

A growing economic challenge: Findings from a survey on building energy efficiency in SA

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ABSTRACT: Saudi Arabia (SA) has been giving significant attention to energy conservation since the year 2014 due to the oil crisis and the extensive energy consumption in the building sector, particularly residential buildings. Buildings in Saudi Arabia occupy between 75%-79% of the total electricity consumption (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Residential buildings are responsible for 49%-52% of the total building consumption in the country (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Air conditioners and refrigerators consume 80% of electricity in residential buildings. This paper aims to explore the following questions: What are the attitudes and design practices among design teams towards energy efficiency? What are the existing building features under the impact of the Saudi Arabian government's energy conservation policy? To be able to tackle these questions, a web-based survey on the energy efficient building design-related attitudes and practices of design teams was conducted. The survey was administered in July and August 2017. We categorized the existing buildings into four timeframes upon the SA policy's agenda: less than five years old (built after 2012), between six to ten years old (built between 2007 and 2012), between eleven to fifteen years old (built between 2002 and 2006), and over fifteen years old (built before 2002). The survey reached 119 participants who are design practitioners in the building construction area. The survey contains 18 questions divided into five categories, i.e. background information, walls, roof, exterior doors, and windows. The participants were asked to answer three to four questions for each building envelope component. The findings of the survey present the main energy efficient indicators which have been used by design practitioners since 2002. This study may advise on the content and format of the future energy efficient design guide and economical retrofitting strategies.

KEYWORDS: Energy Efficiency, Building Envelope, Saudi Arabia, Construction Practice, Economic Challenges.

INTRODUCTION

Buildings have always been associated with energy. Up until the energy boom in the 40s and 50s with the discovery of oil, buildings were more environmentally responsive (Roaf 2004; Maddex 1981). As a result of energy becoming more affordable than ever, architects designed buildings without serious considerations for energy conservation during that time (Maddex 1981). Later on, during the energy crisis, we re-discovered the need to wisely utilize renewable energy and achieve environmentally responsive design in buildings. Building regulations all over the world have been shifted towards more energy efficient buildings (Kharseh et al. 2016) and have influenced both new and existing buildings. This paper provides an overview of findings from a survey related to energy efficient building design practices in Saudi Arabia (SA). The paper is organized into four major sections, the first of which provides important building design contextual information regarding Saudi Arabia and its building regulations. Also, this section reviews the existing literature on energy consumption in the building sector in SA. Section two states the method used in this paper, which is mainly surveys and statistical analysis of survey data. The third section details the findings of the survey with some analyses. Furthermore, this section outlines the participants' characteristics and what the building envelope properties used in the country are. The fourth and final section discusses why this paper is important now more than ever. It also provides key principles behind the lack of using energy efficiency in buildings as well as pointing out possible solutions to improve efficiency.

1.0. BACKGROUND

The country by its nature has limited resources and highly depends on oil as a primary resource. As a new nation, most of the existing building stock in SA were built in the era of cheap energy. Therefore, the energy efficient design standards were not employed in the buildings with exception to the relatively new governmental buildings. Almost all the traditional buildings, which are actually energy efficient, were demolished to keep pace with modern development. Despite the government awareness program and initiatives, which were started in 1985 and updated in 2010 to reduce energy consumption in the private sector, owners choose not to apply any energy efficient products in their buildings because of the higher cost of these products (Saudi Electricity Company 2015). Nevertheless, soon after the oil crisis in 2014, the Saudi government started a new strategy called Vision 2030 (Nurunnabi 2017). One of the major parts of the agenda is to reduce the nation's reliance on oil. The government started enforcing and developing regulations that has been set in the past to increase energy efficiency in buildings (Mohammed 2014: Saudi Electricity Company 2015: Saudi Energy Efficiency Center). Buildings in Saudi Arabia occupy between 75%-79% of the total electricity consumption (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Out of that percentage, residential buildings are responsible for 49%-52%, that is about two third of the total building consumption in the country (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Air conditioners and refrigerators consume 80% of electricity in residential buildings (Taleb et al. 2011).

