Geothermal Heating and Cooling Units: Public awareness and willingness for adoption in Saudi Residential Buildings

Abstract

Energy consumption imposed by the utilization of air conditioning and heating of water in residential buildings is accounting for the majority share of consumption in the various buildings sector. Currently, high efforts are exerted to implement sustainability in the housing sectors and the application of renewable energy solutions is highly recommended to address this issue. This study assessed the level of awareness for home residents of ground source heat pumps for air conditioning and heating of water and their willingness to install it. It was found that a high percentage of respondents would choose to install such system given the motives of which are, Energy prices increase, Environmental impact, and possibility of subsidization by the government. After conducting a significance test, chi-square test, education was found to be highly relative to the knowledge about potential geothermal energy and the gender was also positive in relatively when it came to the willingness of installing ground source heat pumps.

Introduction

The global and regional focus in the building industry is shifting to sustainable construction and buildings by exerting effort to design buildings which utilize eco-friendly systems that run on renewable energy sources (Jamil et al., 2020). In Saudi Arabia, Electricity consumption has been a concern due to the increasing high demand and source of generation which heavily relied on non-renewable sources (Mohammed et al., 2021). Previous reports have shown between the years of 2015 and 2017, Saudi Arabia had been the most country burning crude oil for the purpose of power generation (George & Sandys, 2019) and half of the natural gas consumed domestically is for electricity (Mohammed et al., 2021)A major portion of the consumption can be traced back to the residential sector, in span of a decade, the electricity consumption has increased by approximately 45% in that sector (Al Dubyan & Gasim, 2020). In addition, the domestic consumption measured by kWh/Captia has increased from 7,962 in 2010 to reach its peak in 2015 with consumption of 9,485 kWh/Captia. The residential sector is estimated to grow to meet the expected increase of population withing the kingdom, this will be met with an increase of energy consumption that necessitates alternatives and sustainable infrastructure that would satisfy the demand and decrease the

consumption of fossil fuels (Almushaikah & Almasri, 2021; Alyami & Omer, 2021). (Al-Mayouf & Al-Khayyal, 2011) reported the increase of demand in residential units within the country from 100,179 units per year for the period of 1992-2004, with an estimation of gradual increase annually that reaches up to 164,959 housing units for the period of 2005 to 2020.

The kingdom of Saudi Arabia has initiated strategic vision implemented in increments of 5 years; this vision is the 2030 vision. An essential part of the vision to tackle energy consumption and decreasing environmental impact is achieving sustainability for the building sector, for this purpose "Mostadam" has been developed as an evaluation framework for existing and new buildings in the aim of achieving sustainability (Balabel & Alwetaishi, 2021). it should be noted that the Ministry of Municipal and Rural Affairs and Housing has announced recently the issuance of regulations to commence and facilitate the application of solar energy cells on residential buildings safely (Obaid, 2021). This paper aims to measure the awareness of local residents in energy consumption, their knowledge for renewable energy sources solution that can be integrated within their homes such as Geothermal heat pumps for air cooling/heating and water heating and their willingness for a change via an exploratory public survey distributed in Saudi Arabia electronically that would lead to draw conclusions.

Geothermal Energy

Geothermal energy represents the energy thermally conducted or transported underneath the crust or the surface of the solid earth and it also represents the technology utilized for generating and collecting energy for useful purposes (Tabak, 2009). The heat in certain depth of earth layers is not influenced by the solar energy or heat, however its essentially "created by the gravitational energy and radioactive decay of unstable atoms (Tabak, 2009)" (Allansdottir et al., 2019; Stober & Bucher, 2013; Tabak, 2009). the influence of solar energy dissipates around 10-20m depth, at that level the temperature is irrelevant of the surface of earth and usually constant throughout the year (Boden, 2016; Stober & Bucher, 2013; Tabak, 2009).The ground heat is transported by two essential means: by heat conduction through rocks and by a movement which referred to as advection, where heated fluid moves in bulk. Geothermal energy is considered to be renewable energy due to the fact of the enormous amount of heat stored within the body of the planet and the human consumption is considered to be insignificant relatively to the energy reservoir. Also it would be considered unlimited if the usage by human was sustainable (Stober & Bucher, 2013).

