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The role of smart homes in reducing electrical energy consumption: The experience of Saudi Arabia

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***Abstract*---**This intervention examines the problematical played by smart homes and the extent to which they rationalize and reduce energy consumption in Saudi Arabia. Using an analytical model of various data collected from various relevant Saudi local authorities, some international bodies in the jurisdiction, the study focused on the components of the smart home as a smart lifestyle for the Saudi citizen, with a focus on various smart home. Key findings found a tendency to increase energy consumption in terms of increasing offers of smart home appliance products on the one hand, and on the other hand the effects of information and communication technology (ICT) services, which tend to reduce and rationalize consumption. Digitalization generally tends to increase energy consumption. Smart homes will only be able to enhance sustainability in electrical energy consumption when they are enhanced Rely more on clean and environmentally friendly alternative energies, without enhancing the effects of smart.

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***Keywords*---**Smart Home, Digitalization, Electric Power, Smart Devices, ICT Services.

Introduction

Electric power as a commodity adds immense value to modern life: lighting at night; washing clothes; cooking; running machines; and connecting with people all over the world. It is therefore considered by many to be critical to poverty alleviation, economic growth and improved living standards. Electricity is also an essential component of modern societies and economies and is becoming increasingly important with the growing popularity of electrically powered technologies, such as electric cars and heat pumps. Power generation is currently a guarantee that Consumers are on electricity safely and affordably while trying to reduce carbon dioxide emissions globally and locally as one of the main challenges facing the energy transition.

Smart homes have recently been introduced as an alternative solution to the problems of the classic energy system, represented by both thermal plant emissions, and the risk of power outages due to interruptions in bulk electricity production and distribution plants. Smart homes rely on coordinating devices, sources and energy storage according to the requirements of the owners of these homes via a suitable energy management system. So energy management systems are in themselves the key to optimizing a home's resources (operation, requirements) to maximize the economic benefits of the home while maintaining a comfortable lifestyle. In this intervention, the main features and requirements of a smart home will be identified. This review also aims to address the problem about the extent of the role played by smart homes in some of the Kingdom's smart cities play in reducing electricity consumption.

Previous studies:

- A study (2017) tagged " Energy conservation through smart homes in a smart city: A lesson for Singapore households Current research areas include: (1) energy consumption in Singaporean households, (2) public programs and policies in energy saving, (3) the use of technology in energy saving, and (4) households' perception of energy saving in smart homes. In addition, three case studies on smart homes and smart technology are being reviewed, discussing the maturity of existing solutions. (Bhati, 2017)
- Study (2022) tagged "The Impact of Smart Homes On Energy Consumptions-A Survey", this paper aims to survey research conducted on the impact of smart homes on energy consumption as more smart devices are integrated into homes; the demand for electricity has steadily increased resulting in a rise in the electricity bill over the past few years reported by many consumers. Many people have realized that smart devices require more electricity, which in turn leads to higher electricity bills. (Mohammed, Al Hussaini, Al Esri, Al Hidaifi, & Sherimon, 2022)
- Study (2023) tagged "The Role of Smart Technologies in Reducing Energy Consumption and Promoting Sustainable Practices in Households and Businesses"; this study draws on relevant data collected from recent studies

conducted by engineers and researchers for cognitive integration and knowledge of efforts to develop smart and sustainable technologies. The strategic objective of the study is to help solve key issues of the modern era, especially those associated with smart use and sustainability of valuable and finite resources. This study discusses new ideas, current issues and challenges for a sustainable future based on smart technologies. (AlWadi, 2023)

- A study (2024) titled "Energy Efficiency Assessment in Smart Homes: A Comparative Study of Energy Efficiency Tests", the energy efficiency of smart home technology, such as solar panels, lighting controls, thermostats, and smart devices, was comprehensively evaluated through the study. Significant energy savings have been achieved through energy-efficient settings; smart ovens, washing machines and refrigerators have seen consumption decreases of 10% to 15%, and the research is promoting end-to-end energy efficiency technologies by saving costs, environmental benefits and potential synergies when integrating multiple energy-efficient devices into smart homes. In order to improve domestic energy efficiency, future areas of study include long-term assessments, user behavior analysis, and smart grid integration.

1. The literary background of smart homes and rationalizing their consumption of electrical energy

1.1. Smart Home Concept:

The term "smart home" has been commonly used for two decades to describe homes with controlled energy systems. This automation system emphasizes easier lifestyles for home owners than ordinary non-motorized homes, especially for the elderly or people with disabilities, so that the concept of "smart home" becomes a broader description to include many applications of technologies in one place. (Sowah, 2018).

The concepts of smart homes among thinkers and scientists have also varied according to several perceptions (Table 01). Aldrich defined a smart home as: "a home designed with computer and information technologies that anticipate and respond to the needs of residents, facilitating their comfort, ease, security, and entertainment by managing home technologies and connecting with the outside world." This definition included the technical component of a smart home, regardless of the services provided by its functions. Also, these homes will respond to a wide range of situations. (Anna A. Malysheva, 2024).

Furthermore, Lutulf described the smart home as "integrating with various utility elements through the use of the communication system in the home. It ensures economical, safe and comfortable home operation and involves a high level of smart functionality and flexibility. (Lutolf, 1992).

Smart homes are defined as: "Homes that provide their occupants with a comfortable, safe and energy-efficient environment at the lowest possible costs regardless of their occupants." The Smart Home Association defines a smart home as: "The integration of technology and services through home networks for a better quality of life. (Robles, 2010).

