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OMAN'S SMART AND SUSTAINABLE HOUSING CHALLENGES: THE EXPERTS' VIEW

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ABSTRACT
A smart home usually refers to a house that has been equipped with high tech responsive systems such as heating, ventilation, air conditioning, lighting, appliances, entertainment outlets and architectural elements in which they are all computerized and managed via remote control. In the near future, intelligent homes are expected to provide comfort, convenience and conservation of resources. In this paper we focus on the challenges that prevent Omani families from building their homes to be smart. We processed by collecting data using the Delphi method, which is a research approach used to gain consensus through a series of round questionnaire surveys. Where information and results are fed back to panel members between each round. In fact, the common thing in their answers was that the main reason of not having smart homes in Oman is the lack of public awareness and the high cost of materials. It also shown from the results that there is a significant impact on a person's quality of life if he lives in a smart and sustainable house.

Keywords:
Smart houses, technology, control, future, energy, environment and system.

INTRODUCTION

In light of the world's trend towards developing technology and trying to apply technology everywhere, the feeling of safety, comfort and satisfaction is not enough at home. Rather, technology enhances these feelings if it is applied at home. Referring to the emerging information and communication technologies (ICT), the concept of smart is receiving a great attention worldwide. In particular, in the field of built environment, transversal studies highlight the fundamental role of smart houses and their significant impacts on the quality of user′s life **[1]**. The term "smart house" defines the new urban environment, one that is designed for performance through information and communication technologies and other innovations that provide a better service to people's day **[2]**.

LITERATURE REVIEW

Smart homes provide a comfortable, fully supervised and secure lifestyle for their occupants. In addition, smart homes will save energy and money as well as generate income from the sale of clean renewable energy to the grid. Conversely, a growing number of governments are encouraging the development of promising smart home technologies as part of an expected decrease in total domestic energy consumption. To support smart home integration, a number of rules, regulations and subsidies have already been introduced in some countries, such as encouraging the optimization of heating systems, promotion of energy storage or deployment of smart meters. In order to monitor the environment, a smart home can be controlled when certain appliances like those for lighting and heating are switched on according to weather conditions. Control centers, electricity sources, smart meters and communication tools are all part of the overall Smart Home infrastructure as shown in fig…

Each component of the smart-home model will be discussed in the following subsections.

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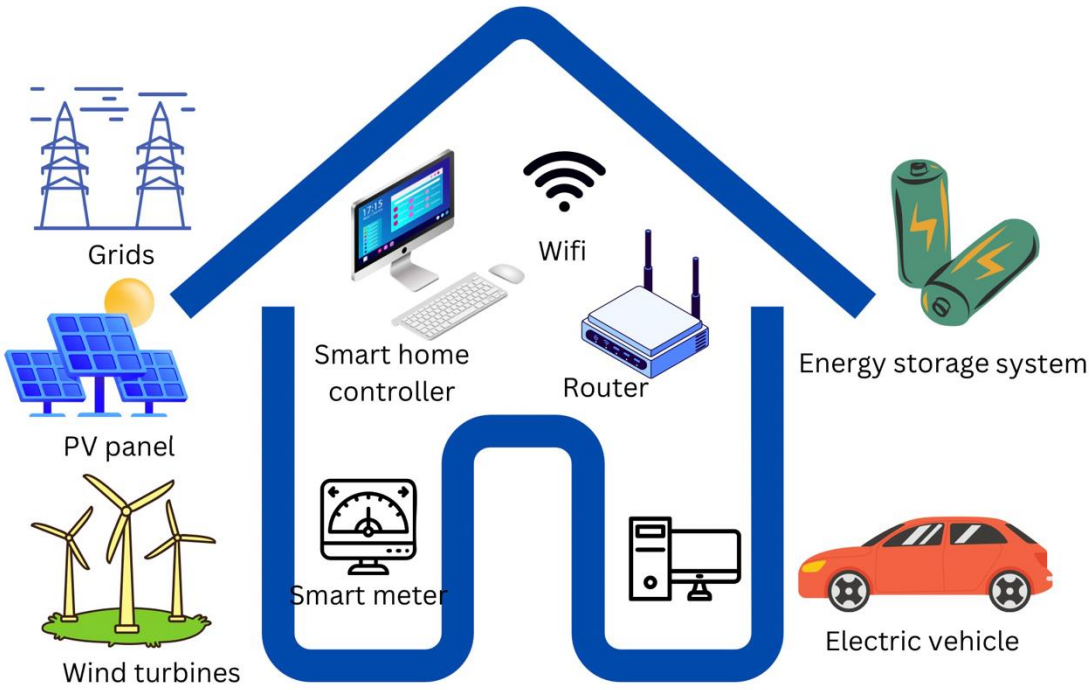

Figure 1: smart technology applications

1- the control center

The control center provides home users with the necessary equipment for monitoring and controlling different household appliances.

