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FACTORS LEADING TO HIGH ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS IN SAUDI ARABIA

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Abstract - In developing countries like Saudi Arabia, the experience of a rapid rate of urbanisation and infrastructure expansion, especially with respect to buildings is immense. The role of buildings is even more important as they account for around 80% of the total national electricity consumption. Based on the 2030 local energy consumption trends, forecasts indicate an increase in domestic energy consumption with a growth rate which could reach 4 to 5% annually. A significant portion of this energy consumption growth results from the inefficient use of energy, and absence of coordinated enforcement and stakeholder engagement.This paper reports on an exploratory public survey to elicit information on respondent's views on issues such as the awareness and applications of sustainable building. The aim of this article is to identify factors influencing the development of sustainable buildings and energy consumption in residential sector in Saudi Arabia. A structured questionnaire was designed and electronically distributed to collect information from respondents across Saudi Arabia, employing a random sampling technique (Snowball Technique). The findings have significant implications for policy makers and practitioners. The implementation of sustainable residential buildings code requires strong support from the public, government and the housing industry.

Keywords - Energy Efficiency, Consumption, Building, Design, Performance

I. INTRODUCTION

The building industry has experienced a considerable amount of developments following economic growth causing exploitation of natural resources. These developments are due to the activities in the extraction of a substantial amount of raw materials as well as consumption of large quantities of energy. Therefore, this situation has been one of the key contributing factors for the increased interest in buildings sustainability, which is even more significant for developing countries and hot climate regions. The development of current Saudi buildings still lacks application of sustainability in which buildings remain heavily dependent on air conditioning, a factor that results in high energy consumption [1]. Building performance generally in Saudi Arabia lacks the application of energy efficient and sustainable technologies. 70% of residential buildings are not thermally insulated [2]. The issue of energy efficiency is not given serious consideration with regard to Saudi building designs [3]. Building sector alone was responsible for about 80 percent of the total energy consumption in 2009 in Saudi Arabia, 70 percent of this rate is a result of the operation of HVAC systems [4]. Reference [5] mentions that this example of unsustainable practice poses a high pressure on the energy consumption in Saudi Arabia as the future projections of energy consumption depict an alarming image of the country. Saudi Arabia has not yet enforced regulations or mandatory building codes that require the incorporation of sustainable and energy efficiency applications into the design of buildings [5],[6]. No previous studies have considered user behaviour and what its effects are on energy consumption [7]. This study will focus on residential buildings as they considered one of the biggest energy consumers and negatively impacting the sustainable development in the country. In order to address the issue of energy conservation in the domestic sector in Saudi Arabia, it is important to explore local public attitudes and cultural obstacles that hinder the establishment of sustainable housing. This paper would therefore examine societal views of energy efficiency, assess the nature of the issue, and explain cultural barriers to establishing energy efficient housing in Saudi Arabia.

II. METHODOLOGY

The research work was based on a survey that was carried out using questionnaire technique which aimed to assess current user behaviour with regard to building energy consumption. A large body of information was sought in relation to building design, area, cultural image, and respondents' perceptions. The research used Survey Monkey as a dissemination platform . Furthermore, the survey was written in two languages: English, for the international public who lived in the area, and Arabic, the local language, so that everyone could answer the questions. The questions were designed to be easily and straightforwardly answered by the participants to avoid speculation. The snowball technique used in the distribution of the survey proved satisfactory. It was conducted in November 2019 using social media web-based links and distributed to the public to encompass the sampling of individuals of different ages, educational levels, and from different locations across Saudi Arabia, to deliver a true picture of the

situation. 822 total responses were obtained in the process with a completion rate of 76 % (628 respondents). Since the answers to the survey questions are in multiple choices or to be selected from a prepared list of possible responses, the normality test and related parameters were not considered as answers may not be treated as continuous data. This public questionnaire statistically identify the significant corroborating data including dwelling related characteristics such as type, area, architectural style, consumption patterns, occupants behaviours, public perception of sustainable buildings and Saudi Building Codes (SBC), and socio-cultural barriers that hinder sustainable development of residential buildings.

III. RESULTS AND ANALYSIS

A. Respondents and Dwellings Characteristics

The survey delivered a huge number of respondents offering a more accurate portrayal of the situation at present. TableI elaborates on the demographic profile of the respondents.

