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Assessment of Current Energy Consumption in Residential Buildings in Jeddah, Saudi Arabia

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Abstract: In the Kingdom of Saudi Arabia (KSA), residential buildings' energy consumption accounts for almost 50% of the building stock electricity consumption. The KSA's economy relies heavily on fossil fuel sources, namely oil reservoirs, whose depletion will negatively affect the future development of the country. The total electricity consumption is growing by approximately 5–8% annually, which would lead to oil production and oil consumption being equal in 2035. Therefore, residential buildings need further assessment as regards their current energy consumption. This research used a survey to explore current user behaviour in residential buildings' energy performance in the city of Jeddah, KSA. The findings of the survey show that several factors impact the energy performance in residential buildings. First, the buildings' thermal properties were found to be poorly designed. Second, the cultural aspects (family member role and generous hospitality), and the majority of users within the buildings preferring a room temperature of below 24 °C, requires a massive amount of cooling due to the climate conditions. Third, an increase in user awareness has helped to slightly improve residential buildings' energy efficiency. Knowing the current high-energy-consumption sources and causes, being able to define opportunities for thermal properties' enhancement, and increasing user awareness of how to achieve self-sustaining buildings are essential.

Keywords: energy consumption; Saudi Arabia; renewable energy; building envelope; energy efficiency; Jeddah

1. Introduction

Worldwide, many countries are investing in renewable energy sources to preserve natural resources for a sustainable future. In the Kingdom of Saudi Arabia (KSA), electricity consumption uses over one-third of the total daily oil production of the country, as shown in Figures 1 and 2 [1,2]. Hence, the KSA government has become concerned about its future economy and is investing in sustainability measures.

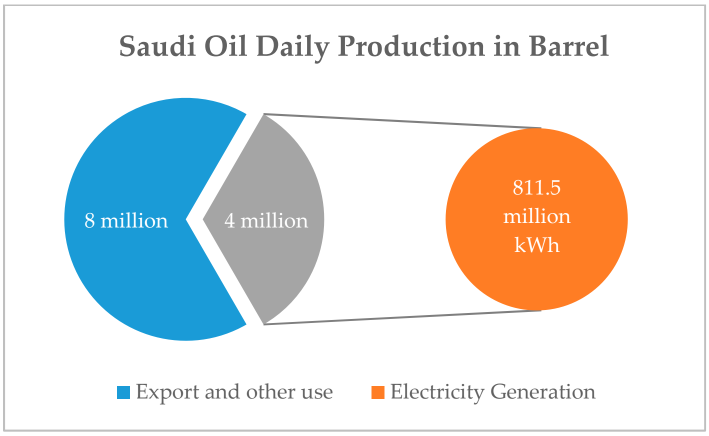

Figure 1. Electricity percentage from daily oil production. Source: [1,2].

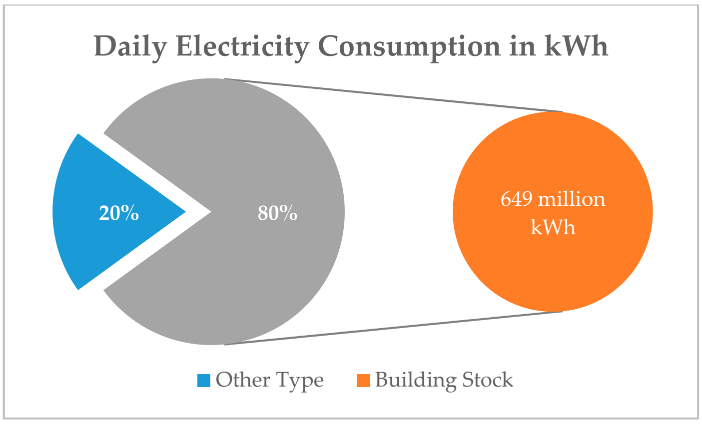

Figure 2. Electricity consumption of the building sector. Source: [3].

In April 2016 [4], the KSA government implemented and deployed the Saudi 2030 Vision. In the context of this paper, sustainable development is defined as development that attains the current generation's necessities without inhibiting the needs of future generations [5,6]. The Saudi 2030 Vision regarding buildings concentrates on developing KSA cities and achieving environmental sustainability [4].

In November 2010, the KSA government introduced the Saudi Energy Efficiency Center (SEEC) and, in March 2018, it started functioning after the Saudi 2030 Vision announcement [7]. In 2018, the KSA government announced a $200 billion investment with Soft Bank, to produce 200 gigawatts of energy using Concentrated Photovoltaics (PV) solar plants by 2030, which should cover the future projected energy consumption by 2035 [8]. Currently, buildings consume around 80% of the total electricity that is generated [9,10]. Now, the government is investing in renewable energy plants.

Nevertheless, buildings' energy consumption is high. The government has focused on lowering current energy consumption. Buildings' energy consumption is the first concern due to its effect on the total energy consumption. Therefore, a new building code was implemented in 2018. Existing buildings are the cause of the current energy consumption and, without redevelopment, this problem will remain.

A total of 2.32 million new residential units need to be built by 2020, of which 33% were delivered by January 2019 (buildings using the previous building code) [9,11,12]. Currently, residential buildings consume around half of the total energy consumption of the building stock due to many defects in the building code, design processes, urban design, and construction applications.

Research has illustrated the significant challenges that KSA buildings are facing, such as high electricity consumption, mainly due to air conditioning (AC) units, which are responsible for up to 70% of the electricity consumption of residential buildings, and a lack of insulation in the building envelope (70% of residential buildings are not thermally insulated) [9]. A governmental report showed that refrigerators used twice as much electricity as ACs in the average week [13]. However, the report did not show any energy measurement values that were able to be compared, such as kWh (Kilowatts per hour). Existing studies do not include the exact energy consumption from all energy users and do not show the building envelope's role in how much energy is used. Unfortunately, the recent changes and developments in the country are also not included in any of these studies. Thus, there is a need to identify the main causes of the high energy consumption of buildings. This study has generated a survey with specific criteria that can show the current buildings' energy consumption and the behaviour of its users. No previous studies have considered user behaviour and what its effects are on energy consumption.

The key driver for energy consumption is the hot–arid climate, which requires the cooling of buildings in order to provide the desired indoor comfort. The need to lower the consumption of fossil fuels requires immediate improvement in buildings' energy performance for efficient energy use to avoid future economic consequences in the country.

This article aims to evaluate the effect of the behaviour of the current users on the buildings' energy performance and takes into consideration the cost aspects. It was difficult to produce more detailed questions in the survey regarding energy consumption. This type of electronic questionnaire only recorded complete questionnaires; partly completed questionnaires were disregarded. It was also not possible to distinguish, in depth, how the electricity per household was consumed, such as in cooling, heating, cooking, cleaning, and ironing. The main reason for this is to gain a broader understanding and identify the main causes of high energy consumption in buildings. The study used a survey with specific criteria to assess current buildings' energy consumption and the relationship with the behaviour of its users.