2- Smart meter

As an input to SHEMS, smart meters are receiving a demand response signal from the power utilities Recent advances in Smart Meters allow monitoring of a wide range of home features, including electrical usage, gas consumption, water use and heating.

3- Applications

The two categories of Smart home overloads can be divided in accordance with their operational characteristics: schedulable and unschedulable. Unscheduled loads, for example printers, televisions and hairdryers, are operated on an ad hoc basis according to the homeowners' wishes with no predictable operating patterns which can be switched or controlled by SHEMS, such as washing machines and air conditioners.

4- Resources of electricity

The most developed sources of renewable energy on modern grids are solar and wind power plants. In recent years many buildings have been fitted with PV solar panels, thermal photovoltaics or micro wind turbines. Solar energy can

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provide a variety of functions, such as a solar water heater WHS, a solar dryer WHS and a solar cooler WHS, for smart homes, besides generating electricity.

5- PLC

PLC is a system for transmitting both power and data over the same cable at the same time, using electricity lines. Fast communication with low data interference is provided by these wired systems. Moreover, the PLC provides a number of communication terminals since all types of power connections are available to transfer data. The PLC is able to communicate with all of these devices using the same cable, because every electrical device in a home shall be connected via power cables.

6- Zigbee

It's a radio communications technique called zigbee. As a wireless communications system using radio frequencies, Zigbee is based on the IEEE 802.15.4 standard. There is no requirement for licenses in respect of restricted areas, e.g. homes. Besides, the Zigbee technique consumes a minimal amount of energy. Therefore, it is suitable for basic home appliances, such as lighting, alarm systems and air conditioners Zigbee usually considers all home devices as slaves with a master coordinator/controller, which is known as a master–slave architecture.

7- Wi-Fi technology

Wi-Fi is a wireless communication technology which complies with the IEEE 802.11 standard. The Wi-Fi offers high data transfer speed and compatibility for a broad range of information-based devices, e.g. computers, laptops, etc.

8- Afid

RFID is a type of wireless communications technique that fits into the electronic product code protocol, which can be in conjunction with other communication methods such as Wifi and Zigbee. It can operate from 120 kHz to 10 GHz for a relatively broad range of frequencies. It's also able to cover a wide range of distances, from 10 cm to 200 m. RFID home applications like energy management systems, door locks and lighting control are being examined by a large number of researchers.

9- LOT

This system is designed to monitor, manage and control smart homes using Internet connections between home devices, users and grid operators. It is therefore cheap, popular and easy to offer smart home services through Internet of Things and cloud computing. Furthermore, according to Table 1, the internet of things systems shall be compatible with a wide range of additional communication protocols such as ZigBee, Bluetooth and so on. As regards Internet of Things schemes, the most important issue is internet hacking. For such internet-based systems, the key challenges are system security and privacy.

Technology innovation has changed the way people live in modern societies, changing their lifestyles and concepts of a simple house into smart homes. A smart house is a simple building developed through the use of modern technology, so that it provides more services to people who benefit from these technologies. Technology has enhanced the safety and security of people, as well as their property.

Three fundamental characteristics are involved in the Smart Home concept. In particular, monitoring via sensor networks is crucial for the purpose of obtaining information or data relating to houses and their inhabitants.

Second, mechanisms are in place to monitor how communications between devices will be used for the purpose of automation and remote access. In addition, user interfaces such as mobile phones computers are enabling users to set preferences and communicate information about such preferences.

Significant efforts have been made to improve the remote-control system in smart homes,

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A telephone line, for example systems that rely on a phone using an overline controller and a computer at home, is in principle the most important element of this system's earlier work.
However, the inability to connect with any client interface is one of the main weaknesses in these types of devices which use a telephone for remote control.

