ENERGY-EFFICIENT BUILDINGS IN PAKISTAN

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ABSTRACT

Pakistan is one of the countries with the highest energy consumption for domestic use. Annual energy consumption by the domestic sector is 45.9 % of the total, while the industrial sector, consumes about 27.5 %. About half of the total energy consumed is used in buildings and/or heating, ventilation and air-conditioning (HVAC) and lighting appliances. The energy consumed for the same purposes in China and UK is 25 to 30 % and 40 %, respectively, even in extreme weather conditions.

Energy deficiency in Pakistan is approximately 5,000 MWe, which results in worst load-shedding in summers and, lately, even in winters. Building new energy sources like dams, coal power plants and renewable energy power projects are some possible solutions, but these are time taking and need at least 2 to 6 years to complete, depending upon the nature of the project.

Fast development of energy-efficient buildings is, therefore, necessary to deal with exacerbating energy-crisis and related environmental impact in Pakistan. Innovations in the prevailing building-design will help the country in reducing the energy burden. These innovations may include improved architectural designs, energy-efficient building materials, electrical appliances and implementation of building energy-efficiency codes. In 1987, the National Energy Conservation Centre (ENERCON), Pakistan, was established under Ministry of Environment, Government of Pakistan, with the aim to build awareness among the masses for energy-conservation, and to make policies regarding energy-conservation structures in the country. But no policy regarding building energy codes has been introduced by ENERCON till now.

In collaboration with Pakistan Engineering Council (PEC), ENERCON has recently finalized the Building Energy Code of Pakistan Energy Provisions 2011 for which statutory notification is under process for necessary amendment in the building by-laws. The implementation of this Energy Code will result in 25 to 30 % of energy savings in the new buildings. This paper discusses important aspects of energy-conservation through building of energy-efficient structures, while taking into account their geographic location, cost-effectiveness, trade-offs and aesthetics.

1. INTRODUCTION

Pakistan is a highly energy-deficient country. The energy consumption per capita for Pakistan is 475 kWh/annum and is 164th on world ranking, while USA is at number 9 with per capita consumption of 12,924 kWh/year. Whereas, world's average consumption per capita is 2,500 kWh/year. Pakistan's installed energy capacity is approximately 19,500 MWe, out of which only about 13,500 MWe is being produced. It is one of those countries in the world that generate its maximum share of electricity from thermal source. The share of thermal energy in Pakistan's energy mix is approximately 70 % and its efficiency is merely 35 to 40 % (Haleel, 2009).

Under this scenario, energy-conservation seems to be the only way out. Pakistan is situated on latitudes between 24^{o}N and 35^{o}N, which means that 70 % of the country remains in sunny and hot climate throughout the year. Thus the major energy use is for cooling and should be the main concern while designing buildings. But, unfortunately, after consuming 55 % of the national energy resources, buildings in the country are still unable to provide a comfortable living atmosphere.

More than one-thirds of the world's energy is used in buildings; the majority of that energy is used in houses and apartments (Clarke and Maver, 1991). A lot of money can be saved to deal with the prevalent energy-crisis by building energy-efficient houses and buildings. Such buildings would conserve a lot of energy that is normally wasted in ordinary dwellings. An energy-efficient new house uses only 10 % to 30 % of the energy used by a house of similar size that is built according to usual contemporary standards. The small additional costs of thermal design may be recovered quickly, and the energy-efficient homes will reduce dependence on expensive and unreliable energy resources.

2. WORLD SCENARIOS

Earlier, energy-efficiency measures for buildings resulted in poor insulation levels, which could lead to health problems because of humidity or air-infiltration. Before the oil crisis in 1973/74, most regulations for energy-efficiency in buildings came from the northern regions (European countries) that are cold enough to considerably influence public health (Figure-1). Requirements on specific constructions, with some thermal characteristics in these regions, first appeared

