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A theoretical framework for early stage energy efficient buildings design process in KSA

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Abstract

The key challenges are the rising demand of energy depletion particularly in housing and misusing the efficient use of limited natural energy resources. Hence, the adoption of sustainable building practices can be considered as the one step towards the sustainable development in the KSA in terms of energy sustainability. The lack of attention paid to the sustainability issues during the conceptual and design stage of the buildings has caused increased consumption of materials and energy during the construction and operational phases of many building projects in KSA. This paper presents a theoretical framework for a design process that may be used at the conceptual and detailed design stages of building projects. The framework will be based on the outcomes from a comprehensive literature review and the design experiments with energy performance measuring tools such as SAP (Standard Assessment Procedure) and GSAS (Gulf Sustainability Assessment System) used to implement the sustainable design principles in a case study. A design process at an early stage of residential buildings will be evaluated by comparing the COBIM (Common BIM requirement) energy analysis with current practices in KSA using process mapping techniques. This paper is part of an ongoing research which aims to contribute to the sustainability improvements in term of efficient energy use in the residential buildings and aid to accelerate the understanding and implementation of sustainable design and construction in the KSA.

Keywords: Sustainable buildings; conceptual framework; design stage; energy efficiency; implementation of sustainable design

1. Introduction

Energy consumption patterns depend on local climate conditions, the culture of the citizens and the policies of the country. Building performance is recognised as a key contributor to the high energy demand from fossil fuels use (Ghiaus, 2004).

Saudi Arabia is an oil producing country, with an economy based on the oil industry. It is also a country characterised by high energy consumption. The hot climate in the region and the design of residential buildings explain to a large extent the high levels of energy consumption (Taleb and Sharples, 2011). Energy consumption in the Kingdom of Saudi Arabia, in the form of electricity, has increased sharply over the last two decades (Al-Ajlan et al., 2006). This increase is due to the rapid development of the economy in the absence of energy conservation polices. Electricity is currently generated in Saudi Arabia by burning fossil fuels (Al-Natheer, 2000).

This large consumption of electrical energy for buildings also represents a major potential for reducing energy consumption (Fasiuddin and Budaiwi, 2011). The Saudi Arabia Ministry of Electricity have stated that over half (51.1%) of electricity is consumed by the domestic sector (SAME, 2010), as all modern residential buildings in Saudi Arabia depend on air conditioning for interior cooling.

In view of the high energy consumption by the residential sector in Saudi Arabia, significant steps are urgently needed in order to reduce energy consumption. Such steps are to be proposed in a framework specifically designed for the environment and climate of Saudi Arabia. This framework, then, would provide solutions that reduce energy demand and guidelines for the design of future energy efficient homes in Saudi Arabia. Furthermore, the framework will support architects, civil engineers, building professionals and

developers to control and manage future sustainable, low energy residential buildings in the design stage, which can then be validated and approved by using energy assessment software tools before the construction stage in Saudi Arabia on the basis of climate, culture and occupants needs.

Many developed countries have dealt with energy saving through the sustainable energy consumption codes and established energy consumption standards based on local climate conditions and citizen's needs. Such codes are absent in Saudi Arabia and are essential to control energy consumption and accelerate the understanding and implementation of sustainable design and construction (Aldossary et al., 2014; Taleb and Sharples, 2011; Chwieduk, 2003).

2. Literature Review

Oil wealth has made Saudi Arabia an economically prosperous country. This has led to the rapid growth in the population of Saudi Arabia which in turn has influenced the construction industry. The growth in the demand for new buildings has in turn resulted in a large consumption of resources, such as energy (Lahn and Stevens, 2011). Consequently this expansion has relied upon continuous unsustainable practices (Taleb and Sharples, 2011; Hepbasli and Alsuhaibani, 2011; Obaid, 2008).

This huge increase in demand for new and modern residential housing units has prompted the use of modern architectural construction methods and design styles in Saudi Arabia. Mubarak (1999) suggests that the prominent modern styles include the Western-styled villa and multiple story apartments.

Residential buildings account for the majority of energy consumption in every country, however, in Saudi Arabia the amount of energy consumed by buildings is considerable. Residential buildings in Saudi Arabia consume more than 50 per cent of the country's produced electricity, where the majority is consumed by air conditioning, due to the harsh dry local climate (Aluwaisheg, 2013).

