Trends in Residential Energy Consumption in Saudi Arabia with Particular Reference to the Eastern Province

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ABSTRACT

Residential buildings are vital in the energy scenario of Saudi Arabia as they account for 52% of the total electricity consumption. The Eastern Province, due to its harsh weather conditions, is one of the most challenging areas in Saudi Arabia in terms of residential energy consumption. The province is vital also because of its large land area, accounting for almost one third of the entire country. This article investigates some of the important factors related to the residential energy consumption i.e. weather conditions, types of dwellings, building envelops, air-conditioning systems and cooking appliances. The analysis in this work is based upon a survey of the actual monthly energy consumption for the year 2012. In this respect, a total of 115 dwellings have been surveyed of which 62, 28 and 25 were respectively apartments, villas and traditional houses.

KEYWORDS

Residential Buildings, Energy Consumption, Energy-Efficiency, Saudi Arabia, Eastern Province.

INTRODUCTION

The building industry has a key role to play in achieving sustainable development in any country. Buildings contribute to environmental issues ranging from the excessive use of resources during the construction and the operation stages to polluting the surrounding environment. Buildings not only use resources such as energy and raw materials but they also generate waste and potentially harmful atmospheric emissions. Buildings are responsible for a substantial proportion of the global greenhouse gases (GHGs) emissions. For instance, the United States (US) Green Building Council [1] suggests that the US commercial and residential building sector accounts for 39% of carbon dioxide (CO_2) emissions per year, more than any other sector in the country. According to Alnaser et al [2], construction and operation of buildings have an enormous direct and indirect impact on the environment. The annual environmental impact of the global building sector includes energy use (42%), atmospheric emissions (40%), raw materials use (30%), solid waste (25%), water use (25%),

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water effluents (20%), land use (12%), and other emissions (13%). Given the massive growth in new construction and the inefficiencies of existing building stock worldwide, in a business as usual scenario, the level of GHGs emissions from buildings is set to rise in future. If the desired targets for GHGs emissions reduction are to be met, emissions from the building sector need to be tackled with much greater seriousness and vigour than the past efforts and in this respect energy-efficient and sustainable buildings are critical to be promoted. In order to develop robust strategies to stimulate the take up of energy-efficient buildings, it is crucial to have a thorough understanding of current practices and future trends in the building sector.

ENERGY CONSUMPTION IN SAUDI ARABIA

The total installed electricity generation capacity in Saudi Arabia 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 [3].

The demand for electricity is experiencing a rapid growth in Saudi Arabia. Since 1990, for example, the demand has increased at an annual rate of 6%. Due to the economic and population growth, 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 1a.

The residential sector is the biggest consumer of electricity – presently it accounts for 52% of the total national electricity consumption as indicated in Figure 1b and it is expected that by year 2025 the demand from this sector would double [4]. The rapid growth in energy demand is largely due to inefficient use of energy which in turn is associated with extremely subsidized tariffs as also highlighted by Alyousef and Stevens [5]. To respond to the energy growth trend, the country needs to take appropriate initiatives not only to boost its power generation capacity but also to make residential sector energy efficient.