There are a wide range of Smart Home systems, but some limitations still exist with regard to the large costs, reduced functionality and difficult use that cannot be adequately guaranteed or developed. For many decades, the smart house has been a dream of science fiction, but only since the beginning of the 20th century, with the widespread introduction of electricity into homes and the rapid development of technology, has it become a reality.

Smart Home systems have been introduced and built in various research or commercial models, but most of them involved security systems. So far, the smart home system includes a lot of different technologies and products have been marketed for more than 10 years. Despite the rapid development of industries in recent years, no major company has yet come forward with smart homes as a popular technology. This is because of a number of reasons, included higher cost, difficulties in installation and use, poor functionality or not being adapted.

Therefore, when designing a smart home system, certain factors should be taken into account. The system must be low cost and affordable in the first place, so that people are able to buy it. Secondly, a smart house system needs to be large enough for easy installation of new devices into the system. Finally, in order to enable devices to be controlled and monitored so that anyone is able to avail himself of them quickly, a comfortable interface for users should be available on the host side so that the devices can be controlled and monitored so that anyone can use it easily. Not only are mobile phones used for making phone calls and sending messages to people today, but they also serve other functions. Continuous and fast technological developments have led to changes in the use of cell phones. With smartphones, they're capable of being used for a wide variety of purposes in our life because their operating systems vary, Some of them use Apple's ios, but others are using android.
Wireless technology such as Wi-Fi and Bluetooth can be used by smartphones to transfer data between the phone and other devices.

Thus, the use of wireless communication for connecting household appliances has become an important feature of most smart houses because of the spread of telecommunications technologies, as described in 16 below. For people with disabilities and the elderly who may require health care, adding technology to their own home environment can give them a suitable life. Disabled people and older people may find it difficult to carry out everyday life activities when they are not assisted by others.in the past, the idea of smart houses has focused on the disabled and the elderly to help them in their daily lives. Different wireless technologies have been used to insert various levels of intelligence in the home191, e.g. Wi fi, RFID, ZigBee and Bluetooth which could assist data transmission, sensing and control. Using Bluetooth and using a smartphone to control it, the devices are directly connected with each other. There is, however, a very high price for the system and users cannot make use of it due to difficulties in using it.

METHODOLOGY

Smart and sustainable housing construction is a relatively new challenge facing the building industry in Oman. In addition, the results from the web survey that [6] have conducted show that there is minimal benefit from asking the general population about such issues because the results show the majority, 52.2% are unaware of what it means. The number of professionals knowledgeable of such matters in Oman is very small. this study has used experienced building professionals as panelists by using the Delphi method. The Delphi technique is a research approach used to gain consensus through a series of round questionnaire surveys. Where information and results are fed back to panel members between each round. We are proposing to adopt this technique to list the challenges facing Omanis to implement smart and sustainable housing. The aim of employing Delphi technique is to achieve consensus through group interaction. A key advantage of this technique is the potential it holds to recognise and acknowledge, social constructivists generally subscribe to an exogenic tradition of knowledge.

The Delphi technique has been found to be particularly useful in the following situations:

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1) Where problem does not permit the application of precise analytical techniques but can benefit from subjective judgements on a collaborative basis.
2) Where it's difficult to meet all the experts at the same time.
3) Where the relevant specialists are in different fields and occupations and not in direct communication.

This research shall investigate and interpret the theoretical and practical knowledge of the panelists with regards to the challenges facing smart and sustainable housing in Oman, setting the stage for future studies of higher intensity. Above and beyond that, this research aims to construct meaning through an interpretation and understanding of the participants' experiences and knowledge. The participants' views are critical to forming the findings of this research and stipulate a specific and locally constructed reality. The paper will attempt to bridge the gap between sustainable housing and the use of smart technologies in improving the smart and sustainability of housing construction in Oman.

The data collection began by sending a survey to ten experts in the field of smart and sustainable houses, they were chosen based on their expertise and knowledge in this field. The questionnaire includes thirteen questions centered around a number of points such as:

- Challenges in applying smart technologies in houses
- The relationship between smart & sustainable housing and quality of life
- Maintenance and special wiring
- Omanis and their move towards smart and sustainable houses

All targeted experts answered the questionnaire, so we obtained ten different opinions on the topics mentioned above. After that the answers were analyzed and discussed, a summary was sent to the experts that included an analysis of their answers and inquiry about the extent of their agreement with the analysis. We also allow them to write any comment on the sent analysis to be mentioned in this paper.

