Trends on sustainability in Saudi building industry: advances and challenges

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In developing countries like Saudi Arabia, the experience of a rapid rate of urbanization and infrastructure expansion, especially with respect to buildings, is immense. In Saudi Arabia, the role of buildings is even more important as they account for around 80 percent of the total national electricity consumption. The issue of energy efficiency is not given serious consideration regarding Saudi building designs, even though sustainability has been a major focus in recent years of the Saudi government; achieving sustainable development has become one of the main goals of Saudi Arabia's economic and social development plan. Based on the local energy consumption trends, forecasts indicate an increase in domestic energy consumption with a growth rate which could reach 4 to 5 percent annually until 2030. This growth in demand is partially attributed to the industrial growth and growing economic prosperity in the Kingdom. A rather significant portion of this energy consumption growth results from the inefficient use of energy and the absence of coordinated enforcement and stakeholder engagement. In order to support sustainable development in the country, it is therefore crucial to improve the energy and environmental performance of buildings. This can be achieved not only by reducing the demand for building energy, but also by integrating renewable and sustainable energy technologies into buildings. This paper provides a brief review of the initiatives, advances, and challenges in the sustainability issues within the Saudi Arabian building sector, and proposes a framework for effective implementation of sustainability in the building sector.

Keywords: energy efficiency; hot climate; sustainable building design; building performance; trends

1. INTRODUCTION

Saudi Arabia, as compared with other developing countries in the Middle East, has experienced dramatic growth in urbanisation at the period of 1990- 2010. Reasons such as substantial rural-urban migration, high fertility rates, concentration of economic activity in urban areas, and international labour migration are the main drivers for this increase of urbanisation levels. Energy consumption is taking place at a rate whereby resource depletion is inevitable (Jamaludin et al, 2014). The increase in global temperature is due to high rates of greenhouse gas (GHG) emissions for which the building sector is perceived to be the largest single cause (Häkkinen et al, 2015). In Saudi Arabia, the role of buildings is even more important as they account for around 80 percent of the total national electricity consumption, exceeding the world average, as stated by Al Rashodi (2014). A breakdown of the consumption rates indicates that residential, commercial and government buildings account for 51.2 percent, 13.6 percent and 13.4 percent respectively. Demand for electricity in the residential sector is expected to double between 2009 and 2025. HVAC (heating ventilation and air conditioning) systems alone are responsible, as Alrashed and Asif (2012) point out, for over 50 percent of the total domestic electricity making it the single largest consumption source. Recently, energy and environmental performance of buildings have become a major focus since buildings are responsible for consuming over 40 percent of the world's total primary energy and releasing over one third of the total CO_2 emissions as mentioned in UNEP-SBCI report, 2009. Hence, sustainability has been a major focus in recent years of the Saudi government and achieving sustainable development has become one of the main goals of Saudi Arabia's economic and social development plan (United Nations Development Group, 2012). In order to support sustainable development in the country, it is therefore crucial to improve the energy and environmental performance of buildings. This can be achieved not only by reducing the demand for building energy, but also by integrating renewable energy technologies and sustainable solutions into buildings. For the aim of improving building energy performance, it is also important to investigate the climatic conditions of the region (Alrashed and Asif, 2015).

2. CLIMATE INFLUENCE ON ENERGY DEMANDS

One of the key characteristics of the desert climate is the high temperature during day that drops sharply during the night. The average temperature in the Kingdom of Saudi Arabia during summer is approximately 45°C, and it is usual for Saudi Arabian summer ambient temperatures to go higher than 46.1°C with mean monthly temperatures ranging between 27.3°C and 37.1°C. Between April and October, relative humidity is low and ambient temperatures are high. The extremely high summer ambient temperatures require suitable cooling systems to ensure thermal comfort for building occupants (Phillip and Lau, 2013). The average temperature in Riyadh throughout the year of 2018 is shown in Figure 1 where clear unpleasant conditions are experienced most of the year.

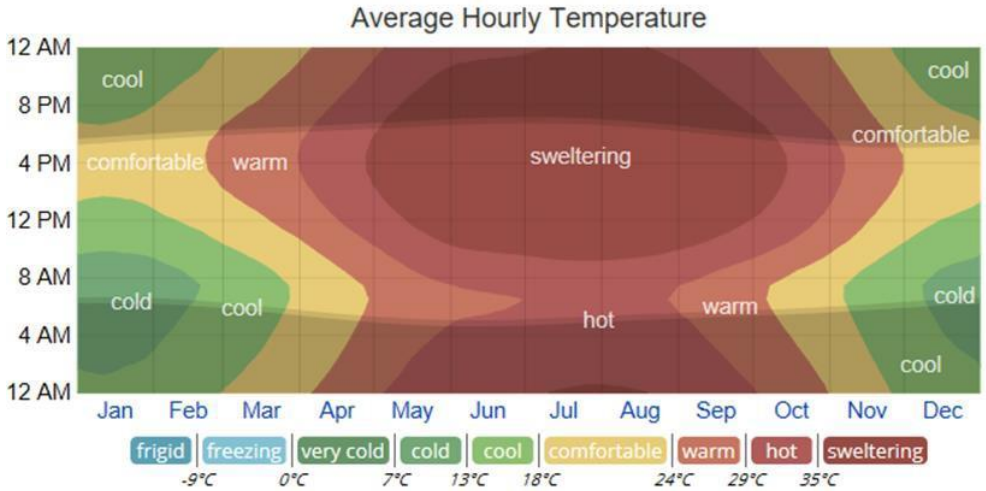

Figure 1: Average temperature in Riyadh throughout the year (Source: Weather spark, Online)

