An Overview of the Use of Solar Energy in Building Construction Projects

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ABSTRACT

Global warming has made climate change one of the most critical issues in sustainable development. In this regard, recent studies have indicated that the rapid growth in building constructions and the rise in fossil fuel consumption in the building sector have resulted in higher greenhouse gas emissions that can lead to irreversible and significant environmental repercussions. In the last two decades, solar energy systems have been seen as some of the most effective methods to reduce fossil fuel consumption in the industry and minimize its environmental impacts. However, the research in developing countries examining the basic requirements of implementing solar systems in the construction industry is limited. Accordingly, this study attempts to investigate the barriers to implementing solar systems via a systematic literature review. This research has employed a qualitative approach using NVivo to analyze the barriers identified in previous research, adopting descriptive and focused coding approaches. Collecting and classifying barriers help reveal the challenges of using solar energy in construction projects, serve as a basis for further research to localize barriers based on the research area, and tackle them to move towards sustainable development.

Keywords: *Solar energy, solar energy barriers, construction projects, sustainable development*

1. Introduction

Increasing greenhouse gas emissions, especially carbon dioxide emissions from fossil fuel consumption, have led to climate change and global warming, which are among the most pressing concerns in the 21st century [1]. Global warming is predicted to continue, and failure to mitigate climate change will lead to significant economic, social, and environmental impacts [2].

The construction industry is responsible for the majority of greenhouse gas emissions due to the increase in fossil fuel use [3].

According to the International Energy Agency, the building sector is responsible for roughly 40% of total energy consumption worldwide and emits significant amounts of carbon dioxide and greenhouse gases [4]. Construction energy consumption rises in tandem with economic development [5]. More environmental issues emerge as energy demand increases, and immediate action to reduce fossil fuel consumption can reduce greenhouse gas emissions and climate change [4].

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Renewable energy is a global solution to reduce fossil fuel consumption and combat climate change in the building sector [3]. Solar energy is a suitable alternative to fossil fuels in supplying the energy required by buildings due to its availability in all countries, its ability to meet growing energy demands, and its usability in construction projects [6]. Therefore, it is important to consider solar energy in construction projects [7]. Even though solar energy has a high potential for use in many countries, there are barriers and limitations to its widespread use in construction projects [8]. Hence, this study examines the current conditions associated with construction projects utilizing solar energy.

2. Literature Review

2.1. The Role of Buildings in Climate Change

Building energy consumption varies with the type of a building and the environment where it is located [9]. Buildings are responsible for about 40% of energy consumption and 50% of carbon dioxide emissions [6]. Energy is consumed at all stages of the building life cycle, but the highest amount of energy is consumed during operations [9]. Typically, 90% of the energy is consumed while the building is in operation, so there should be a significant focus on reducing energy consumption in this period [10].Increasing populations and growing economic activities have led to a rise in construction projects in many countries, especially the developing ones [11]. The increased demand for residential and commercial space leads to higher energy consumption in buildings [12]. According to published reports, energy consumption in buildings worldwide will increase by 1.5% annually from 2012 to 2040 [13]. Therefore, the building sector contributes significantly to greenhouse gas emissions, and the reduction of fossil fuel consumption in this sector plays a significant role in limiting global warming [12].

2.2. Renewable Energy

The increasing energy consumption and environmental concerns have resulted in a global shift to renewable energy [14]. The use of renewable energy instead of fossil fuels requires extensive planning, resulting in a reduction in carbon dioxide emissions by three billion tons [15]. Today, the development of renewable energy technologies in many countries is aimed at reducing their consumption of fossil fuels, thereby addressing climate change issues [16]. In order to succeed in this field, renewable energy must be used worldwide [17]. While many countries use renewable energy, its consumption in the world remains at 8% [6]. Renewable energy use varies from region to region [18]. Solar, wind, small hydropower (for rural use near rivers), and geothermal energy constitute the most popular renewable energy sources in the building sector, reducing environmental damage and global warming [6].