Buildings can extract geothermal energy though heat pumps which are known as geothermal heat pumps (GHPs) or Ground source heat pumps (GSHPs) (Akpinar & Hepbasli, 2007), the system is considered an excellent configuration for air/water heating and cooling for residential units (Akpinar & Hepbasli, 2007; Kim et al., 2013) and it made its application has increased in other sectors such as industrial and commercial sectors (Kavanaugh & Rafferty, 2015). The geothermal heat pump system is conventionally comprised of the following main components: Heat pumps, Heat exchanger loop (horizontal or vertical), Heat distribution unit, compressor, expansion, and reversing valves. Although, the system is utilized for production and distribution of renewable energy, the system would still requires minimal electricity power to operate the compressor and distribute the energy (Jamil et al., 2020). Its been reported that the initial cost of the geothermal systems is one of the discouragements for users, however studies have proved that the running costs through the life cycle of a building utilizing the system would result in net savings (Akpinar & Hepbasli, 2007; Jamil et al., 2020). GSHP systems are still not widely spread globally when compared to other dominant technologies for cooling and heating, however, its worth to note that the state of utilizing the GSHPs is more advanced in multiple European countries and north American countries and less in other regions of the world like, Japan, turkey and Palestine (Karytsas & Theodoropoulou, 2014). In Saudi Arabia, the discussion of geothermal has been on the level of electricity production, up to this date, there are no power plants that extract geothermal energy and convert it to electricity in KSA, it has been reported that there are immense resources of geothermal across the country with Wadi Al-Lith area (Ain Al-Harrah) being the area with utmost potential of power projections (Amran et al., 2020; Demirbas et al., 2016; Lashin et al., 2020). On the building aspect of utilization of geothermal energy sources for heating and cooling. (Jamil & Alhusayni, 2020) has conducted a study in Saudi Arabia in the aim to define the economic feasibility of installing GSHP system for a multistorey residential apartment building. The comparison was based on completing conventional system design and a design of geothermal heat system that would act as a central heating system for water. Results of life cycle costing of the system that included installations and operational costs was concluded by the author in favor of the GSHP, with three times saving in running costs for the period of 5 years.

After the survey of literature and the industry, it's found that there is currently, no application of geothermal for such purposes in buildings locally with lack of studies in this sector.

Materials and methods

A Questionnaire is formed to look into the public awareness on renewable energy sources and assess their preliminary willingness/motives to adopt the application of technologies into their homes that provide heating and cooling from geothermal energy sources. The form was distributed electronically, commencing the survey with a brief description of the research purpose and its expected time to finish, with assurance of confidentiality of personal information. Four sections were designed to conduct the assessment. In first section the participants were requested to fill up information that would describe their demographics, such as their gender, age, education level, and occupation. In the following up section, questions were directed to understand the type of house the participant and their current/potential family are living in. with questions to derive information such as, the region where their house is located at, number of floors within the house, the built area, their social class, the installed HVAC/water system. In the third section, simplified questions that address awareness of energy consumptions were presented to the participants. Finally, in the last section (Section four), the residents were asked if they ever heard about geothermal energy and its utilization for houses/buildings, and the concept of the technology was illustrated and explained briefly to the residents to evaluate their preliminary willingness to install such machines/equipment for their homes. The majority of the survey was designed with multiple choice form of questions to convey the information easier and to interpret the motives behind their input more clearly.

The questionnaire was distributed in a time frame between 25 March and 20 April. It was built on google platform, Google forms, and randomly distributed electronically to homeowners and members of households locally in Saudi Arabia mainly through social media platforms. The survey had interactions to over 19,000 internet users. A total of 126 homeowners across Saudi Arabia managed to fill up the complete survey.

Results

Survey sample

The survey has reached all the regions of Saudi Arabia electronically according to the responses gathered in the google platform, residents living in up to 19 different cities participated with dominance of cities that are in the eastern region of Saudi Arabia (79 responses). The cities were categorized under their official geographical regions as illustrated in Figure 1. The participation consisted of 82% males and 18% females (Figure 2), the predominant group of age of participation was represented by the 22-30 group as both genders totaled with 72 respondents (43%),

followed by the remaining groups with an approximate fair distribution over the age groups as shown in Figure 3. the majority of those who participated are employed and have a steady income. The occupation background of the sample is diverse with majority falling in jobs with a background of engineering and educational (Figure 4).