The focus of this paper is centered on the challenges to the application of smart and sustainable housing construction in Oman. As a requirement for this round to be classified as a Delphi round, The experts will remain anonymous, but their current roles, careers, and years of experience will be described. for the sake of authenticating and validating this study. The following table illustrates the participants careers. There was a total of seven academics, one government officers and two from the private sector. The experts that were selected for this Delphi round were all knowledgeable on sustainability and smart technology issues, but differed as to whether or not they had actually participated in or worked on a smart and sustainable project.

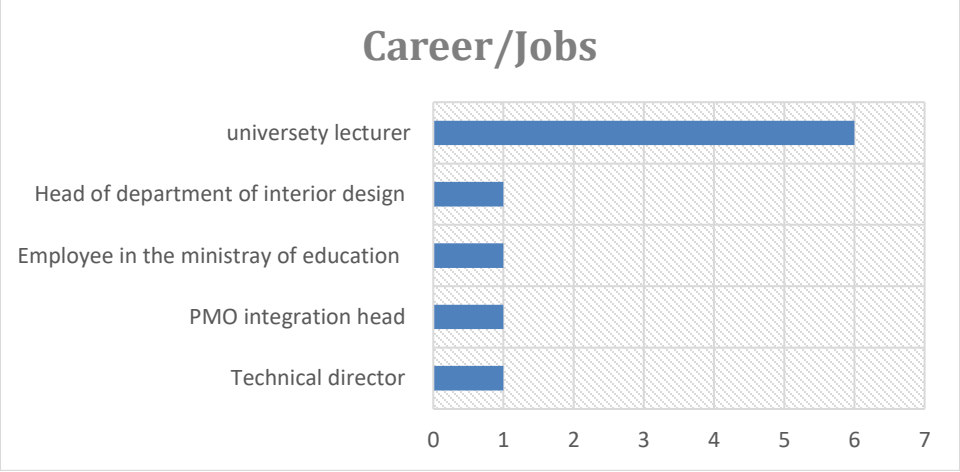

Figure 2: panel career & jobs

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The experts were invited based upon their current roles and responsibilities that are related to or having influence on smart and sustainable projects in addition to their cumulative general knowledge on the subject of smart technologies and their interest in helping to implement it into the housing industry of Sultanate of Oman.

- **Challenges in applying smart technologies in houses**

The panel were asked about the reason of the rare smart and sustainable houses in Oman. And six of them agreed that this is because of lack of awareness and fear to use advance technologies in residential houses. While two of the experts confirms that the reason behind the rare smart and sustainable houses in Oman is due to the high cost and the public are not willing to pay high prices, the particular reason for this circumstance is that most of the Omanis have difficult time financing a conventional construction home, to ask them to invest more is a difficult agenda because they have lack of awareness of the return of investment so they prefer to stay the old-fashioned way. Another expert believes that the country in the last few years has focused on sustainability according to Oman Vision 2040, but still Smart and sustainable houses in Oman are not very common. While the last expert has a different point of view, because he thinks that the smart and sustainable houses are not rare in Oman.

The experts were asked to what extent they agreed with this statement: “a large percentage of Omanis do not think about designing their homes with smart devices” the pie chart in figure 1 shows the experts answers to the previous statement.