Currently the residential building sector in Saudi Arabia is placing intensive pressure on the country's reserves of natural resources. It is estimated that about two-thirds of the electric energy generated in the Kingdom of Saudi Arabia is used by the building industry (Al-Sanea et al., 2012). Hence, conventional construction operations impact seriously on the environment as a result of their excessive use of energy. Continuing in this manner is neither feasible nor sustainable. Viewing this statement from a frame of reference, in 1975 the total peak electricity load was 300 MW. By 2007, it had increased to 34,953 MW. By 2023, according to the forecast of current projections, total peak electricity is set to achieve 57,808 MW (SAME, 2010; Obaid, 2008).

Typically, Saudi residential buildings are designed in such a way that little regard is paid to principles of sustainability. Saudi residential buildings consist of fairly large reinforced concrete structures, with air conditioning units constantly running in each room (Taleb and Sharples, 2011). Al-Ibrahim (1990) asserts that in Saudi Arabia the energy performance of modern architecture is inferior to that of traditional architecture, and that modern residential building materials are not well suited to the hot, arid environment of Saudi Arabia.

Sustainable architecture is the result of an environmentally conscious attitude towards designing, implementing and maintaining buildings and is based on local requirements and needs, construction materials for buildings and reflection on local traditions (Niroumand et al., 2013). This creates the need to design and apply energy-efficient techniques in Saudi residential buildings through the application of sustainable architectural principles (Karam, 2010). According to Aluwaisheg (2013), there are two reasons for this. The first is that there are no strict laws to bind builders to use a certain type of insulation, which can dramatically contribute to the overall conservation of energy. The second reason is that Saudi laws are set to a very low standard when it comes to cooling systems used in buildings, which contributes to high energy consumption levels.

As there are no regulations which are being adhered to, or compulsory building codes which sufficiently set out the energy performance guidelines for the residential sector in Saudi Arabia, which incorporate the principles of sustainable architecture in the country. It has been argued that setting a coherent set of such codes and standards is one of the most important and cost-effective ways to promote the widespread of sustainable practices, especially with regard to reducing residential energy consumption (Karam, 2010).

It appears from all of the above information that Saudi Arabia is heading towards consuming its only major income source before it can solve the problem and consume wisely. However, this can be averted if key stakeholders collaborate with each other to set new regulations and introduce new energy efficient construction methods. According to Hamed (2003), designing sustainable energy efficient residential buildings is no longer a luxury addition, but it is now vital to the survival of the present generation and those yet to come.

The use and implementation of innovative information and communication technologies, such as BIM, and related software in the analysis of energy for residential buildings is an important and effective strategy for energy saving and economic growth (Ishida, 2015). ICT can be applied both in the

conceptual design and detailed design of residential buildings in Saudi Arabia for energy analysis, energy performance, and energy management and conservation purposes. ICT can play a significant role in energy conservation if employed in energy efficient homes in Saudi Arabia to manage energy consumption.

3. Research Methodology

The development of a framework is proposed for the implementation of energy analysis procedures during the conceptual details design phase of a construction project in order to reduce energy demand and specify guidelines for the design of future energy efficient homes in Saudi Arabia.

The energy analysis framework will control and manage energy consumption in residential buildings at the design stage, and can be validated and approved using energy assessment software tools before the construction stage.

This stage also incorporates the proposed energy performance strategies for the Saudi residential sector that were identified in the literature review and during design experiments. The proposed framework is applicable and suitable for Saudi Arabia and the broader Middle Eastern region due to the hot local climate and the manner in which residential buildings are custom-built.

4. Framework Development

The framework is based on the outcomes of a comprehensive literature review and the design experiments with energy performance measuring tools such as SAP (Standard Assessment Procedure) and GSAS (Gulf Sustainability Assessment System) used to implement the sustainable energy policies in the design phase.
The proposed framework takes into account the GSAS system for the development of energy policies and the use of energy based software such as IES for the assessment and validation system which will then manage and regulate the use of energy in residential buildings. The framework will then provide engineering office the opportunity to employ technologies for energy consumption and management.Currently the residential building design process follows the procedure set out in Figure 1.