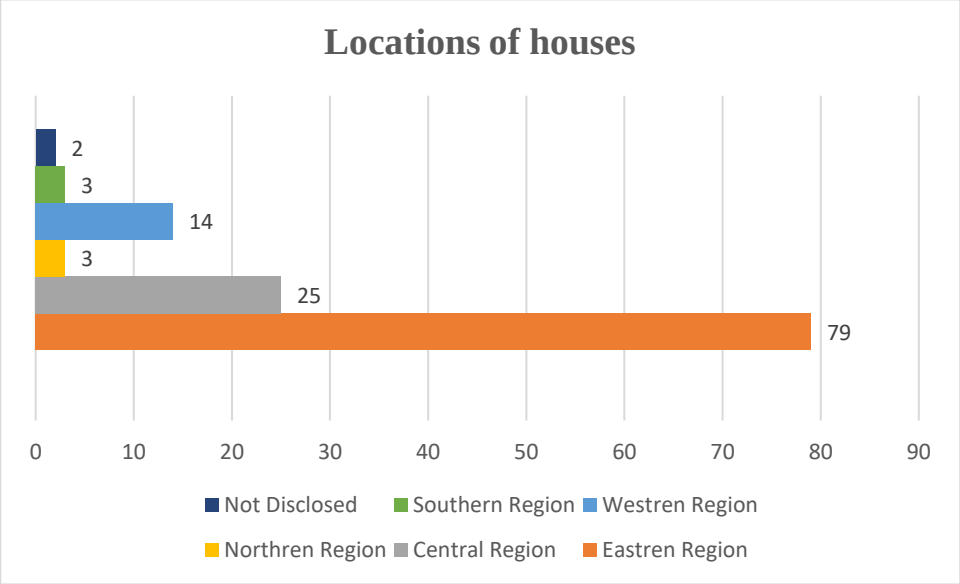

Fig.1 Location of respondents

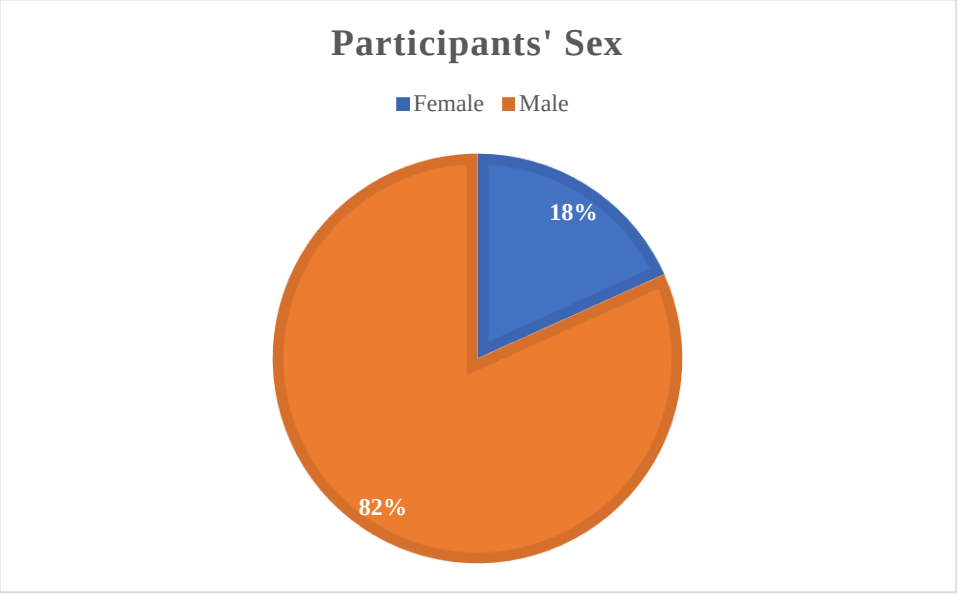

Fig.2 Gender of respondents

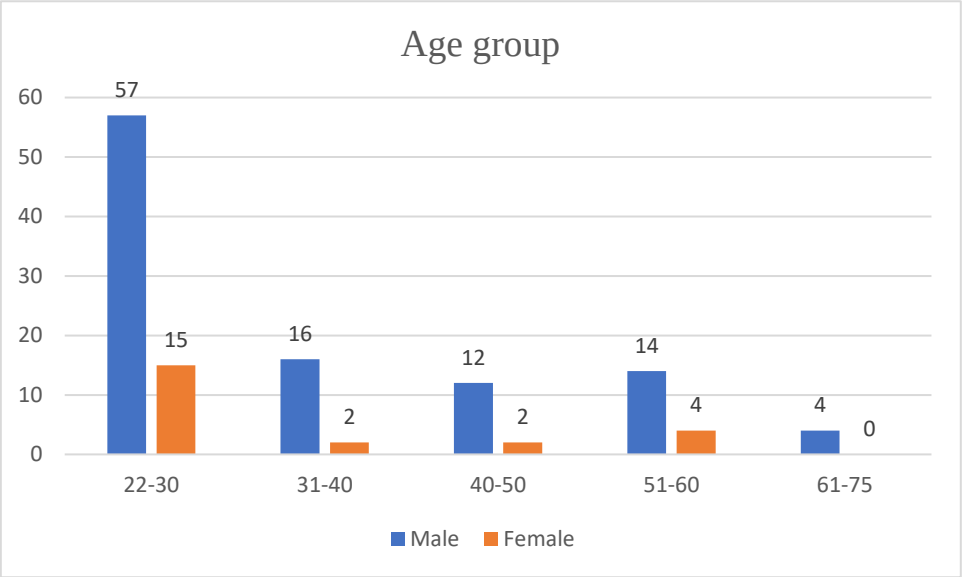

Fig 3. Age group of respondents

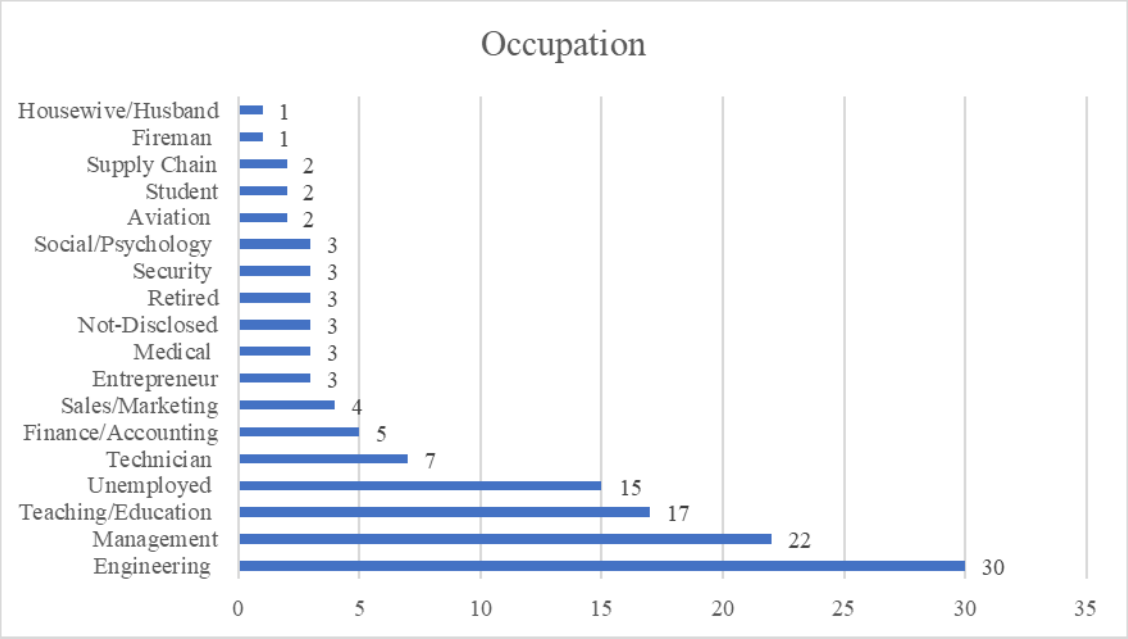

Fig.1 Participants' Occupation

Regarding the education level of those who participated in the study, and as shown in figure 4 approximately, 69% of the residents that filled the form have a bachelor's degree and 19% of the remaining are holders of postgraduate degrees, compiling to 88% together. The sample can be considered an educated sample.

