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Prospects of Renewable Energy to Promote Zero-Energy Residential Buildings in the KSA

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Abstract

With the advent of the 21st century, global warming is one of the major challenges facing the world. The greenhouse gas (GHG) emissions from the consumption of fossil fuel based energy resources are widely regarded as the main driving factor behind global warming and the consequent climate change. Construction industry, owing to its intense energy and material demands, is one of the major sectors to generate greenhouse gases (GHGs). Efforts are therefore being made across the world to develop energy efficient buildings. In this respect, Zero-Energy Buildings (ZEBs) are being developed in many countries.

The Kingdom of Saudi Arabia (KSA) is the largest consumer of fossil fuels in the Middle East as it meets all of its energy needs from oil and gas. The energy needs of the country are expected to rapidly grow in future because of a number of factors such as burgeoning population, high economic growth and low energy prices. The residential sector is responsible for 52% of the total national electricity consumption. Statistics suggest that almost 70% of the total projects in construction sector are related to residential buildings. It is further estimated that 2.32 million new homes are to be built by 2020 in order to meet the demand of growing population.

This article looks into the prospects of renewable energy to promote ZEBs in the residential sector of the KSA. It provides a detailed account of the energy profile of the country. It also reflects upon the fundamental features of ZEBs. In this respect, the article investigates the potential of various renewable energy options to provide green energy for these buildings. It also reflects upon the barriers towards the development of these buildings. Finally, the article provides recommendations to promote the use of renewable energy sources in the KSA.

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Keywords: Zero-Energy Building; Energy efficient buildings; Renewable energy; KSA.

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1. 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 CO2 emissions in the world have grown by 89.5% and by 79% respectively [1]. 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 Jenerio in 1992, and most recently it was addressed in 2010 United Nations Climate Change Conference held in Cancún.

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 about 40% of the primary energy [2]. Similarly, buildings are responsible for almost 47% of national energy consumption in the UK [3]. 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 [4]. These GHG emissions are either direct such as emissions from fuels combustion, or indirect such as emissions associated with the consumed electricity.

The Kingdom of Saudi Arabia (KSA) is one of the most prominent countries in the Middle East with a population of 25.7 million. With a total area of 2.2 million square kilometers the country lies between latitude of 17.5 °N and 31 °N and longitude of 36.6 °E and 50 °E. It has approximately one-fifth of world's proven oil reserves, and is the largest oil producer and exporter of oil in the world. It is the largest consumer of oil in the Middle East and in 2008 the country was the 15th largest consumer of total primary energy in the world [5]. In the wake of the growing importance of the building sector in terms of energy consumption and carbon emissions, it is essential for the KSA to shift towards energy efficient and sustainable buildings. In this respect, this article explores the prospect of renewable energy to promote Zero-Energy Residential Buildings (ZERBs) in the country.

2. Zero-Energy Buildings:

There is growing realizing 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 Zero-Energy Building (ZEB) is also finding increased acceptance especially in the developed countries.

The term ZEB is used for a building that has zero net energy consumption and zero carbon dioxide (CO2) 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 ZEB is provided by Trocellini et al [6] as: "*a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies*". In ZEBs, off-sit 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 as highlighted in Figure 1.

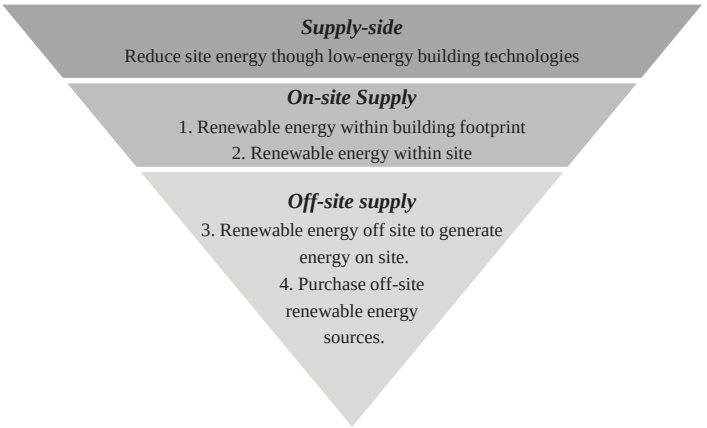

Fig. 1. ZEB renewable energy supply hierarchy - adapted from Trocellini et al [6].