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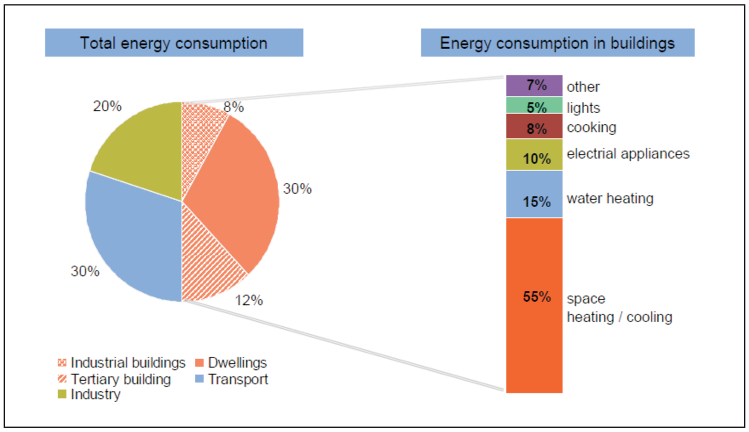
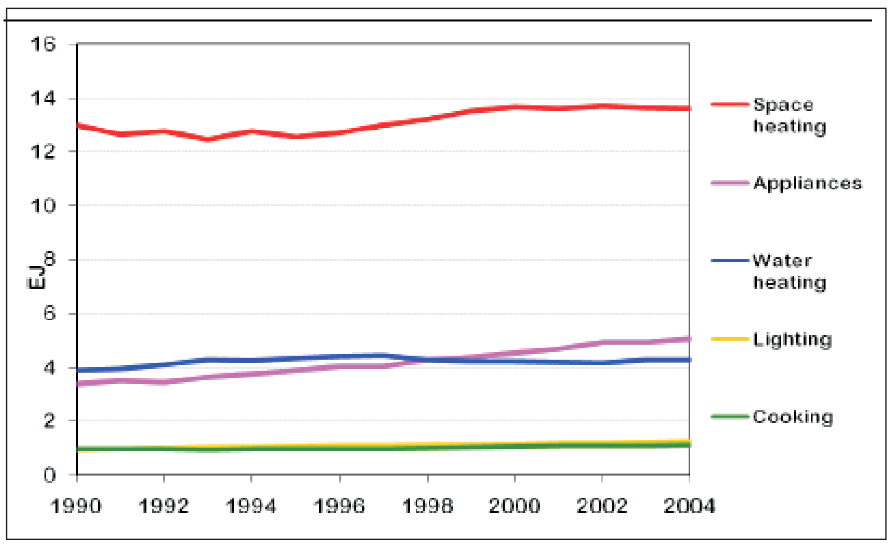


Source: *DG TREN, European Commission*

Figure-1: Total Energy Consumption by Buildings in Non-Energy Efficient Scenario



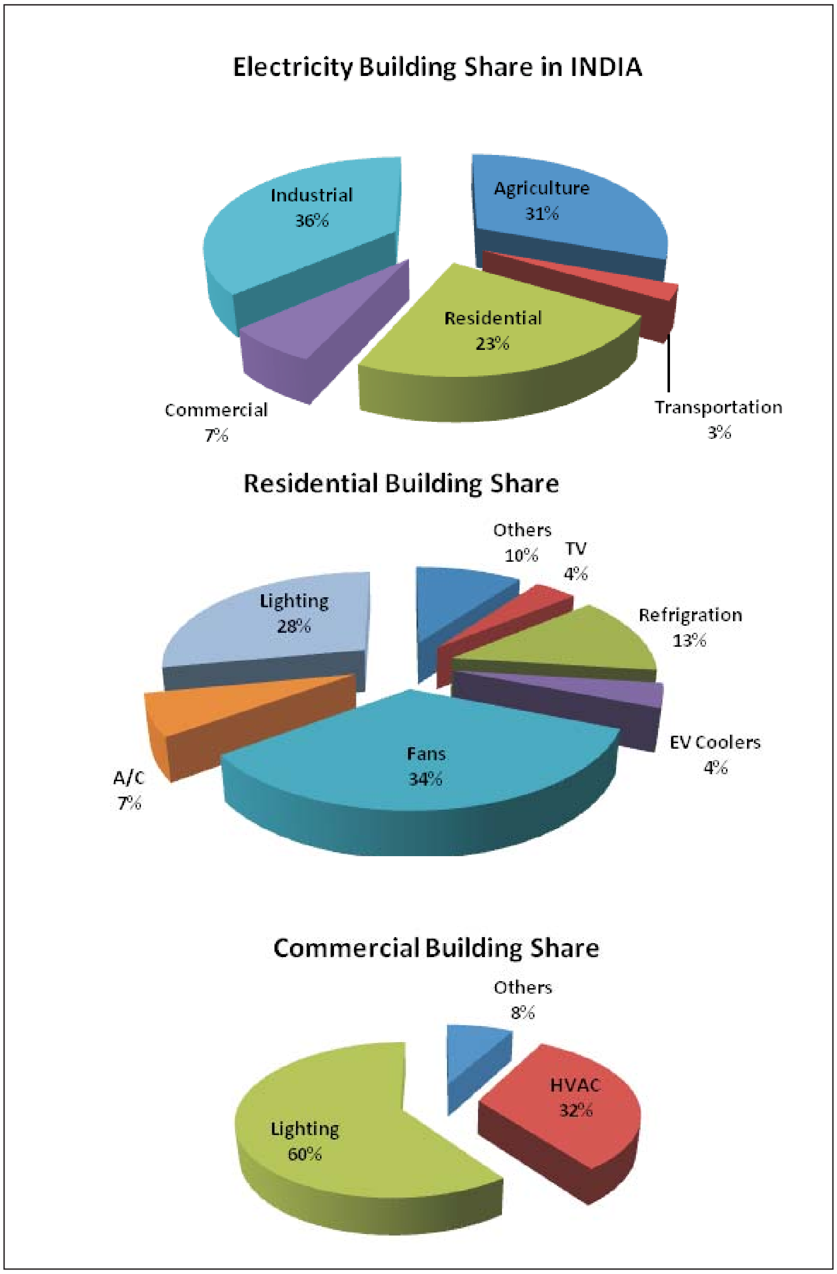
Source: *30 Years of Energy use in IEA Countries (Lausten, 2008)*