According to the Saudi Electricity Company (SEC), when considering electricity consumption rates in 2014, the residential sector led in total consumption amongst all other sectors by a considerable margin as shown in the chart in Figure 2. In 2014, the residential sector alone was responsible for nearly half of the total consumption in Saudi Arabia. An analysis of the monthly consumption during the same year shows how the monthly total electricity consumption in Saudi Arabia closely follows the average ambient temperatures, reflecting the importance of air conditioning in the summer months when electricity demand is double of that in the winter, shown in Figure 3.

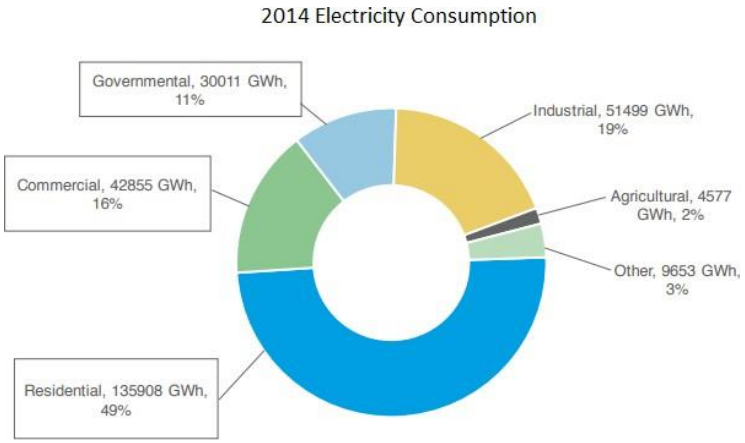

Figure 2: Electricity consumption in KSA during 2014. (Source: SEC, 2015)

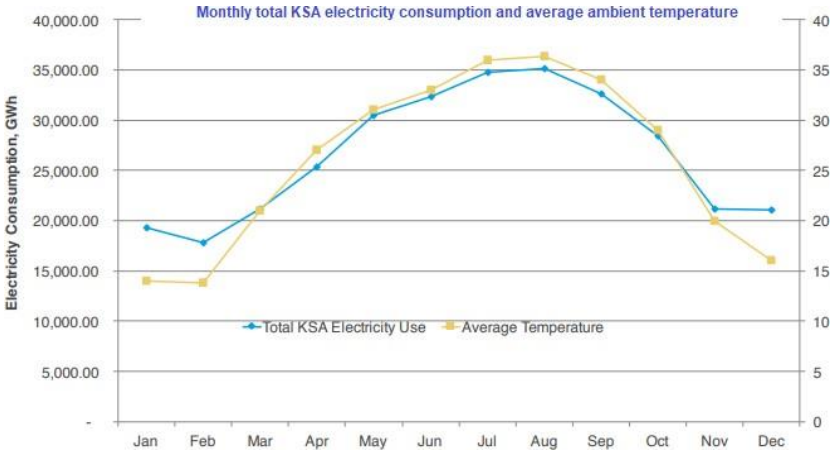

Figure 3: Monthly total KSA electricity consumption and average ambient temperature during 2014 (Source: SEC 2015)

3. CURRENT TRENDS

The volume of construction work in the GCC (Gulf Cooperation Council) countries is dramatically increasing, which poses challenges on energy demand and the environment. The building construction sector in the Kingdom of Saudi Arabia is the largest and fastest in the GCC states. It is estimated that 2.32 million new homes will be built by 2020 in order to meet the demand of a growing population**.** An analysis of Saudi construction by the Ministry of Municipal and Rural Affairs (MoMRA) showed that over the last decade the number of licenses issued for buildings has increased dramatically, with most of these licences for residential and commercial buildings as shown in Figure 4.