ZEB is not a new concept; Esbensen and Korsgaard conducted a study in 1977 on an experimental zero-energy house in Denmark [7]. Over the years, the framework for ZEB has been further developed by researchers. Many countries around the world are now pursuing the idea of Zero-Energy Residential Buildings ZERBs. Some of them have already developed ZERBs mainly for the demonstration/experimental purposes (see Table 1) while others are working on the feasibility of these buildings. Trocellini et al have examined seven ZEBs from different climate conditions [6]. All of these buildings have energy conservation features and use renewable technologies to generate energy. The US Department of Energy (DOE) has set up a strategic goal to achieve '*marketable Zero-Energy Homes in 2020*' [8]. The United Kingdom has also developed four ZERB 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 [9].

Table 1. Number of developed ZERBs per country.

Country	No. of ZERBs
USA	39
Canada	15
Mexico	5
UK	4
Germany, Australia and South Korea	2*
Spain, Japan and China	1*

*for each country

3. Saudi energy sector:

The energy sector in the KSA can be structured into two major categories as governmental and parastatal bodies. The Ministry of Water and Electricity (MoWE) and Ministry of Petroleum and Mineral Resources (MoPM) are the prime governmental bodies associated with the energy sector. In addition, Saudi Aramco and the Saudi Electricity Company (SEC) are the significant parastatal bodies. The MoWE

is responsible for setting policies for the electricity sector and for overseeing private investment in the sector. Saudi Aramco controls the oil and gas production and export. The Saudi energy sector is facing several challenging such as summer peak demand, inefficient use of energy, lack of policy initiative and weak participation of private sector [10]. The National Energy Efficiency Program (NEEP) was established in 2005 to address these issues. NEEP is a national organization that coordinates with many governmental ministries and other stakeholders to address energy and environmental issues.

The total installed electricity generation capacity in the KSA is 44,485 MW, all being supported by oil and natural gas. The respective share of oil and natural gas in the production of electricity is 57% and 43%. In the wake of fluctuating oil prices, natural gas has seen a jump in its share in electricity production- the contribution from natural gas has increased from 37% in 2007 to 43% in 2009 [11]. The power plants employ a range of technologies including gas turbines, steam turbines, combined cycle and diesel engines. The country is yet to explore other energy resources to support the power sector.

The demand for electricity is experiencing a rapid growth in the KSA. Since 1990, for example, the demand has increased at an annual rate of 6%. Growing population is an important factor in this respect as also indicated in Figure 2. Statistics suggest that electricity consumption is expected to increase from193,474 GWh in 2009 to about 280,757 GWh in 2015. Furthermore, the per capita electricity consumption is also increasing rapidly due to factors like urbanization, subsidized tariffs and increased use of energy intensive appliances as shown in Figure 3 (a).

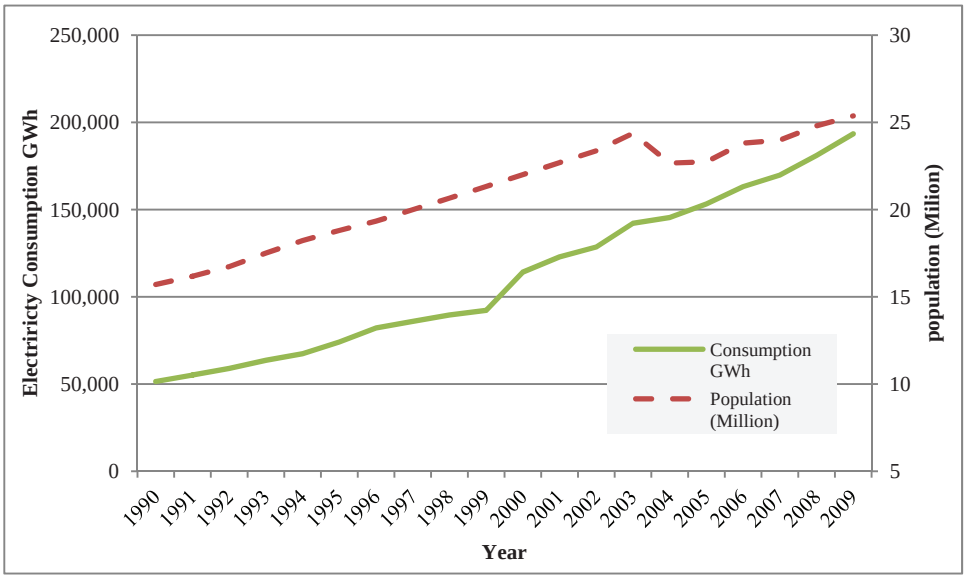

Fig. 2. The population and total electricity consumption for the KSA between 1990 and 2009 [12].