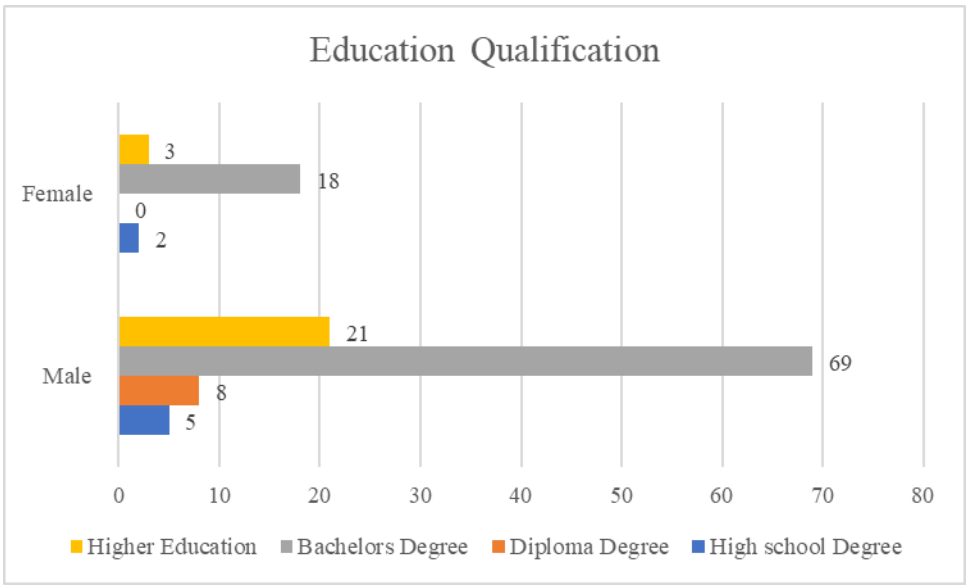

Fig.5 Education Qualification of the Respondents

In relation to the housing sample that represents the accommodation of the respondents, the majority of the respondents lived in two and three stories' houses, in combination, 104 respondents are in those two categories. The remaining 22 participants stated that they live in one floor story house (Figure 5). In addition, the participants have provided information regarding their built area as demonstrated in Figure 6.