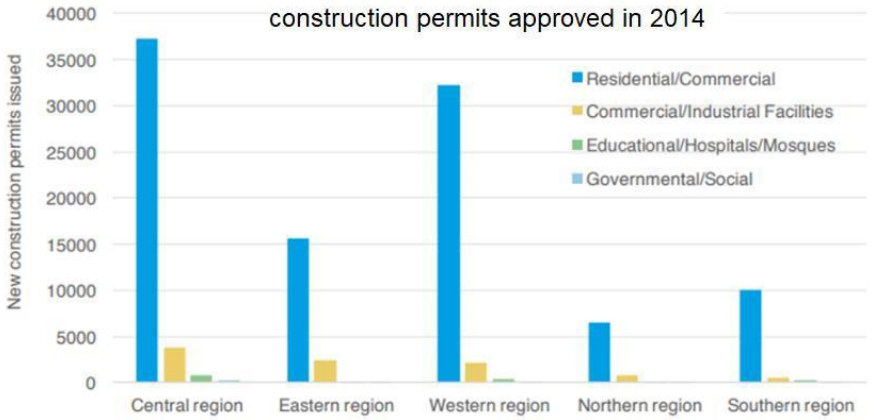

Figure 4: New construction permits approved in 2014 (source: MOMRA)

Urbanisation and industrial revolution, as faced in current times, lead to a number of profound changes, which as a result pose several serious issues at environmental, social, and economic levels. These issues are exacerbated

mainly by the conjugation of three critical factors: growth in population, excessive consumption of resources, and high rates of pollution. The building industry has experienced a considerable amount of development following economic growth causing exploitation of natural resources. These developments are due to the activities in the extraction of a substantial amount of raw materials as well as consumption of large quantities of energy. Therefore, this situation has been one of the key contributing factors for the increased interest in buildings sustainability, which is even more significant for developing countries and hot climate regions like Saudi Arabia.

Taleb and Sharples (2011) illustrate building performance by analysing the sustainability of the Saudi building sector. While identifying the key components of sustainability, namely environmental, economic, and social, they point to the fact that these components are absent in the development of current Saudi buildings. Such buildings remain heavily dependent on air conditioning, a factor that results in high energy consumption because of a large amount of electricity that is used. This situation has resulted in more than half of household electricity being applied for air conditioning given the climate of this region. In addition, building performance has been further diminished in Saudi Arabia due to the high dependence on the burning of fossil fuels as a source of electricity (Taleb and Sharples, 2011). This situation has resulted in detrimental environmental effects that have influenced air, water, and land.

3.1. Energy trends

An inspection of buildings today reveals that high energy consumption is caused by the need for cooling and heating of these buildings. This is even more exaggerated in hot climate regions, where a large amount of energy is utilised in an effort to make buildings more comfortable for occupants. Figure 5 shows that the building sector alone was responsible for about 80 percent of the total energy consumption in Saudi Arabia, 70 percent of this rate is a result of the operation of HVAC systems (KACARE, 2012). Alsurf (2014) mentions that this example of unsustainable practice poses a high pressure on the energy consumption in Saudi Arabia as the increasing future projections of energy consumption depict an alarming image of the country. The situation implies that there is an urgent need to raise awareness on the use of sustainable practices within the building sector.

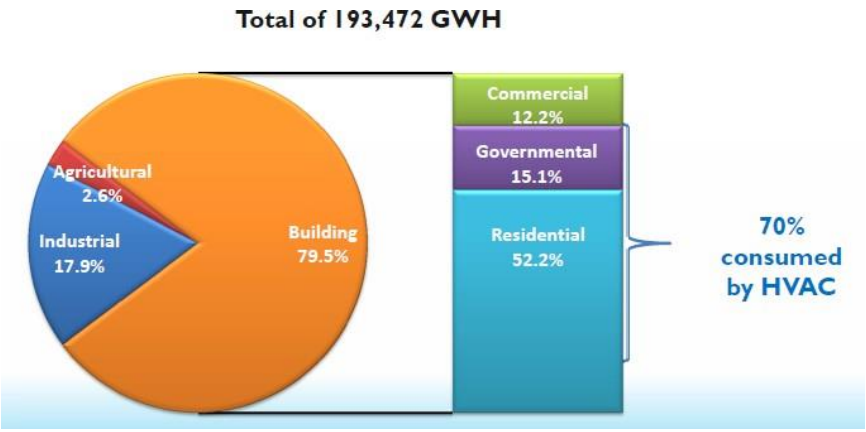

Figure 5: Energy Consumption Patterns in Saudi Arabia (Source: KACARE 2012)

Figure 6 shows the annual electricity peak demand, power generation capacity, and the annual growth in total electricity use consumed and generated from 2000 to 2014 in the KSA. In 2014, Saudi Arabia had a combined power generation capacity of 65,506 MW with peak demand at 56,547 MW (SEC, 2015). The average annual growth rate of peak demand over 2000-2014 was 7.1 percent. Transmission and distribution losses are justifications for the difference between generated and consumed electricity. Projections for the year 2019 include 68,694 MW for generation capacity, 352 TWh for total generation, and 324 TWh for net consumption (BMI Research, 2015).