The residential sector is the biggest consumer of electricity – presently it accounts for 52 % of the total national electricity consumption as indicated in Figure 3 (b). 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 [13]. The country therefore needs to take appropriate initiatives to boost its power generation capacity in due course.

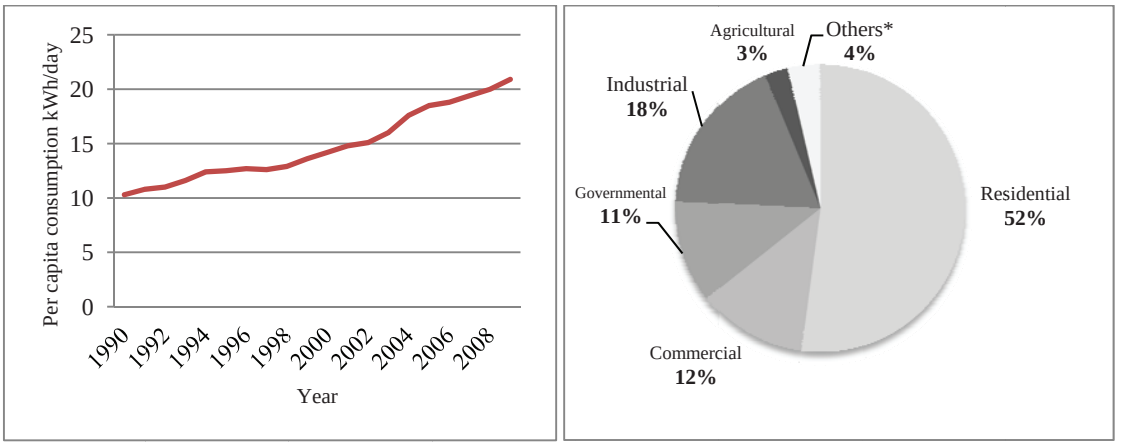

Fig. 3. (a) Per capita consumption for the KSA between 1990 -2009 [12]; (b) electricity consumption per sector for the KSA [12].

4. Saudi residential building sector:

The Saudi construction sector is the largest and fastest growing market in the Gulf Cooperation Council States (GCC States) as shown in Figure 4. The construction sector has a great potential for growth as demand rises for residential, commercial, and industrial buildings. 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.

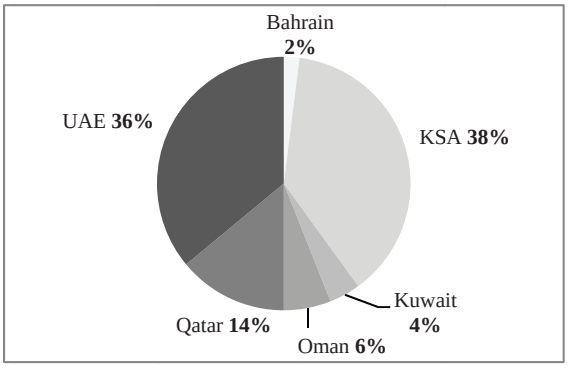

Fig. 4. Construction industry in GCC States [14].

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 Ministry of Municipal and Rural Affairs (MoMRA) indicates that the majority of licenses issued for construction in the KSA were for residential buildings as shown in Figure 5 [15].

