Energy efficient buildings for sustainable construction

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Abstract: Pakistan is facing immense energy crises and demand of energy is increasing day by day. The sustainable solution for this energy demand is to conserve energy and produce smaller portion of energy by non-renewable sources while larger part of energy from renewable sources as Pakistan has more than 300 full light days, wind and a treasure of water sources. Buildings are the prime consumer of energy and there lies a capacity in buildings to conserve energy if designed intelligently. The buildings can be smartly designed to take maximum advantage of natural sources for lightening, heating and cooling purposes inside the building while minimizing the electricity use. The purpose of this paper is to highlight the importance of energy efficient buildings for a better economy, energy conservation sustainable construction. A case study of textile mill is discussed where energy efficient system was installed resulting in a reduced electricity consumption by more than 35%. The investment on transforming a conventional building to an energy efficient building returns in the form of lesser electricity bills and healthier production.
[Engr. Zeeshan Ullah. **Energy efficient buildings for sustainable construction.** *Rep Opinion* 2025;17(12):10-16]. ISSN 1553-9873 (print); ISSN 2375-7205 (online). http://www.sciencepub.net/report. 03. doi:10.7537/marsroj171225.03

Keywords: Energy Efficient Building; Sustainable Construction; Energy Crises; Passive Design

1. Introduction

Energy demand has been increasing worldwide, therefore, the environmental impact resulting from energy production and consumption has become a major public concern. Buildings are one of the biggest contributors to energy consumption in the modern world. Energy consumption in buildings refers to many factors such as lighting, domestic and commercial appliances as well as HVAC systems. Among all building services, HVAC systems play a significant role in building energy consumption [Liddament MW.at. el 2008, Pérez-Lombard L, at. el 2008]. As much as 40% of the energy consumed in office buildings in the EU is used by HVAC systems (Gruber E, 2008).

Many innovative solutions have been proposed for energy-efficient buildings, and there is an ongoing effort in promoting and demonstrating their energy saving potential. The majority of these solutions, however, is directed towards new buildings and future building designs, and is difficult to implement in existing buildings. Across Europe, only about 1% of the building stock is currently being renovated each year, and there have been recent renewed calls for higher renovation rates, as high as 3% (Tofield B, Ingham M. Refurbishing, 2012). As buildings become more energy efficient, small power equipment such as computers are an increasingly significant source of energy end-use (D. Kaneda and B. Jacobson, 2010). A study published by the New Buildings Institute suggest that plugs loads can represent up to 50% of the electricity use in buildings with high efficiency systems (NBI, 2012).

The construction industry can make a leading effort to make the future of earth more sustainable. The global concern about developments is not only economical but the effects on living standards in long run are of utmost importance (Grace, 2008). Sustainable construction is like a three-legged stool; the economy, society and ecosystem all needs to be balanced (Young, 1997). Pakistan is facing energy crises which has adversely affected its agricultural, industrial and economic sector resulting in increased rate of inflation, poverty, unemployment, increased crime rate and frustration among people (Jaweria, 2016). The demand of energy is an ever-increasing phenomenon and for sustainability purpose energy conserved is better than energy produced. Pakistan needs measures to use energy efficiently in domestic sector as it is the prime consumer of energy (Khursid et.al, 2014). The life cycle energy analysis of buildings has revealed that 80-90% of energy is consumed in operating the building while 10-20% is embodied energy. The energy used during demolition process of building is insignificant as compare to the total life cycle energy of the building whereas life cycle energy distribution of building encounters the over-all energy use during construction, operation, maintenance and disposal. Therefore, to design an energy efficient building the operating energy needs to be reduced (Adalberth, 1997).