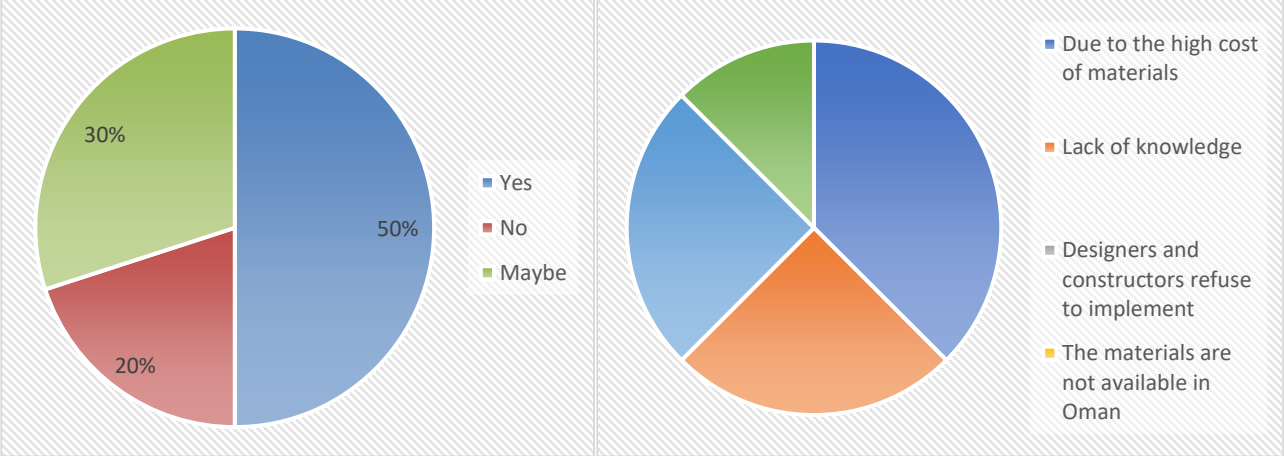

Figure 3: barriers that prevent Omanis to build their houses in smart and sustainable way

Half of the experts answered with yes and 30% of them answered with maybe, while only 20% of them thinks that a large percentage of Omanis think about designing their homes with smart devices. The experts who answered with yes to the previous question (eight to be exact) were asked about the reason behind it from their point of view. And the chart below illustrates the answers results. The answers were as following: 37.5% of the experts thinks that the Omanis do not think about designing their houses with smart devices due to the high cost of materials, and this percentage considered as the largest among all percentages. While two others believe that the reason behind this is lack of awareness and some of them thinks that all of the listed options are possible.

- **The relationship between smart & sustainable housing and quality of life**

Sustainable development is regarded as understanding the strength and links among the human needs and the environment Improving quality of life of the society is the key for sustainable development. [7]. All of the experts agreed that smart and sustainable houses can improve the quality of life. Everyone also agreed on the same reasons such as:

-It will make the living situation much simpler and people will be able to do their tasks in an ease way
-It can reduce the consumption of the electricity which can help people to save more money
-It can help government to focus in improving other sectors instead of spending thousands of rials yearly to upgrades substation to be able to cover the increasing demand for electricity

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-increase the level of security and safety
-Boosting comfort
-Reducing environmental impact
-Promoting a culture of eco-friendly living
-Saving natural resources for future generations

Only one of the experts has a different point of view he thinks the sustainable houses has a positive impact on quality of life while the smart technology does not have a great impact in quality of life because the ultimate goal of having smart homes is serving sustainability. hence, contributing to a better environment.

The most benefit that the user will benefit if he applies the smart and sustainable houses system is the quality of life. 50% of the experts agreed on this point, especially if huge sums of money were paid for the house. While 20% of them believe that if someone pays a lot of money for sustainable materials and smart devices for his house, this will have a significant positive impact on the level of comfort.

- **Maintenance and special wiring**

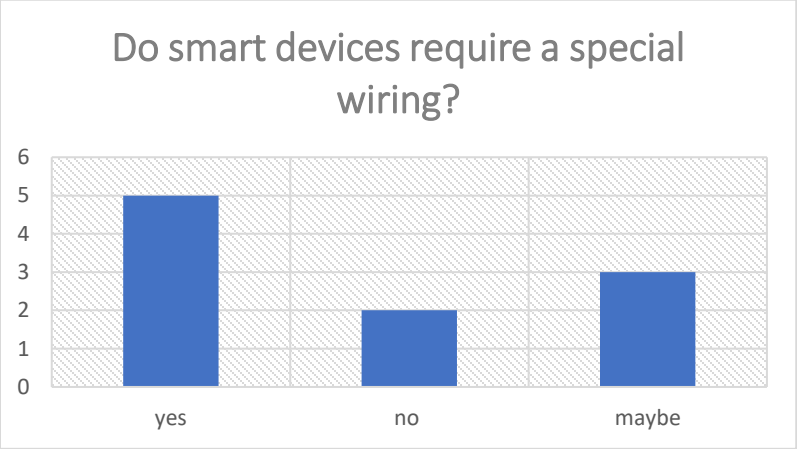

Figure 4: smart devices and special wiring bar chart

Five experts thinks that the smart devices require a special wiring while only two of them do not think so. And this might have two explanations: there are two type of smart devices one of them which require special wiring and the other type do not require that. **Or** the experts have answered from their point of view and their personal experience. Li Jiang in his research said that Smart homes are a building and occupy large area. It has a lot of special control systems, communication systems and wiring. Thus, education of smart home systems requires special laboratories [8].