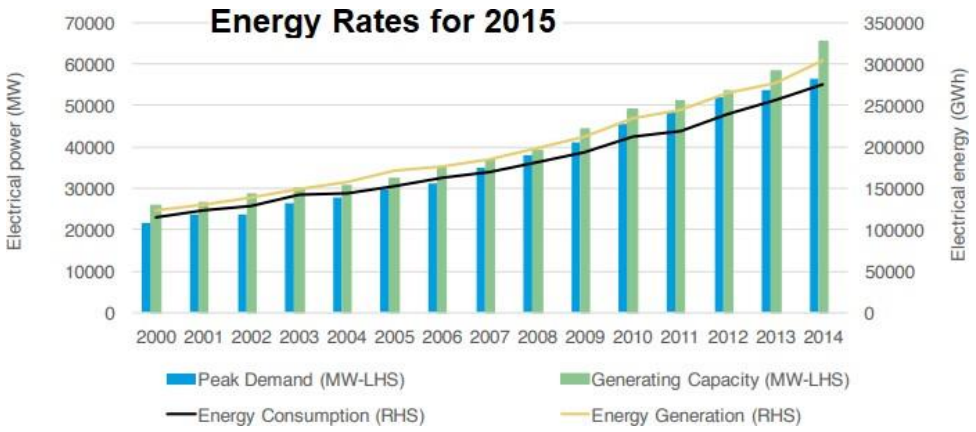

Figure 6: Peak demand, generating capacity, electricity generated, and electricity consumed in Saudi Arabia (SEC, 2015)

According to the British Petroleum (BP) World Energy Statistical Review 2017, Saudi Arabia produced 330.5 billion kWh of electricity in 2016, a 7 percent increase. This implies that Saudi Arabia is faced with a sharply rising demand for power. According to King Abdullah Centre for Atomic and Renewable Energy (KACARE), power demand is driven by population growth, a rapidly expanding industrial sector led by the development of petrochemical cities, high demand for air conditioning during the summer months, and heavily subsidised electricity rates. The country's electric generating capacity in 2016 was approximately 66 gigawatts (GW) with an expansion plan to increase this capacity to 120 GW by 2032, the largest electric power generation expansion plan in the Middle East (KACARE, 2017). Saudi Arabia is the largest producer of crude oil in GCC region with a production of 3.7 billion barrels (bbl) and exportations of 2.6 billion bbl in 2015. However, Saudi Arabia currently is not exporting or importing natural gas and the entire 2.9 QBtu (Quadrillion British Thermal Units) produced is either reinjected into oil fields or consumed by industries such as power, water, and petrochemicals (Saudi Aramco, 2015). By 2021, Saudi Arabia aims to reduce peak demand for electricity by 14 percent and reduce total consumption of electricity by 8 percent.

3.2. Movement toward sustainability

As the KSA is now experiencing a transformation stage, known as Saudi 2030 Vision, the government intends to adopt sustainability measures and apply them to all future projects and encourage such concepts in all sectors. The recent trends in the GCC region suggest that there is a considerable degree of realisation to move towards sustainability in the building sector. In recent years and in terms of green buildings, the GCC countries have made significant progress. The United Arab Emirates (UAE) and Qatar are leading the sustainability trends amongst the GCC countries, also having the highest share of green buildings in the whole Middle East and North Africa (MENA) region. The number of LEED (Leadership in Energy and Environmental Design) registered buildings has increased rapidly across the region, especially in GCC, in the past few years (Asif, 2015). In 2014, there were around 1170 buildings in the GCC region that had a LEED accreditation (Asif, 2015). Of these buildings, 70 percent were located in the UAE. Qatar and KSA are ranked 2nd and 3rd with a respective share of 15 percent and 12 percent, as stated by Asif (2015). The Saudi Green Building Council was established in 2015 to promote and facilitate the green building practice in Saudi Arabia by raising public awareness, helping the construction industry convert to the green building requirements providing training and education, encouraging building materials manufactures and suppliers to produce and supply environmentally responsible products, promoting green labelling, adapt, develop and operate local green building rating system that meet the local environmental requirements while considering the international experience (Alsurf et al, 2014).

Even though, the KSA is trying to build smart and sustainable buildings and "*has announced its intention to spend about US$ 39.9 billion over a period of eight years beginning 2010 for the construction of smart buildings across the Kingdom*" (Ventures Middle East, 2011), the novelty of the Saudi Building Code is yet to be applied on all construction projects, especially residential buildings, where it can be seen and assessed in the near future. In this regard, a very forward step towards sustainability was taken when the government issued the executive regulations of the SBC application by the Royal Decree on Jan 2017 that explicitly states the SBC must be applied and implemented as described in the following table:

Table 1: Government plan to implement the SBC (Source: SBC)