2.3. Solar Energy

With the need to reduce the consumption of fuel resources, solar energy has become an increasingly important solution [19]. Although a heavy canopy of clouds can limit the use of solar systems, solar energy has several edges over other renewable energy sources. As opposed to nuclear power reactors, the use of solar energy does not generate radioactive waste or cause acid rain. There is no noise pollution caused by solar energy systems since most of them are silent [20]. As solar energy creates electricity with no environmental impact, it can be called environmentally friendly energy. Undoubtedly, the process of their construction, installation, maintenance, and burial results in the emission of carbon dioxide [21].

Solar energy is the most abundant source of renewable energy that is accessible and free for all countries [14]. Solar energy has the potential to meet the growing energy demand and can guarantee energy supply [10]. Different parts of the world receive different amounts of solar energy annually. The United States, most Latin American countries, Africa, Australia, India, parts of China, and other Asian countries have an excellent solar energy source, and the use of solar energy in these areas is expected to increase significantly in the upcoming decades [14].

2.4. The Use of Solar Energy in Construction Projects

Among renewable energy sources, the use of solar energy in construction projects is more probable and brings about better results. Solar energy is used in either an active or a passive form [6]. Both methods aim to optimize the use of solar energy; however, the nature and the functionality of each one differ; each is employed based on the regions' needs and climatic conditions, and according to the

demands and objectives of the projects (heating, cooling, or electricity) [22].
Many countries have a proper condition for using solar energy [23], and most people have a positive view on using solar energy in buildings. Nonetheless, this energy is not widely used in the building sector [24]. Therefore, despite the advantages of using solar energy, there are barriers to its use in the building sector, which are assessed and classified in this project through investigating the previous studies to gain a complete understanding of them. The methodology is explained in the following section.

3. METHODOLOGY

The use of solar energy in construction projects is analyzed in this research, and the barriers to using solar energy in construction projects are attained through a quantitative literature review. The papers for this research were selected from reliable journals and databases. The sources were carefully examined, and the required information was extracted. The qualitative analysis software QSR NVivo (Version 10) was employed to analyze the collected data (barriers) qualitatively. The following section discusses the data analysis and coding details. The NVivo software is generally applicable for analyzing texts in qualitative research, coding texts, and examining current codes and their links. Fig. 1 briefly demonstrates the used methodology.

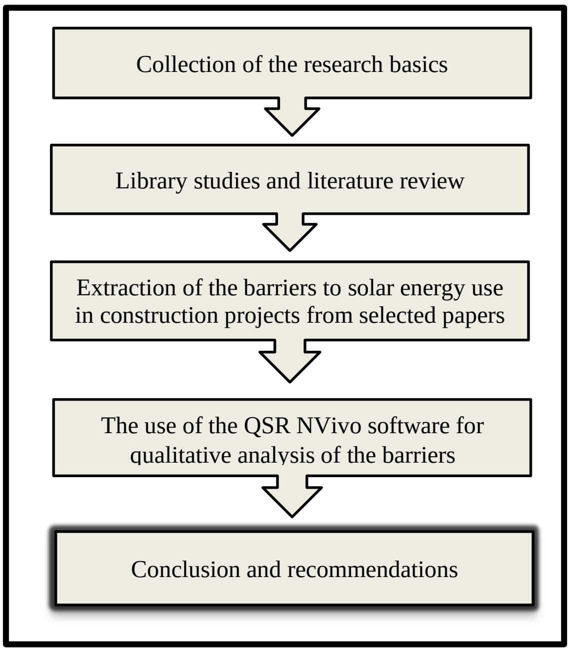

Fig 1: Methodology (Source: Authors)

3.1. Data Coding

In qualitative analysis, coding is often a word or a short phrase symbolically assigned to a piece of text- or image-based data [25]. Coding is a step-by-step process [26]. Since each qualitative research is unique, its analytic approach would also be unique [27]. In this research, descriptive coding and focused coding methods were employed.

3.1.1. Descriptive Coding

Descriptive coding applies to examining documents, interviews, papers, and magazines [25]. First, the data of papers are entered into the NVivo software, and then the coding stages begin. As demonstrated in Fig. 2, the parent node is created based on the defined research objective in this study.

