CASE STUDY ANALYSIS FOR THE DEVELOPMENT AND IMPLEMENTATION OF SUSTAINABLE HOUSING IN THE KINGDOM OF SAUDI ARABIA

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ABSTRACT

Rapid urbanization in developing countries is putting stress on current infrastructure, which is resulting in the rapid consumption of natural resources to cope with the increasing demand of the population. Saudi Arabia is one of the developing countries facing rapid urbanization where its infrastructure is facing a huge demand by the increasing urbanization levels of its major cities. Developing sustainable housing in Saudi Arabia is a must for the preservation of resources for future generations of the region and of the world. In the coming years, several resources (such as fossil fuels and natural water) will be facing shortage if not managed properly. Providing electricity for housing in Saudi Arabia is one of the biggest challenges facing the country, where it is estimated that by 2050 energy demand in the Kingdom will be approximately 120 GW, and to meet this growing demand, 8 million barrels of oil per day will be required. However, implementation of Sustainable Housing in Saudi is still problematic to reach the desired goals of various key Saudi stakeholders. This paper analyses three case studies that have adopted sustainable construction methods and compares them to traditional non-sustainable houses. The outcome suggests that there is a viable chance for development of sustainable housing in the region if supported by the government with less red tape to deal with. This paper recommends that the Saudi governments should mandate new laws to reduce the overall consumption of energy and water to reduce the overall consumption of natural resources to secure the future generation’s demand of natural resources.

Keywords: Saudi Housing Construction, Saudi Sustainable Housing, Saudi Housing Stakeholder, Saudi Renewable Energy, Saudi Housing Case Study.

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1. Introduction

Asia and the Pacific region in 2010 had an urbanization level of 43 per cent which was “the second lowest urban proportion of a region in the world; however, in the last two decades the Asia-Pacific urban proportion has risen by 29%, more than any other region” (United Nations, 2011). Of all the Asian and Pacific sub-regions, South and South-West Asia had the fastest urban population growth rate at an average of 2.4% per year during 2005-2010 (United Nations, 2011). Saudi Arabia is one of the countries that is located in the South-West Asia and is faced with a high percentage of urbanization. According to Al Surf, Susilawati, and Trigunarsyah (2013) Saudi Arabia’s urbanization level increased strikingly from 10% to 75% in a period of 42 years. And according to Bonetti (2009) “The largest and fastest growing building markets are today found in the developing world”. Several factors influence on the rate of urbanization which include:

- Internal migration from rural to urban
- Natural disasters
- Access to better opportunities and services
- Political conflicts. (United Nations ESCAP, 2013)

With this high number of population moving into large cities, the responsibility of governments to provide adequate and sustainable infrastructure and services are ever more important. Some of the infrastructure in developing countries is not coping with the high number of occupants such as electricity and water. The role of sustainability and the utilization of sustainable construction methods are undoubtedly important for the preservation of natural resources. In the coming years, several resources, such as fossil fuels and natural water, will be facing shortage if not managed properly. More people moving into large cities means more buildings will be built, which also means more stress on infrastructure, which can only lead to more consumption of natural resources that will produce more greenhouse gas emissions. According to the United Nations Environment Programme (2009) “Buildings are responsible for more than 40 percent of global energy use and one third of global greenhouse gas emissions, both in developed and developing countries”.

This paper discusses the importance of constructing sustainable buildings where the focus will be on sustainable housing. It analyses three case studies that have adopted sustainable construction methods in their design and are compared to traditional non-sustainable houses. The comparison highlights the effectiveness of reducing energy consumption, water consumption, effective use of sustainable building materials and incorporating the culture into the design to achieve better living conditions for the inhabitants.
2. Natural Resource Crisis in Developing Countries

The world population is consuming natural resources much faster than the planet can replenish. Developing countries are facing numerous challenges aside from depleting natural resources. The uprisings in the Middle East region, which started in 2010 by the unrest in Tunisia followed by Libya, Syria and Egypt, is causing even more chaos than what previously existed. The Middle East and North Africa region (MENA) is considered to be one of the driest regions in the world where natural renewable water sources account for 1.2 per cent of the world’s renewable water resources. Two main reasons are adding pressure on water sources in the region, rapid population growth and high urbanization. Some countries in the region, such as the Kingdom of Saudi Arabia, can afford desalination plants; others are forced to drawing on aquifers faster than they can be naturally replenished, or overdraw on non-renewable water resources (Andersen, 2014).