Phases of SBC implementation			
Phase	Description	Implementation	
		From	To
1	The code is applied to the following buildings: government and administrative buildings, high buildings (towers - more than 23 m), hospitals, hotels.	Royal Decree issue date	End of Aug 2019
2	The code is applied In addition to what was applied in the first phase on the following buildings: mosques, sport buildings, educational buildings, Commercial buildings, Communication towers, Industrial buildings, Buildings less than 23 m, high-risk buildings	End of 1st Phase	Aug 2020
3	in addition to the above buildings, the code is applied to Wedding lounges, Cinemas, theatres, medical centres, rental apartments, residential and recreational buildings	End of 2nd Phase	Aug 2021
4	in addition to previous buildings, the code must be applied to airports, banks, post, TV and broadcasting buildings	End of 3rd Phase	End of Jul 2022
5	At this phase , the code must be applied to all types of buildings	End of 4th Phase	Jul 2023

Whereas the vast majority of countries have managed to lower the energy intensity of their economies, the Kingdom's energy intensity increased significantly over the last two decades. Hence, it is a strategic imperative for the Kingdom that energy efficiency becomes a major topic for all decisions related to an increase in demand for fuel and feedstock.

The first National Energy Efficiency Program (NEEP) was launched in 2003 as a three-year temporary programme to improve the management and the efficiency of electricity generation and consumption in the Kingdom. This programme ended in 2006. To build on the experience gained from the previous programme and to sustain and unify energy efficiency efforts under one permanent roof, in 2007 the Ministry of Petroleum and Mineral Resources, supported by other government entities in the Kingdom, recommended the creation of a permanent national entity. As a result of this recommendation, the Saudi Energy Efficiency Centre (SEEC) was established in 2010. Since then, SEEC has been responsible for the demand-side energy efficiency effort in the Kingdom, with the mission to improve domestic energy consumption efficiency, and coordinate all related activities between governmental and non-governmental stakeholders (Oxford Energy Forum, 2014). In 2012, SEEC launched the Saudi Energy Efficiency Program (SEEP) with the objective of improving the Kingdom's energy efficiency by designing and implementing initiatives and their enablers. The government intends to have a Saudi Energy Efficiency Law and it has been working with an international law firm and the legal representatives from the stakeholder government entities to draft it (Oxford Energy Forum, 2014). The subcommittee focused the Program's scope of work on three main sectors (buildings, transportation, and industry) representing more than 90 per cent of the Kingdom's energy consumption, and five enablers (regulations, Energy Services Companies, funding, governance, and awareness).

Given the increased concern about the direct impact of population dynamics on sustainable development and the economy, the Council of Ministers established a National Population Committee in 2007 to advise the Government on issues related to population and how they should be reflected in various policies and strategies in different sectors. In 2007, the General Housing Authority was established with the aim of increasing home ownership, increasing the supply of housing and residential land, building adequate housing for the needy, developing a comprehensive housing strategy, and proposing regulations, systems, policies and organisations pertaining to housing. In order to enhance the Government's role in housing policy and provision, the Ministry of Housing (MoH) was established in 2011 (MoMRA, 2016). Clearly, the key strategic objectives under the Saudi housing plan are to increase productivity and efficiency in the housing construction sector, make the sector increasingly reliant on local content in line with saudisation, and ultimately transform the country, strategically located at the intersection of Africa, Asia, and Europe, into a global hub for construction innovation. MoH is looking to cutting edge technology, public-private partnerships (PPPs), and operating models to better target regional and international markets by using technology-led housing delivery that can serve as a model for fast construction (MoMRA, 2016). PPP facilitation is a critical part of the MoH's operating model that seeks to leverage new technologies that can speed up housing requirements sustainably. The government has dedicated a budget of US$15 billion towards housing development for the next five years, with more than one million housing units expected to be built during that period. As well as growing demand, investment opportunities are also being driven by the private sector's contribution to the sector. Saudi Arabia aims to raise the contribution of approved real estate developers towards new housing development from 10 percent to 30 percent by 2020 (MoMRA, 2016).

In 2013, the Ministry of Municipal and Rural Affairs and other line ministries developed "Sustainable Urban Planning Guidelines for Urban Growth" in the Kingdom of Saudi Arabia, which address these key issues to achieve sustainable urban planning and community design and thereby aims to reduce the consumption of critical resources. The guidelines, once adopted by the government, are intended to ensure future urban development in

Saudi Arabia matches, if not leads, world's best practice for sustainable urbanisation, especially in desert environments (MoMRA, 2016). The guidelines specifically aim to reduce energy consumption at the municipal level through district cooling, water conservation and building energy efficiency. The Sustainable Urban Planning Guidelines for Urban Growth will be integrated into the standards on planning permission and development control, which is under the review by the MoMRA. A number of relevant planning manuals are now in preparation to help planners and decision-makers to apply the recommended guidelines addressing building urban energy consumption as a subset of climate change concerns. These guidelines propose to introduce new standards for thermal insulation, district cooling and energy efficient buildings to reduce energy consumption and greenhouse gas emissions ((MoMRA, 2016). District cooling involves the provision of cooling to multiple buildings or facilities from one or more central cooling plants that are interconnected to the cooling users via networks of supply and return piping. This system helps to protect the environment as it increases energy efficiency and reduces greenhouse gas emissions and air pollution (MoMRA, 2016). Guidelines also introduced building energy codes, which set a minimum level of energy efficiency for buildings. The Government will update existing building codes and adopt new codes, expecting to achieve substantial energy and financial impact. Given that energy consumption is expected to rise in the residential sector by 2020, enacting new building codes is a key strategy for reducing energy consumption and tackle climate change across the buildings sector (MoMRA, 2016). The Kingdom's recently formed Green Buildings Council and the Green Buildings Forum, which each will act as non-government organisations bringing expertise and advice to government and the private sector on modern, environmentally sound building practices (MoMRA, 2016).