Although these last two definitions share the same views, they differ in terms of technology capabilities and the types of customers to serve. Many academics interested in smart homes link technological features in general, and differ on the technical side in defining these homes in particular. (Balta-Ozkan N, 2013).

Table No. (01): Definitions and characteristics of smart home

Definition based on a theme		Aldrich (2003)	Lutolf (1992)	De Silva et al. (2012)	Reinisch et al., 2011	Scott (2007)	Balta-Ozkan (2014)	Chan et al. (2008)	Diegel et al. (2005)	Alam et al. (2012)
Technology	Sensors						*		*	
	Devices					*	*		*	*
	Integrated systems	*	*	*	*	*	*	*		
Services	Control/ monitor			*	*		*		*	
	Energy management	*	*		*	*			*	
	Support and assist							*		*
	Anticipate and respond	*								
Users' needs	Cost-efficiency		*		*	*		*		
	Comfort	*	*		*	*				
	Emotional	*								
	Security	*	*							
	Healthcare				*			*		*
	Quality of life	*	*	*	*	*	*	*	*	*
	Sustainability				*	*				

Source: Pira, S. (2021), The social issues of smart home: A review of four European cities' experiences, European Journal of Futures Research, 9(1), 3. P 04
According to the thinkers Aldrichultulf, the theory of the smart home is based on the use of information and communication technology, and homes themselves are equipped with computer and information technologies.

From the above, smart homes can be defined as residential buildings connected to different communication systems, and optimization algorithms are used to predict, analyze, enhance and control energy consumption patterns according to predetermined user requirements to achieve optimal economic benefits for the home, within the circle of maintaining predetermined conditions for a comfortable and quiet lifestyle.

2.1. Smart Home Environmental Framework:

According to the classification of smart technologies used in the environment of this home, the modified smart home scenario for seniors is shown for example according to technology classifications, functions and locations (Figure 01). Houses are generally required to be designed according to the retrofitting of their old place. For example, changing the bathtub to a modern shower cubicle, to provide a safer living comfort. In addition to introducing modern and important home modifications, devices designed for seniors can also support their various daily activities. Non-electronic devices, electronic devices and smart devices (expressed in Figure 01 in different colored circles) can be widely relied up on in such homes for the elderly.

In parallel, these devices or external parts of smart systems are distributed in the home environment and most of them are non-constructional, as they are installed on the roofs of architectural components or placed inside the structure. Infrastructure and even inside furniture, such as indoor climate sensors on walls or ceilings for example, pressure sensors in water meters installed on taps, or contact sensors installed on doors. , in this context, non-structural technologies offer a simple change in homes, as they are easy to deploy, requiring a modification to the existing house structure especially for some specific purposes. For example, a drop detection floor can beused instead of slippery floortiles in hazardous areas to deal with occasional emergencies. (Torresen, 2018)

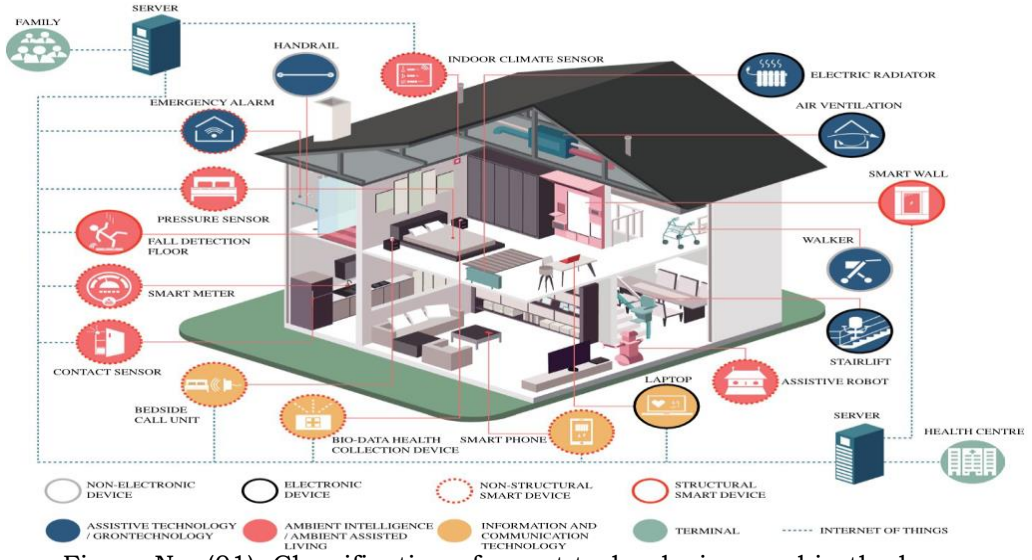

Figure No. (01): Classification of smart technologies used in the home environment

Source : Ma, C., Guerra-Santin, O., & Mohammadi, M. (2022). Smart home modification design strategies for ageing in place: a systematic review, Journal of Housing and the Built Environment, 37(2), 625-651. P 632

2. Electrical power sources for smart home:

Solar and wind power plants have rapidly spread to become one of the most mature renewable energy sources in modern grids. Many buildings are also designed by installing photovoltaic modules or solar thermal heaters. Smart homes can provide various other functions via solar energy besides generating electricity, such as solar water heating, solar drying, solar cooling, and other additional functions. In parallel, the prices of these photovoltaic plants are cheap and their maintenance requirements are low, and this hot water produced from water heaters can be used in many other domestic jobs, such as washing, cooking, ... etc., which enhances the efficiency of household energy. (Parida B, 2011)(Luo, 2024) (Mahesh Kumar, 2023).