2. Background and Related Work

2.1. Overview of Current Energy Demand Scenario in the Kingdom of Saudi Arabia

In the context of hot–arid climates, KSA was ranked among the 10 countries with the highest energy consumption per capita in 2014 [14]. KSA was also ranked as one of the 10 most CO_2-emitting countries in the world [15,16]. According to the Saudi Energy Efficiency Report [17] published in 2013, the primary energy consumption per capita is over three times higher than the world average. According to a study by Alshibani and Alshamrani [1], electricity generation consumes nearly one-third of the daily KSA oil production. Nevertheless, electricity usage is annually growing by approximately 5–8%, which, based on these facts, would potentially lead to oil production and oil consumption being equal by 2035 [1].

Until now, the building stock has consumed around 80% of the total electricity that the Saudi Electricity Company generates per day. Several authors, including from the King Abdullah Petroleum Studies and Research Center (KAPSARC) [15] in 2018, have stated that the energy consumption of residential buildings accounts for approximately 50% of the total electricity consumption in the building's stock (Figure 3) [3,10,18,19]. Remarkably, AC systems account for around 50% of the buildings' stock electricity consumption [9,10]. KSA contains five different climate regions that all have high cooling demands, as shown in Figures 4 and 5, ranging between 40% and 71% for a typical villa's energy consumption [20]. The cooling loads are relatively high in KSA, as seen in Figure 5, and urgent intervention is needed to maximise energy efficiency. The city of Jeddah has an extreme case of high cooling demand in KSA, as presented in Figures 4 and 5.

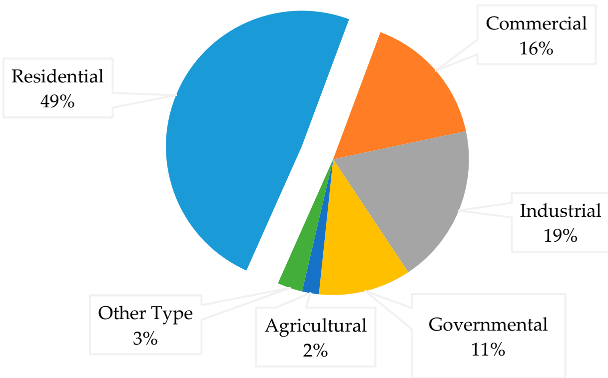

Figure 3. Residential electricity consumption. Source: [20].

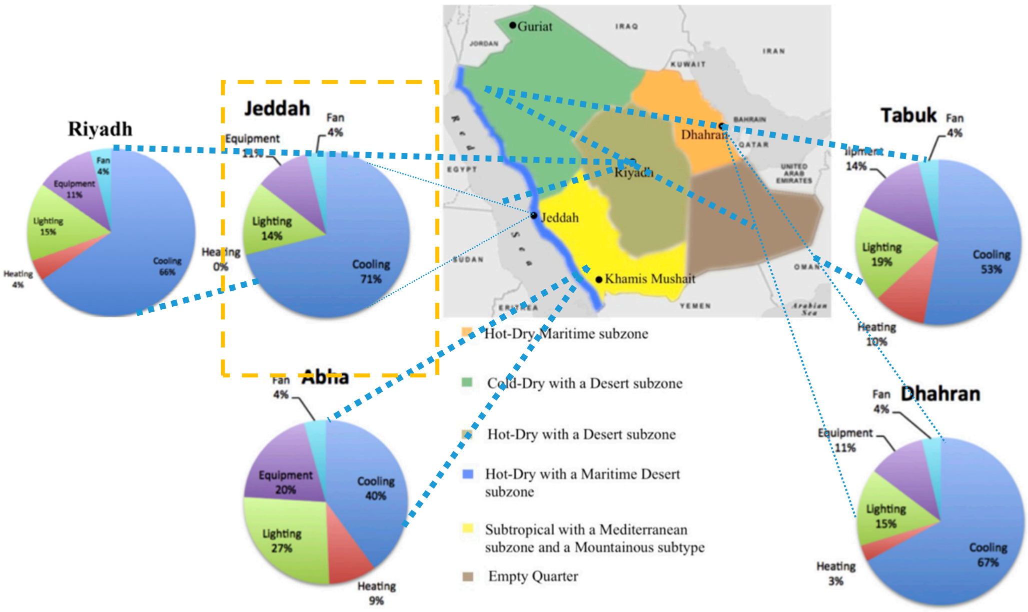

Figure 4. Kingdom of Saudi Arabia (KSA) climate zones and relative energy demands of a typical villa that is 525 m^2 in size and has two floors. Source: [20,21].

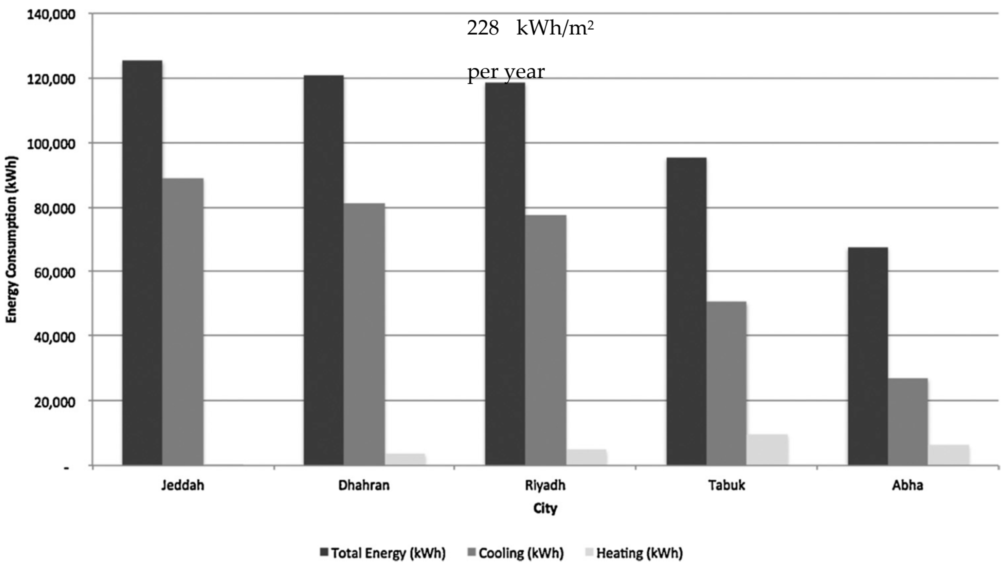

Figure 5. Total annual energy consumption, space cooling and space heating for a villa located in five cities. Source: [20].

