

## Challenges Facing the Application of Zero-Energy Homes in Saudi Arabia: Construction Industry and User Perspective

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### Abstract

The construction sector in Saudi Arabia is led by domestic buildings that impose enormous energy and environmental challenges for the country. The domestic sector is responsible for 52% of the total national electricity consumption. Statistics suggest that the majority of the current construction projects are related to domestic buildings. In addition, the number of domestic buildings is growing rapidly as statistics suggest that in order to meet the needs of the rising population the country needs to build 2.32 million new homes by 2020. In order to promote sustainable development it is vital to move towards energy efficient and environmentally friendly buildings. The Zero-Energy Homes (ZEHs) can be proposed in order to overcome the energy and environmental problems within the residential sector.

The concept of ZEHs has not yet been taken up in Saudi Arabia due to some obstacles. This article looks into the issues hindering the application of ZEHs in Saudi Arabia both from the construction industry and general public (termed as users) perspectives. In this respect various stakeholders including users, architects, engineers, project managers, contractors, and investors have been surveyed to identify various barriers. The article presents the key findings of the survey based upon the responses gathered from 453 user and 122 industrial representatives.

**Keywords:** *Zero-Energy Home, Energy-efficiency, Sustainable design features, Renewable energy applications, Saudi Arabia.*

### Introduction

The world faces a string of serious energy and environmental challenges. The global energy and environmental scenarios are closely interlinked – the problems with the supply and use of energy are related to wider environmental issues including global warming, air pollution, deforestation, ozone depletion and radioactive waste. Global warming is considered to be associated with greenhouse gases (GHGs) that are primarily released from the consumption of fossil fuels. Statistics suggest that over the last three decades, energy demand and carbon dioxide (CO<sub>2</sub>) emissions in the world have grown by 89.5% and by 79%, respectively (Elkinton et al 2009). The issue of climate change has been on the world agenda as a key to sustainable development since the World Commission on Environment and Development in 1987. Subsequently, it was revealed as a part of the Agenda 21 at the United Nation Conference on Environment and Development (Earth Summit) in Rio de Janeiro in 1992, and most recently it was addressed in 2011 United Nations Climate Change Conference held in Durban.

The building sector is a major source of energy consumption. Typically, buildings are responsible for 40% of the total primary energy consumption in most countries. In the US, for example, commercial and residential buildings consume more than 40% of the primary energy (EIA 2012). Similarly, domestic sector is responsible for about 33% of

the national energy consumption in the UK (DECC 2011). The energy used by the building sector continues to increase; primarily because new buildings are constructed faster than old ones are retired. Commercial and residential buildings account for 15.3% of global GHG emissions, including 9.9% for commercial buildings and 5.4% for residential (Baumert et al 2005). These GHG emissions are either direct such as emissions from fuels combustion, or indirect such as emissions associated with the consumed electricity.

### **Saudi Residential Building Sector**

Saudi Arabia is one of the largest countries in the Middle East with a population of 25.7 million. With a total area of 2.2 million square kilometres Saudi Arabia lies between latitude of 17.5 °N and 31 °N and longitude of 36.6 °E and 50 °E. Said et al (2003) classifies the country into five different climatic zones namely Subtropical with a Mediterranean subzone and a Mountainous subtype, Hot-Dry with a Maritime Desert subzone, Hot-Dry Maritime subzone, Cold-Dry with a Desert subzone and Hot-Dry with a Desert subzone. The building styles in Saudi Arabia can be categorised into four architectural styles: Najd style, the Arabian Gulf style, the Hejaz style and the Asir style. In the past, buildings were constructed from local materials that were produced in-situ such as limestone, coral, stone and wood. Typical dwellings used to have thicker walls and roofs for better thermal insulation. Many vernacular architecture techniques such as wind towers, courtyards, fountains and mashrabiya were employed for cooling and daylighting. Contrary to that, modern buildings have thinner walls and roofs, and are made from reinforced concrete.