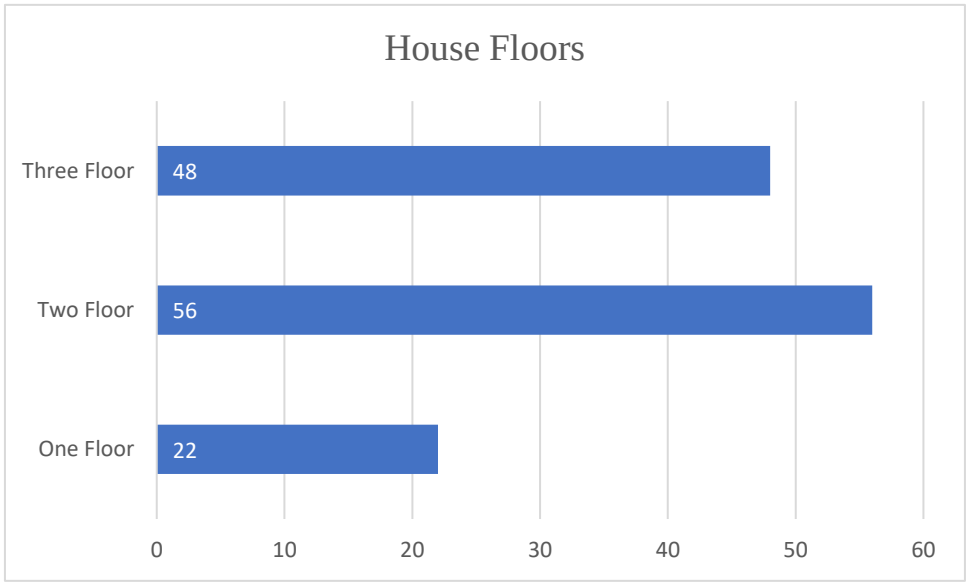

Fig.6 Number of floors of house samples

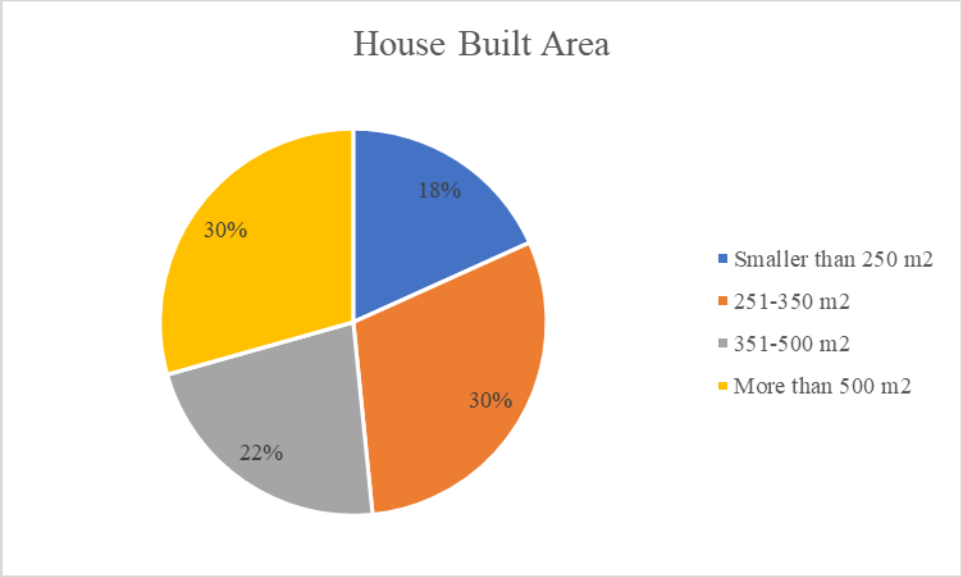

Fig.7 House built area

Participants were requested to describe their social class based on their annual income, the range of three set social classes was referenced from a study conducted by (Alnuaim, 2013) through the Gulf Research Center. Results showed that 70% of the sample of home residents fall within the range of middle class (46,800 - 458,400 SAR), while 23% reported that their annual household income is More than 458,000 SAR which identifies them as upper class. Only 7% represented the working class from the sample with an annual income of less than 45,000 SAR (Figure 7).