Different climates require different building techniques to achieve ideal energy performance. In SA, there are generally five different regions; each region is also distinguished from the rest by its unique climate, culture, and tradition. The climate of the western region, which is coastal land, is characterized by its hot tropical weather with hot-humid temperatures in summer and relatively warm conditions in winter. On the other side, the eastern region is hot-humid in summer, but cold in winter. Northern and southern regions generally located on mountains, therefore they are cool in summer and winter. Finally, the central region, which located between three deserts, is hot-dry in summer and cold in winter (Al-Jadeed 1994). Similarly, different types of buildings come with different functionalities, and therefore are important to understand the construction practices that have been used on all kind of buildings to achieve energy efficiency. Afterward, we must narrow down our focus to the residential buildings, as this sector has been shown to occupy most of the energy consumption in the country. In order to have a holistic approach and a better understanding of the practices that have been used in buildings, we should collect data about all the five regions in SA as well as all types of buildings before we focus our study on residential buildings.

According to a survey done by Al-Surf (2013), 52.2% of architects and engineers, who are affiliated with the Saudi Council of Engineers (SCE), which consist of a variety of professions; including mechanical, electrical, chemical, civil, and computer engineering as well as architecture, have not heard about sustainable housing before. The lack of awareness among the respondents in the previous study (Al-Surf 2013) could explain to some extent why energy efficient techniques are not considered in the construction practice. However, since the previous study involved many professions that are not related to construction, we saw a need to conduct a study on construction practice with more focus on building envelope. Therefore, this survey study is proposed to reach a wider platform with a specific target at building construction professionals such as architects, civil engineers, and contractors who have direct and great impacts on practices of existing buildings. Another objective of this study is to attain the design settings and information of building envelope of residential buildings, which may guide us for our future study of baseline model development.

2.0. METHODOLOGY

The present study employed a quantitative method to explore the following questions: What are the attitudes and design practices among design teams towards energy efficiency? What are the existing building features under the impact of the Saudi Arabia government's energy conservation policy? To be able to tackle these questions a web-based survey on current as well as the previous building design attitudes and practices among the design teams was conducted.

The survey was designed to collect a database about the energy efficient design-related methods and materials that have been used in building practices, especially about building envelope. The survey was sent out between July and August 2017 to the Saudi Green Building Forum group and other groups on social media that involve practitioners in the construction field. The total number of members from all the of groups was 1,833, of which only 119 have participated in the survey. The participants were asked to answer the questions on the survey based on their own experiences with designing and constructing buildings. The survey contains 18 questions divided into five categories, i.e. background information, walls, roofs, exterior doors, and windows. From the survey findings, we could establish a baseline for construction materials and methods that were used in existing residential buildings in SA. Additional data were gathered through different resource, to give context to the Saudi situation. Several sources have been used to collect additional information about building systems and existing typical retrofitting technology for creating building envelope. The result of this study may also provide insight on the content and format of future energy efficient design guide, and economical retrofitting strategies.

3.0. SURVEY FINDINGS

In this section, we analyze the data we extracted from the survey. The section is organized according to the online questionnaire structure which is mentioned in the previous section.

3.1. Characteristics of participants

The participants were asked to answer six questions about background information such as age, profession, experience, type of projects, region, and city. As shown in Figure 1, most participants were between the age of 25-34 (59%), and only 4% were 55 or older. The mean age was 35.79 ($SD=7.8$), and the mean year of professional experience is 8.97 ($SD=3.84$). The high number of younger participants also reveals the high percentage of young professionals who are currently working in the building construction area in SA. The same figure also shows that there is a high number of young professionals (age between 25-34) among both architects (72%) and civil engineers (63%). On the other hand, a significant portion of contractors (67%) are between the age of 35-44. While respondents of other disciplines, i.e. computer science, construction management, interior design, planning, electrical and mechanical engineering, and drafting, have reported to be between the age of 45-54.

In regard to the profession perspective, architects form the majority (66%) of the participants in this survey (Figure 2). Additionally, figure 3 shows that 37% of respondents have 5 years or less experience, and 34% have between 6-10 years, while 14% for each categories 11-15 and >15 years of experience. These data reveal the lack of experience on the Saudi construction market with about 71% of respondents having 10 years or less of experience, and only 24% having more than 10 years of experience.