The Saudi construction sector is the largest and fastest growing market in the Gulf Cooperation Council States (GCC States). This sector has a great potential for growth as the demand for residential, commercial, and industrial buildings continues to rise. The country is experiencing a renaissance, pushed up by the oil boom, to develop its infrastructure, and it has one of the most active construction markets in the world. Figures suggest that the value of building construction sector comprises nearly half of the total construction projects value in the Saudi construction industry (Venture 2011). One of the significant issues that buildings are suffering from is excessive energy consumption. In a survey undertaken by the Saudi Government, it was discovered that about 60% of the total electricity consumed in summer is used in air conditioning systems (El-Hamid and Khair-El-Din 1990). According to the Saudi Ministry of Water and Electricity (MoWE) (2009), the electricity consumption in the country has increased by 35% over the last two decades largely due to intensive use of air conditioning systems. A study undertaken by Dincer et al (2004) on the sectoral energy and exergy flows in Saudi Arabia for 12 years between 1990 and 2001 shows that between 45-55% of the total residential energy consumption goes toward air-conditioning of buildings. Additionally, the average energy consumption in the residential sector for air conditioning system, cooking, appliances and lighting, are 52%, 30%, 10%, and 8%, respectively.

An analysis of the construction sector suggests that most of the projects being undertaken are residential buildings in order to meet the demand for new homes - the statistics provided by the Saudi Ministry of Municipal and Rural Affairs (MoMRA) indicate that the majority of the licenses being issued for construction in Saudi Arabia are for residential buildings (MoMRA 2011). The residential sector is expected to experience a significant growth in future as the population is rising at a rate of 2.5 % per year and only 24% of the Saudi nationals have their own homes (Deloitte 2010). Estimates suggest that around two-third of the population is under the age of 30 years. To meet the needs of the constantly growing population, the country has to build 2.32

million new homes by 2020. Recently, the Government has established the Ministry of Housing as a measure to coordinate the upcoming growth of domestic buildings.

The demand for electricity is experiencing at a rapid growth in Saudi Arabia. The residential sector is the biggest consumer of electricity – presently it accounts for 52 % of the total national electricity consumption (MoWE 2009). Owing to factors like burgeoning population, high economic growth, and low tariffs, the electricity demand in this sector is expected to double by the year 2025 (Obaid and Mufti 2008). The country therefore needs to take appropriate initiatives to boost its power generation capacity in due course. It is therefore crucial for Saudi Arabia to improve the energy consumption trends in residential buildings and to move towards energy efficient buildings. An appropriate solution in this respect could be to develop Zero-Energy Homes (ZEHs).

### **Zero-Energy Home**

There is growing realization in the world that the energy consumption in buildings and the consequent GHG emissions are required to be curtailed in order to promote sustainable development. A great emphasis is being placed on the development of energy efficient and low energy/carbon buildings. The concept of ZEH is also finding increased acceptance especially in the developed countries.

The term ZEH is used for a building that has zero net energy consumption and zero CO<sub>2</sub> emissions. These buildings essentially incorporate advanced energy saving features and renewable energy technologies respectively to reduce the consumption of energy and to generate energy without releasing GHG emissions. A precise definition of ZEH is provided by Trocellini et al (2006:1) as: *“a residential building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies”*. In ZEH, off-site renewable energy generation can also be employed in case the on-site renewable systems are not practical or are not sufficient to support the energy requirements of the building.

The ZEH is not a new concept; Esbensen and Korsgaard conducted a study in 1977 on an experimental ZEH in Denmark. Over the years, the framework for ZEH has been further developed by researchers. Many countries around the world are now pursuing the idea of ZEH. Some of them have already developed ZEHs mainly for the demonstration/experimental purposes while others are working on the feasibility of these buildings. The US Department of Energy has set up a strategic goal to achieve *‘marketable Zero-Energy Homes in 2020’* (US DoE 2011). The UK has also developed four ZEH projects. One of these is the Beddington Zero-Energy Development (BedZED). Besides incorporating excellent insulation features, this development employs solar photovoltaic and biomass resources to generate energy (Twinn 2003).