3.3. Sustainability assessment and examples

Recently, there has been some research on sustainability assessment and solutions in Saudi Arabia. One example is the work done by Alyami and Rezgui for developing sustainable building assessment tool called Saudi Environmental Assessment Method (SEAM). SEAM is the first developed tool to assess the level of sustainability in the Saudi built environment. It includes exclusive criteria and categories originally designed to suit the Saudi climatic condition and social and economic aspects. SEAM is delivering a new, applicable weighting system to prioritise the Saudi national plan in accordance with sustainability principles (Alyami and Rezgui, 2012). Others (Bannani et al, 2016) have focused on the concept of sustainability in non-domestic buildings since these construction rates are expanding throughout the country. In this study, the most influential elements were identified and the Analytical Hierarchy Process (AHP) has been adopted to assess the weight of the criteria for Saudi Arabia leading to the Saudi Sustainable Assessment Criteria Framework. Nine criteria and 36 sub-criteria were defined in this framework for inclusion as the most appropriate assessment criteria for sustainable non-residential construction in Saudi Arabia. These criteria include water efficiency and energy efficiency, IEQ, materials selection, effective management, land and waste, whole-life cost, quality of service and cultural aspects (Bannani et al, 2016).

There are some mega construction building projects with proven or attempted sustainable and energy conscious solutions in Saudi Arabia such as the King Abdullah City for Atomic and Renewable Energy (KACARE), which was planned using the Sustainable Built Environment Tool (SuBET) framework to achieve a high sustainable urban design standard (Alwaer and Clements-Croome, 2010). Another example is King Abdullah Financial District (KAFD) project, which adopted an applied sustainability design approach to deliver a number of key objectives, such as minimising water use and energy consumptions, improving indoor air quality, and reducing greenhouse gas emissions (Bannani et al, 2016). Another distinct and well-known example is King Abdullah University of Science and Technology (KAUST) which was one of the winners of the American Institute of Architects' Top 10 Green Buildings awards for 2010. KAUST's new campus is Saudi Arabia's first LEED certified project and represents the world's largest LEED Platinum project. The Project's design brief included clear instructions to create a low-energy, efficient, and highly sustainable campus that must be understood in its local and regional contexts (Elgendy, 2010). Sustainable strategies incorporated into the design included, but were not limited to, bringing buildings closely together to minimise the areas of the buildings facades exposed to the sun and encourage passive ventilation between them; mitigating solar gain by using appropriate orientation and shading, incorporating low energy cooling techniques such as chilled beams, heat recovery wheels, and displacement ventilation to reduce the cooling and ventilation loads; covering the campus's roofs with large solar photovoltaic arrays for electricity generation; and implementing sustainable operations plan which includes using green cleaning materials and extensive recycling programs (Elgendy, 2010).

3.4. Challenges

Saudi Arabia so far has no mandatory building regulations, which would require the incorporation of sustainable technology applications and energy efficiency principles into the design of buildings (Alsurf, 2014). Hence, due to rapid population growth and economic development, attention must be given to ensuring sustainable building performance and avoiding further energy demands with consequential economic and environmental costs. Coordinated enforcement of the regulations and standards ought to be optimised by developing a unified enforcement approach and coordinating the various government entities' enforcement efforts in order to ensure high levels of compliance. Lack of engagement of government and private sector stakeholders to ensure practical initiative design and buy-in for smooth implementation has a significant influence on sustainable building industry

in Saudi Arabia (Oxford Energy Forum, 2014). Moreover, the absence of enforcement of these regulations and requirements from the policy side, in addition to the lack of energy policies or strategic plans that determine benchmarks for energy reductions, may hinder the efficiency of such requirements. For example, the SBC has mandated thermal insulation against heat for all new buildings since 2010 as this has been proven to reduce energy demand for buildings by 30 to 40 percent. However, new buildings continue to be erected without proper insulation (Lahn et al, 2013). One of the main challenges in Saudi Arabia is the lack of property tax. This is the reason why large pieces of land can still be found in the inner suburbs of the city. This stands in the way of development. In the last few years, there has been an increase of more than 50 percent of the price of land in Saudi Arabia (Alsurf et al, 2014). As a result, the cost of land generally constitutes half of the cost of erecting a building while in Europe this ratio is about one third (Fattah, 2013). This is why authors like Ferris-Lay (2011) argue that the cost of land is a leading constraint, which makes it a challenge for developers in Saudi Arabia to build affordable and sustainable housing.