For example, energy storage can constitute (ESSs) in the system SHEMS Serves as a cornerstone, so that the stored energy is managed according to

predetermined goals. There are many energy storage system technologies in the energy markets. In this area, batteries and fuel cells can be considered the most suitable types of energy storage for smart home applications, the structure of a fuel cell is very similar to a battery. During the charging process, hydrogen fuel cells use electricity for the purpose of producing hydrogen, which in turn will feed the fuel cell to generate electricity during the discharge process, but the disadvantage of fuel cells is that they have relatively low efficiency compared to batteries. However, fuel cells provide a very clean storage environment with the possibility of adding additional storage tanks for hydrogen. And this is exactly what olated houses in remote areas need are. However, with regard to wind power, which although more economical for large plants, its market has remained very shrinked especially with regard to small wind turbines in homes, these small wind turbines usually require a wind speed of at least 2.7 m/s to generate minimum power, a speed of 25 m/s for rated power, and a speed of 40 m/s for continuous generating power. These turbines are relatively expensive, intermittent, and constrained by special maintenance compared to a solar power plant. (Wan C, 2015) (El-Azab, 2021)(Vasilis Fthenakis a b, 2009) (Ma Lei, 2009).

Biomass energy has recently become a promising alternative to renewable resources for smart homes. Therefore, many researchers have recommended some experts in the field of renewable energies, the use of biomass energy for different types of smart homes. (Lukáš Janota a b, 2023). Heating is the main function of biomass in these buildings. Accordingly, a biofuel generation system has been installed for many buildings that have the advantages of this system. (Pardo, 2020) (Ambaye, 2021).

The distributed clean energy generated by smart homes provides many benefits to potential smart grids. Thus, the effects of smart homes on future energy grids should be studied at scale. In the near future, smart homes will play a key role as an energy supplier in modern grids, not just as an energy consumer.

With the historical development of the industrial revolutions, human societies have rapidly accelerated changes within their living conditions and almost irreversibly. The growth of cities, accompanied by the acceleration of production, and the effects of dynamics imposed by the modifications of the capitalist system, in light of the search for quality of life, or what is traditionally known as living comfort, among various other realities that have led to the growth of energy sources. Recent decades have witnessed the emergence of local and global movements promoted by governmental and non-governmental organizations to urge the search for alternatives or less harmful mechanisms that may contribute to reducing the effects of excessive consumption patterns, including electrical energy consumption.(AI), Machine Learning, Data Analytics, and Internet of Things (IoT), three-dimensional printing, and other technologies, to establish, expand and monitor the effectiveness of sustainable development and environmental compliance worldwide. (Andrade, 2022).

In this regard, the International Energy Agency's 2024 Electricity Report is the basic reading of recent trends in electricity consumption, as it provides an in-depth and comprehensive analysis of various modern policies and market

developments in this context, providing projections until 2026 for electricity demand and supply, and carbon dioxide emissions. The IEA's Electricity Sector Report, published regularly since 2020, provides insight into the evolving power generation mix. It gives some appropriate solutions to rationalize energy consumption through a number of proposals that will enhance the energy efficiency of the country, according to the following:

3. Ways to rationalize electrical energy consumption:

Some of the methods that enable the energy consumption assessment test in a smart home can be listed according to the following: (Gilani, 2024)

- **Electricity bill measurement:** Comparing monthly electricity bill readings with others allows the user to know whether or not the increase in energy consumption has increased;
- **Electricity meter:** relying on the electricity meter to measure the energy consumption of each separate device, enables to know the amount of energy consumed by some device seven when not in use;
- **Monitoring energy usage via mobile applications**: Many of the available applications allow tracking energy consumption in a smart home, with the ability to provide detailed statistics on high-energy consumption devices;
- **Consult energy experts:** Automatically contact professional energy consultants to review the energy consumption of the smart home, and provide appropriate advice to improve energy efficiency.

In addition to all this, you can also resort to some other tips to enhance the energy efficiency of smart homes according to the following:

- **Use LED lights:** Changing ordinary home lights with high-efficiency LEDs to use them for less energy, with a longer duration, allowing for a lot of energy and money savings in the long run;
- **Set up the right lighting:** Choose to use different types of lighting in different aspects and aspects of the house based on the supposed use. Such as installing bright lighting in dark areas, and warm lighting in areas with calm and comfortable atmosphere;
- **Voice control:** Smart home voice controllers for the purpose of control install the settings of the devices, rather than leaving them running continuously for long periods of time;
- **Motion sensors:** They are placed in the smart home to detect the presence of movement, and activate the lighting automatically which saves more energy when the room is empty of room residents;
- **Relying on effective heating and cooling methods:** There are smart heating and cooling systems that save a lot of energy as a technology that insulates the house well, and put in place effective ventilation methods to maintain the right temperature in the house;
- **Smart home appliances:** These devices are specifically designed to save energy. For example, smart refrigerators that intelligently manage energy consumption and reduce wasted energy;
- **Reduce over charging:** monitor the charging of mobile devices, and disconnect the charger once the charging process is complete, once the charger is left plugged in, this may cause more useless power consumption;
- **Smart cleaners**: relying on smart cleaners that allow the preparation of the

required formula based on actual needs, thus saving time, water and energy;
- Smart Power Sockets: Connect all devices to smart power sockets. to remotely control their on and off, helping to save energy when devices are not in use;
- **Review energy use:** This is done periodically to identify energy-consuming devices, including improving their use or replacing them with more efficient devices.

The development of artificial intelligence can lead to the complete strengthening of the control center of the smart home, while connecting separate smart home elements in the family, thus forming a complete smart home environment. Bluetooth and Zig Bee, various other networks are the basis of a smart home interconnection. The interconnection between device communication standards, cloud connectivity standards, and other basic communications is the general trend. This entire smart home development trend is fully aligned with the available data, providing a valuable smart family solution for users, and their enjoyment of a smarter and more convenient living experience.