In Jeddah, the high cooling demand appear to be due to both its high temperatures and its high humidity. This is reflected in the number of Cooling Degree Days (CDD), which is around 6587 °C (Table 1) [20,22]. In the past, the energy performance of historic buildings was influenced by urban design, so the surrounding buildings controlled air movement and solar radiation, as shown in Figure 6 [23]. The building envelope acted as a storage buffer to store heat during the day and transfer it later, when needed, to the indoor space.

Table 1. Cooling and heating degree days for the five cities in KSA. Source: [20,22].

City	Cooling Degree Days (CDD) (°C-days)	Heating Degree Days (HDD) (°C-days)
Jeddah	6587	0
Dhahran	5953	142
Riyadh	5688	291
Tabuk	4359	571
Abha	3132	486

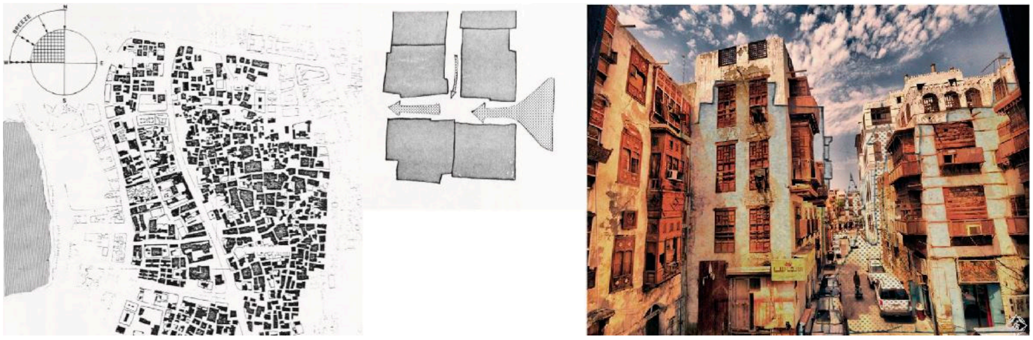

Figure 6. Urban and air movements circulation in the historic district of Jeddah. Source: [20,22].

Within the last five decades, the number of buildings in Jeddah has expanded rapidly due to the population growth, from about half a million [24] to over four million [25]. Thus, the demand for housing and the fast growth of the population have driven the need for urgent construction of dwellings, illustrated in Figure 7 [26], which have avoided the traditional building design values. In turn, this has resulted in buildings that depend entirely on AC systems. Moreover, human lifestyles and user comfort standards around the world have changed, and in general, the need for cooling has increased enormously [27]. In 2018, the government implemented a new building code to ensure better energy performance of new buildings. As previously mentioned, the existing building stock results in massive energy consumption. Building designers need to investigate the main causes of this high consumption and how existing dwellings can be refurbished for more efficient energy performance.

Figure 7. New neighbourhood buildings in Jeddah. Source: [26].

2.2. Related Studies

A number of studies observed and examined the energy consumption of residential buildings in KSA [13,18,28]. The annual governmental report indicated that refrigerators used twice as much electricity as ACs in the average week [13]. However, the report did not demonstrate any energy measurement values that were able to be compared, such as kWh (Kilowatts per hour). A study by Aldossary et al. [28] that focused on residential buildings suggested that fundamental retrofitting improvements could generate a reduction of 37% in KSA residential buildings' energy consumption. A comparable study by Howieson [18] concentrated on how improving the building fabric performance coupled with ventilation ground pipes could lead to a decrease of approximately 80% in the cooling demands in KSA, achieved by adding a small chiller unit to a water reservoir. This research pointed to clear improvements that could be made without any fundamental enhancement of the building envelope. The solar radiation effect results in high cooling demands due to heat transfer from the building envelope. No earlier studies have considered user behaviour and what its impacts are on energy consumption. Unfortunately, the recent changes and developments in KSA are also not taken account of in any of these studies. Therefore, there is a necessity to identify the main causes of the high energy consumption of buildings.

2.3. KSA 2030 Vision Influence

The KSA government has prioritised sustainable measures as the gateway to a better future. As mentioned earlier, the Saudi 2030 Vision was implemented in April 2016 [4]. Sustainability is one of the leading aspects of the Saudi 2030 Vision, and energy consumption stands as a critical indicator. The Saudi 2030 Vision states:

> "Our vision is a society in which all enjoy a good quality of life, a healthy lifestyle and an attractive living environment". [4]

This specific aim illustrates an understanding of the necessity of a high quality of living but also respects the environment and takes into consideration future responsibilities. The government is taking serious steps to change the country's economy from an oil-based economy to a multi-source economy, starting with the 2030 Saudi Vision, which it intends to implement in all of its aspects. The government has introduced many programs such as the Saudi Energy Efficiency Center (SEEC).

In 2017, the International Energy Agency (IEA) [29] stated that KSA was targeting a 120-gigawatt electricity generating capacity by 2032 to accommodate the country's electricity needs. Then, in 2018, the government decided to invest in renewable energy sources to cover the projected energy consumption for 2035. By July 2018, the KSA government announced a $200 billion investment to produce 200 gigawatts by 2030 using Concentrated Photovoltaics (PV) solar plants [8]. In November 2018, the National Committee of the Saudi Building Code (SBC) released the new building code to the public. The new SBC requirements and processing programs are intended to optimise new buildings' energy performance. However, the 5.47 million existing housing units [13] will still create a massive cooling demand.

To sum up, it is essential to make plans to promote alternative energy sources. Nonetheless, knowing the causes of high energy consumption is critical to ensure holistic, sustainable future development.

In 2018, the building stock used about 80% of the electricity produced in the country (see Figure 2), which has driven the government to enhance buildings' energy performance. Many reasons have been put forward for the high current energy consumption, including government subsidies, cheap electricity tariffs, a lack of building insulation, affordable AC units, the accustomed lifestyle, and the desire for a comfortable temperature range.

The KSA government in 2018 implemented several actions to avoid a future economic crisis as a consequence of high energy consumption, which included a new SBC, activated SEEC, no longer subsidising services such as water, electricity and gasoline, and plans for renewable energy sources.

Notably, the decision to stop subsidising electricity has led to a slight growth in energy efficiency awareness, which is apparent when people compare energy prices. Energy users started to be aware of their electricity usage when the price per kilowatt (KWh) increased by 260% from 0.05 to 0.18 SAR (0.013 to 0.048 USD) [30]. At the same time, a citizen account was created for a specific income range and launched to cope with the increased prices.

Current residential buildings need further developments to control and manage heat transfer through the building skin (envelope). There is a necessity to evaluate and assess current buildings' energy consumption in order to define the need for future developments. The recent changes have not yet been investigated concerning building energy consumption and user behaviour.

This research aims to explore and prove how the behaviour of users affects residential buildings' energy performance.