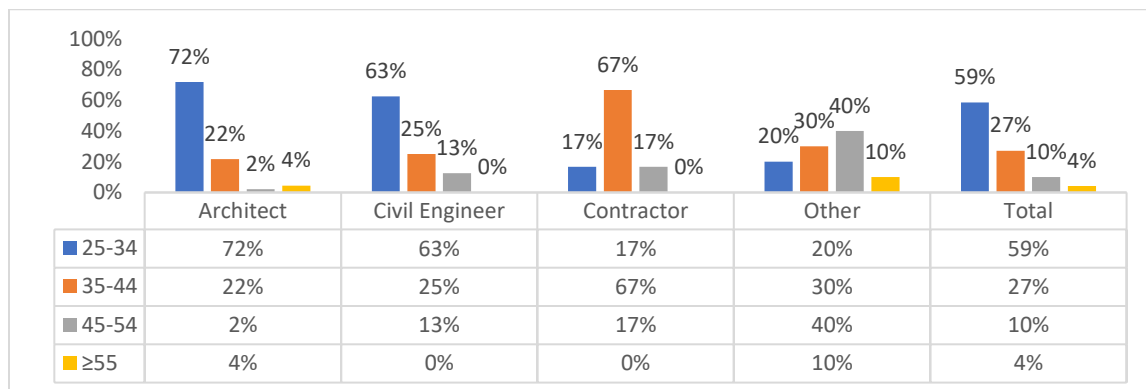


Figure 1. Percentage of age in respect to professions and total percentage of age.

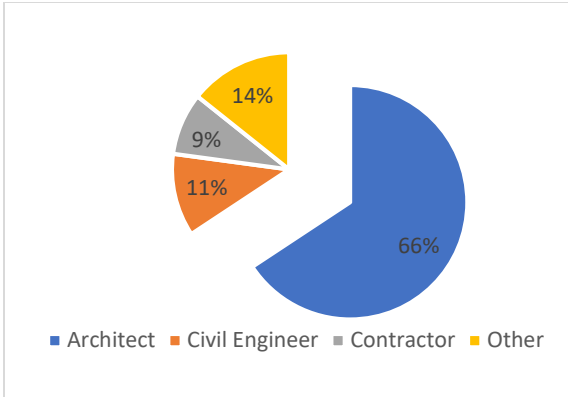


Figure 2. Profession percentage.

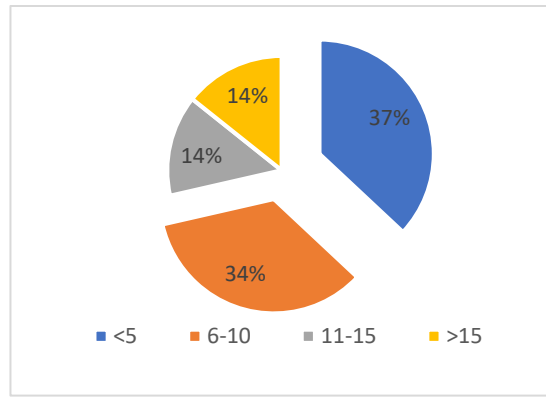


Figure 3. Experience percentage.

3.2 Building envelope properties

The first question in the building envelope component section, determines how frequently participants use thermal insulation, if they use any. The second question determines how they have been using the thermal insulation in building envelope in their practices within indicated years. We categorized building ages into four periods: five years old or less (built after 2012), between six to ten years old (built between 2007 and 2012), between eleven to fifteen years old (built between 2002 and 2006), and over fifteen years old (built before 2002). Finally, the participants had the option to input values that they have used in their projects.

The answers related to the wall insulation usage in all types of building projects are shown in Figure 4. It shows a clear trend that wall thermal insulations have been increasingly adopted in practices in the last 15 years. However, a dramatic change has happened in the past five years. This significant increase in wall insulation usage could be due to the economic challenge that the country has been facing since 2014, which encouraged people to be aware of the importance of using such products and techniques to cut energy costs. On the other side, the responses of the wall thermal insulation usage before 2012 also reveal that practitioners in the building construction area in SA were way behind with the governmental energy policy timetable, which was initially developed in 1985 and updated in 2010 (Saudi Electricity Company 2015). It is also worth mentioning that, even though there is great increase of wall thermal insulation adoption in practices in last five years, there is still a high percentage (25%) in practitioners who have not accepted the implementation of thermal insulations into walls in their practices.