Here it can be said that the smart home is a concept represented by a dwelling governed by communication networks, sensors and devices that can be monitored, accessed or controlled remotely, so that services are provided that respond to the specific desires of users, in order to achieve which sensors, controllers and actuators are used, thus primarily achieving security monitoring, controlling temperature, humidity and air quality inside the residence, and optimizing energy use.

Smart home technology, also known as home automation or automation (from the Latin word "domus" meaning "home"), allows homeowners to manage smart equipment through the smart home app on their Smartphone or other networked device, providing security, convenience, convenience, and energy efficiency. Smart Home, which is part of the Internet of Things (IoT), comes together, to exchange consumer usage data and automate activities according to homeowners' preferences.

4. Strategies to improve energy efficiency in smart homes:

Mostly these strategies may revolve around the following:
- **Home Energy Management Strategy**: Using energy management systems that intelligently control the consumption of appliances, improving the timing of energy use;
- **Renewable Energy Sources Integration Strategy**: Relying on technologies to obtain energy from renewable sources, such as solar panels, which increase dependence on the same house for energy; (Zhou, 2016)
- **Two-way interaction strategy**: Enhance interaction between consumers and electricity companies while providing a two-way interaction medium to support the full integration of smart devices and smart homes;
- **Sensing and Control Systems Strategy**: Inclusion of systems that sense and control energy in intelligent ways, such as adjusting lighting and temperature based on the presence of the population; (Missaoui, 2014)
- **Population-centric design strategy**: Ensure that technology not only works properly but also corresponds to residents' presence, adapting to their daily

lives.

Providing energy in smart homes has become necessary in light of the environmental and economic challenges facing the global community, based on sustainable energy sources in smart homes can lead to reducing energy consumption, and here several mechanisms can be distinguished to achieve improved energy efficiency in smart homes, which can be summarized as follows:(Alzafarani, 2018, February)

1. *Energy Consumption Monitoring:* Using real-time energy monitoring and analysis systems, smart homes offer systems to automatically monitor and analyze energy. These systems include features such as using lights according to need, programming the temperature to be high when absent and adjusting it to the maximum comfortable degree when needed, displaying information on energy consumption to improve customer awareness, and enabling users to control some home appliances through mobile applications to reduce electricity use and reduce energy waste.
2. *Lighting control:* It includes several aspects, some of which can be limited to:
   a) Use of motion sensors: lights automatically turn on when a person enters the room and turn them off when no one is around, reducing unnecessary energy consumption;
   b) Smart App Control: Use mobile apps to control lighting more flexibly from anywhere;
   c) Scheduled lighting: Programming lights to turn on and off automatically at specific times, saving energy consumption;
   d) Use of energy-saving lamps: This means relying on energy-saving lamps that significantly reduce energy consumption compared to conventional lamps;
   e) Adaptive lighting systems: adapt to the natural light available in the room, and adjust the intensity of artificial lighting accordingly.
3. *Heating and cooling automation***:** programming the system to make the smart home warmer when residents are not present, and adjusting the temperature to be comfortable when needed; In this context, heating and cooling automation is an essential part of strategies to improve energy efficiency, in order to achieve this, it is necessary to rely on the following:
   a. Remote control technologies: mobile applications are used to adjust the temperature when an individual is away from home, reducing wasted energy;
   b. Use motion and time sensors: install sensors that adjust temperatures based on time, day or activity in the room;
   c. Automatic Programming: Take advantage of systems that program the temperature based on daily lifestyles, and adjust settings automatically
   d. Intelligent control systems: use machine learning systems to analyze data and optimize settings over time, to achieve maximum efficiency;
   e. Energy monitoring and analysis: Integration of monitoring systems that analyze energy consumption and alert to any inefficient use that could lead to energy waste.
4. *Reliance on mobile applications:* It is used to remotely control household appliances to analyze electrical energy consumption and reduce waste, including:

- ☞ Central Control: Users can control all home appliances through a single app, making it easy to monitor and adjust power consumption from anywhere; (Mekali, 2018, December)
- ☞ Device scheduling: Enable users to schedule the timing of devices on or off to avoid unnecessary consumption, especially during times of high energy demand;
- ☞ Providing information to consumers: display data on energy consumption in a way that makes it easier for them to understand monitoring their consumption; (IKRAM, 2024)
- ☞ Automatic Control: Smart systems can learn from user habits and automatically optimize consumption settings based on data analysis; (Madhunala, 2024, February)
- ☞ Use data for improvement: Systems can collect data on energy consumption, and this accumulated data may enable these systems to continuously improve their performance thanks to machine learning.

5. *Colorful LED consumption indicators:* use indicators to alert consumers to different standards, alert the population to different energy consumption cost levels and raise awareness of energy efficiency, so LED rapid visual notices present consumption levels, as different colors can reflect different levels of consumption, such as green for low consumption, yellow for moderate consumption and red for high consumption; these signals can motivate people to adopt controlled consumption behavior;

6. *Energy Management Systems:* It includes a combination of monitoring, analysis and control of energy consumption, which contributes to reducing aggregate demand or during peak periods, and here we can distinguish between several policies, including: (Sirisumrannukul, 2024)
   A. Energy monitoring policy: by installing sensors and smart meters to monitor the real-time energy consumption of each device;
   B. Analysis and reporting policy: where aggregated data is analyzed to understand consumption patterns and generate reports that help make informed decisions on how to optimize energy use;
   C. Peak optimization policy: Use dynamic power burden control strategies to reduce device consumption during peak demand times to reduce loads on the power grid, and maintain its stability.