Sustainability has been identified worldwide as a necessity and the application of sustainable construction is vital for the conservation of natural resources for future generation needs. In the KSA, the application of sustainability techniques and measures to building construction is still mostly considered as a luxurious option and mainly provided for parties and people who have the financial capacity to afford it (Al surf, 2014). This is the result of lack of public awareness of the benefits of sustainable construction. Sustainable measures should not only be applicable at the design stage of the building, but also during the in-use stage of buildings, the operation and maintenance. In fact, government bodies and building professionals should pay more attention to the in-use stage in a sustainable way.

Saudi Arabia is also trying to position itself to make use of the emerging sustainability trends in the building sector. The Saudi Building Code development and mandatory thermal insulation for all new buildings are positive indications for sustainable development (Asif, 2015). There is, however, a lack of appreciation by some stakeholders of the construction industry. For example, in a recent Saudi Electric Company (SEC) survey, only 580 out of 15000 new commercial buildings (15 percent) have applied the compulsory thermal insulation (Asif 2015). The situation is even worse in some parts of the country. Jeddah city, for example, is the poorest in its compliance with thermal insulation where only 52 out of 5200 buildings are having compulsory insulation (Asif, 2015). According to SEC (2015), contractors have failed to abide by the regulations despite repeated warnings by the SEC.

In developing countries, including the KSA, the design of buildings does not usually take into account the prevailing climate of the areas. In such regard, human thermal comfort is affected by the indoor thermal environment of a building and is responsible for a majority of the building energy consumption. Also, important factors such as the surrounding and site characteristics, building materials selection, architectural design, and orientation are not given serious consideration (Ghabra et al, 2017). This leads to buildings whose indoor climate is poor, which has a negative impact on comfort, efficiency, and health (Madhumathi and Sundarraja, 2014). Mandatory energy efficiency regulations for buildings, if enforced properly, can constitute a strong driving force for the construction industry; including architects, real estate developers, and construction companies, to start integrating sustainable and energy efficient solutions into buildings. However, at present, national standards apply only to new buildings and are often voluntary or poorly enforced so a mandatory regulatory framework is required to ensure that all buildings implement sustainable practices (Myrsalieva and Barghouth, 2015). Current responsibility for enforcement usually lies with municipalities, which often lack financial and human capacity (Ghabra, 2017). Designing, constructing and renovating buildings according to energy efficient specifications will require an upgrading of skills, knowledge and expertise of professionals in the construction sector – including architects, designers, contractors, installers and others – to properly inspect and review site plans, building designs and construction sites, capabilities which are still lacking in most of the Gulf Region in general and Saudi Arabia specifically (Ghabra, 2017).

Investigating building materials and the related embedded energy has been an essential part of sustainable building development. The main concern has been on whether these materials have a high thermal mass (Sinha et al, 2013). In Saudi Arabia, almost all types of building constructions have been built by reinforced concrete, which contributes considerably in building shapes (Marzouk et al, 2014). Unquestionably, this material was a revolution in the field of building industry where building structure was concerned. However, this material does not enjoy the same performance when it comes to the thermal properties. Reinforced concrete construction has poor thermal behaviour in hot climates making it a weak barrier in front of heat flow (Marzouk et al, 2014). The effect of the building envelope depends on the thermophysical properties of materials affecting the rate of heat flow in and out of building, hence affecting the indoor thermal conditions and comfort of occupants (Marzouk et al, 2014). These thermophysical properties of materials used in the building industry in Saudi Arabia have not been given serious attention. In addition, it was thought until recently that the embodied energy content of a building was small compared to the energy used in operating the building over its life. Therefore, most effort was put into reducing operating energy by improving the energy efficiency of the building envelope. Research has shown that this is not always the case. Embodied energy can be the equivalent of many years of operational energy (Milne, 2013). Research by CSIRO has found that the average house contains about 1,000 GJ of energy embodied in the materials used in its construction. This is equivalent to about 15 years of normal operational energy use. For a house that lasts 100 years this is over 10 percent of the energy used in its life (Milne, 2013).

Table 2 highlights the barriers hindering the utilisation of these resources in the Saudi residential sector aiming to promote Low Energy Houses.