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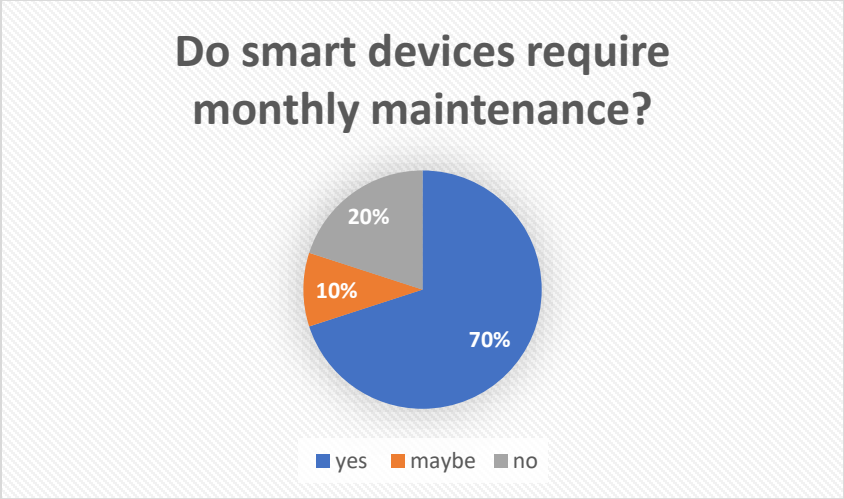

Figure 5: smart devices and monthly maintenance pie chart

The pie chart above illustrates the results of the experts on our question (do smart devices require monthly maintenance?) and it can clearly be seen that seven of them think that smart gadgets do not require a monthly maintenance. Joshua Z. Rokach in his research confirms that the smart devices require monthly maintenance where he said, "The Maryland Public Service Commission required the state's utilities to pay for smart meters, for the time being. Smart houses enjoy no such subsidy. The resident pays for installation and a monthly maintenance fee, just as for a burglar alarm." Which means the smart devices really need monthly maintenance. [9]

Speaking about smart devices, have you ever wondered what would happen to the smart houses if the internet goes down? Regarding to [10] All smart home devices are connected to the internet in a smart home environment. But the experts have different point of view they think that sustainable houses will not be affected, unlike smart homes because most smart devices are connected to the internet. Since most devices are connected to the internet, this will open another topic for us, which is security breaches and how we can make sure that our house will not get hacked. The experts have suggested several solutions that people can follow to secure their houses from hackers:

1- Educating yourself regarding the attacks, how they occur and how to avoid them
2- taking the advises of technology experts
3- buying from well-known companies
4- Stay up to date on security updates

This is not much different from how we can protect our homes with smart devices. Experts have mentioned several devices that we can use at home to protect its privacy and security, including:

1- By using smart locks
2- camera monitoring
3- sensors and alarms
4- remote managers
5- Through the Internet and telecommunications companies

- **Omanis and their move towards smart and sustainable houses**

M M Yusoff 2020 accentuate the importance of Improving the quality of life for sustainable development by stating, "Development will grant people with a new form of living security and hope. Besides, one of the major objectives for development is to ensure that the society who lives will experience a good quality of life by managing to fulfil the human needs. There are two central needs by inhabitants'; first, the biological needs that are essential to the survival of the society and second, cultural requirements that are necessary for the functioning and growth of the residents of the development area". Therefor, Omanis must move towards smart and sustainable homes, but when will that happen? The pie chart below shows the experts prediction regarding the topic.