With respect to the residential building projects, out of the 28 participants who work in residential projects, only one participant used wall insulation on buildings that were built between 11-15 years. Even though the number of participants using wall insulation in residential buildings has dramatically increased, still over a third of the participants say they never use wall insulation. Among all types of buildings, the residential buildings have a higher number of energy consumption, yet the number using wall insulation is way less than the rest of building types. This will result of wasting energy and thus burden the economy. From these findings, we may conclude that it was common for buildings that are between 11 to 15 years old to have almost no wall insulation in residential buildings.

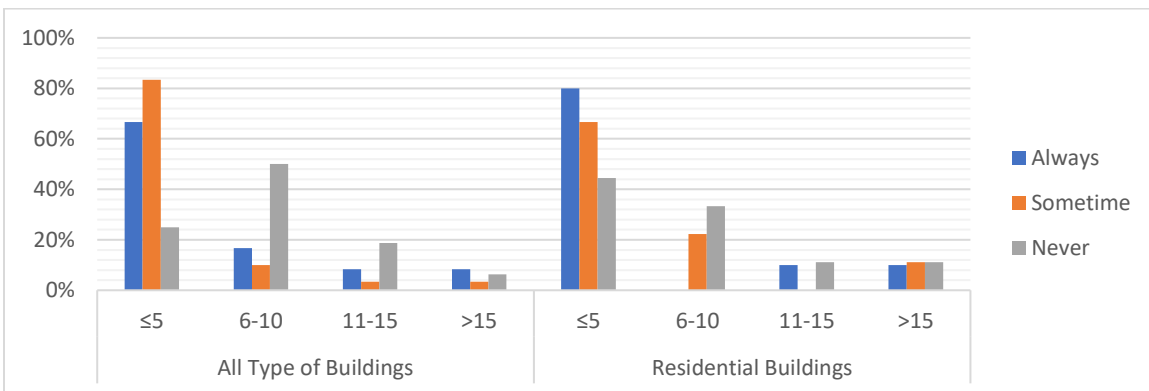


Figure 1. Thermal insulation in walls.

With regards to window types in buildings that have been built for over fifteen years, single-pane window usage occupies 60%, forming the majority. On the other hand, double-pane window usage contributes just 40% of the total number on that category (Figure 5). As we move forward, the results in the figure show that between 6-15 years ago the number of participants who used double-pane windows are equal to the number of participants who used single-pane windows. Correspondingly, in the residential building category, most of the responses were in favor of double-pane windows for the past five years, however, for older buildings, it is clear that the significant number of participants used single-pane windows (Figure 5). The trend of utilizing double-pane in the past five years will be further explained in the discussion section of this paper.

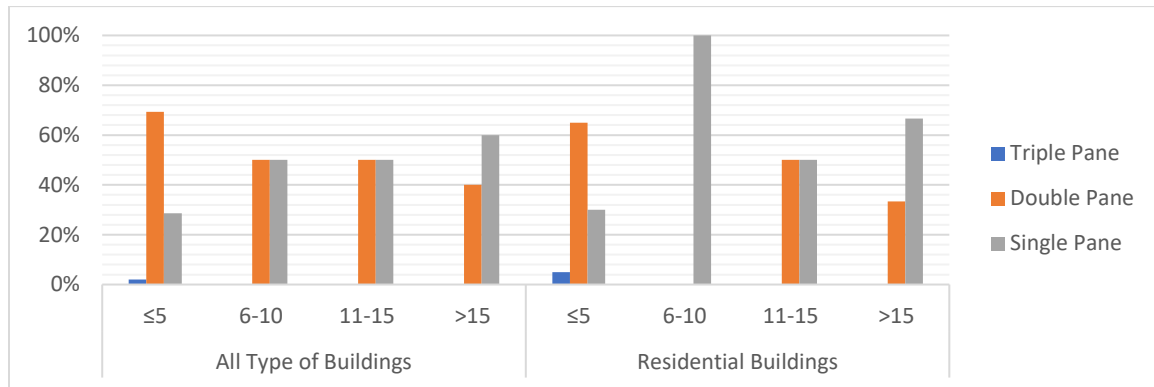


Figure 2. Thermal insulation in windows.