4. Analysis of the role of smart homes in enhancing electrical energy consumption in the KSA:

By 2024, there will be more than 400 million smart homes worldwide and these figures illustrate the growing trend in the use of smart devices wherein 2022 alone, 500,000 compatible products were traded Matter* in the market, another 5 million will reach customers by 2025.5 million (smart) compliant home gadgets will be shipped **Matter By the end of 2030.As more businesses enter the market, consumers have access to a wide range of options and prices. Having more options makes creating a fully connected and manageable home environment

* *Matter* is a standard for smart home technology that allows devices to communicate and communicate with other Matter-compatible devices, and this wireless technology, developed by more than 170 organizations, allows working with a variety of voice assistants and applications, such as: Alexa, Google Assistant, Siri, Google Home

easier. Home automation figures predict that by 2023, the global smart home market will be about $100.42 billion. With an expected annual growth rate of 31%, experts predict that the global home automation market will be worth $81.6 billion by 2023. (G., 2024)

1.4. Electricity consumption in the Kingdom of Saudi Arabia:

Globally, the energy sector is undergoing significant changes, driven by increased access to electricity. In this context, participants identified five factors, referred to as the "five factors", that would drive future electricity demand patterns. They consist of disrupting demand from emerging uses of electricity, decarburization, decentralization of distribution, democratization of access to energy, and digitization of electricity uses.

Decarburization efforts and climate commitments are increasing the share of renewable energy in total energy. It is worth noting that the potential for renewable energy development is great in the GCC region. For example, electrification of the transport and desalination sectors could significantly increase electricity demand in the region in the future.

Electricity is therefore strategically important because extreme weather conditions lead to a high demand for electricity for cooling purposes. Against this backdrop, anticipating future demand trends is critical to ensuring a reliable and affordable electricity supply in the Kingdom. Historically, electricity demand growth in Saudi Arabia and the GCC region has been primarily driven by population growth and rising living standards. However, recent policy-driven reforms have changed the relative weights of these demand drivers. Price reforms and efficiency measures are currently the main factors affecting electricity demand. (Mikayilov, 2020)

It is also expected to account for most changes in future electricity demand. However, addressing market failures and barriers to taking full advantage of energy efficiency and price reforms requires multifaceted efforts. Successful policies require appropriate institutions and systems, the ability to leverage technical capacity, information and awareness.

One of the main challenges facing the energy sector in the GCC region is to meet cooling demand while decarbonizing it score supply. In this region, cooling accounts for up to 70% of the electricity load. In Saudi Arabia, electricity demand growth will continue to bedriven by high energy requirements for cooling buildings. The Kingdom's share of the energy used for cooling ranks third in the Group of Twenty, a group of leading rich and developing countries, after the United States and China.

Although these shares may change later, cooling is expected to remain a major driver of electricity demand in the future, with the potential for significant energy savings. Globally, indirect emissions from the use of electricity for space cooling could account for 18% of the total increase in global carbon dioxide emissions by 2050. Moreover, room air conditioners al one will add about 165 Giga tonnes of cumulative CO2 equivalent emissions by 2050, 30% of CO2 equivalent emissions.

Which will come from the coolant. These emissions will cause global warming of about 0.5°C by 2100. (Krarti, 2020) (Krarti, 2020)

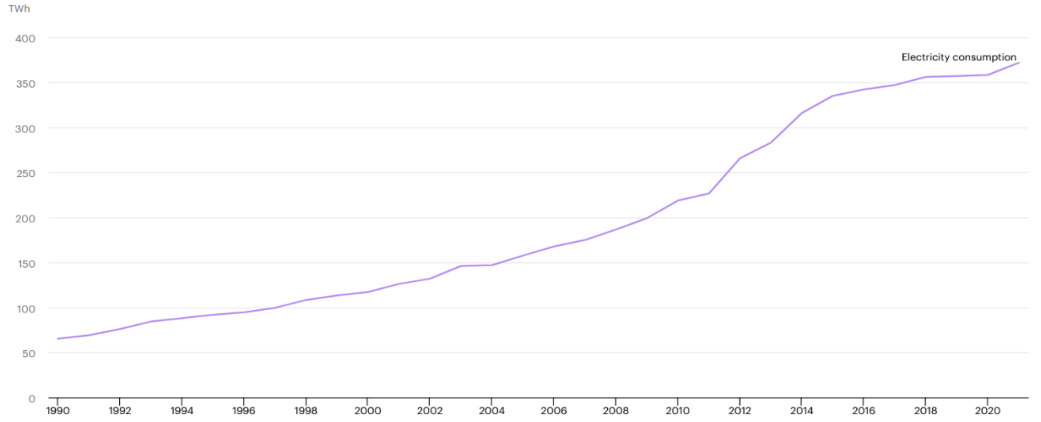

Figure No. (02): Electricity consumption 1990-2021

Source: International Energy Agency,2023,Energy Statistics Data Browser, available at : https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=SAUDIARABI&fuel=Energy%20consumption&indicator=TotElecCons ,(last visited 07/04/2024)

Percentage distribution of electricity sources in housing, the percentage of dwellings that use various sources of electricity in the Kingdom reached 99.9%, where 98.4% of dwellings use the public grid, and 1.1% use the private network. The share of households using solar energy as a source of electricity was 0.4%, while 0.1% used private generators (Figure 05):

When we compare countries' total energy consumption, the differences often reflect differences in population size. It is useful to look at the differences in energy consumption per capita. This interactive graph shows the average energy consumption per person each year.