The concept of green construction is now strongly attracting the interests of developers and stakeholders due to the environmental impacts of construction. The terms green construction, green buildings, high performance buildings, sustainable construction and sustainable buildings are interchangeably being used in literature (Amos and Albert, 2016). The objective of green construction is to minimize the environmental and ecological impacts of construction while increasing the use of renewable energy, improvement of building performance in terms of efficient energy use, indoor air quality, safety and comfort (Grace, 2008). The Pakistan Green Building Council (PGBC) is working for the development of green building technology in Pakistan. Recently the National Energy Efficiency and Conservation Act 2016 is passed by the Senate and National Assembly of Pakistan whose objective is to prescribe the energy conservation codes for buildings for the efficient use of energy. This ENERCON Act 2016 along with Pakistan Engineering council will try to implement energy conservation codes by law (PGBC).

This paper finds how energy efficient building plays its part in energy conservation and design requirements of energy efficient building. It has been found that the efficient use of sunlight can reduce the electricity demand of a building and building can be designed in such a way to get maximum output form day light. Moreover, a case study of textile mill in Pakistan has been discussed in detail which is made energy efficient building resulting in a striking reduction in its electricity bills.

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2. Energy Efficient Building

The energy consumption over the world finds buildings as the main consumer and also the total resource consumption and emission in the world are greatly affected by the buildings. A building throughout its life cycles consumes energy in directly from construction, operation, maintenance and destruction of the building and some amount of energy is indirectly used while during the construction material production of the building (Sartori, 2007). There is a definite potential of energy conservation in buildings but it is not a one night process. There are multiple options to reduce the operating energy in buildings. These energy efficient buildings are being adopted all over the world. A reduction of 50% in energy use by 2020 is the goal of Dutch government while European Union is expecting 20% reduction in its building energy use by the year 2020 (Hoppe et. al, 2011).

Buildings represent a very high energy consumption percentage compared to other economic sectors. Although percentages vary from country to country, buildings are responsible for about 30–45% of the global energy demand (D.A. Asimakopoulos and M. Santamouris, 2012). Commercial buildings, and primarily office and university buildings, are classified amongst the buildings presenting the highest energy consumption (DECC 2013, H.M Chung 2014). In a research, it has been revealed that energy efficient buildings can save equal to or even more than 30% of energy as compare to traditional building (Zainordin et.al, 2012). The design of energy efficient building involves the resourceful use of active and passive design techniques to get the best output from natural, renewable and non-renewable sources of energy. The core purpose of building design is to make building comfortable in terms of air, temperature and light requirements. The active design of building uses the purchase energy which is electricity, natural gas, solar panel or wind energy to make building comfortable providing it with HVAC (heating, ventilation and air conditioning) system, electric lights etc. while the passive design techniques employ the ambient energy sources by predicting the sun path the best use of sunlight is made possible to best utilize its energy within the building's overall design both for heating and cooling purposes in the form of sun light for heating and lightening the building. It also includes radiant panels and heat pumps. Designing passively means working with the nature instead of working against it. Energy codes of Pakistan categorize the building into five energy systems namely Building envelope, lightening, mechanical and electrical systems, HVAC and service water heating. The building envelop has a potential of saving 40% of energy while lightening can save 29% (ENERCON). To save the energy following measures can be adopted to design an energy efficient building (Sabahat, 2008).

2.1 Building Orientation

The most important component of energy efficient building design is the orientation of the building. Building needs to be oriented in such a way to get maximum of sun heat in winter and to avoid it in summer. The best way is to put the building facing south and openings on west and east must be small as solar radiations have high intensity in these directions. Before deciding the orientation of the building, it is important to consider the wind-rose diagram of the area which gives better idea about the direction of wind. Usually wind blows from south toward north providing a better air flow inside the building if proper windows on both sides are installed (Autodesk). The purpose of internal design of the house is to put those areas of house on south side which demand more lightening and heating. The path of sun has been shown in the figure 1, it can be seen that in summer sun is high while in winters it lowers in the sky. The west side of the house is more prone to heating so the garage, stores, bathrooms and laundry can be placed on this side while bed rooms on north side which will help in cooling during summer. The living area can be placed on south with shading to as their lightening requirement is more.