3. Research Approach (Methodology)

The research work was based on a survey that was carried out using questionnaires in Jeddah City, which aimed to assess current user behaviour with regard to building energy consumption. The survey aimed to give a broad understanding of user energy behaviour and its effects on residential buildings' energy consumption.

The questionnaire focused on determining energy costs and user behaviour in light of the drastic increase in the price of energy. The survey targeted the householders (male or female) who were responsible for the energy bills. In December 2018, 396 completed surveys were gathered, which, considering an infinite universe, resulted in a 90% confidence level with a 5% margin of error. The research used Google forms as a dissemination platform for the questionnaire after a pilot survey was conducted, tested and evaluated.

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 survey design required the participants to fill in all of the required questions to be allowed to submit the survey. Hence, it was not possible to know how many actual distributed surveys were attempted as the system automatically discarded the semi-/not-filled-in attempts. The survey was conducted in December 2018 using social media web-based links and an in-person link distribution in a shopping centre, The Red Sea Mall.

4. Results

4.1. Demographic Profile

Three hundred and ninety-six completed forms were returned, equating to 333 respondents who actually lived in Jeddah; the rest lived outside of Jeddah. The survey results indicated that around 80% were Saudis, and the rest were expatriates. The majority of the respondents were male (76.9%) and out of all the respondents, 70.6% of the respondents were married. A total of 44.1% of the respondents were between 20 and 34 years old and 39% were between 35 and 49 years old. A total of 57.1% of the respondents held a bachelor's degree.

Furthermore, the survey revealed that most of the respondents worked as an employee of either the government (34.5%) or the private sector (36.6%). Table 2 elaborates on the demographic profile of the respondents.

Table 2. Demographic profile of respondents.

Total Respondents	-	396
Respondents from Jeddah Item	- -	N = 333
Residency Status	% of Responses	Frequency of Respondents
Saudi	79.9	266
Non-Saudi	20.1	67
Gender	-	-
Male	76.9	256
Female	23.1	77
Marital Status	-	-
Divorced/Widowed	0.9	3
Married	70.6	235
Single	28.5	95
Age	-	-
Under 20	3.0	10
20–34	44.1	147
35–49	39.0	130
50–64	13.3	44
Over 64	0.6	2
Educational Status	-	-
Incomplete high school education	0.6	2
High School education	18.0	60
Bachelor's degree	57.1	190
Master's degree	18.0	60
Doctoral education	6.3	21
Occupation	-	-
Government	34.5	115
Business	10.2	34
Private sector	36.6	122
Retired	2.1	7
Unemployed	14.2	55
Household Size (number of people)	-	-
Fewer than 3	9.3	31
3–5	43.9	146
6–9	39.9	133
10–16	6.3	21
More than 16	0.6	2

More than 80% of the 333 respondents had lived in Jeddah for more than 10 years (see Figure 8); hence, it is assumed that they might have reliable information and understanding about the recent changes.

4.2. Income Levels

Figure 9 summarises the monthly income levels of the respondents in three categories: low income, average (middle income) and high income. Around 57% of the respondents fall above or below the national average income, which is around 2.6 K USD [31]. Low-income accounts for (23.1%) of the respondents (they belonged to the less than 1.3 K USD income group), the rest of the respondents fall into the high-income group (salary above 8 K USD).

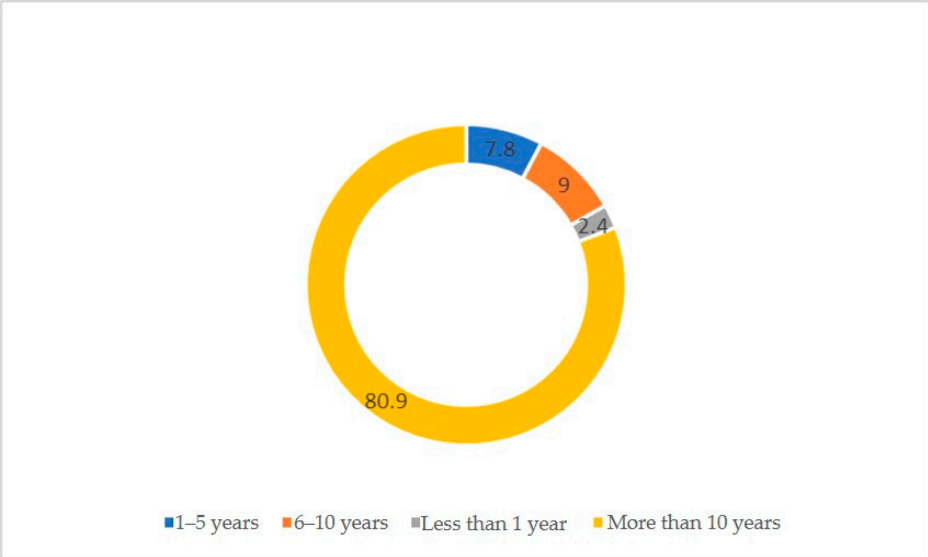

Figure 8. Duration of living in Jeddah.

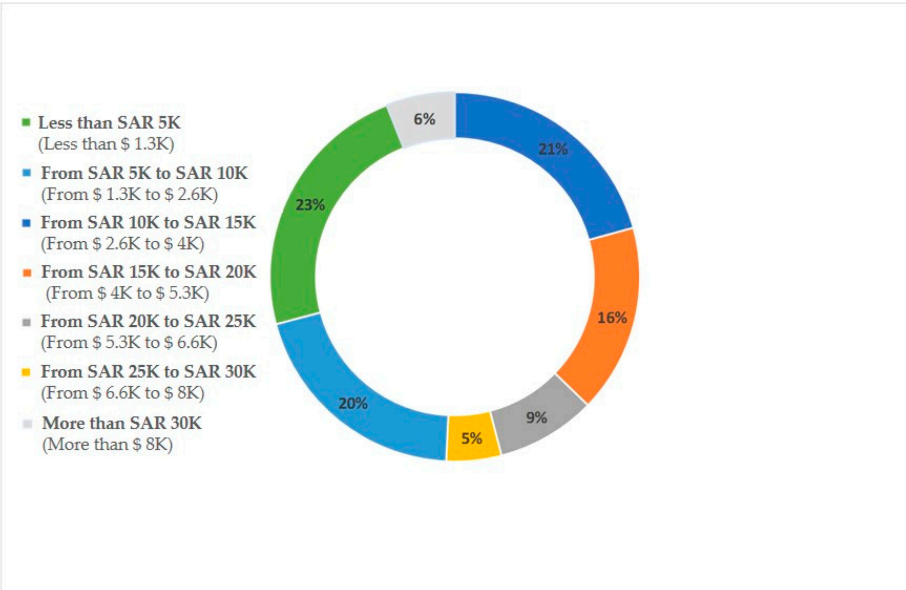

Figure 9. Monthly income of respondents.