Characteristic 1		Characteristic 3	
Gender	**Percentage**	**Educational status**	**Percentage**
Male	76%	Secondary or below	11%
Female	23%	Diploma	14%
		Bachelor	50%
Prefer not to say	1%	Postgrad - Master or PhD	25%
Characteristic 2		**Characteristic 4**	
Age	**Percentage**	**Location**	**Percentage**
18-24	9%	Central Region	30%
25-34	37%	Eastern Region	14%
35-44	34%	Western Region	21%
45-54	12%	Northern Region	9%
55+	8%	Southern Region	26%

Table I Respondents Demographic Profile

The majority of the respondents were male (76%) and out of all the respondents, 30% located in the Central Region. A total of 37% of the respondents were between 25 and 34 years old and 34% were between 35 and 44 years old. Half the respondents held a bachelor's degree. Furthermore, 73% of participants stated that they are the main households, responsible for paying utility bills. This might contribute to a better responses and more accurate answers for questions about dwelling properties and energy consumption.

The data revealed that about 47% of respondents were residing in detached houses (Villas) compared to 37% living in flats. This comes in line with the fact that villas are considered the most common hosing unit type as Saudis tend to adopt as seen in recent development [8]. Based on the survey output, almost half of the total respondents live in old buildings (over 10 years), as illustrated in Fig. 1. The age of housing units determines both their general state and level of energy efficiency. Indeed, a recent study of residential buildings in Dhahran city has shown that recently constructed housing units have walls and roofs insulation and often double-glazed windows[9]. Moreover, existing old dwellings are usually in poor condition and need to be renovated.

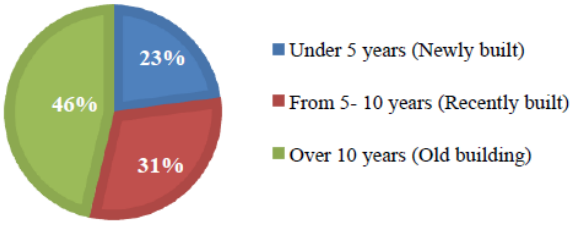

Fig. 1 Categorisation of the age of respondents' dwellings

The size of the dwelling plays a significant role in building energy performance[10]. The results showed domination of properties with areas of 150 to 300m² representing 31% of the responses whereas adobes of areas between 301-500 m² come second with a share of 22%. According to the Ministry of Municipality in Saudi Arabia, the average area of a residential site is 625 m² where only 60% of the site can be built on [8]. Average area of properties in Saudi Arabia is large compared with similar dwellings in Europe [8]. Over the last few decades, the average total dwelling area has increased from 300 m² to 500 m² [10]. The Saudi society is known by the tendency of having medium to large family size in general. This is reflected in the survey data as 50 % of the respondents have more than 5 members living in the dwelling whereas families of size 3-5 members represent another 40% of the total responses. This is in line with other findings which revealed that the typical family size in Saudi Arabia has a value of 6 people [10], [11].

Half the respondents have 4 or more bedrooms in their houses indicating the large family size stereotype about Saudis. These rooms will definitely require cooling during the very hot summer months of Saudi Arabia to ensure occupants' thermal comfort. Survey outputs indicate the amount of energy used to operate the additional spaces in the house that as a result will increase the cooling load and hence the energy consumption.

B. Energy Consumption Patterns

A positive indication is that the majority of respondents are well informed about their cost of electricity. About 80% of respondents knew the amount of their monthly electricity bill. This question was strongly correlated to the question asking the respondent if he or she is the household. The electricity prices were subsidized until 2018 when the government initiated a new energy conservation scheme and one of the measures was to increase the electricity tariff for all sectors. In residential sector,

prior to 2018 the price for consuming 1 kWh was 0.05 SAR (0.014 USD) whereas now it costs 0.18 SAR (0.048 USD)/ kWh, an increase by 260 % . Respondents were asked to enter their average monthly electricity cost. The mean of the entered average cost values was 743.45 SAR (198.3 USD). When comparing the monthly cost of electricity required to operate the respondent's house with the monthly income, 53% of respondents considered it high. Reference [8] reported in his study the difficulty of being able to afford utility bills. This indicates the need for energy efficiency measures in residential sector in the KSA.

According to survey results, nearly half of responses confirmed most to all of the day house occupancy during the weekdays whereas one third reported part of the day occupancy (i.e.,5 to 8 hours). This can be attributed to the commitment to schools and/or work during normal working days. The long hours house occupancy may be caused by the fact that in Saudi culture, it is to some extent common that the wife should take care of the house and preferred not to be employed, a socio-cultural stereotype.

A positive sign is that the majority of respondents (73%) knew which house appliances can place high pressure on operational energy demand, namely the ACs. However, this indication does not necessarily mean that same respondents know about sustainability or house efficiency. The vast majority of respondents (86%) use air conditioning to cool their houses. This is no surprise due to the fact that the KSA is renowned by its hot temperature most of the year where average ambient temperature can reach 45°C [10]. Amongst all types of air conditioning in the KSA, Window and Split systems seem to be popular in Saudi housing. These two types exist and operate separately or can be combined in one dwelling as the respondents stated. Most of AC operation in respondents dwellings take place in both bed and sitting rooms according to 74 % of survey responses.