Figure-2: Energy Usage Proportion in IEA Countries

during the period between the two World Wars, when some countries regulated the introduction of simple insulation in the form of air layers in cavity walls or double layer floors of timber beam.

The first real insulation requirements for the U-values 10, R-values and specific insulation materials or multi-glazing, date back to the late 1950s and the early 1960s in Scandinavian countries. These insulation requirements were developed to improve energy-efficiency and comfort in buildings. Comfort was the prime motivation for raising the requirements – in view of increasing standard of living, people demanded better and improved living conditions.

In many countries, the oil supply crisis of the early 1970s catalysed the development of energy-efficiency requirements for buildings. These countries already enforcing efficiency-regulations generally raised their requirements during the early 1970s to further reduce energy-consumption and decrease dependence on oil. During the 1980s and 1990s, the energy-efficiency requirements were set or increased in most of the member countries of International Energy Agency (IEA) and Organisation for Economic Cooperation and Development (OECD). The reason for focusing on

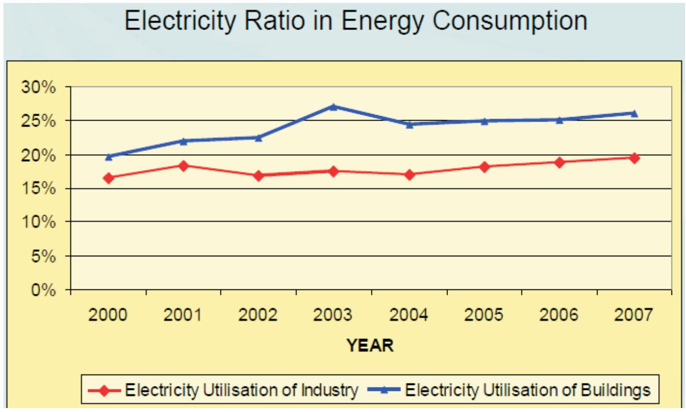


Source: *The Bureau of Energy Efficiency (BEE), 2008*

Figure-3: Total Energy Consumption by Buildings in India

OECD countries is that these nations are among the highest per-capita electricity consumers. The graph of electricity consumption in IEA member countries from 1990 to 2004 (Figure-2), shows that more than 50 % of the share was used for space heating and cooling (Lausten, 2008).

Rapidly developing countries having the economic capacity to install cooling or heating systems, such as India and China, seek to improve comfort and reduce the dramatic increase in energy-consumption by regulating energy-efficiency in buildings. Examples of India and Turkey are elucidated below:



Source: *Electrical Power Resources Survey and Development Administration (EIE), Turkey*

Figure-4: Electricity Ratio in Industry and Buildings, Turkey

2.1 India

The Bureau of Energy Efficiency (BEE) was set up in March 2002, under the provisions of the Energy Conservation Act (2001), to provide a legal framework for the government's energy-efficiency initiatives in the country.