Within a period of 40 to 200 years, non-renewable natural resources, such as oil, natural gas and coal, will be consumed if not managed in a sustainable way to last for future generations (Ting, Mohammed, & Wai, 2011). Availability of natural resources in any country can mean economic prosperity and a better life style of its residents. Oil, for example, has made the Kingdom of Saudi Arabia a rich country and it has dramatically transformed from a tribal desert country into one of the world’s largest oil producing and exporting countries. The world population is aware of the current climate change and global warming is no longer a myth. On the contrary, it is a reality, where MENA opinion polls show that 80 per cent of the population consider this matter to be very serious (Andersen, 2014).

Preservation and managed use of natural resources for the sake of future generations is one main concept that is common among all the definitions available in the literature on Sustainability. Miranda and Marulanda (2001) argue that a key point for sustainable construction is “the consideration to minimize energy wastage, taking rational advantage of the natural conditions without altering them and allowing other living forms to live and be preserved”. Hence, preservation of natural resources can be achieved through the application and adaptation of sustainable construction methods. Developing countries are still under development and that gives them the advantage of applying the concepts and applications of sustainability while projects are still under development.

Saudi Arabia is one of the developing countries in Asia, and applying sustainable applications and systems to the built environment at this stage can help preserve the country’s natural resources for future generations. Husain and Khalil (2013) point out the environmental challenges facing the Kingdom of Saudi Arabia:

- Air quality deterioration in urban areas
- High energy demand and consumption due to regional population growth and economic development
- Concerns about safe drinking water supplies due to a scarcity of fresh water
- Industrial pollution
- Waste management
Sustainable Development in Saudi Arabia is considerably new and the concept was first formalized through King Abdullah’s initiative in 2010 where the only sustainable project at that time was King Abdullah University of Science and Technology (KAUST). In 2013 the number of sustainable and green projects has risen to reach 140 projects where 40 of them are located in the Kingdom’s capital (Rasooldeen, 2013). In the fourth Saudi Green Building Forum (SGBF), the Secretary General of the SGBF, Faisal Al-Fadl, signed a Memorandum of Understanding with UN-Habitat’s Regional Office for Arab States’ Director, Dr. Mostafa Madbouly, launching the first Arab Network for Green Buildings. “The agreement aims at enriching professional architecture and the science of green buildings, through creating a forum for knowledge and experience exchange to contribute to sustainable urban development. It also aims to conserve architectural heritage and natural resources while limiting the detrimental effects of urbanization on the environment. This will further add to the experience of professionals in Saudi Arabia, Egypt and other Arab countries, in both the public and private sectors” (UN-Habitat, 2013)

The literature presents numerous discussions on the issue of energy and conserving the consumption of energy around the world and in developing countries in particular (Bhattacharyya, 2009; Erdmenger et al., 2009; Fenerty-McKibbon & Khare, 2005; KAUST Industry Collaboration Program, 2013; Khare, 2005; Kikuchi, Bristow, & Kennedy, 2009; Liao, Yao, & Chin, 2008; Malla, 2009; Say & Yucel, 2006; Schumacher, 1985; Ting et al., 2011). The bottom line is “To become a sustainable society, the world must consume less energy” (Ting et al., 2011). Energy is not only essential to cater to human needs and allow them to maintain their activities including social, cultural, technological, medical, and economic development, but also it is a matter of protection of the environment and prevention of pollution.