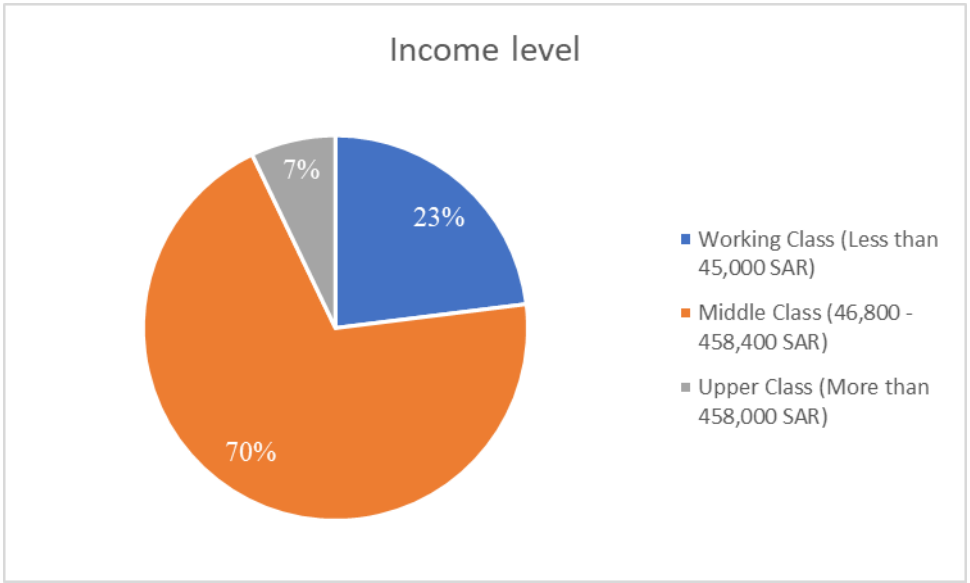

Fig.8 Income level

In addition, information regarding the type of HVAC and water heating system for the participants' houses, were seek, only 30 households have installed central HVAC system, while the remaining of households utilized

Split units (68 households) and Window units (26 households) which are running on depleting fossil fuels generated electricity. Window units are infamous for its high consumption of electricity in comparison with the other types of HVAC systems, especially with larger space to cool, it was found that five houses of the sample with over 500m^2 built area utilize such type. Only two respondents have declared that they are not sure of which type of HVAC is installed in their homes. On the other hand, 96 households stated that their water heating systems are single units while the remainder utilize central units.

Knowledge about renewable energy

In an attempt to establish an understanding of the awareness of the local residents about the possible environmental impact relating from the excessive use of energy consumption, over 58% responded that they are aware of such impact with 31% of the sample stating they are willing to learn more, while only 16% of the remaining stated that they are not aware of such impact questionnaire. On the other hand, when asked about their satisfaction of their monthly electric consumption, more than 70% stated their dissatisfaction with their monthly.

There were initiatives by the government to introduce renewable energy and sustainability within homes, respondents were asked about their knowledge of their existence, only 42% responded that they are aware of them, while over 57% said they haven't heard of such initiatives locally.

Knowledge about geothermal

In the last section of the questionnaire, questions about the geothermal energy and its systems, which considered the main topic of the paper were presented to the respondents. At first, we have assessed if residents were aware of the potential of energy within the layers of earth that can be harnessed for the use of cooling, heating both air and water in houses, responses showed that 70% were unaware of such potential. Furthermore, they were asked if they heard about geothermal energy systems, over 74% also asserted that they don't have knowledge about it, however, 44% of those stated that they are interested to learn more about it. Finally, after explaining the correlation of energy consumption from non-renewable sources with negative environmental impact and that renewable energy sources is one of the solutions to address this issue, it was illustrated to the residents who would be interested to implement a design of geothermal heat pumps for air conditioning and heating water within their homes that the installation of such systems requires a high initial cost due to the potential excavation. However, as studies have shown that over a period of time, that costly investment could be returned and reflect positively afterwards. The explanation was in an attempt to investigate the willingness of the respondents to adopt such system. 17.5%

answered that they would be interested installing such system for the sole purpose of decreasing the environmental impact, while 9.5% stated that their drive for installing such system would be to their dissatisfaction of their monthly electric bills. Moreover 30.5% replied that they might consider it if it was incentivized or subsidized by the government, while the remaining majority answered they would for all the above reasons and only 3.2% stated that they wouldn't consider installing a geothermal system for their homes.

Chi-Square test

Moreover, The survey results was statistically analyzed by the chi-square test to identify possible relation between the registered data and the expected data compared to the sample (Franke et al., 2012; Kathleen et al., 2018). Chi-square allows to test the independence of the demographic variables of respondents to their knowledge of renewable energy and geothermal energy in general and their willingness to adopt it for their homes to provide insight (Table…). Significance relation was set to be with the limit of 0.05. it was found that knowledge about the potential of energy stored in the layers of earth was positively related to the variable of education. When respondents were asked about their intention to install geothermal pumps as an HVAC system and water heating in their homes, the only variable that showed positive relation to such decision was the gender variable. The remaining variables, and their relationship with knowledge about initiatives issued by the government and geothermal energy technologies did not record any significance as their P-value were higher than 0.05.

Table 1: Chi-square tests for independence relation with demographic characteristics.