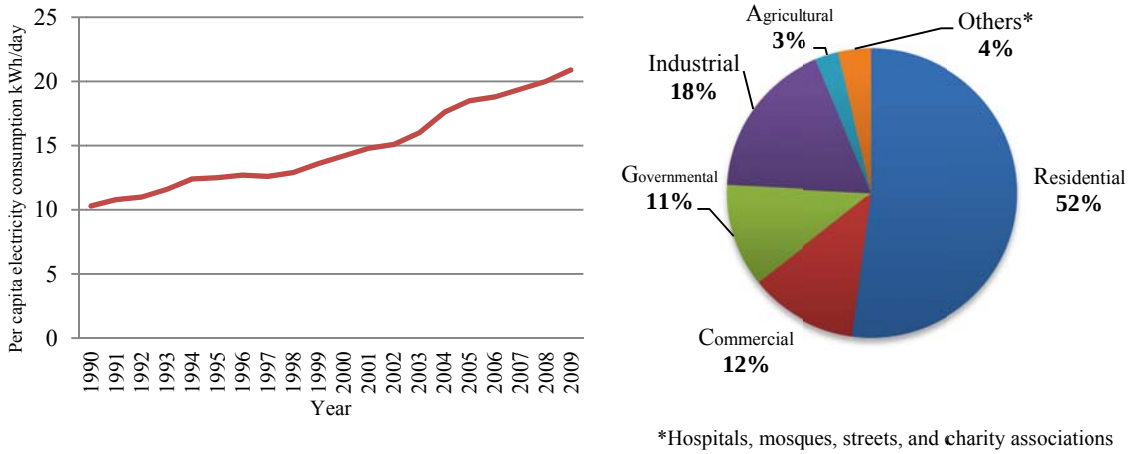

Figure 1a. Per capita energy consumption in Saudi Arabia [6]; Figure 1b. Energy consumption by sector [6].

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 Saudi Arabia were for residential buildings [7]. In addition, 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 [8]. 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.

In a survey undertaken by the Government, it was discovered that about 60% of the total electricity consumed in summer goes into air conditioning [9]. According to the Saudi Ministry of Water and Electricity (MoWE) [6], the electricity consumption in the country has increased by 35% over the last two decades largely due to intensive use of air conditioning in summer. It is therefore crucial for Saudi Arabia to improve the energy consumption trends in residential buildings and to move towards energy efficient buildings. This paper aims to discuss the energy trends in the Saudi residential sector based upon a survey of the actual monthly energy consumption for 115 housing units in the Eastern Province.

Saudi Arabia can be classified climatically into five different inhabited climatic zones: Subtropical with a Mediterranean subzone and Mountainous subtype (for example Khamis Mushait); Hot-Dry with a Maritime Desert subzone (for example Jeddah); Hot-Dry Maritime subzone (for example Dhahran); Cold-Dry with a Desert subzone (for example Quriat), and Hot-Dry with a Desert subzone (for example Riyadh) [10]. The Eastern Province is a vital region in Saudi Arabia because of its large land area, accounting for almost one third of the entire country. Due to its harsh weather conditions, it is one of the most challenging areas in Saudi Arabia in terms of residential energy consumption. Dhahran represents the Eastern Province weather which is subject to Hot-Dry Maritime subzone where the maximum temperature occasionally higher than other climatic zones and the mean temperature is higher than most of the climatic zones (see Table 1).

Table 1. Temperature comparison between Saudi represented climatic zones [11]

Location	Maximum Dry-Bulb Temperature (°C)	Mean Dry-Bulb Temperature (°C)
Dhahran	45.7	25.8
Guriat	43.9	19.8
Riyadh	43.7	25.12
Jeddah	41.7	27.9
Khamis Mushait	34.3	18.9

SURVEY

The survey has been carried out on the monthly electricity consumption of dwellings in Dhahran region, which represents the Eastern Province of Saudi Arabia, for January 2012 to December 2012. A total of 128 responses were received; however, 13 of them were rejected due to incomplete information. The types of dwelling studied in the survey - apartments, traditional houses and villas – represent over 90% of the dwellings in the province [12]. The traditional house in Saudi Arabia is a house where minimum one external wall is shared with a neighbor and does not have a fence (i.e. 100% of the land is built). The villa is a free-standing (detached) residential building surrounded by fence. Generally, more than half of the responses are apartment type of dwelling (Fig. 2a). The responses were categorized depending upon some energy parameters including type of air-conditioning system, thermal insulation, glazing system, energy source for cooking, dwelling age, and conditioned area. The survey

shows that 92% of dwellings are using mini-split and window-type as air-conditioning systems (Figure 2b). It is also found that thermal insulation and double-glazed system are used within 60% and 50% of the survey dwellings, respectively. In terms of the source of energy for cooking, about 60% of the responses suggested that use of gas for cooking within their dwellings while the rest were using electricity.