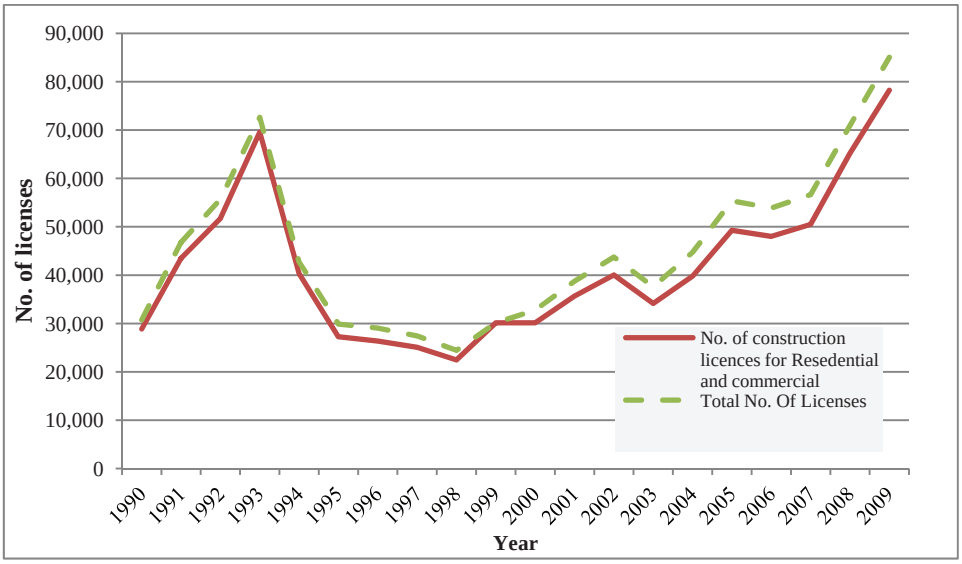

Fig. 5. Number of construction licenses issued between 1990 -2009 for residential-commercial buildings in the KSA [15].

The residential sector is set to experience a similar growth in future as the Saudi population is rising at a rate of 2.5 % per year and only 24% of the Saudi nationals have their own homes [14]. 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.

One of the significant issues that residential buildings are suffering from is excessive energy consumption. In a survey undertaken by the Government, it was discovered that about 60% of the total electricity consumed in summer is used in air conditioning [16]. According to the Saudi MoWE, the electricity consumption in the country has increased by 35% over the last two decades largely due to intensive use of air conditioning in [12]. It is therefore crucial for the KSA 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 ZERBs. Renewable energy would have to play a vital role in the development of ZERBs.

5. Renewable energy potentials:

The KSA has enormous potential for renewable energy in general and solar energy in particular. However, despite the availability of substantial renewable energy resources, the electricity generation in the KSA depends mainly on fossil fuel resources. These renewable energy resources are yet to be tapped. Since 1970s, many studies have shown the potentials of solar and wind energy in the country but these technologies have not been exploited in a meaningful way.

The geographic location of the KSA is ideal for harnessing solar energy. According to the Saudi Solar Radiation Atlas, the country annually receives around 3245 sunshine hours accounting for a solar radiation figure of over 2200 kWh/m² as shown in Figure 6 [17].

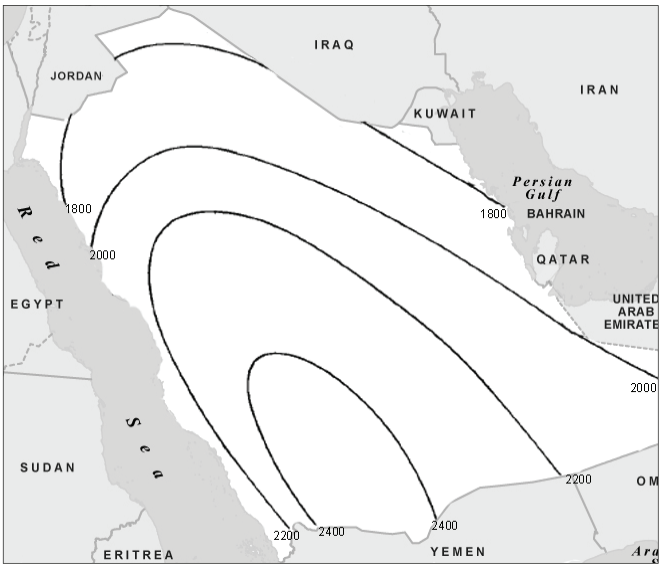

Fig. 6. Annual global solar radiation falling on the KSA per kWh/m² [17].

Since 1970s a number of research projects have been undertaken to evaluate the prospects of solar energy for applications like solar water heating, solar distillation of water, solar air heating, solar cooking, solar drying of agricultural produce and other product, solar lighting, solar refrigeration, solar water pumping, solar communication, and solar transport [18]. These studies have shown promising results for application of technologies like solar photovoltaic, solar water heating and solar drying while options like solar refrigeration and seawater desalination face some technical and economic barriers.