Fig 2: Parent node (Source: Authors)

All the barriers extracted from the papers are considered codes. Then, codes are classified into a similar concept. Codes that have mutual content are assigned a mutual code. Coding in NVivo is saved in nodes and tree nodes [28]. As shown in Fig. 3, parent nodes are supported by several child nodes. If needed, new nodes are generated.

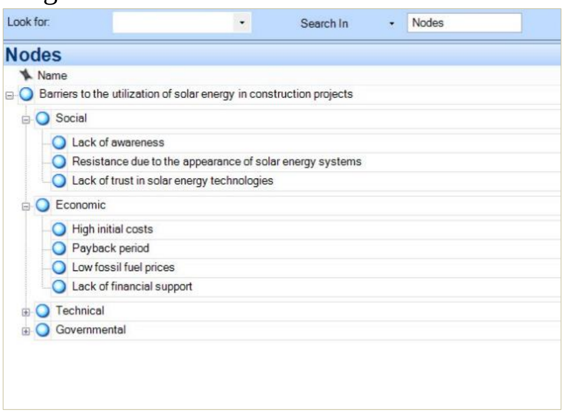

Fig 3: Coding Details (Source: Authors)

3.1.2. Focused Coding

In order to finalize the coding process, focused coding is required [25]. This stage focuses on analyzing and reviewing nodes, their content, and their selected names. Moreover, it helps generate structured tree nodes. Fig. 4 demonstrates the tree node of barriers in using solar energy in construction projects based on their qualitative analysis through NVivo.

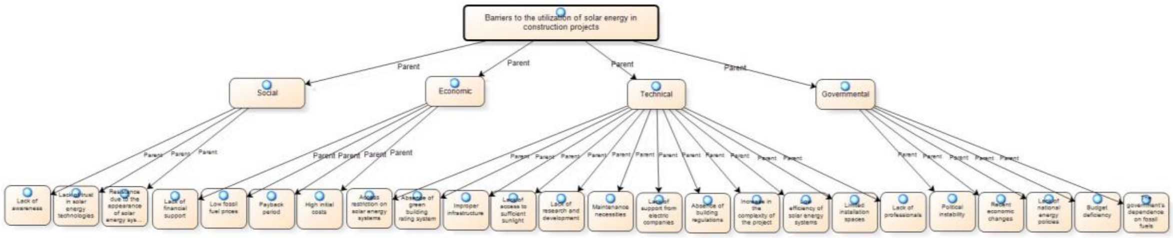

Fig 4: Structured tree nodes of barriers to the use of solar energy in construction projects (Source: Authors)

4. Findings

After analyzing the studies available on the use of solar energy in construction projects, it was found that various studies have examined the barriers in accordance with their own research area. This results in the lack of a complete list of barriers since only a few are mentioned. Moreover, despite the similarities seen in the works of researchers, there is no final and absolute list regarding the classification of barriers, and there has been little attempt at integrating barriers to the use of solar energy. This research identified 24 barriers through the analysis of previous studies on the use of solar energy in construction projects as well as the qualitative analysis of barriers in QSR NVivo. According to descriptive and focused coding methods in QSR NVivo, these barriers are classified into social, economic, technical, and governmental groups. Section. 3 discusses the research methodology and coding details. Table 1 represents the barriers and their classification resulted from qualitative analysis in QSR NVivo. The classification of barriers helped provide a better understanding of the prospective problems and challenges regarding the use of solar energy in construction projects. Additionally, the classified list of barriers can be used as a basis for future research.

Table 1: The conceptual framework of barriers to the use of solar energy in construction projects

Classification	Barriers
Social	– Lack of trust in solar energy technologies [21, 29, 30, 31, 32] – Resistance due to the appearance of solar energy systems [9, 21, 31, 33] – Lack of awareness [9, 14, 21, 31]
Economic	– High initial costs [9, 21, 30, 31, 33] – Payback period [9, 14, 21, 30, 33] – Lack of financial support [9] – Low fossil fuel prices [9, 14]
Technical	– Low efficiency of solar energy systems [9, 14] – Lack of research and development [14, 16, 21, 33] – Access restriction on solar energy systems [9] – Maintenance necessities [9, 16] – Lack of professionals [14, 29] – Lack of support from electric companies [9] – Absence of building regulations [9, 21] – Increase in the complexity of the project [9] – Limited installation spaces [9, 21, 31, 30] – Improper infrastructures [21] – Lack of access to sufficient sunlight [9, 14]

