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Consensus-based low carbon domestic design framework for sustainable homes

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ABSTRACT

The paper proposes a low carbon domestic design framework for sustainable homes in Saudi Arabia, characterized by a rigorous climate and unique regional socio-cultural features. This is informed by (a) an in-depth investigation of the Saudi domestic building stock, including landscaping, massing, space layout, building fabric, on-site renewable potential, and occupants' lifestyles; and (b) a consultation with 40 experts across Saudi Arabia. The consultation was carried out using the Delphi Technique in multiple rounds. The established framework factors in architectural design strategies, building envelope design, and on-site renewable energy strategies for Saudi Arabia, taking into account socio-cultural considerations. A consensus between the consulted experts was achieved. The proposed framework is applicable and suitable for Saudi Arabia and beyond, including the Middle Eastern region.

Contents

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1. Introduction

The building sector, being the largest consumer of electric energy, represents a major potential contributor for reducing energy consumption in Saudi Arabia [1,2]. Official sources, such as the ministry of electricity in Saudi Arabia [3], state that over 50% of energy in the form of electricity is used to operate a wide range of appliances in domestic buildings. natural sources of energy, such as solar radiation and wind, should promote the wide use of on-site renewable energy technologies, including photovoltaic [4–6], as alternatives to non-renewable energy sources. many developed countries have addressed the energy agenda via a stringent regulatory environment [7,8]. However, these codes and regulations do not exist in Saudi Arabia [9,10].

The paper aims to develop a low carbon domestic design framework for sustainable, low-carbon homes in Saudi Arabia. This will also involve a presentation of the weaknesses of architectural design and building fabric, identified by authors in previous studies. In order to present these strategies, relevant studies from existing literature will be reviewed and an appropriate methodology, in meeting the objectives of this paper, will be established. In the light of this, the paper is structured into five main categories; (a) related work, (b) methodological approach, (c) results and analysis, (d) established low carbon domestic design framework for sustainable homes, and (e) conclusion, recommendations and future work.

This research contributes to the body of knowledge by proposing a framework for the design of low energy homes taking into account the hot climate of Saudi Arabia, as well as the specific cultural requirements of the region. This framework will address various aspects such as architectural design (form), house envelope design, construction materials (fabric), and on-site renewable energy solutions, taking into account local socio-cultural issues. Architecturally, the proposed strategies cover building design, shading devices, heating, ventilation, air conditioning (HVAC), and massing. In terms of house envelope (design and construction materials used), the framework will cover building fabric design strategies, such as the design of the external walls, roofs, floors and external glazing. The low carbon domestic design framework will also offer strategies for use with renewable energy resources. Generally, the framework will assist architects, civil engineers, building professionals and developers to design low energy buildings in Saudi Arabia. Furthermore, the framework is scalable to other countries in the middle East region."

2. Related studies

Aldossary et al. [11] investigated the energy consumption patterns of domestic buildings in hot and arid climates in Saudi Arabia. They selected multiple domestic buildings (three houses and three flats) in different locations in Riyadh city and employed IES-VE tool to simulate each building individually, taking into account architectural design (form), construction materials (fabric), and occupants' behavior. They reported the design weaknesses in existing homes in Saudi Arabia that result in high energy consumption and high CO_2 emission rates. These identified weaknesses are related to architectural design (form), house envelope (fabric), occupants' behaviors, and inexistent onsite renewable energy uses. Furthermore, they suggested some possible energy retrofitting solutions to enhance energy efficiency in these existing homes. They employed IES-VE simulation tools to validate the efficiency of these solutions that offer energy saving of up to 34%.

Conversely, Aldossary et al. [12] conducted a related study within the city of Jeddah (known for its hot and humid climate). The results confirmed and were similar to the former study of Riyadh. The proposed energy retrofitting program helped achieve simulated energy saving of up to 37%.

In hot climatic conditions, air conditioning systems are employed to cool down the indoor spaces to attain a satisfactory level of thermal comfort. This requires over 70% of consumed energy [11,12]. However, means to minimise energy demand for air conditioning have been implemented in order to attain the satisfactory level of thermal comfort. Several studies have discussed how to reduce energy consumption for air conditioning. Zaki et al. [13] advocate the use of passive architectural design principles in terraced houses, with a view to promoting natural thermal comfort for residents. They have adapted the design strategy of passive architecture to terraced houses to lessen the demand for mechanical cooling. They attained a major energy reduction (approximately 83%) through the use of passive architecture design principles. Wang et al. [14] analysed the efficiency of water thermal storage walls in new and retrofitted buildings. They found that when using variance analysis there were four major structural parameters influencing energy consumption and attainment of the satisfactory level of thermal comfort: (i) building shape coefficient, (ii) orientation of the building, (iii) glazing ratio of the southern wall, and (iv) the structure of interior partitions."

Kuzman et al. [15] compare different construction materials, including different types of construction for passive houses (e.g. wood farm, solid wood, aerated concrete, and brick). They also looked at the advantages and disadvantages of the most common construction materials used. Their methodology employed Analytic Hierarchy Process (AHP). They found that wood construction could promote energy efficiency in domestic buildings.

Oliveira Panão et al. [16] discuss the minimum amount of energy that would be required by near Zero-Energy Buildings (nZEB) in Mediterranean domestic buildings. They found that most efficient solutions are concerned with the thicknesses of thermal insulation which should be between 0.04 and 0.06 m. Double Glazing is one of the most important solutions (the thickness should be 6/16/6 mm, corresponding to *U*-values.) Finally, they discuss what level of energy consumption should be used in a near Zero-Energy Building. The energy demand is strongly dependent on the primary energy indicator assumed, which could significantly differ from country to country.

3. Methodology

The research methodology was designed to (a) identify low carbon strategies and techniques applicable to the Saudi Arabian climate and context and (b) the development of a suitable methodological framework. In order to establish an efficient low