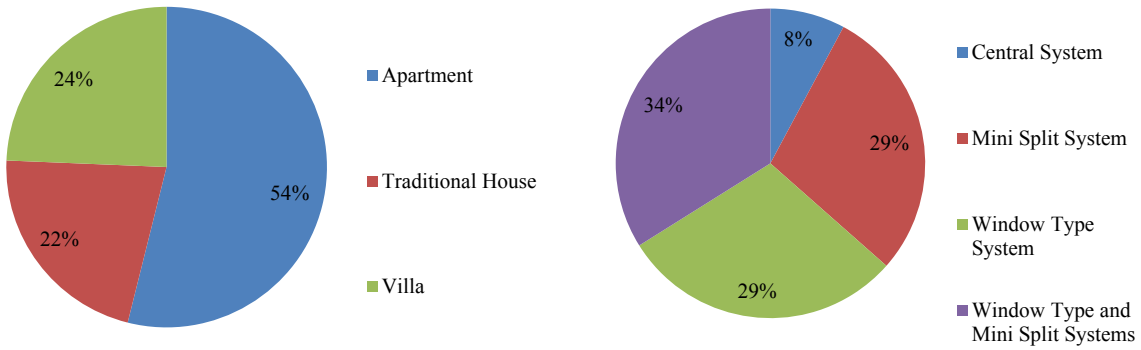

Figure 2a. Survey type of dwellings; Figure 2b. Survey type of air-conditioning systems

ANALYSIS

The results indicate that the annual energy consumption for the surveyed dwellings varies from 27 to 401 kWh/m² whereas the average value is calculated to be 176.5 kWh/m². The energy consumption for 43% of all dwellings is between 125 and 174 kWh/m² (see Figure 3a). In terms of types of dwellings, the average annual energy consumption for apartments, traditional house, and villas is respectively, 196.5, 156.5 and 150 kWh/m². It is observed that the energy consumption for apartments is higher than the other types (see Figure 3b). The survey results also reveal that the annual energy consumption per square meter especially for apartments and traditional houses decreases when the conditioned area increasing and vice versa (see Figure 4).

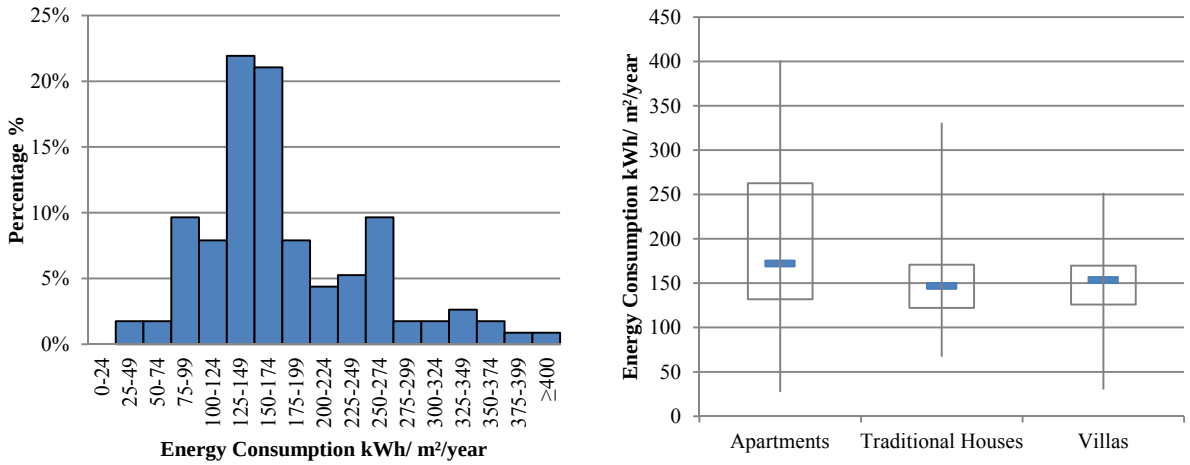

Figure 3a. Distribution of energy consumption for all survey dwellings; Figure 3b. Box Plot of the energy consumption for all type of survey dwellings.

