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Energy performance of buildings: The evaluation of design and construction measures concerning building energy efficiency in Iran

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ABSTRACT

The main purpose of this study is to identify and evaluate the design and construction measures concerning building energy efficiency in Iran. In this regard, reducing energy consumption and using renewable energies are the main approaches of this paper. Thus, firstly, the most applicable renewable energy system in building industry has been identified; then, the design and construction measures have been identified and evaluated with respect to their effects on the building energy-performance; utilization of renewable energy systems as well as energy consumption patterns. In this way, utilization of renewable energy has been evaluated on the basis of experts' opinion and energy consumption has been evaluated on the basis of energy simulation. The primary result of this research revealed that, passive solar energy is the most applicable renewable energy system in urban areas and buildings in Iran. Furthermore, 23 design and construction measures were identified and categorized into 12 groups. Finally, the groups of measures are evaluated and classified into three levels of high, medium, and low importance with respect to their effects on buildings energy-performance.

1. Introduction

Sustainability in construction developments has to result in the creation and responsible maintenance of a healthy built environment, based on ecological principles, and through an efficient use of resources. Buildings not only use the existing resources such as energy and raw materials but they also generate the waste and potentially harmful atmospheric emissions [1]. Clearly, sustainability in the construction industry offers an outstanding response to the current environmental and socio-economic problems [2]. In this regard, green building is now becoming a flagship of sustainable development in this century that takes the responsibility for balancing long-term economic, environmental and social health. Green building offers a considerable opportunity to create environmentally efficient buildings by using an integrated approach for design so that the deteriorative impacts and devastating effects of buildings on the environment and public health can be diminished. Green building does not only reduce the deteriorative impact of buildings on public health and environment, it also cuts operating costs, enhances occupant productivity and facilitates sustainable development of the society.

In the present time, one of the most critical global issues is the pollution caused by the consumption of fossil fuels. Buildings are the largest consumer of energy and decisive factor in greenhouse gas emissions. Buildings operation accounts for about 40% of global energy and carbon dioxide emissions. Therefore, sustainability in general, and energy efficiency in particular have become the key measures of building performance [3]. Because of a great amount of fossil fuel consumption in non-energy-efficient buildings, environmental pollution has increased notably. In order to reduce the energy used in buildings and the relative effects on the climate, several strategies seem to be necessary, including energy demand reduction, adoption of passive systems and improvement energy efficiency [4]. Implementing such strategies in a green building would normally raise the initial capital costs of the building compared with a conventional home. Yet, the added benefits regarding energy savings over the time are believed to collectively offset part of this increased capital cost [5]. Motawa and Carter [3] emphasized that with a slight increase in up front building cost of 2%, a lifecycle savings of about 20% of the initial building cost can be achieved.

Energy consumption in households is a focus in many countries [5]. The main purpose of this study is to identify and evaluate the design and construction measures concerning building energy efficiency in Iran. In this context, firstly, the most applicable renewable energy system in building industry is identified, then, the design and construction measures are identified, validated and evaluated with respect to their effects on the building energy-performance;

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renewable energy systems utilization and energy consumption. In this way, utilization of renewable energy is evaluated on the basis of experts' opinion and energy consumption is evaluated on the basis of energy simulation.

2. Literature review

There are numerous studies related to energy and energy efficiency, which emphasize on various optimal strategies to improve energy performance and design and construct sustainable buildings. A review of literature showed that the studies related to the purpose of this research can be classified into the following two categories:

- **Building efficient energy performance.** Balaras et al. [6] assessed and compared the influence of envelope thermal insulation, age and conditions of the heating system on the heating energy consumption and the resulting environmental impacts on buildings; based on 193 case studies. They concluded that approximately 38% of the audited buildings have the annual heating energy consumption higher than the average European consumption. Saroni and Hestnes [7] evaluated and compared the lifecycle energy consumption in a typical as well as an optimized building. The results of their research clarified the important difference in energy consumption due to the differences in the design and construction practices of buildings. Ramesh et al. [8] evaluated and compared the lifecycle energy consumption in both residential and office buildings. The findings of their research disclosed that the operating and embodied phases of energy usage are significant contributors to the buildings' lifecycle energy demand. Furthermore, the buildings' life cycle energy demand can be lowered by reducing the operating energy significantly through application of passive and active technologies even if it would lead to a slight increase in embodied energy. Taleb and Sharples [9] provided an overview of the current situation of buildings and identified some measurements for increasing the energy and water consumption in order to develop sustainable residential buildings in Saudi Arabia. They defined and applied some energy optimization criteria on simulated model using Design Builder (an energy simulation software), to propose the number of effective criteria on reducing energy consumption. In another research, Chang et al. [5] developed an optimal design for water conservation and energy saving. The plan suggests utilizing green roofs in green buildings. More recently, Qaemi and Heravi [10] carried out an investigation to find the most feasible renewable energies in Iran. They studied renewable energies in respect a couple of major approaches: (1) The feasibility and economic justification of using renewable energy systems (such as the applicability in urban areas, reducing fossil fuels consumption, the effects on the initial construction costs, and the effects on operations and maintenance costs); and (2) The existing obstacles for using renewable energy systems (including lack of government support, awareness, technical technologies, appropriate facilities and planning approaches, in addition to significant initial costs).
- **Building energy performance criteria.** Juan et al. [11] studied several systems including Leadership in Energy and Environmental Design (LEED) [12], Building Research Establishment Environmental Assessment Method (BREEAM) [13], and Green Building Tool (GB Tool). Their purpose was renovating and improving energy performance of office buildings. Soussi et al. [14] studied the energy performance of a solar cooled office building located in Tunisia using the TRNSYS software. The simulations assessed the real case study and analyzed the impact of its architectural characteristics and passive techniques on its energy requirements in order to analyze the effect of these passive techniques and propose solutions to take advantage of them in winter and prevent their overheating effect in summer. They analyzed isolation of the wall and cool roof, window glazing type, trombe walls and shading. In another research, Yoo et al. [15] evaluated some measures to reduce energy consumption in construction sector. They emphasized that high-efficiency window systems can play an important role in reducing energy consumption in buildings. They measured the thermal performance (U-factor) of different window systems and analyzed their effects on energy savings in the central and southern regions in South Korea. Mwasha et al. [4] focused to explore the principal sustainable energy performance indicators in order to model the energy performance of the residential building envelope and develop an approach for determining the most appropriate sustainable energy performance indicators. Gong et al. [16] studied passive design, as the most economical effective strategy for reducing energy consumption inside residential buildings. This paper presented an approach in which the orthogonal method and the listing method were integrated to explore how energy consumption is minimized in residential buildings by optimizing seven passive design measures. They asserted that the passive design could reduce annual thermal load of building considerably. This paper indicated that the external wall insulation thickness and the sunroom depth are the two most important parameters affect the annual thermal load.

3. Methodology

As shown in Fig. 1, the methodology of this research comprises six main stages as follows:

- Identifying the most applicable renewable energy system in building industry in Iran.
- Identifying the design and construction measures concerning building energy efficiency (i.e., non-renewable energy consumption and renewable energy system utilization).
- Validating the design and construction measures based on the Green Globes rating system.
- Evaluating the measures with respect to energy consumption, by utilizing energy simulation.
- Evaluating the measures with respect to passive solar energy utilization, as a renewable energy system, by using experts' opinion.
- Determining the most effective design and construction measures concerning building energy efficiency.

The above mentioned stages are explaining through the following subsections:

3.1. Identifying the most applicable renewable energy system

As the economy expands and population continues to rise, designers and builders are facing a unique challenge to meet the demands of new and renovated facilities that could be accessible, secure, healthy, and productive while minimizing their impacts on the environment [1]. In the past decade, the emphasis on green building design has directed mainly to the development of energy saving technologies such as solar panels and wind farms [5]. The purpose of this section is to identify the most applicable renewable energy system in Iran, as a developing country.

Currently, several types of renewable energies are used for different applications. However, in this paper, the renewable energy systems that are more common, accessible, and useful for buildings have been surveyed, including: active solar energy, passive solar energy, wind energy, geothermal energy, and fuel cell.