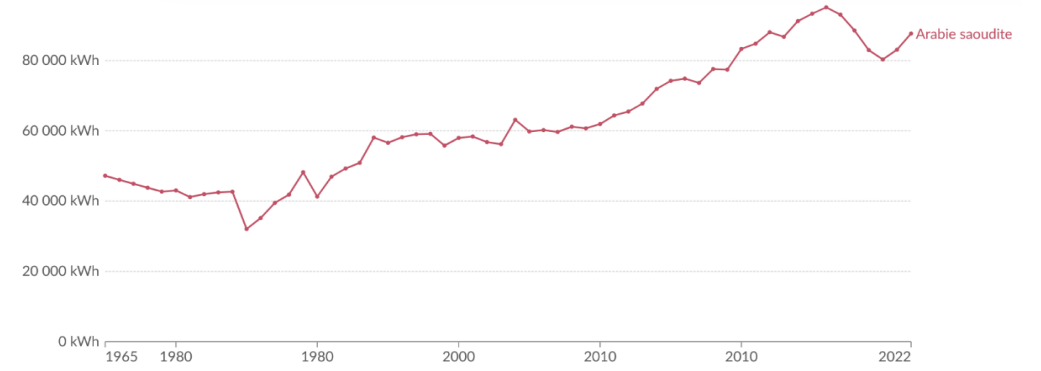

Figure No. (03): Energy consumption per person (measured in kilowatt-hours per person.)

Source: International Energy Agency, 2023, Energy Statistics Data Browser, available at : https://www.iea.org/data-and-statistics/data-tools/energy-

statistics-data-browser?country=SAUDIARABI&fuel=Energy%20consumption&indicator=TotElecCons,(last visited 07/04/2024)

More households are interested in rationalizing electricity consumption in 2022, and the percentage of households that expressed interest in rationalizing electricity consumption increased from 66.1% in 2021 to 91.9% in 2022, an increase of 39%. 86% of households conserve energy consumption in electrical appliances used in homes. However, the percentage of households willing to spend money to replace older appliances with new, more energy-efficient appliances decreased slightly from 57.6% in 2021 to 56.4% in 2022, while the percentage of households interested in using solar energy in homes reached 53.1%.

The Riyadh region has the highest consumption of residential electricity. As the most densely populated region, this region received the highest share of household electricity consumption at 28.5%, followed by Makkah at 24.4%, while Al Baha received the lowest share of energy consumption. Electricity by 1.3% at the level of the Kingdom's regions (Figure 04):

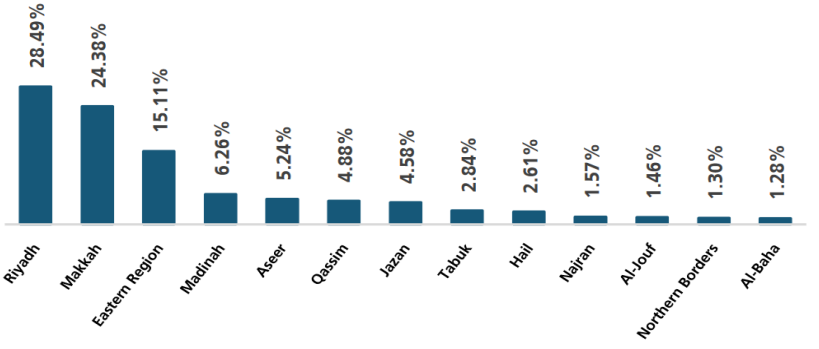

Figure No. (04): Share of electrical energy consumption in homes across all regions of the KSA in 2022

Source: General Authority for Statistics, (2022), available at: https://www.stats.gov.sa/sites/default/files/Household_Energy_Statistics_2022_EN_0.pdf, (last visited 13/04/2024)

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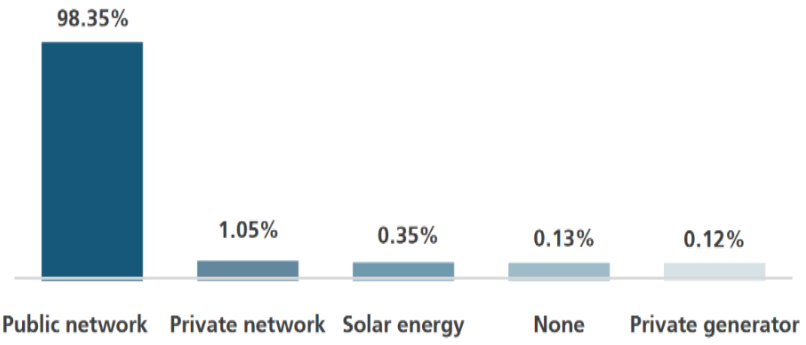

Figure (05): Share of electricity sources used in homes throughout the KSA in 2022

Source: General Authority for Statistics, available at: https://www.stats.gov.sa/sites/default/files/Household_Energy_Statistics_2022_EN_0.pdf, (last visited 13/04/2024)

Private electricity meters are the most common in Saudi Arabia, with 84.8% of households using private electricity meters, while 15.2% use shared electricity meters. The Northern Borders region recorded the highest share in the use of private electricity meters at 93.5%, while the Jazan region recorded the highest share in the use of shared electricity meters at 30.0%.

