
Sarah A. Al-Ghamdi, Alaa Al-Gargossh, and Khalid A. Alshaibani

Abstract—Buildings have become one of the fastest growing energy consumption sectors. Energy is used to operate the buildings' systems that are necessary for ensuring the comfort of the building's occupants; such as air-conditioning. In other hand, good energy management will assist to conserve the valuable natural resources and reinforce the global sustainability. The paper discussed the increase of electrical energy consumption in Saudi Arabia due to rapid economic development and the absence of energy conservation measures. Office buildings represent the commercial sector that consumes 14% of the total buildings energy consumption in Saudi Arabia. The new Tariff and the raise of the electricity rates have highlighted the problem of the energy consumption in office buildings and proved the need to develop energy conservation policies for sustainable development. The purpose of this paper is to shed light on some of Saudi retrofitting studies to explore energy conservation opportunities in Saudi office buildings and review some of the international retrofitting studies in order to develop solutions that can be applied in Saudi Arabia. The studies led to the result that the building envelope has a direct effect on electricity and energy consumption and that glazed facades work as a transmittal for heat. In order to analyze the impact of glazing factor in Saudi Arabia and the need for retrofitting, an office building with 36% glazed facade was selected, and some recommendation was discussed to minimize the energy consumption.

Keywords—retrofit, energy conservation, glazing.

I. INTRODUCTION

In order to achieve a bright energy future with minimal environmental impact, it must be taken into consideration that problems with energy utilization are related not only to global warming, but also to many other environmental concerns as air pollution, acid rain, stratospheric ozone depletion and the main concern is the emission of carbon dioxide (CO2). Nowadays, improving the energy performance isn’t just for saving the environment but due to economic reasons as various organizations in different sectors is constantly under pressure to reduce energy consumption. The reduction in energy consumption leads to reduction in operating costs, and thereby helps to improve the profitability; as energy cost is one of the main cost drivers for businesses [1], [2] and this stands side by side with conserving the valuable natural resources.

The world three primary economic sectors of energy use are industry, buildings and transportation. Buildings have become one of the fastest growing energy consumption sectors and they are the responsible of more than 33% of the global CO2 emissions [3]. Thereby, improving the energy performance of existed buildings is undoubtedly considered to be one of the most sustainable and feasible measures for creating sustainable buildings with less energy consumption profiles [3].

Energy is used in buildings to operate its systems that are necessary for ensuring the comfort of the building’s occupants; such as air-conditioning, heating and ventilation which all consume over 40% of the total energy, while the rest are used for lighting, elevators and equipment...etc. The good energy management of those systems in a building will assist to conserve the valuable natural resources; where many changes can be made to save energy and money [4]. These changes are called (Green Retrofitting). Low carbon retrofit can be achieved by improving the building envelope and systems with the primary intention of improving energy efficiency, saving money and reducing carbon emissions [4], and any building which performs badly in terms of energy consumption, comfort conditions or environmental impact is a potential candidate for retrofitting [5]. Whatever shortcoming or deficiency in the performance of one of the building systems would have to be compensated by other systems, otherwise the desired objectives would be compromised. The impact of the performance of such systems would be reflected on the quality of the environment, productivity and long-term economics of the facility [6]. Therefore, a total system approach of energy management that considers all systems together and their interaction as one system is critical in achieving the desired objectives of energy efficiency retrofit [6]. There is a wide range of possible retrofit actions, and they all have impact on each other either at the time of installation or after operation. Thereby, choosing the correct combination of actions increases overall effectiveness [5].

There are two key retrofit activities that stand out as major carbon reducing opportunities in multi-occupied commercial properties: The first is low disruption retrofits to the envelope which intended specifically to improve energy efficiency, and the second is accelerated replacement of existing systems and equipment [4]. Assessing the performance and potential of an existing building will indicate which remedial actions will produce the most effective results. Such actions may relate to the building, its systems and its users [5]. However, the building envelope cannot be deduced from its performance alone, because a building and its systems have such complex
patterns of interaction that make it difficult to know how the different parameters are affecting each other [5]. It can be assessed by analyzing the energy performance of existing building for representative periods of energy use per day and per year, based on internal records or on utility bills, and by the evaluation of emissions or comfort levels.

It must be taken in consideration that one of the greatest barriers to retrofit and improve the energy efficiency or even add renewable energy technology in buildings is the high capital cost of projects. Whether upgrading a chiller, installing a solar photovoltaic system, or implementing a bundle of improvements under a whole-building retrofit, clean energy projects require large up-front investments, followed by a long period of payback through savings in energy bills [7]. It is real that Retrofits do not yield the same profit margin as do construction projects begun from the ground up, but they are safer in the current economic climate [8], and it is difficult to generalize about the cost effectiveness of different measures which depends on climate, local energy prices and the type of conditions for a particular building [5].