The period during which air conditioning is used in the home where about 90% of respondents use air conditioning continuously both day and night times. This reflects the considerable amount of kWh being consumed to operate the air conditioning during the summer period. This finding fall in agreement with [5] who mentions that this example of unsustainable practice poses a high pressure on the energy consumption in Saudi Arabia as the future projections of energy consumption depict an alarming image of the country.

One of the objectives of this survey was to conceptualise occupants behaviour and awareness. Participants were asked of their reaction when they feel cold during AC operation. More than half of respondents tend to lower the AC cooling intensity.

Allowing fresh air to pass through the house is considered as a healthy household practice. This can be achieved by opening windows to allow the natural air exchange process. Survey Results depict that half the respondents (53%) tend to sometimes open their windows whereas 8% never do. Other responses vary from often to always open the windows. Opening house windows is mostly driven by the need to refresh indoor air as told by 86% of total respondents. Only 2% of respondents open their windows to cool the house which in Saudi Arabia would only be applicable to regions of moderate temperature (mountain regions). A list of potential reasons that may prevent house occupants from opening their windows was suggested to the respondents. As the country is characterised by its harsh climate conditions, the reason (Hot outside weather) dominates respondents reasoning by 43%. Furthermore, keeping windows closed to prevent the dust comes as second strong reason with a percentage of 29. Other reasons such as Block outside noise, Maintain AC interior cool air , and Keep privacy were also considered but only attracted minority.

C. Public Perception and Willingness

It is important to mention that nearly three quarters of respondents lack awareness about sustainable (also called green or energy efficient) buildings as suggested by survey outputs. A fundamental objective of thisquestionnaire was to arrive at adetailed andaccurate assessment of people's awareness and willingness to adopt sustainability measures into housing. This reflects an alarming picture as this lack of awareness about sustainability may reinforce the non-sustainable practices during building use. Conversely, about 61% of respondents seem to know about thermal insulation materials and their role at reducing energy consumption at building operation phase.

Following the previous two figures, respondents were asked if or not their houses are being thermally insulated. Out of all respondents, 43% of them live in non-insulated dwellings whereas 26% do not know for sure. Only 197 live in houses with thermal insulation. Previous literatures [12],[13]reported that new buildings in SA continue to be erected without proper insulation. This practice significantly influences the building performance with respect to energy as many other official sources provide the potential energy reduction that can be achieved with proper thermal insulation of the building envelope [1], [14]-[17].

Respondents using single glazed windows in their dwelling represent 47% of the sample compared to 52% having windows with double glazing, according to the survey results. Previous studies have proved that using single glazing is not the best option when considering window design as this may not be as efficient as double glazed windows in term of heat gain and transmittance [8], [18].

Respondents willingness to pay more for a house that has better energy efficiency methods was assessed in this survey. The finding reports that exactly half of

responses confirmed willingness to pursue energy efficient houses whereas the other half were unwilling or not sure. Possible justification of negative responses regarding respondents willingness are shown in Table II. This is in accordance with [5] statement that in the KSA, the application of sustainability techniques and measures to building construction is still mostly considered as a luxurious option and mainly feasible for parties and people who have the financial capacity to afford it.

Answer Choices	Responses
Not sure of the effectiveness of energy efficient technologies	26%
The cost of electricity consumption in my house is not high	8%
I cannot afford applications of sustainability	32%
Not familiar with sustainability and energy saving subjects	34%

Table II Reasons for Not Moving to a More Efficient House

The survey revealed the key architectural influences resulting in high energy consumption. Respondents confirmed that they were satisfied with the quality of natural lighting in their dwellings. Shading is an important factor that must be taken into account. However, shading devices were not applicable in about 36% of respondents houses in addition to another 36% who assessed the quality of shading as between poor and fair. The rating of the quality of internal thermal comfort in respondents houses was as follows: 42% assessed it as poor to fair whereas 48% assessed it as good to excellent. Some barriers are rooted in the religion (Islamic culture). For instance, the concept of gendersmixing in the same place is contrary to Islamic culture, and therefore domestic buildings are designed to allow the separation of genders.