“Energy conservation is the need of the hour” (Ting et al., 2011), this is the bottom line that needs to be clear and understood by all energy consumers. New technologies and techniques have been developed to help reduce the daily consumption of energy and water. Achieving sustainability rating in a building using any of the world known rating systems such as LEED requires a building to comply with energy and water conservation requirements. For example, the minimum LEED requirement to get a building certified in terms of energy efficiency is a 10 per cent improvement in the proposed building performance in a new building or a 5 per cent in a major renovated project (U.S. Green Building Council, 2014). It is also a requirement under LEED to have an on-site renewable energy source.

Providing electricity for housing in Saudi Arabia is one of the biggest challenges that is facing the country, where it is estimated that by 2050 energy demand in the Kingdom will be approximately 120 GW, and to meet this growing demand, 8 million barrels of oil per day will be required (Husain & Khalil, 2013). This high demand of fossil fuel will not only put stress on the Kingdom, but will also put stress on the whole world. Saudi Arabia was the world’s largest producer and exporter of total petroleum liquids in 2012, and it was also the world’s 13th largest consumer of total primary energy in 2009, of which about 60 percent
was petroleum-based. In order to meet domestic power needs and to free up oil and natural gas for export, Saudi Arabia has set a goal of producing almost half of its power from renewable fuels by 2020. Having a sustainable and renewable source of energy is one of the methods to sustain the future for generations to come in the Kingdom specifically, and in the whole world in general.

For the past few years, the Kingdom of Saudi Arabia has been the highest per capita oil consumption country in the world. Daily oil barrel consumption equates to 4 million barrels and about 1.5 billion barrels per year, which is the equivalent to 48 barrels a year for every man, women and child. In comparison, the US consumes 9 barrels a year, and Japan consumes 5 barrels a year for the same individuals (Aluwaisheg, 2013). Not much has been done to preserve and conserve the use of Saudi Arabia’s main source of income and to make things worse, there is no alternative transportation system other than the use of private transportation methods. Buildings account for the majority of energy consumption in all countries, but in Saudi Arabia “housing uses up nearly 80 percent of all electricity produced in the country, 70 percent of which is used for air conditioning alone” (Aluwaisheg, 2013). Aluwaisheg (2013) further states that there are two reasons for the over-consumption behavior occurring in Saudi Arabia. The first reason is because there are no strict laws to bind builders to use a certain type of insulation, which can contribute dramatically in the overall conservation of energy. The second reason is that laws are set to a very low standard when it comes to cooling systems used in buildings, which contributes to having high energy consumption levels.

Water scarcity is a reality in countries such as Saudi Arabia, where in 2009, it registered less than 90 cubic meters of renewable fresh water sources per capita. Figure 1 shows the levels of renewable water sources in the Gulf Co-operation Council (GCC) nations, where the severe water scarcity threshold stands at 500 cubic meters per capita per year. In 1980, Saudi Arabia consumed about 10 million cubic meters of water and it has increased significantly to reach 17.5 billion cubic meters in 2010, which corresponds to a 75 per cent increase (Samad & Bruno, 2013). For this reason, water conservation strategies are a must in buildings in Saudi Arabia for the continuation of fresh natural water resources in addition to non-natural water resources through desalination of seawater. According to the Saudi Gazette (2013) “in 2012, the Kingdom began operations at the world’s largest solar-powered water desalination plant in the city of Khafji, with a capacity of 30,000 m$^3$/day”. This new plant will help the water scarce country to meet the high demand from the population and at the same time is powered by natural resource of energy.
3. Research Method: Case Study Analysis

The data presented in this paper is based on three case studies from Saudi Arabia that have applied sustainable construction methods in their design. These three case studies are compared to a traditional residential building in Saudi Arabia that has not adopted sustainable construction methods. The comparison is to show the difference between applying sustainable construction methods to a residential building and to illustrate the benefits of applying sustainability. Case studies present us with new information by observing the case we want to analyze, “new knowledge is discovered by exploration by which we mean examining artefacts or situations or events. This is primarily achieved through observation, in the broadest sense of the word, and by reflection on what it is we are observing and by discussing this with knowledgeable informants and colleagues” (Remenyi, 2012).