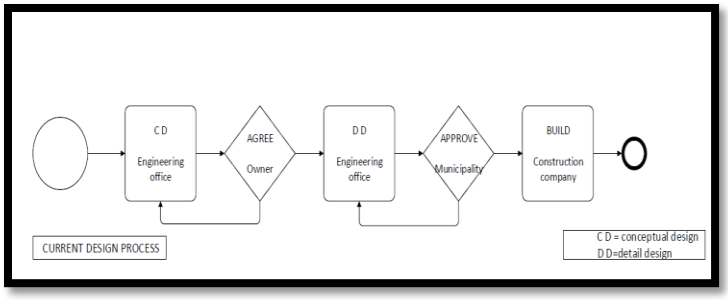

Figure 1: Current Design Process of new residential buildings in Saudi Arabia

Here the first step necessitates the land owner to go to the engineering office for a conceptual design of the residential building. This is known as the design phase. If the owner agrees with the design then the process moves along for the detailed design of the residential building. If the owner for some reason does not agree (s) he will then go back to the engineering office for a revised conceptual design of the residential building.

The detailed design then has to be approved by the local municipality in order to progress to construction. This is known as the approval phase. Once the detailed design of the residential building has been approved by the local municipality it can then progress to the construction phase. As soon as the construction is complete it should obtain final approval from the local municipality in what is known as the operational phase before being occupied.
The proposed residential building design process would follow the procedure set out in Figure 2.

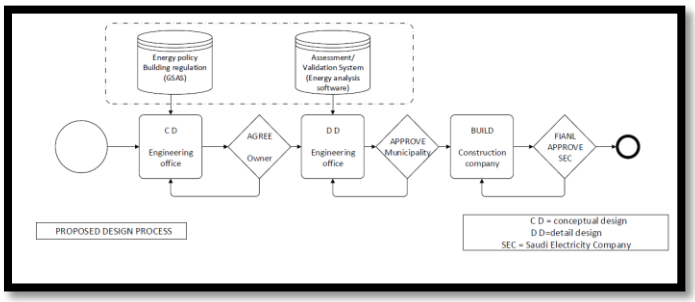

Figure 2: Proposed Design Process of new residential buildings in Saudi Arabia

This proposed design process is fairly similar to the current design process up to the point where the final approval has to be gained by the Saudi Electrical Company (SEC) who will assess the residential building against its own energy standards before connecting the electricity supply to the new residential building. If for any reason the SEC do not give approval it will go back and inform the construction company of the necessary

re-work to be done regarding the energy supply in particular the electricity supply to the residential building which should be sufficient to bear the load of modern energy efficient domestic appliances in order for the residential building to gain final approval.

In addition to this, during the design phase it is proposed that energy policies and building regulations and codes based upon the GSAS (Gulf Sustainability Assessment System) should be incorporated and adhered to for energy requirements of the residential building when setting out the conceptual design of the residential building as it is then utilized for analysis of energy efficiency and alternative comparisons to improve energy economy of the residential building.

Once in agreement and moving forward towards the detailed design of the residential building, it is proposed that an assessment / validation system is put into place utilizing energy analysis software to validate the residential building design based on energy performance.

The requirements for energy analyses depend upon the detailed design. Energy analyses are required especially when there is a potential for significantly improving the energy performance of the residential buildings.

5. Conclusions

This framework differs from other studies, as it takes into account the GSAS (Gulf Sustainability Assessment System) alongside the local Saudi climate, environmental conditions, and residential needs. The GSAS (Gulf Sustainability Assessment System) is used as a benchmark for the low energy consumption definitions, standards and policies that are incorporated into the proposed framed for Saudi Arabia.

This will lead to, (a) adherence to sustainable energy policies during the conceptual design phase and (b) a validation system during detailed design with the use of BIM Energy analysis software tools in the established framework. Consequently, this framework will act as a reference for developers, architects and civil engineers required to design energy efficient residential buildings in Saudi Arabia to meet all local requirements, needs and environmental challenges.

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Focussing on Multidisciplinary Research, Promoting Future Low Carbon Innovations, Transferring Knowledge and Stimulating Networking among Stakeholders to Ensure the UK Achieves World Leading Status in Energy and Sustainable Development. https://www.weentech.co.uk/cesd-net/

The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:
Dr. Singh is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.
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