As for the energy used for cooking in the household sector, the percentage of households using energy for cooking in the housing sector reached 98.7% in 2022, while 1.4% of households reported that they do not cook in the home. The results showed that the share of households using gas (cooking gas) amounted to 85.5% of the energy used for cooking, while the percentage of households using electricity for cooking reached 12.7%. The percentage of households using other types of energy for cooking is 0.4% (Fig. 06) and (Fig. 07):

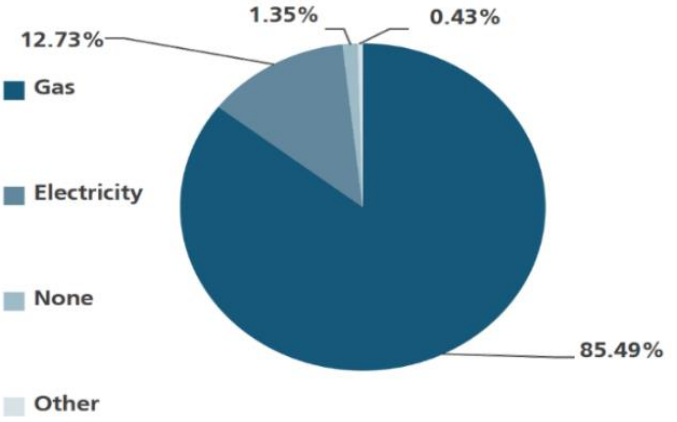

Figure No. (06): Share of electricity sources used in residences throughout the KSA in 2022

Source: General Authority for Statistics, available at: https://www.stats.gov.sa/sites/default/files/Household_Energy_Statistics_2022_EN_0.pdf, (last visited 13/04/2024)

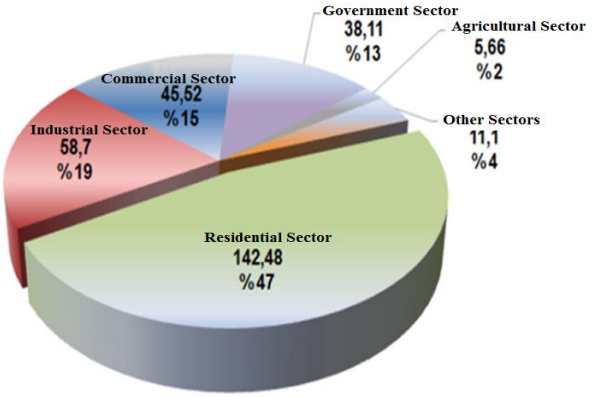

Figure No. (07): Electrical energy consumed in KSA by sector in 2021(thousand Giga watt-hours)

Source: General authority for statistics, (2021), Electrical energy statistics publication, available at: https://www.stats.gov.sa/en/1042 ,(last visited 07/04/2024).

2.4. Smart Home Market in Saudi Arabia:

According to the Saudi Arabia Smart Home Market Report and Analysis - Opportunities and Outlook 2023-2030, the size of the smart home market in Saudi Arabia, when taking into account the analysis by product (lighting control, HVAC control, home healthcare, smart kitchen, home appliances, smart furniture, security and access control, entertainment and other controls), and by programs and services (behavioral, proactive), indicates that setting up the appropriate smart home equipped with lighting Heating and appropriate electronic devices can be controlled remotely from anywhere connected to the Internet in the world, using a smartphone or other device connected to the network. The smart home has the advantage of having connected devices over the Internet, allowing the user to perform many functions such as safe access to the home, lighting control, temperature adjustment, and other vital functions. This is because these smart home devices are equipped with self-learning skills, all owing them to automatically adjust the system according to the home owner's requirements. The smart home also provides great benefits to the user, such as achieving highly effective cost optimization, providing and improving security, while reducing energy consumption, and also helping to easily handle daily household tasks. In this context, smart devices widely used in homes include smart TVs, smart lock systems, smart security cameras, and smart entertainment systems. From this stand point, and in order to obtain competitiveness in this field, and by knowing the market dynamics and current trends of the "smart home market", the following can bead dressed:

1.2.4. The most prominent drivers of the smart home market in the KSA:

One of the most important factors driving the growth of the smart home market in Saudi Arabia is the increasing reliance on smart computing devices, corresponding to the growing number of Internet users in the Kingdom, against the high demand for reduced energy consumption, accompanying the increase in

disposable income, and the continuous expansion of product portfolios offered by manufacturers in the country. In addition to the growing government initiatives to develop smart cities, such as NEOM Smart City, this has been a strong incentive to promote the growth of this market, in addition to Saudi Arabia's Vision 2030, which is represented by the government's planning to develop public service sectors such as health, education, infrastructure, entertainment and tourism, which will further encourage market growth.

In this context, the increasing integration between artificial intelligence (AI) and the Internet of Things (IoT) in smart home devices is one of the most important factors to enhance customer experience and satisfaction, and thus its reflection on improving market growth as well, on the one hand, and on the other hand, the high initial investment cost of smart home devices is likely to hinder market growth during the forecast period.

2.2.4. Sector Analysis Smart Products in KSA:

Based on the segment of some smart products in the Kingdom's market, the increasing demand for smart speakers within the context of advanced and multifunctional devices, so that smart speakers can be connected using Wi-Fi, Bluetooth and other wireless protocols and powered by AI-led virtual assistance, was a strong catalyst for the sector to grow at a higher compound annual growth rate during the study period. Increasing disposable income in Saudi Arabia and increasing digital transformation can also be considered other factors also that fuel the growth of the smart speaker market in the country. Moreover, the increasing number of smartphone users has allowed the development of applications to stream music to a specific device, thus increasing the demand for smart speakers.

In another context, the increasing adoption of smart homes, the rapid rise of multi-functional devices, and the growing popularity of customization, such as smart kitchens, smart coffee makers, smart kettles, smart water heaters, smart washing machines, smart dishwashers, smart ovens, smart stoves, smart stoves, smart vacuum cleaners, smart refrigerators, smart furniture, smart tables, smart offices, smart chairs, smart sofas, and other smart home appliances, are all factors driving market growth.