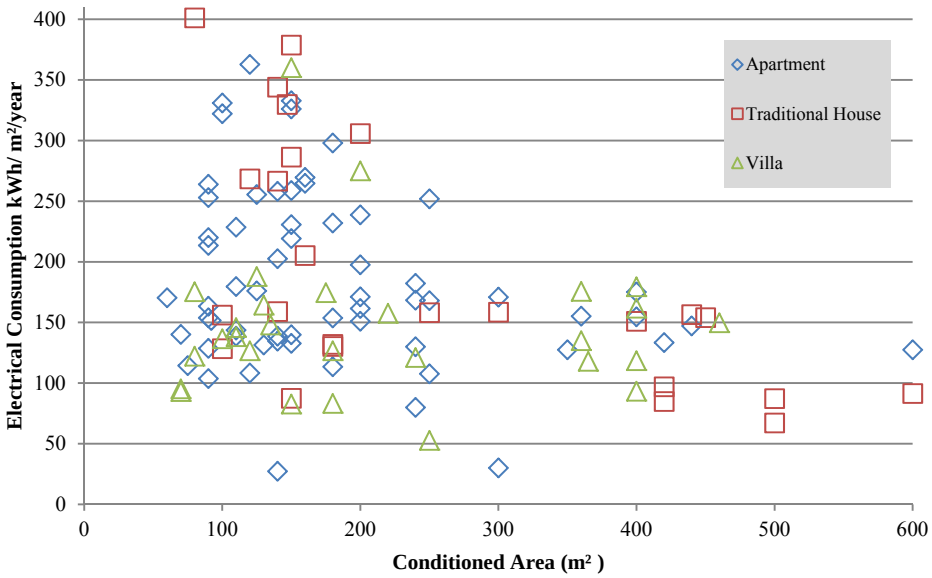

Figure 4. The annual energy consumption per square meter for all type of survey dwellings

The survey results indicates that the use of thermal insulation started almost 20 years ago and none of the dwellings built over the last five years is un-insulated. (see Figure 5a). While the use of double gazing system has increased during last ten years, the single-glazing system is still being applied (see Figure 5b).

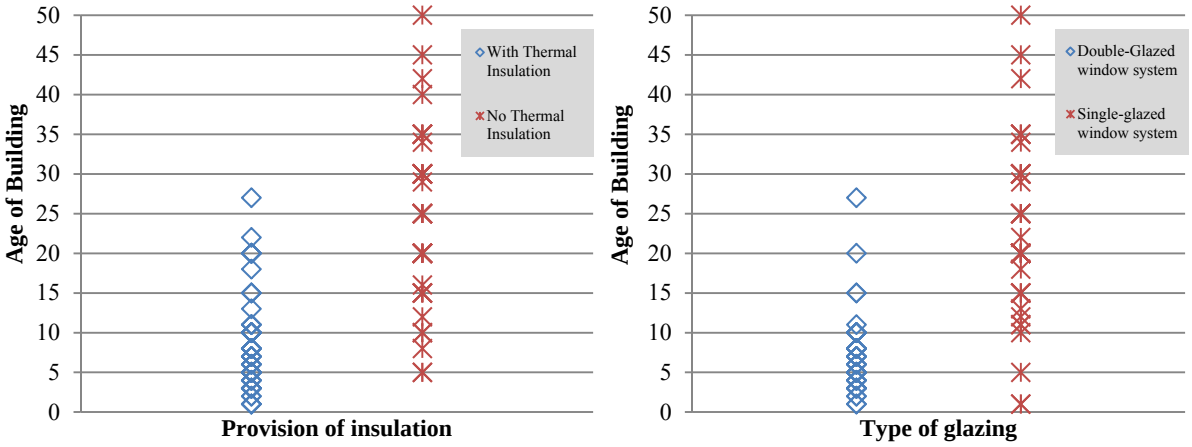

Figure 5a. The type of dwelling in terms of insulation provision; Figure 5b. The type of dwelling in terms of type of glazing

The types of air-conditioning system used within the majority of the surveyed dwellings are window-type system and mini-split system. The use of central system has only started in recent (See Figure 6a). In terms of the energy source for cooking, use of electricity has started within the last 10 years (see Figure 6b).