Table 2: Barriers to promote LEHs in Saudi Arabia - source: (Alrashed and Asif, 2012)

Type	Barrier
Energy efficiency measures	- Lack of awareness about the energy-efficiency measures such as the glazing system, the thermal insulation, the energy-saving lighting fixtures, and energy-efficient appliances and its rating - Cheap electricity tariff - Personal passiveness to buy the energy-saving fixtures - Unclear maintenance responsibility - Lack of expertise in efficient-buildings
Sustainable design features	- Lack of acceptability of sustainable design features due to aesthetic aspects and safety issues - Perception that it wastes necessary space and money - Disturbance in terms of noise, as well as, attracting insects and dusts - Concerns about maintenance - Perception that it may affect the lifestyle of users - Uncertainty of the adaptability of these solutions in the Saudi climate - Some of the solutions are not applicable in all regions and kind of residential buildings in Saudi Arabia - Technical issues and faults - Perception that some of the solutions are old style and does not meet the current user's aspiration - Lack of awareness about most of sustainable design features - Non-suitability for Saudi families as some of the features may constrain future expansion and penetrate user's privacy - Regulatory and policy related challenges from the local authorities - Not in line with existing style of typical residential buildings in Saudi Arabia - Lack of expertise in the sustainable design
Renewable energy applications	- Non-suitability in residential buildings due to safety issues - Uncertainty of the applications performance in the Saudi climate - Regulatory and policy related challenges from the local authorities - Enormous subsidies on fossil fuel based energy including oil and gas - Lack of public awareness on renewable energy - High capital cost of renewable technologies - Lack of policy initiatives in terms of government targets for renewable technologies and absence of due subsidies/financial incentives on renewable technologies - Lack of information concerning performance, durability, reliability and cost effectiveness of renewable technologies - Lack of private sector stakeholders/renewable entrepreneurs - Capacity issues with micro-renewable systems - Lack of reliable weather data - Lack of acceptability of renewable energy applications due to aesthetic aspects Lack of government subside on renewable energy applications - Lack of interest in the renewable energy from the national media and the relevant agencies - Lack of expertise in the field of renewable energy application

4. CONCLUSION

This review reveals that even though there are promising research activities, policy supports and growing public awareness, the Kingdom has wide scope for further developments in order to ensure (through the utilisation of its resources at their fullest potential) that all the viable state-of-the-art technologies for energy conservation and management in buildings are implemented. Even before the Saudi 2030 Vision that outlined a future for the Kingdom beyond oil and gas, the government considered it "*a strategic imperative that energy efficiency become a major topic for all decisions related to the increase in demand for fuel and feedstock*" (Oxford Energy Forum, 2014). Al Surf et al (2013) have further discussed the issue of rapid urbanisation and have explained that fuelling this exploding urbanisation rate is the lack of regulation to control the current and future urbanisation rate. Assaf et al (2010) elaborate on the causes of housing shortage and state that "*It has become a challenging task for the government as well as private real estate sector in the kingdom to provide affordable housing to lower and medium income group families in urban areas mainly due to high demand, escalating prices and non-preference to vertical expansion apartments*". Overall, AbdulSalam et al (2014) conclude that the housing sector is driven or influenced not only by development, but also by geographical region, climatic condition, environmental considerations, and cultural requirements. According to Taleb and Sharples (2011), building performance generally in Saudi Arabia lacks the application of energy efficient and sustainable technologies. In the last two decades, energy consumption in Saudi Arabia has sharply increased, specifically, peak load which approximately reached 24GW in 2001 and it is expected to reach 60GW by 2023 (Fasiuddin and Budaiwi, 2011). Also, according to the Saudi Arabia General Authority of Statistics, the population of Saudi Arabia reached 29,994,272 in 2013 and is likely to reach 37,610,985 by 2025 (AbdulSalam et al, 2014). Yet, an energy conscious attitude continues to be virtually absent in the developing world, and this also pertains to Saudi Arabia, as mentioned by Al Surf (2014). The housing sector is in need of stronger governmental regulation. Lack of suitable land to be developed, citizens not being able to have

adequate financial and material support to acquire housing, and inefficient housing market have contributed to the housing shortage in the Kingdom. Generally, the main building design challenges in the region can be categorised into two levels: regulatory and climatic. This implies that there is a need to develop and implement a compulsory regulatory framework with the aim of delivering energy efficient buildings. Moreover, if energy efficiency is to be achieved in residential buildings in particular, an integrated holistic cross-disciplinary design approach should be adopted in local building energy efficiency practices in the Gulf Region in general and in Saudi Arabia in particular (Ghabra, 2017). Finally, while the industry has used tools specific to sustainable construction, to date no assessment tools has been developed that broadly considers Saudi Arabia's specific climatic, societal and cultural contexts. Hence, there is a need to develop a building sustainability assessment tool to measure the extent to which the sustainability agenda are implemented in buildings in Saudi Arabia (Bannani et al, 2016).

> *''…to improve the sustainability standards in the building sector it is important to increase awareness on the subject amongst various stakeholders including regulatory bodies, building industry and residents. Besides introduction of new policies and regulations, energy efficient technologies and solutions, it is also critical to improve energy consumption habits and lifestyle. In the wake of low electricity tariffs and cheap conventional energy prices in GCC countries, it is important to have strongly supportive government policies to promote sustainable buildings. Government subsidy to enhance the thermal performance of building envelops and feed-in-tariff schemes, for example, could be of help in this respect"*(Asif, 2015)

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