Case study analysis is considered to be a qualitative approach to research. It differs from quantitative research due its nature of observing a case study in the field and interpreting data from the field to the research. “Methodologies used in the interpretivist paradigm are mainly qualitative rather than quantitative, and often involve field work – that is, study of the phenomena under consideration in their natural setting” (Oliver, 2004). Yin (2009) defines case study as “an empirical enquiry that investigates a contemporary phenomenon within its real life context, when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used.”

3.1. Non-Sustainable Case Study

King Abdullah University of Science and Technology KAUST Industry Collaboration Program (2013) has conducted studies on several types of buildings in Saudi Arabia and has analyzed those buildings in terms of two main aspects, i.e. energy consumption and water consumption. The report also discusses in detail how to preserve energy and water by promoting alternative passive design aspects and the use of certain technologies to reduce the overall amount of energy and water consumed. Figure 2 illustrates the typical layout and form of a house in Jeddah, which was the base of the analysis done by KAUST Industry Collaboration Program. The house consists of two floors and it accommodates a family of
five members. As a baseline for a typical Saudi house located in Jeddah, figures 3 and 4 illustrate the amount of energy consumed by the house if it was insulated and if it was not insulated. The total energy consumption (baseline) for a non-insulated residential building in Jeddah amounts to 1,044.6 kWh/m² a year, of which 81.7% is used for cooling alone. Whereas, the total energy consumption (baseline) of an insulated residential building in Jeddah amounts to 588.4 kWh/m² a year, of which 69.7% is used for cooling.

Figure 2 Layout and Shape of Typical Housing Unit in Jeddah (KAUST Industry Collaboration Program, 2013)

Figure 3 Energy Consumption of Housing Unit (non-Insulated House) (KAUST Industry Collaboration Program, 2013)
To compare between sustainable and non-sustainable measures, Table 1 illustrates where it is possible to save more than 50 percent of the overall energy if sustainable measures are utilized, such as insulation that saves on energy consumption from the reduction in cooling loads.

Table 1 Primary Energy Consumption in Housing (Unit) in Jeddah in kWh/m²y (KAUST Industry Collaboration Program, 2013)

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Sustainable Measures</th>
<th>Non-Sustainable Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling</td>
<td>410.3 (69.7%)</td>
<td>853.9 (81.7%)</td>
</tr>
<tr>
<td>Heating</td>
<td>0.3 (0.1%)</td>
<td>12.9 (1.2%)</td>
</tr>
<tr>
<td>Hot Water</td>
<td>40.4 (6.8%)</td>
<td>40.4 (3.9%)</td>
</tr>
<tr>
<td>Lighting</td>
<td>86.8 (14.8%)</td>
<td>86.8 (8.3%)</td>
</tr>
<tr>
<td>Equipment</td>
<td>50.6 (8.6%)</td>
<td>50.6 (4.8%)</td>
</tr>
<tr>
<td>Total</td>
<td>588.4 (100.0%)</td>
<td>1,044.6 (100.0%)</td>
</tr>
</tbody>
</table>

In comparing the water use and conservation percentage of water, Figure 5 illustrates the reduction rate if sustainable measures are utilized. The percentage of water reduction when utilizing sustainable methods such as water-saving devices for example, in faucets, showerheads and kitchen sinks can reach up to 49 percent. The installation of a water-saving device is the easiest way to reduce water consumption, but it incurs a cost.
burden upon the consumer. Providing government subsidies can offset this initial cost burden or other benefits such as incentives and grants.