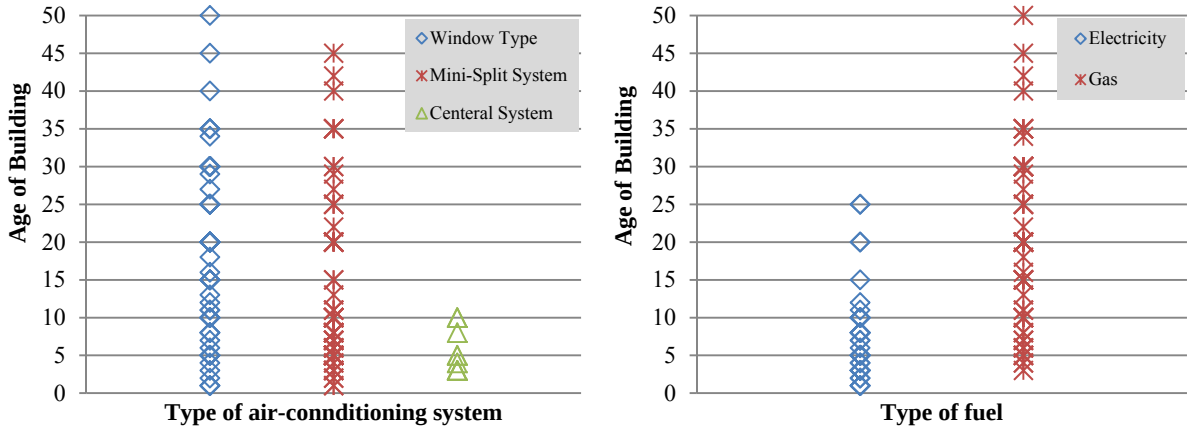

Figure 6a. The type of air-conditionning system in the survey dwellings; Figure 6b. The source of energy for cooking in the survey dwellings

DISCUSSION AND CONCLUSIONS

The study highlights some energy consumption and efficiency trends in the residential sector in the Eastern Province of Saudi Arabia. The annual average value of energy consumption amongst the surveyed dwellings has been found out to be 176.5 kWh/m². In a global perspective, this value appears to be smaller than the values for average Canadian and European dwellings, which are respectively 281 kWh/m² and 200 kWh/m² [13, 14]. On the other hand, it is greater than the corresponding average US value of 145.6 kWh/m² [15]. The energy consumption value investigated in this study is also much greater than the benchmark value for energy-efficient residential buildings, which is, for instance, less than 75 kWh/m² in Denmark, France and Sweden [16]. Among the three dwelling types in this study (i.e. apartments, traditional house and villa), villa tends to have lower consumption compared to other dwelling types especially apartments.

In Saudi Arabia, four types of air-conditioning systems are mainly used in residential buildings: window-type, mini-split, central and evaporative cooler. Given the fact that the Eastern Province is subject to high humidity, the use of evaporative cooling system is limited. While the air conditioning in the Eastern Province is largely dominated by window-type and mini-split systems, the use of central systems has started to emerge over the last few years. The survey results reveal that in terms of type of air conditioning, the lowest average energy consumption is associated with dwellings using mini-split systems (see Table 2).

Table 2. Average energy consumption for survey dwellings based on the type of air-conditioning systems

Type of air-conditioning system	Average energy consumption kWh/m²/year
Central	221.5
Mini-split	144.3
Window-type	183.3
Window-type and Mini-split	156.8

The application of thermal insulation and double-glazing systems has become common over the last 20 years. This might be due to the encouragement by the Saudi Government through

increasing the public awareness about the importance of these parameters especially the thermal insulation. In 1985, the Saudi Government started to pay attention to the significance of thermal insulation and its impact on the energy saving. Thus, many encouraging policies have been developed to promote the application of thermal insulation within new buildings. Subsequently, in 1994, the government made it mandatory for all government projects to have thermal insulation. These initiatives appear to have a positive impact on the increased use of thermal insulation across the board including the residential sector.

The surveyed dwellings started to be supplied with electric cooking appliances within the last decade. Although, the use of natural gas is less harmful for the environment in comparison with fossil fuel based electricity, the use of the latter is becoming more and more common for cooking needs [17]. Presently, there is no gas pipeline network in Saudi Arabia and the provision of gas is through refillable cooking gas cylinders. The opportunity of having zero carbon emissions with electric appliance is higher if supplied with energy from renewable energy recourses.

The value of average energy consumption in the Eastern Province tends to be lower than some of the prominent global figures; however, it is higher from the energy-efficient benchmarks. Therefore, in order to increase the energy-efficiency in the Saudi residential sector rapidly some energy issues are required to be tackled further. The residents, for example, should be encouraged to use mini-split systems and avoid other types especially the central system. The stimulation programme to use thermal insulation should stay alive and attention should be paid to other factors such as the application of double-glazing system.

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