	Are you aware of environmental impact/harm of increased energy consumption in households without the use of renewable energy?	Are you aware of the government initiatives for implementing sustainability in houses?	Do you know that earth have enough energy to be utilized for cooling and heating air and for water heating with minimum use of electricity?	Have you heard about Geothermal energy?	Installing geothermal equipment requires excavation and high initial cost however it can return the investment in 5-10 years. Would you be interested in installing the equipment for your home?
Age	0.53	0.10	0.24	0.81	0.11
Gender	0.35	0.32	0.3305	0.1855	0.01**
Education	0.21	0.88	0.0015**	0.1627	0.79
Annual Household Income	0.82	0.91	0.152	0.155	0.23
Occupation	0.27	0.43	0.23	0.47	0.46

Unit: P-value

Significance of relation: $P < 0.05$

Discussion

The need of transitioning towards sustainable housing has been increasing and has been the focus for governments globally over the previous couple of decades (Al Mulhim et al., 2022). in Saudi Arabia, and with the rise of the country's economy when oil was discovered, generation of power was highly subsidized by the government, although, the tariffs prices have increased recently(Alyousef & Stevens, 2011; Bah & Saari, 2020), but compared to many countries and when taking the average monthly income of households, tariffs are still considered affordable for the average household. Taking this into consideration, it was found that 70% of the respondents are not satisfied with their monthly electricity bills while over 50% stated that they are aware of the correlation of environmental impact and increase of energy consumption from their homes. The permission of implementing renewable energy sources for households has only been initiated within the country and is currently limited to solar panels as announced by the Ministry of Municipal and Rural Affairs and Housing recently (Feb, 2021), about 57% answered that they are not aware of governmental initiatives for sustainability and adoption of renewable energy solutions.

From a point of view of decision making in the house, it should be noted that the contextual nature of the culture of homes in in Arabic societies should be taken into consideration as they are conventionally composed of multiple members that would contribute to the household. It was found from the study, that the majority of the random sample of resident wouldn't oppose to installing a geothermal heat pump for the conditioning of their indoor air and heating their water due to previous mentioned motives including the increase of energy prices, environmental impact and possible incentives. therefore, other options for renewable energy solutions for homes other than solar panels, only seems viable to appear. Geothermal heat pumps can have its presence within Saudi Arabia as few studies showed its potential (Jamil & Alhusayni, 2020). Currently the presence of geothermal systems in Saudi Arabia is almost nonexistent. This highlights that there are multiple obstacles or difficulties that would be overcome once legislation for it is issued, and adoption increases by the public. Obstacles such as importing specialized investors or workers to facilitate and provide a supply for the potential demand of renewable energy solutions for homes with affordable prices to the homeowners. Furthermore, raising further awareness of homeowners by issuing inclusive campaigns of renewable energy solutions for homes, also the answers of the survey showed that 30% would only consider the implementation of geothermal heat pumps if it was incentivized by the government, an approach that was taken by other countries like the United States Of America (Yunita Anwar, 2011) , few times, a

bill was passed for those who purchase and install geothermal heat pumps for their homes by redeeming 30% of their expenditures on the system from their federal tax credit. Incentives were also for beyond the level of an individual; corporate were benefiting from such incentives by a redemption of 10% of their expenditures on installation and purchase of the system. Currently in Saudi Arabia there aren't imposed income taxes on individuals, however, incentives can take similar forms and concepts to motivate those who might consider installing such systems.

Conclusion

The aim of this study was to assess the level of home residents' awareness on renewable energy solutions such as ground source heat pump technology in Saudi Arabia, their willingness to install such a system and to discuss the obstacles and motives. In conclusion geothermal is unfamiliar technology in Saudi Arabia, and those who are informed about it have an education and engineering background. The increase of electricity tariffs for residents and environmental impact are the main motives for installing renewable energy solutions according to the responses of those participate. The challenge for adoption of the system is its high initial cost of the system due to the requirement of excavation around the house and in the case of Saudi Arabia, the need of specialized companies that are scarce in the market. given all that, operational costs of the system is considerably low, therefore, it offers a high potential of return of investment for those who would choose to install GSHPs. This study can be an insight for governmental entities that strategize the implementation of renewable energy solutions for homes and for potential investors in the future.

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