the best value for the individuals, and likewise positive effects on society [13]. As a result, sustainable buildings have better indoor air quality, comfort, and economy, likewise sustainable building more likely to convince buyers for possessing a direct impact on their health and happiness. In non-green buildings, there are literally hundreds of contaminants in the materials used to construct homes, these dangerous chemicals have been linked to childhood asthma, adult respiratory problems, and headache. Often called "sick building syndrome", these contaminants directly affect the

health of occupants in big cities. However, theses problems can be easily eliminated by using the green materials [16], [18].

Benefits of sustainable building on economic perspective

The financial benefits of sustainable buildings are 10 times more than the average initial investment required to design and construct a sustainable building in long term. The benefits of life cycle cost savings on utility costs and maintenance costs make building green especially attractive to owners, and certain aspects of sustainable design mirror value engineering principles in right-sizing the building and systems [19], [8]. A sustainable building should be constructed or renovated by techniques, technologies, and materials that reduce the dependence of houses on fossil fuels, and minimize sewage. Without doubt, the greatest benefit of green buildings is to lower energy and water bills [11]. A survey of 99 sustainable buildings in the US indicated that an average of 30% less energy was consumed by green buildings in comparison with non-green buildings [19]. Similarly, the results of several studies showed that sustainable buildings can save for [14]:

- 36% of total energy use and 65% of electricity consumption;
- 30% of greenhouse gas emissions;
- 30% of raw materials use;
- 30% of waste output, and;
- 12% of potable water consumption.

Benefits of sustainable building on environmental perspective

The buildings and the built environment play a major role in the natural environment. Interestingly, green buildings have the potential to reduce the negative effects on the environment and offer business and occupant health related benefits [6], [18]. Sustainable buildings use energy, land, and water more efficiently, and produce less waste and pollution than conventional buildings. In green buildings, often the used materials are recycled, and low or non-toxic materials [11]. Protecting the environment is certainly the primary benefits of sustainability in construction industry. Today modern American buildings should consider environmental issues, and follow sustainable criteria for constructing and renovating the buildings in different areas, such as: site selection, materials and resources, energy use and air pollution, water quality, and indoor air quality [16]. According to USGBC [13], a building project should clearly measure and indicate that all processes in constructing and renovating a building are safe and clean for the environment. Perhaps the easiest way is to understand the principles of sustainable building design, and how negative impacts of the buildings can be reduced or eliminated through more effective planning, design, construction, and operation in sustainable building projects based on the guidelines of green standards.

CONCLUSION

As mentioned earlier, the major aims of this study were to understand the sustainable building, and its advantages as well. From the study, it was concluded that the sustainability can minimize the harmful impact of the conventional buildings on environment, economy and people in using green materials, technologies. “Sustainable” or “green” buildings use key resources like energy, water, and materials more efficiently than conventional (non-sustainable) buildings. Furthermore, sustainable buildings increase natural light, incorporate high-performance systems, rain-water system, and improve air flow for occupants. Sustainable building has many obvious benefits to builders, buyers, and others, but these benefits cannot be achieved without applying proper a sustainable (green) standard like LEED, which is a proper rating system to assist designers and builders in understanding and implementing sustainability in construction industry. Accordingly, if sustainable principles can be used in building projects, then numerous benefits of green buildings may be achieved, as follows:

- Environmental benefits:
  Enhance and protect biodiversity and ecosystems;
  Improve air and water quality;
  Reduce waste streams, and;

Conserve and restore natural resources.

- Economic benefits:
  Reduce operating costs;
  Improve occupant productivity, and;
  Optimize life-cycle economic performance.
- Social benefits:
  Enhance occupant health and comfort;
  Improve indoor air quality;
  Minimize strain on local utility infrastructure, and;
  Improve overall quality of life.

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