![Water Consumption Diagram](image)

**Figure 5 Reduction of Water Consumption by Saving & Reuse System (KAUST Industry Collaboration Program, 2013)**

### 3.2. Sustainable Case Study

Sustainable projects are considerably new in Saudi Arabia and not many projects can be used as case studies due to their high security nature and lack of available sources. For the purpose of this paper, three residential building projects, which are in their pre-construction phase are analyzed as case studies. A design firm based in Beirut, Lebanon (named “The Other Dada”) is the designer of the three projects, which will be built in Saudi Arabia. The firm’s policy states that they believe in Sustainability as being a collaborative effort. The Other Dada’s design process is organic, dynamic and interactive. The three residential building projects have total land occupancy of 5,850 square meters, they are:

- Fence House
- Doomsday House
- Landform House

This case study analysis will be looking at the projects from the following perspectives:

- Energy Consumption
- Water Consumption
- CO₂ Emissions
- Cultural Aspects
- Building Material

Table 2 lists the three case studies and their profiles in terms of Energy Consumption, Water Consumption, and CO₂ Emissions.
The fourth element to analyze in the case studies is the cultural aspect. The three houses were designed to respect the unique culture of Saudi Arabia. For example, as we see in figure 6, the Fence House has implemented the courtyard typology of the traditional Saudi house as discussed in several literature references, including (M. Al Surf, Susilawati, & Trigunarsyah, 2012; AlGhamdi, 1995; Mahmud, 2009; North & Tripp, 2009; Sidawi, 2008), where the house looks inward onto a courtyard rather than outwards. This typology is common in Saudi Arabia because this design provides privacy for the residents due to having all the rooms of the house looking inward onto a courtyard. This feature has been carefully considered in the Fence House where the courtyard was designed to be a beautiful garden in addition to serving the function of privacy.
The Doomsday House, figure 7, was designed in accordance with what the client asked for and that is to have a bunker-like house where he and his family can have shelter in case of emergencies or wars. The name of the house comes from the type of incident that may or may not occur, which is a doomsday event. The design of the house basically transformed the concept of the courtyard and the privacy issue and walled the southern and western walls so that no openings are found. In front of the house, from the eastern and northern sides, the house has a courtyard where the facades facing the courtyard have maximum exposure to daylight and the view of the garden. An integrated system of shutters allows the house to become totally impervious to the outside. The design includes a bunker that extends on two floors and that can shelter the whole family.

The Landform House design, figure 8, has been approached differently because of the client’s needs. The client requested the designer to respect the form of the land and design the house around it. This design feature promoted sustainability by preserving the current landform and not demolishing or excavating any unnecessary land. The house was designed in relation to the landform in three separate parts, public, private and service area. In traditional and historical buildings, landscape was a main part of the design of an Islamic background. This design feature gave the occupants a sensation of resemblance to paradise.
as foretold in the Holy Quran. “Bustan” or “Jannah” as described in Holy Quran is a paradise that residents joyfully indulge in within the boundaries of their privately enclosed houses. The Landform House design accomplishes that by introducing a variety of landscaping features that are from the environment and provide a winding pathway between parts of the house. The Landform House, in addition to respecting the form of the land it is designed to be on, it respects the culture of the Saudi traditions by separating the public parts of the house from the private parts.

![Figure 8 The Land Form House (Dada, 2013)](image)

All of three houses were designed to use sustainable building materials such as Low-voc paints, no formaldehyde Glues, locally sourced materials whenever possible, mineral wool insulation, including 30% of Pozzolan material in the concrete mixture, and photocatalytic concrete. These building materials, in addition to the other methods and techniques used, will increase the amount of energy saving which will reduce the overall impact on the environment.