4.3. House Type and Ownership

The data revealed that about 64% of respondents were residing in apartments and only 3% in independent houses. The remaining 33% of respondents were living in villas (see Figure 10). The data revealed that more than 52% of the respondents owned their own houses, while 48% rented their abodes.

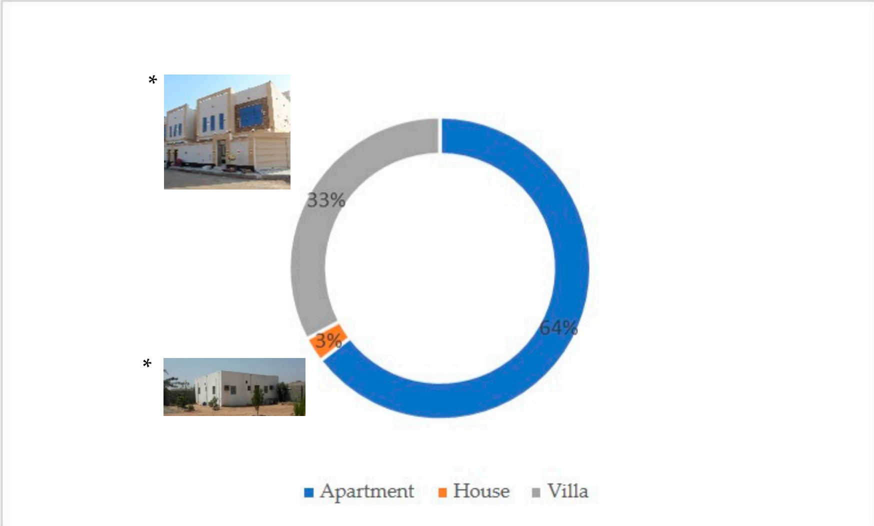

Figure 10. Housing type. * The pictures were taken from Google search.

Furthermore, 14% of the households who rented spent above 30% of their income on rent; only 15% were spending less than 10% of their income on rent (Figure 11).

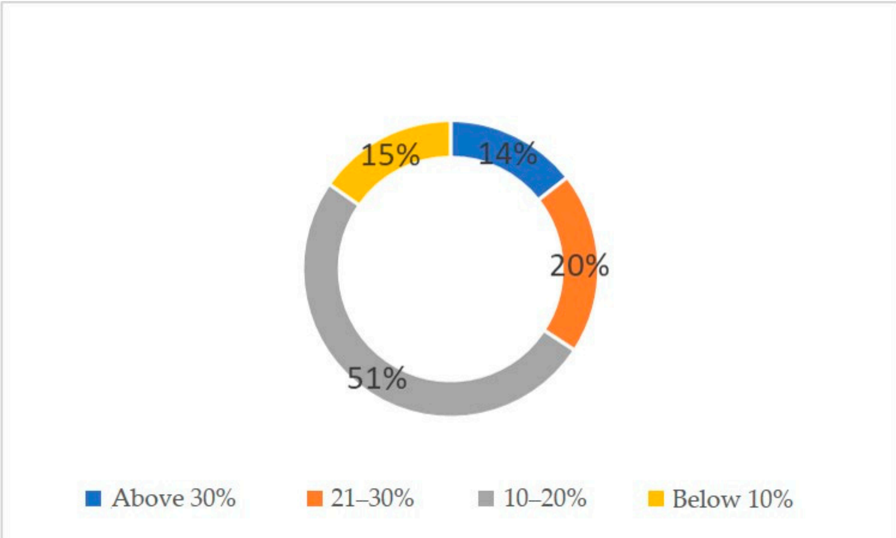

Figure 11. Proportion of income spent on rent.

4.4. Energy Efficiency

Household energy efficiency is a significant concern for architects and other professionals working in the field of low-carbon buildings. Survey results indicate an optimistic scenario with lights and electrical appliances, where more than half of the respondents were using energy-efficient lighting appliances including Light-Emitting Diode (LED) lights (45.9%) and Compact Fluorescent Light (CFL) lamps (12.9%). However, the rest of the respondents, around 41%, are still using a combination of energy-efficient lights and other types of essential appliances (Table 3). In fact, the users were open to other efficient strategies after they experienced such positive results with the efficient lighting strategy changes.

Table 3. Use of lighting appliances.

Lighting Appliances	% of Users	No. of Users
LEDs	45.9	153
CFL	12.9	43
Halogen	8.4	28
CFL & LED	6.6	22
Halogen, LEDs	6.6	22
Others	19.6	65

Thermal insulation was also an essential motive of energy efficiency plans. However, the survey results indicated that only 30% of the respondents reported that their houses were insulated, while 70% of the houses were not adequately insulated (Figure 12). Therefore, to upgrade the wall properties by adding proper insulation as a first step is an achievable possibility to achieve more efficient energy consumption.

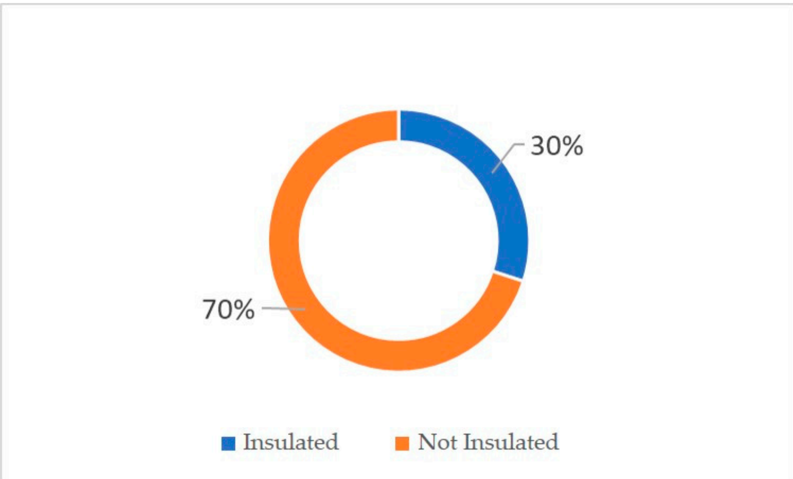

Figure 12. Thermal insulation.

Due to the hot–arid climatic conditions, air conditioning appliances are the primary items that increase electricity demands in Jeddah. Central AC and split ACs are more energy-efficient than AC window units and could reduce energy consumption levels by around 48% [32]. Figure 13 showed that 32% of the respondents were using a combination of Split and window ACs, 8% were using central AC, and 31% were using Split ACs. A total of 28% of respondents relied upon window AC units, which are less efficient. Hence, decentralised Heating, Ventilation, and Air Conditioning (HVAC) systems were widely preferred over central systems.