Being the emerging economic giant in Asia, India has raised its electricity consumption per capita from 402 kWh/year in the year 2000 to 571 kWh/year in 2009. The Indian government is striving hard to harness the demand vs. production ratio. In this regard, the Energy Conservation Act (2001) was constituted (BEE, 2008).

Having the primary objective of reducing energy intensity of the Indian economy, the Bureau's mission is to develop policies and strategies with a thrust on self-regulation and market-principles.

2.1.1 Energy Conservation Building Code (ECBC) Development Process

An extensive data collection was carried out for construction types and materials, glass types, insulation materials, lighting and HVAC equipment (see Figure-3). Furthermore,

- base-case simulation models were developed;
- stringency analysis was done through detailed energy and life-cycle cost analysis;
- a stringency-level for each code component was established;
- a code was finalized.

The code was launched on 27th May 2007 with focus on commercial buildings and new construction. The code on building components included:

- Building envelope (walls, roofs, windows);
- Lighting (indoor and outdoor);
- Heating ventilation and air-conditioning (HVAC) System;
- Solar-water heating and pumping;
- Electrical systems (power factor, transformers).

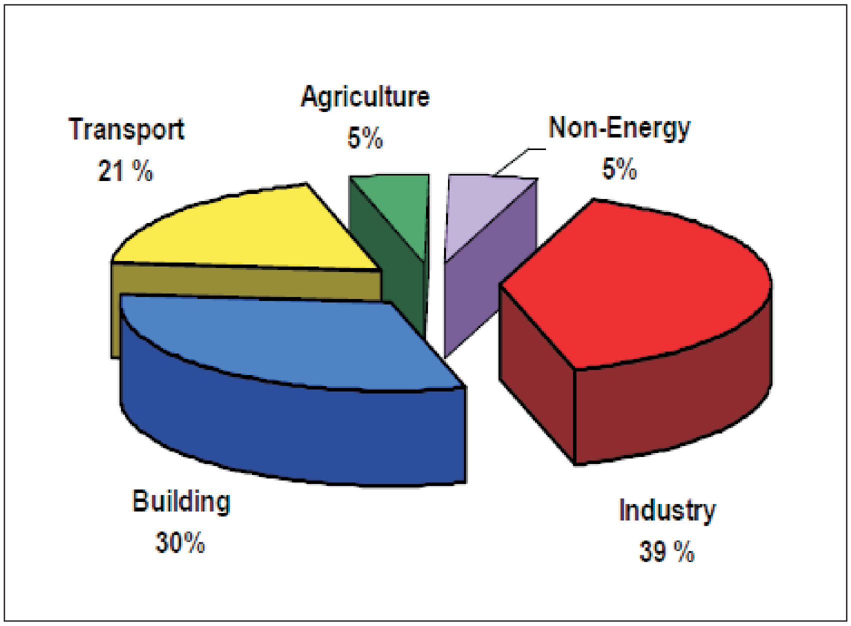
2.2 Turkey

Due to its effective energy-efficiency policies for buildings, electricity consumption in Turkey was reduced to 25 to 30 %, against the average of 50 % as seen earlier (Figure-4). The total population of Turkey is 70.5 million and per capita electricity consumption is 2,692 kWh/yr (Keskin, 2008).

2.2.1 Energy-efficiency Activities

An Energy Efficiency Policy was prepared by Turkish Ministry of Energy and Natural Resources (MENR), followed by:

- Energy-efficiency implementation by the General Directorate of Electrical Power Resources Survey and Development Administration;
- Some energy-efficiency projects supported by international donors, such as UNIDO, the World Bank, JICA, GTZ, and the European Union;
- The goals of capacity-building and awareness raising was achieved to some extent although big-scale energy-efficiency enhancement was not ensured in all sectors;
- Preparation and adoption of 'Energy Efficiency Strategy' by MENR for Turkey in June 2004.



Source: *Electrical Power Resources Survey and Development Administration (EIE), Turkey*

Figure-5: Electricity Ratio (by Sectors), Turkey

Turkey's industry has one of the best energy management system that can serve as a good example for other countries (Figure-5). Almost 1,000 energy managers were trained and certified in a programme comprising lectures and practical applications on energy-management methods (Buyukmihci and Calikoglu, 2009). With this programme in industrial plants, which consume more than 2,000 TOE energy, a perceptible energy-efficiency increase was achieved. Under the Energy Audit Scheme, more than 100 plants were audited. The mandatory regulation for heat insulation in new buildings, labeling of household equipment, air conditioners and lamps are some other effectively implemented programmes.