	− Absence of a green building rating system [9]
Governmental	− Lack of national energy policies [14, 16, 21] − Political instability [16] − Budget deficiency [16] − The governments' dependence on fossil fuels [21] − Recent economic changes [9, 21, 31]

(Source: Authors)

5. Discussion

By analyzing different studies and identifying and classifying the barriers, it was found that economic and technical barriers are the biggest challenges in using solar energy in construction projects on a global scale. These barriers differ in importance concerning their research scope. Due to the relatively new nature of solar energy technologies compared to fossil fuel technologies, there is a growing effort in developed countries to remove technical and economic barriers [16]. Solar energy use in developing countries is faced with more technical and economic barriers due to financial and human resource limitations [34].

In addition to technical and economic barriers, social and governmental barriers are of great importance in developing countries. Despite the environmental advantages of renewable energy use, solar energy is not widely used, especially in developing countries, and the social resistance can significantly reduce the use of solar energy technologies in these countries. Additionally, in developing countries, especially the poor ones, there are no specific policies and regulations governing the use of solar energy, which prevents the use of solar energy systems [14].

The analysis of barriers also indicated that despite the specific classifications of barriers, some are effective in creating or intensifying barriers in other classifications, which can be further discussed. For instance, governmental barriers, mentioned in a few studies, affect many other classes. This shows that focusing on solving governmental barriers can lead to the reduction or elimination of many barriers from other classes. Furthermore, a review of economic barriers reveals that they are somewhat interdependent and can influence one another. Economic barriers, including initial costs of solar energy use, play a great role in people's decision-making and indirectly affect social barriers. In general, the successful progress of renewable energy use includes the development of policies and frameworks, which lead to the competitive use of renewable and sustainable energy sources [21].

6. Conclusion And Recommendations

The growing greenhouse gas emissions and climate change due to excessive fossil fuel consumption have highlighted the need for renewable energy sources. Since the building sector consumes considerable energy during operation, replacing fossil fuels with renewable energy sources is critical to reduce environmental pollution and achieve sustainable development. Due to its availability and great potential of meeting the growing demands of energy, solar energy is a proper alternative for reducing greenhouse gas emissions and climate change, which can be easily used in construction projects. Despite the numerous advantages of using this energy in the building sector, significant barriers have hampered its optimal use on a global scale. This project examined solar energy use in construction projects. Through qualitative literature review, the required data were extracted from previous studies. Afterward, the existing barriers were classified through descriptive coding and focused coding in the qualitative analysis software of QSR NVivo (Version 10). Finally, 24 barriers were identified, presented in 1) social, 2) economic, 3) technical, and 4) governmental groups.

Results of this research reveal the barriers to implementing solar energy systems in the construction industry. According to the analysis results, some barriers were found to be globally important, whereas some were limited to specific countries. Globally, the main focus is on economic and technical barriers. Initial cost, payback period, and limited installation spaces are the most important barriers often mentioned in various related studies. In research conducted in developing countries, the substantial barriers identified are lack of awareness and knowledge, lack of professionals, lack of research and development, and absence of a national energy policy. In contrast, other factors, such as climate, political instability, and dependence on fossil fuel revenues, were the least mentioned in previous studies, demonstrating that the focus of this research is on a specific area.

This research collects and categorizes barriers found in previous studies by conducting a qualitative analysis in QSR NVivo. Collecting and classifying barriers help organize the information and provide construction project managers and designers with a clearer perspective on the challenges of solar energy use in construction projects. Making an organized image of barriers will create a proper background for tackling the barriers in future research. Therefore, future research can explore some solutions to tackle these problems. Furthermore, since countries face various barriers to using solar energy, future research should identify the challenges of using this energy in the context of Iran to reduce or eliminate these barriers following the governing conditions in the construction industry.

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