Additionally, the question regarding satisfaction included several variables, to get a broader understanding of a user's opinion of their home. The variables covered two aspects, namely, services and indoor comfort. The survey results revealed that respondents in Jeddah were satisfied with most of the building level settings, services and amenities, such as room size (79.9%), water and sewer services (57.4%), water and sewer tariffs (64.9%), availability of daylight (72.7%), thermal comfort (64%), window ratios (72.7%), and outdoor acoustic quality (65.5%). However, the level of satisfaction was low (25.7%) regarding electricity tariffs (Figure 14). This was due to the recent 260% increase in electricity tariffs after the government stopped the subsidy of electricity tariffs. Remarkably, the satisfaction with the thermal comfort appeared high, due to the long period use of ACs in indoor spaces. Central AC systems are not often used.

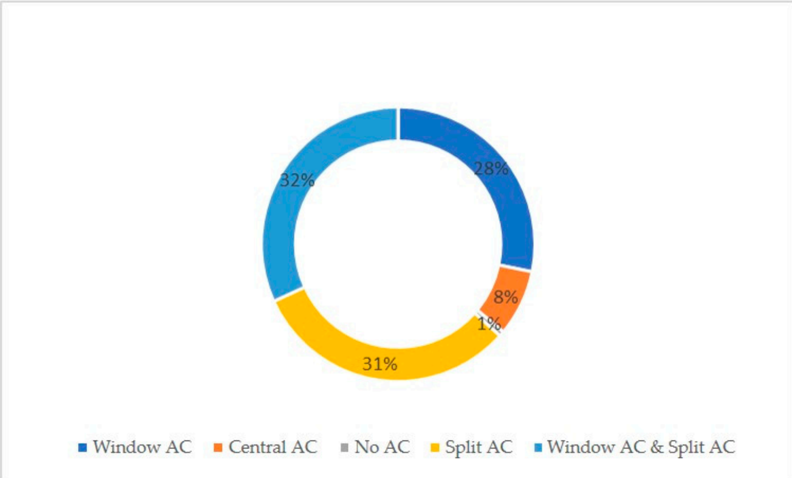

Figure 13. Types of air conditioning.

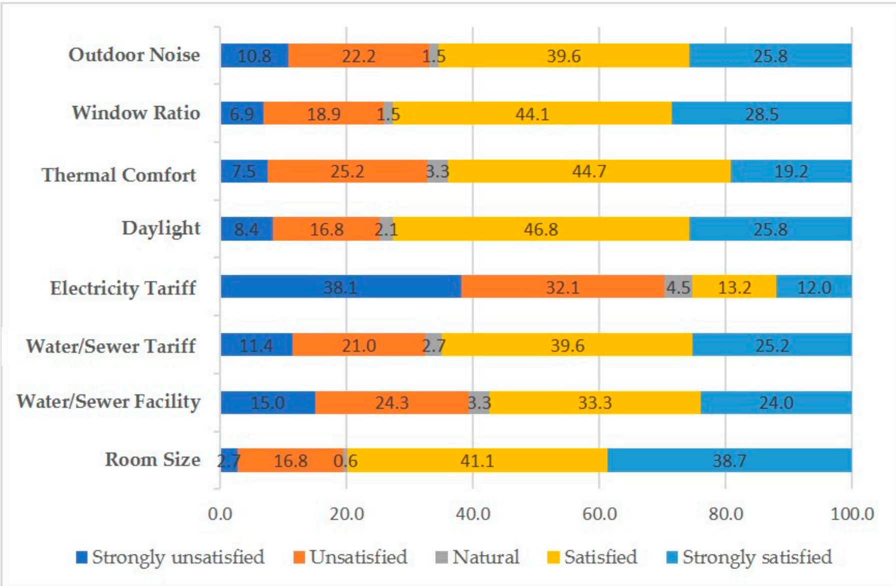

Figure 14. Level of satisfaction on different variables.

Figure 15 also confirms that the majority of respondents (45.1%) preferred to keep their room temperature at 22–24 °C; 34.4% of respondents wished to maintain a temperature of 19–21 °C, and some respondents (8.1%) wanted to keep the temperature lower than 19 °C. Correspondingly, almost 80% preferred 19–24 °C due to the affordable fuel prices when using their AC units.

The amount of time per day that households use an AC unit also determines the electricity consumption. The survey showed that around 53% of households use the AC for more than 21 h. per day on average, and another 23% use it for 18–21 h. Only 9% of the households used the AC for less than 10 h (Figure 16).

The Saudi government is trying to withdraw subsidies to reduce the use of electricity and water. The recent hike in tariffs was reflected by an increase of over 400% in the electricity bills of 13% of households (Figure 17).

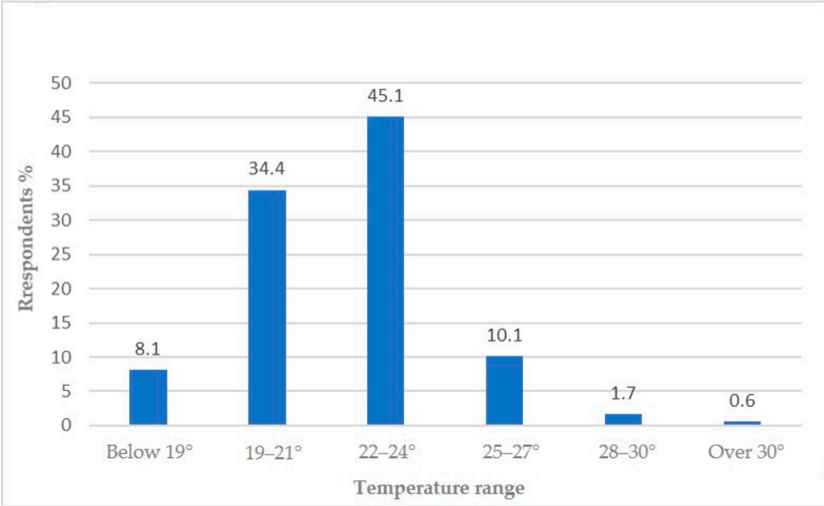

Figure 15. Preferred indoor temperature.