### **Research Survey**

The concept of ZEH is new to the Saudi construction industry and there is a lack of pertinent studies in the country. The concept of ZEH relies on three principles including the provision of sustainable design features, the use of low-energy technologies and the application of renewable energy resources. A questionnaire-based survey has been conducted to identify the important barriers under these categories, which have hindered the promotion of the ZEH concept in Saudi Arabia.

The participants have been selected randomly from different regions covering all climatic and architectural zones in Saudi Arabia. The survey was conducted with some of the important non-governmental stakeholders in the construction industry (i.e. architects, engineers, project managers, construction contractors, developers and

investors) and users employing web based and in-person approach. A total of 575 responses were received of which 453 were from users and the remaining 122 from industry.

### Results

The results show that energy-efficiency in Saudi residential sector received more attention. The major issues covered in the energy-efficiency part are the daylighting, artificial lighting system, natural ventilation, glazing system, electrical appliances, and thermal insulation. It has been indicated from the results that there is an acceptable level of awareness and implementation of the concept of energy-efficiency among both users and professionals. Generally, daylighting, natural ventilation and energy-saving fixtures are extensively used by dwelling users. However, more than 40% are not aware of the energy rating of their appliances and equipments. Also, more than 60% of users are using fluorescent lamps which are more efficient than other lamps such as incandescent and tungsten-halogen lamps. In spite of the fact that about 40% of users are using double-glazed system in their dwelling, more than 50% of them are not aware of the influence of the glazing system on the building energy performance. The survey shows that only 16% of users have insulated external walls in their current dwelling, and about 30% of them are using polystyrene as thermal insulation.

Survey participants were asked about a number of sustainable design features to check their acceptability towards the concept of sustainable design in general and these features in particular. Results suggest that with different level of acceptability depending on the type of feature, most of the examined features are attractive to users as indicated in Figure 1. It is also seen that users are happy to pay more for constructing or purchasing a sustainable dwelling. Moreover, about 39% of professionals consider that the view that sustainable design changes the life-style of the users is not a barrier; while 32% consider it as a minor barrier.