There is a possibility that some parts of the building are brighter while some are dark that can be made more comfortable by high windows and reflectors inside the room. When only light is required while the heat is not needed windows can be shaded well to avoid morning and afternoon heat gains of the building as well. Windows pose vital importance in passive building design as they provide solar energy for heating cooling and lightening. The location and weather condition change the design of passive building but the design guidelines for windows remain the same. The elevation, size and glass type of windows help in maximizing heat gain in winter and minimize it in summer. Depending upon the climatic conditions windows of different frames, U-factor and glazing types may be provided (Autodesk). The windows glass of high performance has 10-40% solar transmittance (Sabahat, 2008).

2.4 Landscaping

Summer is longer in Pakistan and climate is very hot in most of the regions of country. In summer shading of windows and landscaping is required for cooling. Trees can be planted on north side of the house and suitable plantation is also recommended on southeast and southwest of the building which will make it more comfortable in summer. The windows and wall can get shade with shrubs, trellises, trees and pergolas (Sabahat, 2008).

2.5 Thermal Insulation

Thermal mass of the building plays a vital role in heat gain and loss of the building. Thermal insulation is provided to retain the heat space of the build while avoiding the excess heat gain as well. This acts encountering the conduction, radiation and convention phenomenon (Autodesk). The cooling load building can be reduced to 30% by providing thermal insulation which is also possible by sandwiching the polystyrene sheet (Sabahat, 2008).

2.6 Surface to Volume ratio and Ground Surfaces

The surface to volume ration affects the gain and loss of heat. Along with thermal mass the S/V ratio needs to be minimized which in turn minimize the heat lost in cold weather and the heat gain in hot weather (Sabahat, 2008). The temperature of ground surface and rooftops can be controlled by making it more reflective by lightening the color or vegetation.

2.3 Building Energy Index (BEI) and Return On Investment (ROI)

BEI is expressed in kWh/ m^2/ year of a building which depicts its energy concumption in one year. The total energy for the complete year in the form of electricity is divided by the total area of the bulding to get building energy index (Tahir et.al, 2015). BEI is representative of the energy performance of the building and in design phase it can be estimated for the proposed building to set a benchmark for its energy perfrmance (Mclean, 2014). The installation of energy efficient construction requires more initial investments as compared to traditional constrcution but the return on investment is very usefull tool to decide wether to go for energy efficient building or not. ROI gives an idea about time in which aditional initial investment of newly installed enrgy efficient tools is returned. Techniques should be selected in such a way that ROI period is as small as possible.

2.4 Life Cycle Cost Analysis of Energy Efficient Building

Now it is more common to analyze any facility or investment in terms of cost and environmental or social impacts for the whole project life cycle in case of buildings from construction to demolition. In case of Green building or energy efficient building the additional initial cost may not convince the owner to build such type of structure. Sometimes, a more economical solution may not necessarily have good environmental impacts or in other words sustainable (Grace, 2008). The life cycle cost savings of energy efficient buildings via maintenance and utility cost makes it more interesting for owners (Alexia et.al, 2008).

3. Case Study of Textile Mill in Pakistan

The following is the case study of textile mill where the consumption of electricity was very huge and some passive energy measures were taken to reduce its electricity use for lighting, cooling and humidity system. Following is the detail of issues and their solutions.

3.1 Lightening Issues and Solution

Too many lights were installed in spinning unit. Most of them were energy savers and tube lights which consume more electricity. During initial visit, it was recommended that lights should be replaced with LED’s. Some of the LED’s which have installed are of low grade and low quality which will not give proper saving specially after first few hours of operation. Only good quality lights should be purchased and installed at Spinning Unit. A combination of COB, LEB Tube Lights, SMD’s, LVD’s, High Bay and Street Lights have to be used for enhanced energy saving.