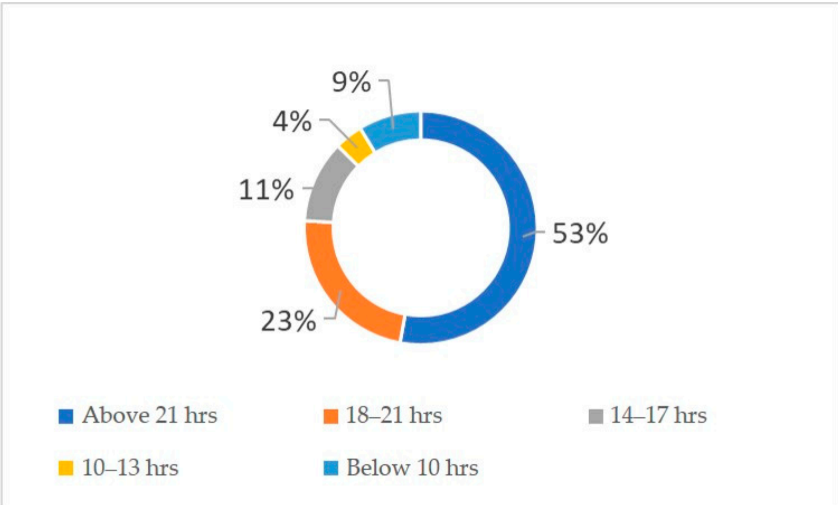

Figure 16. Air conditioning (AC) use by households (in h).

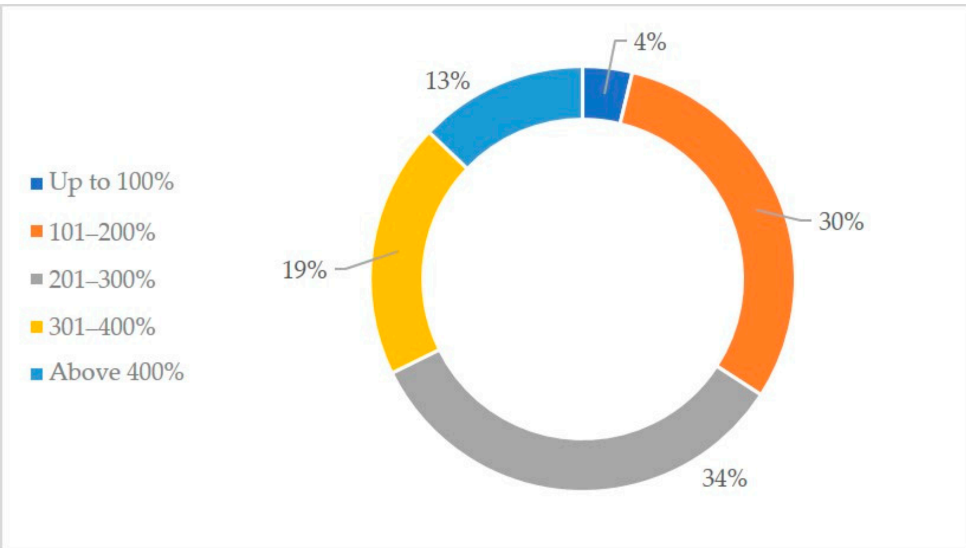

Figure 17. Increase in electricity bills after New Tariff 2018.

It was observed that the increased electricity tariffs in 2018 had a significant impact on household spending on electricity (Table 4). A total of 14% of the households surveyed had a less than 10% increase in their electricity bills. However, 62.6% spent around 20% of their income on electricity. Approximately 4% of households spent above 30% of their income on electricity, with the potential consequence that they must either compromise their savings or cut down their spending on other essential expenses to cope with the electricity bills.

Table 4. The percentage of income spent on electricity bills.

Spending on Electricity of Income	Number of Households
Above 30%	3.8%
20–29%	19.6%
10–19%	62.6%
Below 10%	14%

It was interesting to note how much a household spent on electricity per square meter of built-up area. Results revealed that 31% of households spent more than 5 SAR (1.33 USD)/m^2 on electricity, while only 7% spent less than 1 SAR (0.26 USD)/m^2. A total of 62% of the households spent 1–5 SAR (0.26–1.33 USD)/m^2 to cope with their electricity needs (Figure 18).

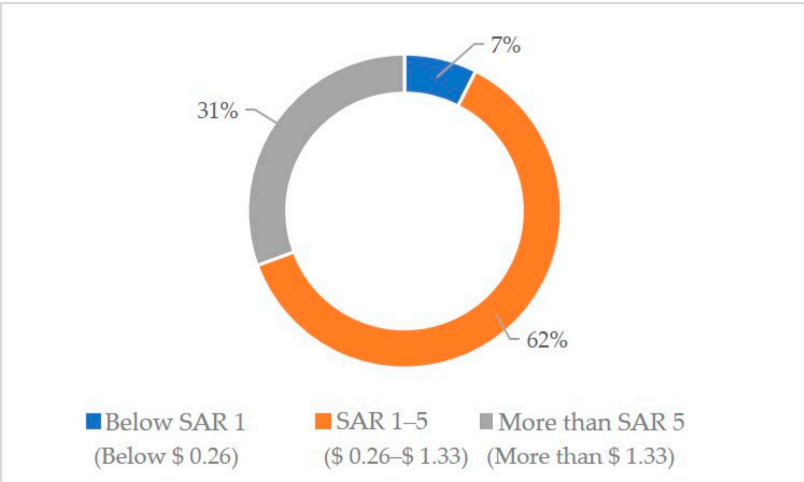

Figure 18. Spending on electricity/m^2.

5. Discussion

The focus of this study was understanding the causes of the high residential building energy consumption in Jeddah and the effects of users' behaviour on energy consumption. The study included different factors such as cost, user behaviour, and the buildings' thermal properties. The study tried to provide a broader understanding of the current energy consumption situation and lay a foundation for further energy assessments and possible solutions.

Though other studies had collected statistics for the same building types, the energy consumption was not explained and the recent increase in electricity bills was not taken into consideration. Many researchers [18,33,34] showed that approximately 70% of the energy consumption was used for cooling the space. These researchers also recommended using better insulation in the building envelope for better energy performance. Furthermore, Hijazi [18] mentioned that any data outcomes from simulation software should be analysed carefully due to the expectation of errors. Aldossary [34] explained the difficulty of being able to afford utility bills. Nonetheless, the General Authority for Statistics showed, in their annual report of 2017 [13], the average weekly usage of electricity per machine, which is not measurable with regards to energy consumption. It would be more helpful if it reported the kilowatts per hour. The study findings explored a basic understanding of the energy consumption per square meter using kWh units. There is a need to retrofit residential buildings, but to be able to do this, relevant information needs to be collected so that appropriate practical solutions can be decided upon and then applied.

5.1. User Behaviour

The results perceived as valid were based on the majority of households whose residents were educated (bachelor's degree or higher) and had lived in the area for more than 10 years. Just over half of the residents own their houses and almost two-thirds live in apartments, which were partly a result of the government-implemented Sakani ("my house") program [11].