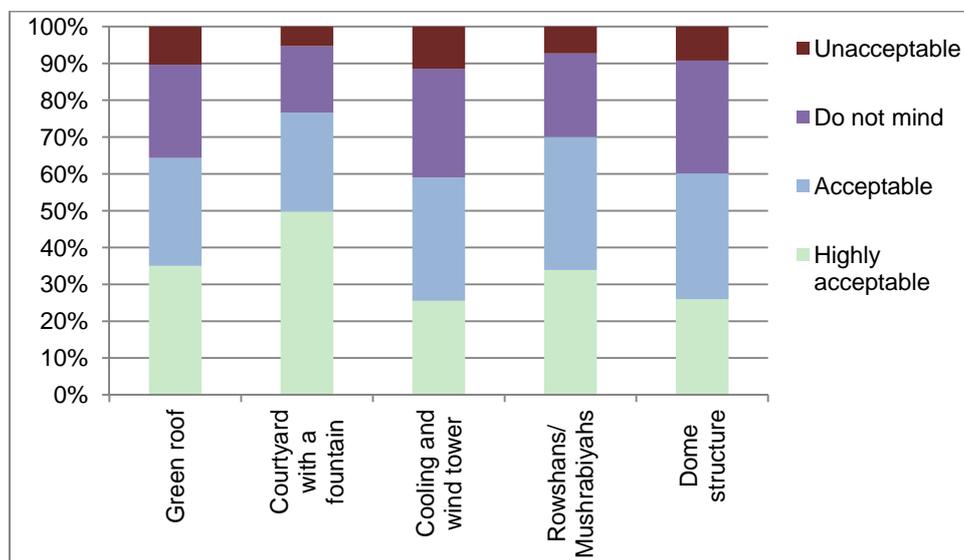
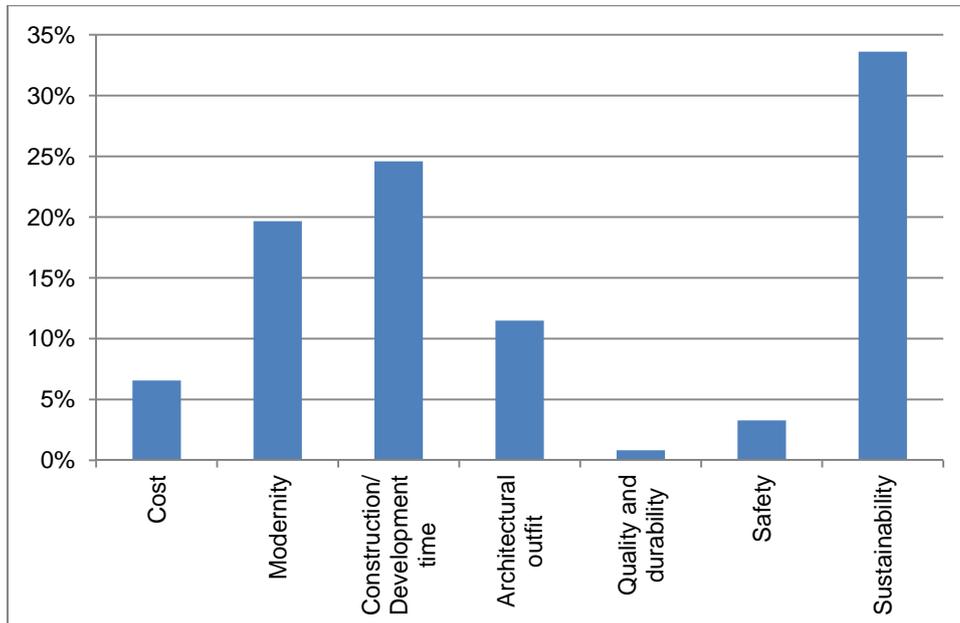


Figure 1: The acceptability of some sustainable design features by residential building users

In comparison to factors like cost, construction time, architectural outfit, quality and safety, sustainability has been regarded by about 33% of the professionals as the least important factor (see Figure 2). Similarly, in terms of the most important factor to be

considered in construction projects, cost has been highlighted by 34% of the professionals while sustainability has been highlighted by only 2.5% of them.



**Figure 2: Factors described by the construction industry professionals to be on the bottom of their priority list**

In terms of renewable energy resources, Saudi Arabia has enormous potential for solar energy across the country and for wind energy along the coastline. Anon (1999) indicates that Saudi Arabia annually receives around 3245 sunshine hours accounting for a solar radiation figure of over 2200 kWh/m<sup>2</sup>. It has vast open terrain as well as a long coastline, with significant potential for wind power. Despite the significant potential for solar and wind power, these resources have not been exploited as yet. The state of affairs can be attributed to a number of barriers. This survey tends to highlight the barriers hindering the utilization of these resources in the Saudi residential sector (see Table 1). The results show high acceptability from users to utilize renewable energy resources within their future dwellings. It also shows that photovoltaic panels are more attractive to users than micro-wind turbines. Furthermore, about 47% of users accepted purchasing electricity from renewable energy resources if the price stays the same, while about 28% of them accepted even if it a bit costly than purchasing it from the conventional resources.