3.2 Day Light Harvesting

The facility was simulated for day light harvesting with the help of Design Builder 12 Sky lights of dimensions (8ft x 6ft) were fitted on the ceiling, the working plane was fixed at 1.5 meter and found that the average Lux introduced in the building by Sun was around 55 Lux which is almost equal what the artificial lights are creating averagely. To keep the heat from the sun entering the facility from the sky lights, it is recommended to use Low E-glass (tampered).
It is highly advisable to go for Sky lighting to save energy consumed by the artificial lighting i.e. approximately 30-35 KW for day timings. For night remaining 10- 15 KW which will be due to good quality LED’s and efficient fans installed can be converted to Solar Light. Resultantly 40 to 50 KW of lighting could be saved. All tube lights, energy savers and other lights were replaced with LED (COB, High Bay, Led tube lights, SMDs, Street Lights) as per the area requirement. When going towards day light harvesting, airtight aluminum or Upvc windows with Low-E glass were used to reflect back the heat that is coming from sun.

3.2.1 Cooling
The actual cooling requirement was around 571 KW, if the HVAC (heating, ventilation and air conditioning) was properly designed. But HVAC that was running in the factory was not designed as per the facility and Spinning textile. After the expansion of the factory the current design became invalid and because of this the cooling and humidity requirement yield higher power than it was required in case of proper design.

3.2.2 Interior lighting
With properly lighting design and use of optimized LEDs, the requirement came to 12KW as compared to the 40 KW previously being used. And it can even go lower if the day lighting is properly harvest. Air intake areas were small and not properly designed. Expansion of air intake areas resulted in lower energy consumption of cooling system. To further reduce the energy consumption of the cooling system, fall ceiling could be placed in the ring section too. On average, the humidification plants in textile plants consume about 15% to 25% of the total energy of the plant. The control system consists of variable speed drives for supply air fans, exhaust air fans and pumps in addition to control actuators for fresh air, recirculation and exhaust dampers. Energy savings in the range of 25% to 60% is possible by incorporating control systems in the plants depending on the outside climate. The entire system can be controlled through a central computer. It was calculated that additional 1% of the energy can be saved if the building envelope is properly insulated

so as to prevent the escape of heating and cooling in the building.
With above mentioned steps 30% to 60% reduction was achieved in cooling system consumption, which is the major energy consumer in spinning unit and 70% reduction in lighting energy consumption was achieved.

4. Conclusions

This paper emphasis the importance of energy efficient building as Pakistan has been facing energy crises for a decade in the form of load shedding. Energy has direct relation with economic development as industries in Pakistan highly use electricity. A unit of electricity saved is better than a unit generated. Conservation of energy is concern of the Nations now a day. More than 50% of electricity generated in Pakistan is consumed inside buildings for lightening and HVAC. It is concluded from the literature and case study discussed in this paper that energy use for lightening and HVAC can be reduced by passively designing buildings to get maximum from ambient sources. Textile Industry is the backbone of Pakistan GDP and its electricity consumption is very high that can be controlled via energy efficient techniques. The new lightening appliances are very effective to conserve energy, moreover, incandescent convert 90% energy to heat which also increase the cooling demand. The new fans with plastic body are more efficient as they require less electricity as compared to old heavy steel body fans. Properly designed windows with glazed glass is helpful for efficient HVAC.

Worldwide trend in green building construction shows that the hindrance to its adoption is lack of awareness and more initial cost. The life cycle cost analysis of energy efficient system can satisfy the owner for additional cost. Pakistan government should take measures for the awareness of energy efficient buildings to construction stake holders and also for the implementation of National Energy Conservation Act 2016. Moreover, an incentive system can also be devised to rate the buildings and provide certificates for energy efficiency which will be helpful for people to switch from traditional to energy efficient buildings.