Due to the hot–arid climate conditions and poor building insulation, 70% of households have started to become aware of the benefits of insulating their homes. As a result, the massive cooling demand, which also corresponded the daily use of ACs, increased electricity bills. Households maintain their thermal comfort by using AC systems extensively. This is due to many factors such as poorly thermally insulated buildings, low energy prices, rising comfort standards, and the affordability of AC units. Air conditioning units are used for a very large number of hours per day. A total of 99% of households use AC systems, and two-thirds of these use AC systems for over 18 h a day due to the climate conditions and cultural aspects within Saudi Arabia. The head of the household's partner and young children, and/or the housekeepers spend the majority of their time in the house; therefore, houses are occupied continuously. Almost 80% of the respondents stated that their comfortable temperature range was 19–24 °C. Most households would not accept temperatures above 25 °C.

Households have started to become aware of energy efficiency, as reflected in a study that shows that almost half of the households use LEDs. Hence, recently, the government tried to make the general public more conscious of efficient ways of using lighting and air-conditioning systems through various sorts of media.

In general, households are satisfied with selected variables such as outside noise, window ratio, thermal comfort, available daylight, water tariffs, sewage tariffs, and room sizes. The users are also satisfied with their thermal comfort variable, as they use AC for long hours, but unsatisfied with the increase in electricity tariffs. The increases in electricity tariffs were accompanied by other increases in tariffs such as the 5% Value-Added Tax (VAT), sewer tariffs, water tariffs, and gasoline prices.

The government supports the increase in electricity tariffs and also provides an assigned amount (based on income range) using the citizen account. The citizen account is a programme connected to every Saudi citizen who needs support from the government, which follows certain requirements and procedures. The government citizen account programme positively reflects respondents' satisfaction with the indoor comfort variables and the sewer and water tariffs.

Any retrofitting schemes, proposals, or designs should consider making the abodes naturally cooler and also need to take into consideration implementing air conditioning units that are more energy-efficient, sustainable, run at a cheaper rate or can be supplied with cheaper energy sources.

User energy efficiency awareness is regarded as evidence to support the feasibility of introducing new retrofitting solutions. The households started questioning and analysing why their energy bills had increased and how they could reduce it. For example, around half of households upgraded their lights to LEDs in response to the government's announcement that it was increasing energy bills. However, there are opportunities for improvement in terms of building insulation, daylight, and efficient AC units to lower energy consumption. For example, there are techniques for improving energy performance such as high-heat-resistant insulation, shading devices, and a seven-star AC labelling system. The study promotes retrofitting strategies on an individual scale. The study showed three income categories for the respondents; every category needs to be provided with a different solution and various levels of governmental support.

The energy efficiency awareness of households has increased, as reflected in the electricity bills. To illustrate, the study showed that one-third of households had their electricity bill increase by just

200% on average, while electricity tariffs had increased by 260% and had a 5% tax added to the bills. The study showed that approximately 53% of households had an increase in their electricity bills of between 200% and 400%. Notably, the increase in electricity bills affected the monthly percentage of income spent on electricity—now at 10–20% for approximately 63% of households. The money spent by Saudis on their monthly electricity bill is still lower than in many European countries such as Germany, Belgium and Denmark, where bills are in the range of 1–5 SAR (0.26–1.33 USD) per m^2 [35].

5.2. Energy Consumption Behaviours

The study results indicate that around two-thirds of households spend 1–5 SAR (0.26–1.33 USD)/m^2 (0.18 SAR (0.048 USD) per kWh) per month, which is a lower price than in Europe [35] but 260% more than what Saudis paid before the price hike. According to the survey, the biggest problem that households are facing is how to lower electricity costs by lowering energy consumption, especially after the increase in tariffs. Nevertheless, the government could face a future economic crisis if the energy consumption stays at the same level.

In KSA, the SEEC mandated energy labelling of all electrical machines, which provides the energy consumption level to the buyers. The SEEC also offers efficient AC units at discount prices to the middle and lower classes, and these can also be paid for in instalments. The building envelopes are not able to maintain a constant cool temperature in indoor spaces for long periods. These observations point to the necessity of developing the building envelopes' thermal properties. Then, active measures could be applied due to the high cooling demand in the hot–arid climate region. This could be achieved by architects redesigning the building envelopes to optimise energy consumption to keep the indoor temperatures naturally as cool as possible, so that the use of air conditioning systems can be kept to a minimum.

The study showed that almost every household uses AC units; this is reasonable due to the harsh climate conditions and the availability of cheap AC units. A total of 91% of residences used individual AC units (window, Split), which could allow for individual retrofitting solutions. Thus, apartments can be redesigned individually to be more energy-efficient. Inevitably, individual options could affect the building envelopes' codes in the future.

All of the above findings point towards the necessity of retrofitting new buildings, which would affect the total urban energy design, gearing it towards being more energy-efficient and producing a more sustainable environment. The findings of the questionnaire also indicated that households within residential units became aware of the importance of their electricity consumption (energy efficiency) after the tariffs increased. In addition, buildings' thermal properties (heat transfer) need further improvements to achieve energy efficiency. To sum up, the existing residential buildings in Jeddah were designed based on the affordability of AC units and subsidised energy bills, which resulted in poor thermal building designs and high energy consumption. Thus, improving existing buildings ought to come through enhancing the thermal properties of the buildings and then applying proper active measures on a case-by-case basis.

6. Conclusions

This study aimed to assess how current user behaviour affects the energy performance of residential buildings in Jeddah. The results showed a clear development of opportunities in building thermal properties (heat transfer) including all the related factors such as building materials, insulation, shading devices, etc. Nonetheless, increasing user awareness is also essential for the development of more sustainable solutions. Despite the increase in electricity tariffs, households still use their AC units for long periods since they spend a significant amount of time in their homes. However, households will not accept any solution that would result in indoor temperatures above 25 °C.

In brief, short-term solutions to improve building energy performance are necessary to ensure sustainable plans and the efficient use of energy. The study indicated that several factors impact the energy performance of residential buildings. First, new residential buildings' thermal properties were found to be poorly designed. Second, the majority of users prefer a room temperature below 24 °C, which requires a massive amount of cooling. Third, due to the climate conditions and the typical lifestyle of KSA, housing units are occupied for more than 18 h per day. Fourth, an increase in user awareness has helped to slightly improve residential buildings' energy efficiency.

Existing housing units consume massive amounts of energy and require further detailed investigation into their energy performance, energy costs, and the effect of user behaviour on energy. There is a need to formulate a set of architectural redesigning (retrofitting) parameters for self-sustainable buildings.

7. Limitations

It would have been difficult to produce more detailed questions for the survey regarding energy consumption. The type of electronic questionnaire that was used was limited as it only recorded complete questionnaires; partly completed questionnaires were disregarded. It was also not possible to determine, in detail, how the household's electricity was consumed, such as for cooling, heating, cooking, cleaning and ironing. Extra information regarding the energy levels of AC units, LEDs and other machines would have helped define the energy rankings of these appliances.

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