**Table 1: Barriers to promote ZEHs in Saudi Arabia**

Type	Barrier
Energy-efficiency measures	<ul style="list-style-type: none"> <li>• Lack of awareness about the energy-efficiency measures such as the glazing system, the thermal insulation, the energy-saving lighting fixtures, and energy-efficient appliances and its rating</li> <li>• Cheap electricity tariff</li> <li>• Personal passiveness to buy the energy-saving fixtures</li> <li>• Unclear maintenance responsibility</li> <li>• Lack of expertise in efficient-buildings</li> </ul>

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- Sustainable design features
- Lack of acceptability of sustainable design features due to aesthetic aspects and safety issues
  - Perception that it wastes necessary space and money
  - Disturbance in terms of noise, as well as, attracting insects and dusts
  - Concerns about maintenance
  - Perception that it may affect the lifestyle of users
  - Uncertainty of the adaptability of these solutions in the Saudi climate
  - Some of the solutions are not applicable in all regions and kind of residential buildings in Saudi Arabia
  - Technical issues and faults
  - Perception that some of the solutions are old style and does not meet the current user's aspiration
  - Lack of awareness about most of sustainable design features
  - Non-suitability for Saudi families as some of the features may constrain future expansion and penetrate user's privacy
  - Regulatory and policy related challenges from the local authorities
  - Not in line with existing style of typical residential buildings in Saudi Arabia
  - Lack of expertise in the sustainable design

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- Renewable energy applications
- Non-suitability in residential buildings due to safety issues
  - Uncertainty of the applications performance in the Saudi climate
  - Regulatory and policy related challenges from the local authorities
  - Enormous subsidies on fossil fuel based energy including oil and gas
  - Lack of public awareness on renewable energy
  - High capital cost of renewable technologies
  - Lack of policy initiatives in terms of government targets for renewable technologies and absence of due subsidies/financial incentives on renewable technologies
  - Lack of information concerning performance, durability, reliability and cost effectiveness of renewable technologies
  - Lack of private sector stakeholders/renewable entrepreneurs
  - Capacity issues with micro-renewable systems
  - Lack of reliable weather data
  - Lack of acceptability of renewable energy applications due to aesthetic aspects
  - Lack of government subsidy on renewable energy applications
  - Lack of interest in the renewable energy from the national media and the relevant agencies
  - Lack of expertise in the field of renewable energy application
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## Discussion

It is observed from the survey results that though the majority of industry professionals are familiar with the three main principles for ZEHs - sustainable design features, the use of low-energy technologies and the application of renewable energy resources - there is a lack of experience. The percentage of professionals with adequate experience for energy-efficiency measures, sustainable design features and renewable energy applications are 26%, 11% and 10%, respectively. Additionally, the cheap electricity tariff is a major barrier to achieve ZEHs Saudi Arabia. The electricity tariff varies between 0.05 SR (£0.0085) and 0.26 SR (£0.044) depending upon the consumption. With such a low tariff, renewable systems with high capital cost become less attractive to stakeholders. These low tariffs reflect on the users' behaviour as only 16% of users have their external walls thermally insulated. The study also shows that there is a lack of public awareness on the subject, which needs to be addressed.

Unlike sustainable design features and renewable energy applications, energy-efficiency in buildings has received more attention in Saudi Arabia. The country has made considerable progress toward energy-efficiency in the building sector. A key development is the establishment of the National Energy Efficiency Programme (NEEP) in 2005. The NEEP is a national organization involves with many governmental ministries and other organisations to help in achieving a cleaner environment and more reliable and affordable energy system. The NEEP has made some significant initiatives including developing energy-efficiency codes for new buildings, initiating energy-efficiency training and awareness programs, as well as, issuing energy-efficiency standards for selected household appliances. This is also reflected in the wider use of energy-efficiency measures. Despite these developments, there is still a lack of awareness in users regarding some important areas such as thermal insulation, multi-glazing and air infiltration. It is vital to educate users because often they are to decide on the construction details of buildings and the choice of domestic appliances.

## Conclusions

The results of the questionnaire survey reveal that the construction industry in Saudi Arabia regards sustainability as one of its least important priorities. Other major factors that hinder the uptake of ZEHs include lack of awareness and expertise, cheap electricity tariffs, aesthetic issues and absence of supportive government policies. The apprehension about renewable energy technologies in terms of their cost effectiveness, maintenance, performance, durability and reliability is also regarded as a hindrance. In order to promote ZEHs, the government needs to formulate conducive policies to encourage both the construction industry and public.

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