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Table 1 Potential Energy Conservation Area

Sr.#	Conservation Areas	Saving Potential
1	Building envelope	40%
2	Overall lighting potential	29%
3	High efficiency lighting (LEDs)	72%
4	Fluorescent Tube Ballasts	83%
5	Lamp fixtures or luminaries	50%
6	Air Conditioner	18%
7	Printers	19%
8	Heaters	17%
9	Copier	10%
10	Fan	5%
11	Computer	2%

Source:ENERCON 2013

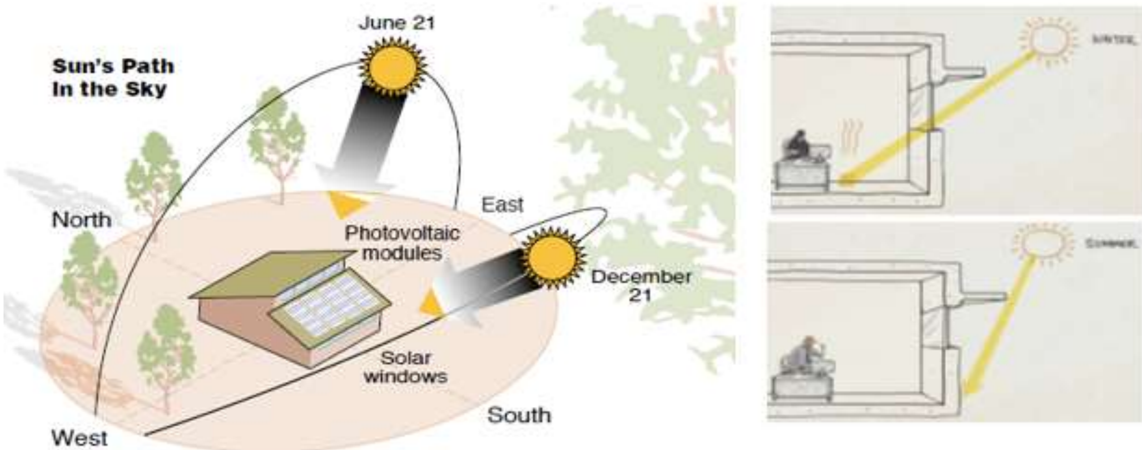

Figure 1: Summer and Winter Solstice
Source: Google images

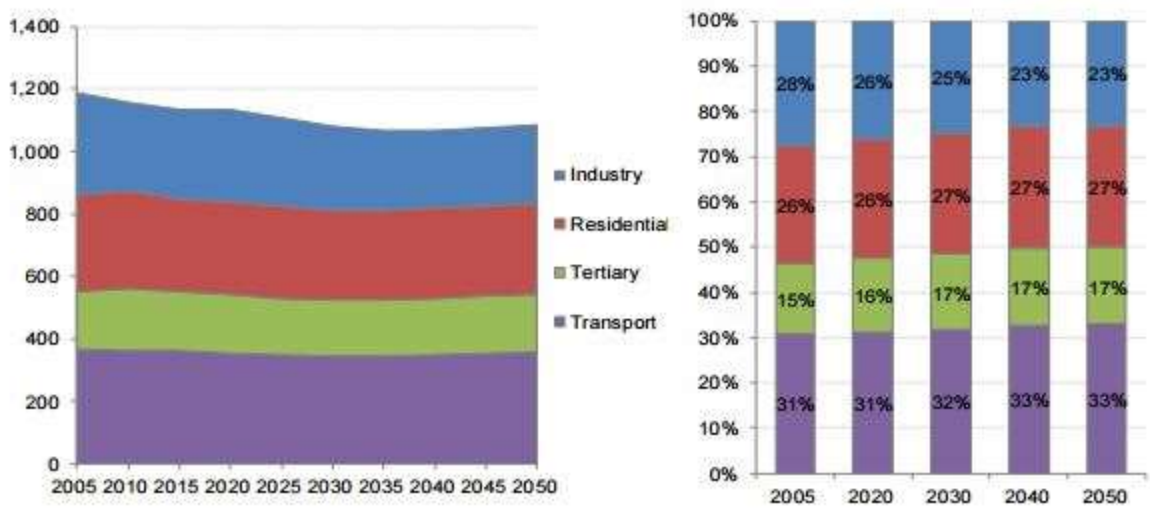

Fig 2 Energy Demand by different Sectors
Source: EU Reference Scenario 2016 – Energy, transport and GHG emissions - Trends to 2050

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