About two-thirds of participants have reported neither always nor sometime using thermal insulation in roofs since 2012 (figure 6). On the other hand, the number of participants who never use insulation in roofs has been drastically decreased from two-thirds before 2002 to only one-third in the past five years. Therefore, the results show a clear trend in utilizing thermal insulation in roofs for all building types. In residential buildings, however, there is a slight improvement in roofs insulation usage (figure 6). The previously mentioned figure reveals that the vast majority of participants have never utilized roofs insulation before the year of 2002. However, the number has decreased by 50% from 2002 to 2006, then jumped to 75% from 2007 to 2011, and eventually went down to 62% after 2012. This fluctuated pattern will be discussed further later in this paper. The data provide a convincing evidence against the usage of thermal insulation in exterior doors. A cursory glance at figure7 reveals that there is a slight increase of thermal insulation usage in exterior doors for all building types beside residential buildings. Yet, the majority of participants never utilized any kind of insulation. On the other hand, the result in residential buildings category show no strong evidence of insulation usage in exterior doors.

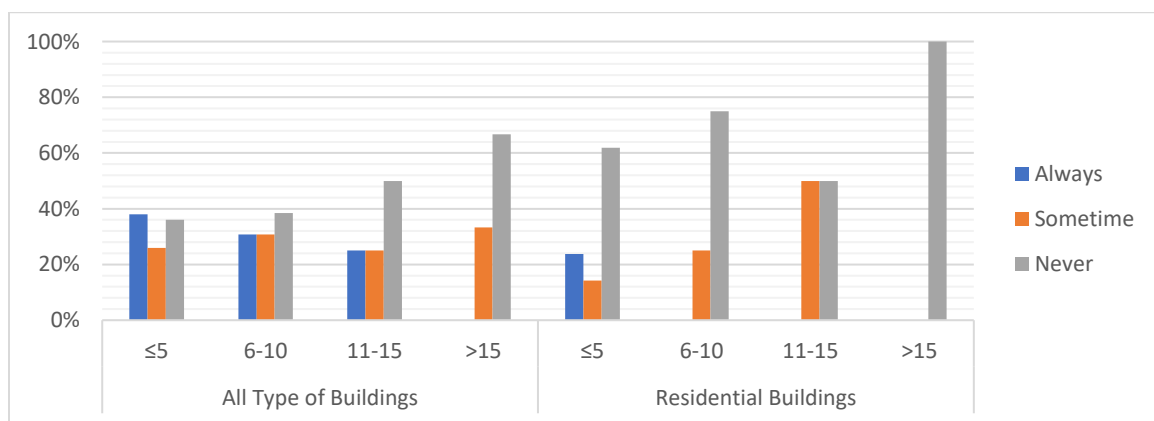


Figure 3. Thermal insulation in roofs.

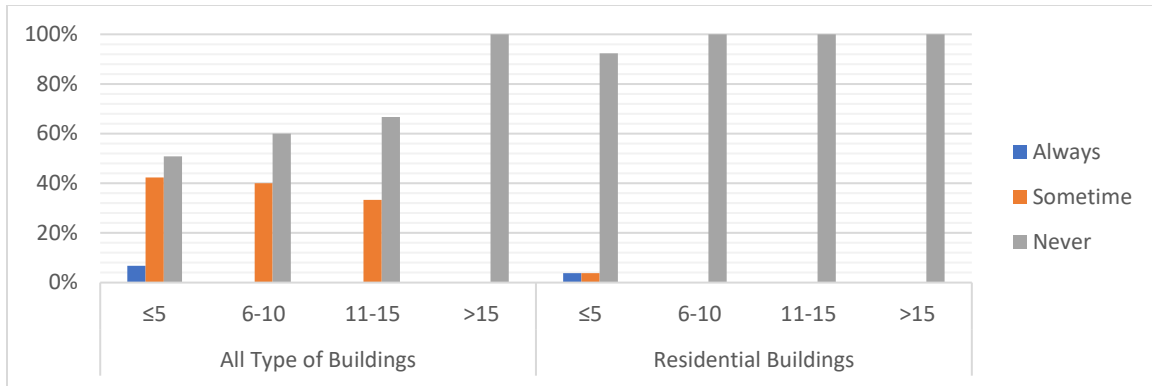


Figure 4. Thermal insulation in exterior doors.