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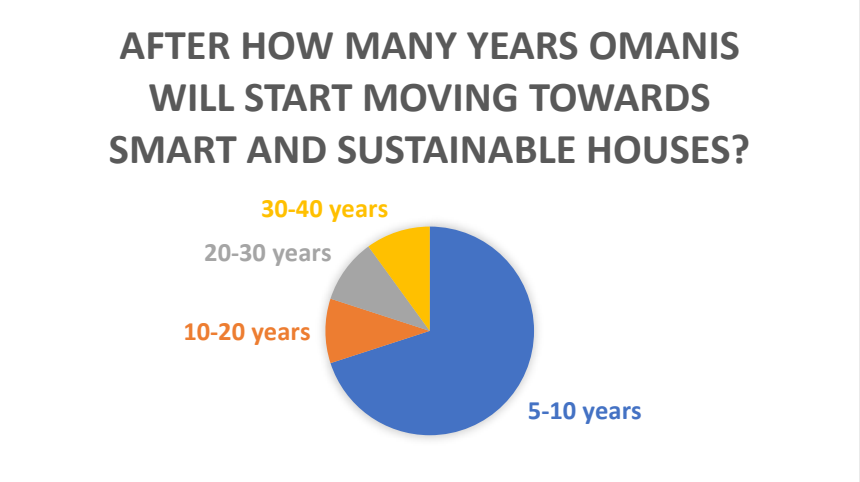

Figure 6: expected years to move towards smart and sustainable houses pie chart

As it shown in the diagram, 70% of experts believe that Omanis will turn to smart and sustainable homes after five to ten years. As for the rest, their opinions differed from ten to forty years. The main reason that will push Omanis to implement smart homes is to control home functions remotely, according to 50% of experts' opinion. Reducing energy consumption comes in second place, as agreed upon by 40% of the experts.

Finally, the experts were asked how likely they are to change their houses to better suit the environment and all of them were dedicated to adapting and constructing their houses smartly and sustainably to better align with the environment. by focusing on the 3 aspects of sustainability, social, environment and economic. The concept of sustainable development was described by the 1987 Bruntland Commission Report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development is regarded as understanding the strength and links among the human needs and the environment. While smart technology makes life more convenient. For example, you can use voice assistants to control your lights or set timers without ever having to leave the comfort of your couch. You can also pre-program devices like thermostats or security systems so that they are always running efficiently. These two concepts if were used in the right way all of human needs will be fulfilled.

Delphi method (second round):

After analyzing the results of the first survey, another survey was sent to the experts. The second survey included five questions, four of them asked whether they agreed with the results or not, while the last question asked whether they had any comments on the survey or the results in general. The results for the second survey were as follows**:**

Topics	No. of experts who agreed	No. of experts who disagreed
- Challenges in applying smart technologies in houses	9	1
- The relationship between smart & sustainable housing and quality of life	8	2
- Maintenance and special wiring	10	0
- Omanis and their move towards smart and sustainable houses	10	0

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As is clear, the table above shows there are some experts who do not agree on challenges in applying smart technologies in houses & the relationship between smart and sustainable housing and quality of life. Based on this, another survey will be required.

Recommendations:
Rapid growth and urbanization in Oman led to people being preoccupied with themselves and how to keep up with cultural development and losing the scientific aspect, which is considered essential and complementary to the civilizational aspect. The solution requires meeting not just cultural needs of the population but low-cost housing. Thus, the previous research suggested that sustainable and smart technologies should be incorporated into housing design that must include economic, social and environmental goals.

Lack of public awareness as to the benefits of such developments and the high cost of materials have been identified as the most significant challenges to implementing smart and sustainable housing construction in Oman. Additionally, public unawareness of the benefits and potential of smart technologies to achieve sustainability are challenges in the way of development. This leads to the lack of key contractor's interest in applying sustainable housing and low levels of investment in smart and sustainable housing construction. To overcome those challenges and to enable the implementation of sustainability in housing development projects, there is a need to educate the public on the benefit of sustainable housing and smart technologies. There is also a need to encourage key project stakeholders and contractors in designing sustainable housing and utilizing smart technologies. Government support and involvement is also required in the form of implementation of laws and regulations that could enforce the adoption of sustainable methods, provision of financial incentives, and provision of affordable sustainable housing that utilizes smart technologies. It also required from the government to support citizens financially and give them funds with comfortable monthly installment that allows them to build a smart and sustainable house. This will help solve the problem of the high cost of building materials.

CONCLUSION

Based on the research analysis, this paper covered four different topics related to smart and sustainable houses. However, it was concluded that the barriers that prevent Omanis from building their homes in a smart and sustainable system is because of lack of awareness and fear to use advance technologies in residential houses. Not only that, the high cost also considered as another reason and the public are not willing to pay high prices because most of the Omanis have difficult time financing a conventional construction home, to ask them to invest more is a difficult agenda because they have lack of awareness of the return of investment so they prefer to stay the old-fashioned way. This study also confirmed that smart and sustainable houses can improve the quality of life.

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