II. INTERNATIONAL RETROFITTING IN THE COMMERCIAL SECTOR

The green building retrofit is becoming widespread at United States, as the office buildings and education facilities constitute the largest percentage of all retrofit activity which is 50%. By 2014, the United States green retrofitting and renovation market is expected to increase by 20-30% and it was reported that the most green retrofit activities concentrated on the use of more energy-efficient lighting or natural day lighting, and nearly 92% installed more energy efficient mechanical and electrical systems [3] Eight interactive strategies were made to get the optimal retrofit solution as shown in table.3. It is clear from the results that the most significant savings was a result of controlling the amount of lighting either natural or artificial and also managing the interior temperature, which made a total annual energy savings of 4.4 million $.

Another study with a similar target but wider vision was conducted by The Department of Energy (DOE) to reduce the energy consumption in the United States medium office buildings to 50% [9]. The aim of DOE was to create technologies and design approaches that enable net-zero energy buildings at low incremental cost by 2025. The study includes the modeling assumptions used in the Energy modeling simulations for both baseline and advanced prototypical buildings in 8 different climate zones around United States by using EnergyPlus simulation program. The prototype medium office building was simulated in each climate locations to determine if the 50% energy savings goal was achieved. The baseline inputs has included all the detailed information of building envelope, lighting, Miscellaneous Equipment, HVAC Systems, Variable Air Volume and Service Water Heating. In addition to that, a Cost-Effectiveness Analysis was set to ensure the saving results and efficiency recommendations for each climate zone are included, along with the results of the energy simulations. The recommendations can be summarized as following:

- Enhancing the overall materials specification.
- Applying an advanced window shading measures.
- Reducing the windows area particularly for the east and west façades.
- providing occupancy sensor control of HVAC setpoints and terminal unit damper positions.

And the utilization of renewable energy sources in addition to the existing site energy must be taken into consideration with reporting on the impact of energy measures on carbon emissions [9].

In Europe, a life cycle assessment case study was conducted in seven retrofitted public buildings to determine the balance of energy and environmental benefits and drawbacks for retrofit actions. For most of the case studies, the retrofit actions involve about 50% of energy saving for heating and the improvement in the envelope thermal insulation (high-efficiency windows, and thermal insulating boards) has the most significant benefits [10].

This leads to result that the building envelope has a direct effect on electricity and energy consumption because windows work as a transmittal for the sunlight; this will raise the interior temperature and the need for air conditioning that will consume more energy.

III. ELECTRICITY GROWTH IN SAUDI ARABIA

Electrical energy consumption in Saudi Arabia has increased sharply during the last two decades due to rapid economic development and the absence of energy conservation measures [11]. In 2007, the per capita consumption has reached 19.4 KWH per day which is 7080 KWH per year [12]. The reports of Saudi Electricity Company showed that about 73% of the electric energy generated in Saudi Arabia is used for operating buildings (Fig. 1), and 65% of this energy is consumed by air conditioning [13]. The excessive demand for air conditioning in the Kingdom of Saudi Arabia is a direct result of the extreme temperatures during summer, when the ambient temperature frequently reaches 46 degrees C at night [12]. Peak loads reached nearly 24GW in 2001 which is 25 times their 1975 level and are expected to approach 60GW by 2023 and the total investment needed to meet this demand may exceed $90 billion [12].

Consequently, there is an urgent need to develop energy conservation policies for sustainable development. If energy conservation is taken into account, the forecast demand can be reduced by 5–10% and this is equivalent to 3–6GW of additional capacity, which represents a possible $1.5–3.0 billion saving over the next 20 years. And if only savings on air conditioning are considered, the return on investment is equivalent to 400–500MW p.a. of generating capacity and that will save up to $0.25 billion p.a. [12].
To study the effect of some possible treatments for the glazing, the Visual-Doe energy simulation program was used where climatic data of Dammam Area was used [33]. The analysis has shown the importance of utilizing daylight effectively. Daylight in such area could reach up to 16000 lux (excluding direct sunlight) on the vertical surfaces that exposed to any orientation for about 50% of the working year (07:00 to 17:00) (Fig. 5)

Such large amount of external daylight show its importance a potential natural source for reducing the use of electrical light inside the building.

The results indicate that the glazing used could admit an average internal illuminance of more than 500 lux for about 85% of the working year. However, the studies has shown also that reducing the existing glazing area from about 31% to 10% can results in a reduction in energy consumption by 20%. However, if the owners want to keep the same area of glazing, changing the glazing material with a better solar heat gain coefficients (SHGC) can help in reducing the energy consumption by up to 6% (Fig. 7).

To use daylight effectively without causing an increase in internal loads due to heat gain, optimization studies need to be carried out.

While the international studies concentrated on the importance of providing retrofitting solution for both: the envelope and the systems of the building, the studies in Saudi
Arabia were limited to either the building systems or the envelope.

And since most of the studies had proven that the building envelope has the most significant effect on the energy consumption, the large glazed facades in the office buildings in Saudi Arabia should be treated by minimizing the glazing area especially for SE and SW facades, or by providing shading, and better results can be achieved by using insulation materials in addition to the glazing treatment.

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