4. Discussion

From the case studies, it is evident that utilizing sustainable measures is a must for the survival of Saudi Arabia’s natural resources and to conserve on the load it puts on the global scale. It has been shown that the majority of energy consumed in residential buildings in Saudi Arabia, over 80 per cent, is due to cooling the indoor environment. Designing buildings that account to permitting daylight and reducing direct sunlight will evidently reduce the cooling load and reduce the energy consumption overall. Selection of certain building materials that are environmentally friendly is crucial to reducing the Heat Island Effect. Design elements can be largely divided into architectural technologies (a passive method) and equipment-related approaches (an active method). The use of the two architectural
design methods can help reduce the overall consumption of energy and help improve the environment.

In Table 2, the amount of energy and water consumption in addition to the amount of CO₂ emissions was illustrated. Energy saving in the Landform house reached 27 per cent when sustainable measures were incorporated into the design. Water consumption saving reached 29 per cent across all houses, which mean that water consumption, can be greatly reduced, and high saving percentages can be easily achieved if sustainable methods are used. CO₂ emissions can also be greatly reduced where the Landform house had a great CO₂ emission reduction by 29 per cent, which equates to 67,000 Kilograms per year.

In Figure 3 shows that the remarkable increase in cooling loads, reaching more than 80 per cent due to lack of insulation, can quite heavily put a burden on the energy production in Saudi Arabia. This case is true because, as discussed earlier in this paper, there are no strict laws to bind builders to use a certain type of insulation, which can contribute dramatically in the overall conservation of energy. In contrast, the same housing unit registered a reduction in cooling load simply by adding appropriate insulation (Figure 4). From this data, it is evidently crucial that the Saudi government must put strict laws on the types of insulation that should be used and other laws have to be applied to promote the use of sustainable methods to come to the overall reduction in consumption of energy and water.

“The average amount of water consumption in KSA is 325 L/capita/day, the third-highest after the U.S and Canada. The average discharge of easily recyclable gray-water amounts to 288 L/capita/day, or 89% of total consumption” (KAUST Industry Collaboration Program, 2013). This water consumption level is extremely high when taking into account that Saudi Arabia is considered to be a water scarce country with an annual renewable water resource of 86.45 cubic meters (The World Bank, 2013). The easiest way to reduce water consumption is by the installation of a water-saving device, but it incurs an initial cost burden on the consumer that can be offset if the government provides subsidies or other benefits to reduce the initial cost for the benefit of the long-term cost savings and water conservation. In the baseline water consumption case study done by KAUST Industry Collaboration Program (2013), Showers and faucets account for 43% and 30% of water consumption, respectively, considerably higher than for other outlets. This suggests that by installing a gray-water collection system, water can be 100% reused for toilet use and selected cleaning.

5. Conclusion

This paper has discussed the effect of rapid urbanization on the built environment of Saudi Arabia, and the stress it puts on the local infrastructure, which leads to more consumption of the world’s natural resources. Preservation of natural resources can be achieved through the application and adaptation of sustainable construction methods. Developing countries are still under development and that gives them the advantage of
applying the concepts and applications of sustainability while projects are still under development.

This paper concludes that the use of sustainable construction methods in Saudi Arabia is a necessity for the survival of the country’s natural resources. The Saudi government should promote the use of sustainable technologies, such as water-saving devices for example, in faucets, showerheads and kitchen sinks where consumption reduction can reach up to 49 percent. Energy saving techniques must be applied in housing in Saudi Arabia, where this paper has shown that an overall reduction in energy consumption can reach more than 50 percent.

This paper research method has been conducted on three case studies that are in the design phase, and as such, it is recommended that future research and analysis are done on constructed residential buildings to evaluate the effectiveness of utilizing sustainable methods and validate the outcomes of this paper. Saudi Arabia is strongly moving towards implementing sustainable and green construction methods, but more data is needed to convince the public and the government of the necessity of applying them now while the country is still under rapid development. It is also recommended that Saudi stakeholders get involved to reduce red tape to help hasten the application of sustainability on current construction and future ones as well. Finally, mandating new laws by the Saudi Government to reduce the overall consumption of energy and water to reduce the depletion of natural resources is a major outcome.
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