3.2.4. Increasing Smart Homes in KSA

The smart home market and the smart small home appliance market in Saudi Arabia have seen significant growth in the smart home population year-on-year, with the potential to expand further in the next few years. Therefore, smart homes and smart kitchen appliances are among the most important components of the smart device ecosystem, for the self-learning of smart home devices, and help them automatically adjust the system according to the diaries and routines of the owners of the house. With the increasing use of broadband and the wider internet, and improved network infrastructure, users have increasingly been empowered to choose wireless and technologically advanced elements to ensure greater security for their families. The following figure reflects this vision:

Figure No. (08): Smart home appliance revenues in the KSA, in million US dollars, 2019-2022

Source : Mordor intelligence ,2024,Saudi Arabia Small Home Appliances Market Trends, available at:https://www.mordorintelligence.com/industry-reports/saudi-arabia-small-home-appliances-market/market-trends?fbclid=IwAR002IpmkPEjJGAZ_NqpeBQEUKyS2Bp4-psFFi7z2IuNN9jiQE7Dcp_xoKI_aem_AaHzfKfqwlMnD8-ykpZwHJGxF0GdpKxSg2rglbyok79aER-fDWI8Hz3_EBnSVgkB6ZKe_Ijazt48XXKVNQ8pziLm,(last visited 07/04/2024).

5. The role of smart homes in reducing electrical energy consumption in the KSA:

Energy-efficient consumer appliances drive the Kingdom's market, as there are various factors that stimulate the demand for consumer appliances in Saudi Arabia. The most important of these factors are that local consumers prioritize devices that offer value for money, benefit from a reasonable warranty period, and a penchant for the prestigious brand. This is worth noting the remarkable shift towards more energy-efficient models across several categories. This change is due to the desire to better manage energy bills and increase awareness of sustainability issues and the environment.

For example, a survey conducted by Saudi Arabia's General Authority for Statistics, which surveyed 45,520 households, revealed that in 2022, nearly 58 percent of households in Jazan were willing to invest in replacing older appliances with more energy-efficient alternatives as part of their commitment to energy conservation.

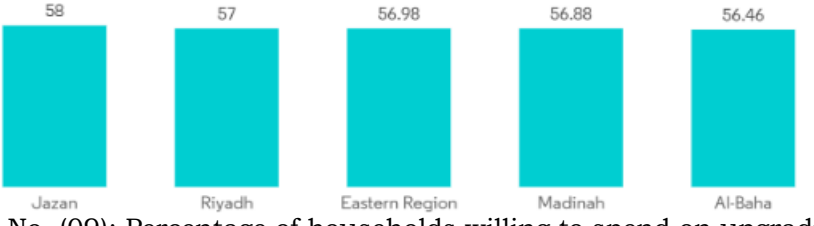

Figure No. (09): Percentage of households willing to spend on upgrading to energy-efficient appliances in the KSA in 2022

Source: General Authority for Statistics (Saudi Arabia)
https://www.gmiresearch.com/report/saudi-arabia-smart-home-market/?fbclid=IwAR08VAIxxqs8zACgJ6iJDecoVE_L5aa6YnHqneu7xswSyIMxTBIkNyHbZi0_aem_AaFlfTyHlsjaJiige4-ohyss72sxjK7yNaz0xvj6lyc-DE-7wq9pYMrI6ysCsPwGolLsVOeJEfRqEr21PAjQPaya

Conclusion

In the end, it can be said that smart homes have become an increasingly common trend in the modern world in general, and in Saudi Arabia in particular, this has led to the spread of several accompanying technologies such as the Internet of Things (IoT) to the integration of homes with devices that can be controlled, and monitored centrally usually through a smartphone or tablet, and other modern technologies. These devices can vary from simple tools such as smart thermostats, lights and locks, for example, to more devices advances such as smart refrigerators, smart ovens, entertainment systems and others. The ability of smart homes to change the way they live cannot be overestimated. This paper explored how smart homes can enhance electrical energy efficiency, including sustainability, while enhancing home security. Furthermore, this study discussed how smart homes use the right electrical energy to meet individual needs and preferences.

Modern electronic home appliances are also exacerbating power grid quality problems, such as high harmonic contents, unbalanced loading, and unpredictable short-circuit currents. On the other hand, Saudi power grid authorities do not charge home owners fees according to the impact of their buildings on energy quality. Therefore, all proposed energy management systems in this country are mainly concerned with the economic profits resulting from reducing electricity consumption or even selling electrical energy to utility grids.
So, hopes for smart homes that should boost energy consumption in Saudi Arabia have yet to be justified. Instead of saving energy, these homes brought in additional energy consumption, which had greater effects on energy increases than the effects of the energy cuts. Energy consumption is likely to continue to grow because energy-reducing effects often tend to trigger mechanisms that lead to this.

In the future, the Kingdom's grid authorities should determine energy quality restrictions based on price to ensure the proper exchange of energy between both smart homes and grids. A possible future trend is to model the behavior of smart cities through smart homes grouped in different operating scenarios to infer possible power grid scenarios for stability and quality.

In conclusion, the various sample papers on smart homes highlight the potential of this emerging technology to change the way electricity is consumed according to the patterns in which we work and live, and according to our interaction with our environment. However, they also emphasize the need for a thoughtful and ethical approach to the development and implementation of smart home technologies. The smart home revolution is still in its infancy, and there's a lot to learn about how these devices will control our lives in the years to come.

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