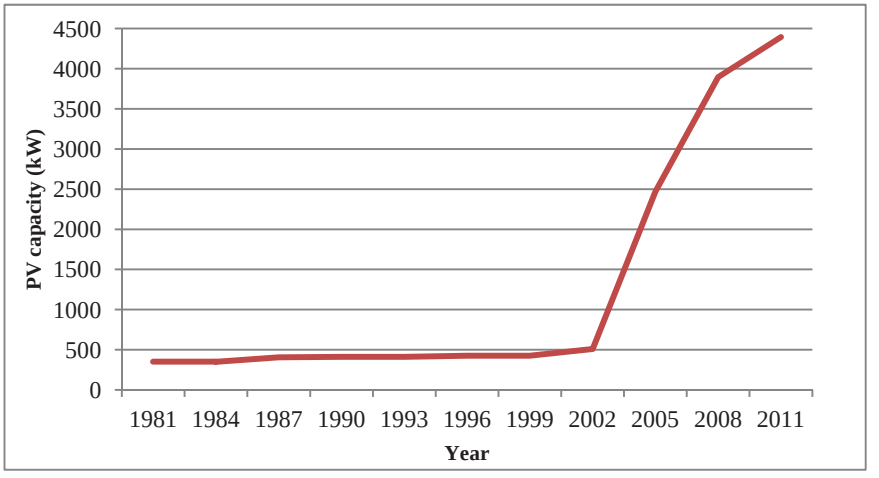

Fig. 7. Cumulative PV installed capacity in the KSA between 1981-2011[19], [20].

One of the earliest solar energy projects in the country was development of solar village in 1981. The Solar Village is a major research project - with 350kW capacity of Solar PV - located about 50km

northwest of Riyadh. Another successful example is application of solar water heating in almost all residential buildings in the industrial cities of Yanbu and Jubail [18]. Recently, solar energy has received considerable attention from concerned authorities as the total installed capacity of solar PV has jumped from 0.5MW in 2002 to 4.4MW at present (see figure 7). Another 10 MW solar PV project is under construction in the city of Dhahran.

The KSA has vast open terrain as well as a long coastline, with significant potential for wind power. Amin and El-Samanoudy conducted one of the earliest studies in this respect, which highlights the two vast windy regions along the Arabian (Persian) Gulf and Red Sea coastal areas [21]. A study undertaken by Rehman and Ahmad shows that the mean annual wind speed at 50m above ground level is 6.7 m/s over Yanbu (Red Sea) [22]. Their study also shows that the higher values of monthly mean wind speed for Yanbu - ranging from 7.1 to 7.8 m/s - are in summer months, complementing the greater load demand on national electric grid. Several other studies have also indicated the healthy potential for wind power within these regions. Despite these studies, wind power has yet to take a start in the KSA. The SEC is considering taking an initiative in this respect as two projects have been announced by SEC to identify the potential locations for grid connected wind farms and to conduct feasibility study for wind-diesel hybrid systems.

6. Barriers for renewable energy resources in the KSA:

Despite a significant potential for solar and wind power in the KSA, these resources have not been exploited as yet. The state of affairs can be attributed to a number of policy related, technical, financial and cultural barriers. Some of the important barriers in this respect are as followings:

- Enormous subsidies on fossil fuel based energy including oil gas and electricity.
- Lack of public awareness on renewable energy.
- High capital cost of renewable technologies.
- Capacity issues with micro-renewable systems.
- Lack of policy initiatives in terms of government targets for renewable technologies and absence of due subsidies/financial incentives on renewable technologies.
- Lack of reliable weather data.
- Lack of information concerning performance, durability, reliability and cost effectiveness of renewable technologies.
- Lack of acceptability of renewable energy applications due to aesthetic aspects.
- Lack of private sector stakeholders/renewable entrepreneurs.

It is vital to address the above hurdles in order to promote renewable technologies in a meaningful manner. Following recommendations can be made to pave the way for renewable energy in the building sector in the KSA.

- The Development of supportive state policies for renewable technologies i.e. setting up national targets for installation of renewable energy, appropriate level of subsidies for renewable technologies, development of energy codes/regulations for buildings and ease of planning permissions from local authorities.
- Human resource development – there is need to develop scientists, engineers, technicians, and sales and marketing personnel.
- Enhanced public education and awareness.
- Indigenous production of technologies.
- Further studies on the feasibility of wind power.

7. Conclusion:

The construction sector in the KSA, led by domestic buildings, is imposing enormous energy and environmental challenges for the country. The residential sector 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 ZERBs can be proposed in order to overcome the energy and environmental problems within the residential sector. Renewable energy can be capitalized to support the energy needs of the ZERBs as the country has rich potential for renewable energy. In terms of solar energy, the KSA is one of the richest countries in the world as it has 3245 sunshine hours per year with an annual solar radiation figure of 2200 kWh/m². There is however a wide range of policy related, financial, technical and cultural barriers that are hindering the progress of renewable energy. It is imperative for the country to formulate conductive policies to tackle these barriers.

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