To conclude this section, there is a significant difference of thermal insulation usage in buildings of all kinds. In regard of commercial and governmental buildings, the results reveal that thermal insulation has always been used and steadily improving in these kinds of building types. However, while there is growth in the number of practitioners who use thermal insulation in residential buildings, the number remains statistically insignificant. We can safely draw from the findings that the common ordinary residential buildings that were built before 2002 have no proper thermal insulation in walls, roofs, doors, and to some extent windows. This result provides a strong evidence that buildings falling into the residential category require a critical improvement in their envelope to reach a high level of energy efficiency.

4.0. DISCUSSION

In this section, we will identify the key factors behind the lack of energy efficiency techniques used in buildings. We will also discuss why this energy efficient design-related survey is important now more than ever. Lastly, we will point out some potential strategies and future works to improve energy efficiency in buildings.

4.1. Discussing survey findings

The number of contractors and other disciplines in the field of construction before 2002 and up to 2006 is higher than architects and civil engineers. Oppositely, architects and civil engineers form the majority of young professionals since 2007. The result yields a positive correlation between the increased number of architects and civil engineers on one side, and the increase of thermal insulation usage on another. A further investigation on the correlation between the trend of insulation usage and the trend of architect practitioners rate is needed in the future as there is still not enough evidence.

Even though the first edition of Saudi building code was published in 2007 (Saudi Building Code 2007), the growth rate in thermal insulation usage between 2007 and 2011, particularly for windows and roofs, has been relatively low comparing it to the growth rate of previous years. However, thermal insulation usage has been drastically increasing since 2012. There are two explanations for this gap. First the Saudi building code has not been formally enacted yet, thus practitioners have no obligation to apply the codes to their design. So, there is a need to enforce the Saudi building code as it will eventually help make more energy efficient buildings. The second explanation would involve economic factors; in the light of the economic resurgence, which took place between 2007 and 2011, the consumption in private sector has peaked (Bahgat 2012; Nurunnabi 2017). As a result, many buildings have been erected at this time with less than expected use of insulation. Good economic status makes people care less about energy consumption as it becomes affordable, thus they ignore using thermal insulation to lower their utility bills. Therefore, this may indicate that a negative correlation is possibly existing between economic growth and thermal insulation usage in buildings, particularly in the residential sector.

It has been observed in the findings section that commercial and government buildings have relatively better thermal insulation than residential buildings. These buildings, as opposed to residential buildings, usually involve higher construction standards, especially in windows. The cost of double-pane windows and the lack of awareness and informative data on the importance of utilizing high energy-efficient windows, are the main reasons why people in Saudi Arabia choose so-called affordability over efficiency. Furthermore, with the affordable cost of electricity bills, many decide to overlook the advantage of using energy-efficient windows as they normally cost much more than single-pane windows, which becomes a burden on buildings' owners, and investors.

The previously mentioned reasoning applies to walls and roofs, which also are consistently ignored by most of practitioners. Doors have received even less attention; they usually are not thought of as a critical building component in energy consumption; however, exterior doors are frequently used more than any other envelope components. Its mechanism demonstrates a high level of heat transfer in and out the building which causes a significant impact on energy conservation. In addition, the government, in the form of the Saudi Electricity Company (SEC), does not promote the importance of thermal insulation application in exterior doors. As shown in the SEC booklet for thermal insulation requirements, we can see that door insulation has been completely ignored in both existing and new buildings (Saudi Electricity Company 2015). Investigating the impact and potential benefits of using thermal insulation in residential exterior doors is thus also needed.