Furthermore,in terms of potential planning for residential housing, many of the questions in the survey centred on understanding the public's thoughts on the design of future homes with an emphasis on energy savings.As a result, multiple questions were incorporated into the questionnaire testing people's view as well as intention to encourage and adopt proven energy saving techniques and requirements. Fig. 2 depicts the issues that may hinder the sustainable development of residential building in Saudi Arabia. Based on respondents' views, households in general have no awareness of sustainable or low energy buildings. Moreover, the majority of respondents are in agreement that issues such as shortages of sustainable products in Saudi markets, lack of trained labour or technicians, and escalating prices of sustainable construction materials and products strongly negatively influence the sustainable development of housing sector.
Fig. 2 highlights the overall desire of the population to embrace and recognise sustainable buildings, while certain elements would undoubtedly face slow adoption or acceptance, in particular those relating to the size of the houses or the decrease in rooms number. Reducing the dwelling size to proportionally fit the household members seem to be controversial as the responses indicate.

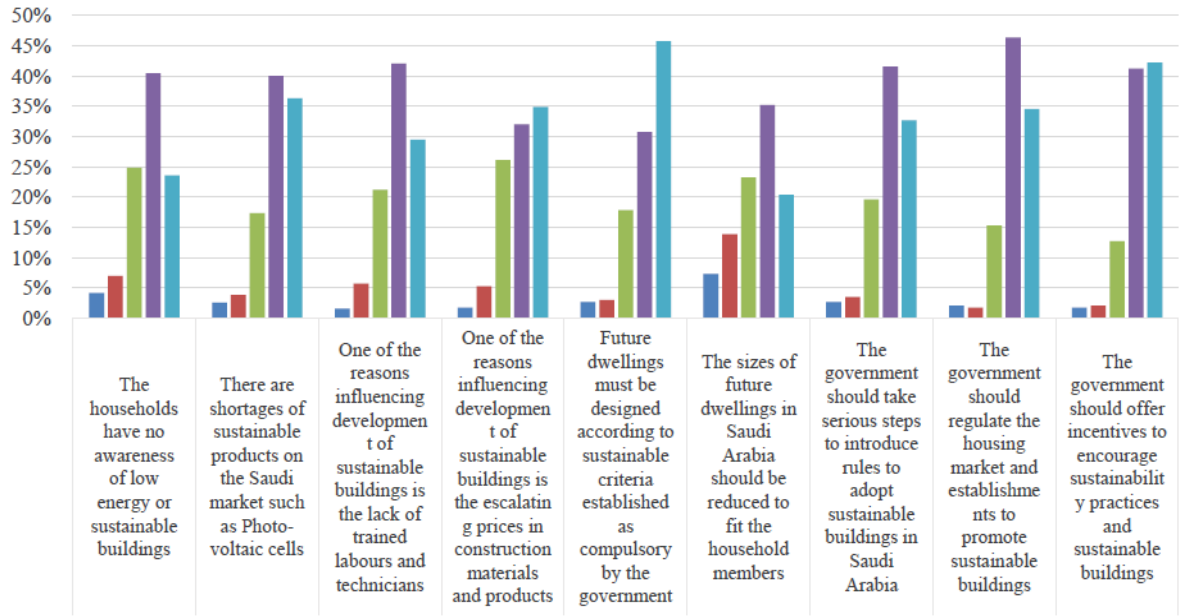

Fig. 2 Respondents views on building related issues

To conclude the questionnaire, the participants were asked about their opinion regarding whether residential buildings in Saudi Arabia meet sustainability and energy saving standards or not.

More than half the respondents stated that Saudi houses do not comply with sustainability features in addition to another 36% who are not sure of the answer. Clearly, this indicates the urgent need to develop sustainable or energy efficient guidelines for the public to follow and enforce such building codes or requirement that enhance residential building performance.

IV. CONCLUSION

This study addressed public views of sustainable homes in Saudi Arabia and identified main factors contributing to high energy use. An in-depth survey was used as the main tool for study.In brief, short-term strategies to enhance energy building performance are required to ensure sustainability plans and energy conservation. The study showed that many aspects had an effect on the energy efficiency of residential buildings.Firstly, the thermal properties of recent residential buildings were found to be poorly designed. Second, the majority of occupants prefer a room temperature below 24°C, which requires a significant amount of cooling. Third, owing to the climatic conditions and the typical lifestyle of the Saudis, housing units are occupied for more than 18 hours per day.

Saudi Arabia is abundant in solar energy, and it is possible that this natural resource may be used to satisfy and cover its energy needs. Finally, there are strategies for enhancing energy efficiency, such as heat-resistant insulation, shading systems, and efficient or high labelling housing appliances as the seven-star ACs. A set of architectural (retrofit) criteria for self-sustaining buildings needs to be devised and encouraged by offering incentives from both the government and relevant stakeholder.

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