To conclude this section, the survey method is one of the most common methods used in developing baseline models for energy consumption (Attia et al. 2012). Usually a survey is applied to estimate the energy usage in many countries. In Saudi Arabia, there is a need to introduce a prototypical model studies that represent most of the country's building stock, especially with the increasing difficulties in optimizing energy efficiency in residential buildings. It is challenging to introduce a prototypical reference for residential buildings without understanding the current construction method used in terms of thermal insulation. Fortunately, we know for a fact that the majority, if not all buildings, especially residential ones, are built in reinforced concrete. However, there is no available data that reveals the methods and materials used in thermal insulation of the existing buildings. The result of this study is preliminary; however, it could be employed to lay some fundamental understandings for the next prototypical model development.

4.2. Importance

In this section, we will turn our attention to explain the importance of timing to conduct this study on energy efficient design-related surveys. Saudi Arabia is facing an energy crisis due to a combination of different factors, such as booming population, challenging economy, and water scarcity (Bahgat 2012). As a result of the energy crisis, the Saudi government has started to raise the cost of energy, i.e. electricity and gasoline, starting from the first day of the year of 2018 (Mohammed 2017; Saudi Press Agency 2017). On top of that, the government has also started enforcing 5% of value-added tax (VAT) for the first time in the country's history, thus many experts anticipate an apparent increase in the cost of living. Gasoline jumped by 127% and is projected to continue rising by 80% each year until the year of 2020. Similarly, electricity was increased by 260%. Saudis have been long accustomed to low energy prices, now that they have a drastic increase in the cost of living in general and energy cost in particular, it became challenging for them to acclimate to the new situation. This challenge will motivate Saudis to learn more about what methods are available to conserve energy in buildings and associated cost savings.

Sometimes, while it is the best option, consulting experts to study the insulation's condition in buildings costs a lot and seems an undesirable option with the challenging living cost. The result of this paper could be used as a baseline for current insulation usage status in buildings. This baseline could be used to show what kind of insulation has been used or not in the majority of buildings, just by looking at its age. This will help the government of Saudi Arabia as well as the people to know what they need to add or upgrade in their buildings in order to reach a higher energy efficiency standard. On the broader context, this paper could be used to help the government to determine how much energy is wasted and the burden to the country's economy, from there, they will be able to make a decision on how to mitigate this issue. Correspondingly, in a smaller context this paper will help owners to determine whether they need to add or upgrade any insulation with no or minimum consultation. For example, most of the buildings older than fifteen years lack insulation in walls. Knowing that, owners could apply complete thermal insulation coverage on all the outside surfaces of exterior walls, which helps inclosing the thermal bridging.

4.3. Suggestion

There is a potential to save energy through implementing some of the retrofitting measures. It has been proven that energy efficiency could be achieved through retrofitting existing buildings, specifically with upgrading components to meet the highest, yet economically viable, standards of energy efficiency. However, energy-efficient retrofitting is not common yet in Saudi Arabia (Kharseh et al. 2016), this might be because of two main reasons: First, there is a shortage in awareness about sustainable design in communities. Second, the lack of available information to the public on how much energy saving can be achieved by retrofitting technologies in a specific project. Studies have shown that upgrading existing buildings to current energy efficiency standards in SA could effectively reduce building loads (Al Surf et al. 2013). Energy efficiency upgrades do not only save building operational energy, but also save the cost associated with constructing new buildings. With the high rate of existing buildings and increased energy costs, it is important that the government of SA start to work extensively on promoting energy efficient retrofitting strategies for residential as well as commercial buildings.

CONCLUSION

As mentioned earlier in this paper, Saudi Arabia has been giving significant attention to energy conservation due to the extensive energy consumption in the building sector, particularly residential buildings. The result of the survey could prove that most of the existing residential buildings in the country do not have appropriate thermal insulations of building envelopes nor implemented according to the energy efficiency standards. From the conventional view, demolishing and then reconstruct a building used to be deemed as an easy and financially feasible strategy for building owners, however, after the increase in energy cost as well as living cost this is anticipated to be changed. Nevertheless, all energy saving analyses need a comprehensive process of building feature study, technology selection, and energy prediction or simulation upon an in-depth data collection of the current building conditions and user characteristics. However, there is no such framework available aiming at quantitative analysis on the pros and cons of architectural and technological features in Saudi Arabia. There was also a need to conduct a comprehensive study that shows current construction practices that have been used in the past years.

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