2.2.2 How it Works

The Ministry of Public Works and Settlement (MPWS) is the body responsible for enforcing the regulatory framework of the building sector in Turkey.

- The Building Standard (TS-825), sets thermal insulation standards for new buildings and at renovations of existing buildings with 15 % ratio or more (mandatory since 2000).
- Regulation on heating insulation in buildings was last revised in October 2008. After the 1999 earthquake, building inspection agencies were established in 19 provinces in 2001 to carry out inspection of buildings. These agencies are also authorized to control new buildings' heat-insulation.

3. TYPES OF REGULATIONS

Energy-efficiency requirements can be set in different ways and methods as referred by the IEA. These are:

3.1 Prescriptive Method

When using the prescriptive method, energy-efficiency requirements are set for each component of the building. This could be a thermal value (U-value) for windows, roofs or walls. The prescriptive method can include efficiency values for technical installation, ventilation, orientation of buildings, solar gains, and the number and size of windows. To comply with a prescriptive standard, each part of a building must meet its specific prescribed value.

A simple version of a prescriptive building-code set thermal values for the essential 5 to 10 building parts. In the most complicated systems, energy-efficiency requirements are set for all parts of the building and installations, including heating installation, cooling units, pumps, fans, and lighting. In some cases, these requirements are even adjusted according to the size of the equipment/the size or the percentage of windows based on floor area/ the outer wall.

In general, instructions for the prescriptive method are easy to implement. U-values can be followed by descriptions of typical constructions that fulfill the needs, and the requirements for equipment can be combined with the labelling of products. A prescriptive method could require an appliance to be labelled 'A' or 'B', or rated with energy stars. Every product being used in the building has its green-star rating termed as 'labels' and it can be matched with the building specifications.

3.2 Trade-off Method

Trade-off method sets values for individual building parts and/or for parts of the installations, akin to the prescriptive method. However, in meeting a general standard for efficiency, a trade-off can be made between the efficiency of some parts and installations such that some values are exceeded while others are not met.

The trade-off is generally made in simple terms. Trade-off can be made between U-values for the building shell, or between the building shell and the energy-efficiency requirements for heating and cooling installations. The trade-off model provides more freedom and flexibility than the prescriptive method. The calculations are simple and can be done by hand or using a simple spreadsheet.

3.3 Model-building Method

In the model-building method, values are set for each building part and/or for the parts of the technical installations. Based on the values and the characteristics of the actual building, a model-building value is calculated with all the set values for losses and efficiency. This calculation follows a clearly defined method. The actual building is then calculated by the same method using the actual values for the individual building parts, heating, cooling, and ventilation systems. The total result of the calculation is compared with the model-building value and the actual building value must be better than that of the model-building.

The most complicated models take into account all parts of the technical systems in these calculations, including heating systems, ventilation, cooling, lighting, built-in equipment. Renewable energy can be included in the calculations to make a solar collector, for instance, reduce the general energy-efficiency requirements for the heating system or even the insulation level.

The model-building method gives more freedom and flexibility to architects and constructors than a prescriptive model. Expensive systems can be changed with improved efficiency in parts of the building or installations, where efficiency will be more cost-effective.

3.4 Energy-Frame Method

The energy-frame method for a building sets a maximum limit on energy-loss from the building. This is usually set as a total frame for the building, a value per square meter of the building area or as a combination. The energy-frame will then be followed by a procedure on how to calculate the energy losses from simple values, such as the U-values, temperature, surface and heat gains from sunlight. Values for the individual parts are not set in this model but only for total loss or use of energy.

This method enables the constructor to build parts of the buildings that are less energy-efficient when other parts are made better than typical constructions. For example, this method can, also help avoid limiting the size of the window area, as improved windows or increased insulation can adjust for the additional heat losses or larger sun gains by having a larger surface for windows. As long as the overall value is met, the building plan is approved.

The energy-frame method can also be defined as an overall thermal value (adjusted U-value), per square meter of building floor area. Again, it will be the constructor's decision to document that the building is built on the standard of the model-building given by the overall values.

Similar to the model-building method, the energy-frame method gives more flexibility in fulfilling the requirements and this can easily be adapted to the most economic solution. On the other hand, it increases the need for making complicated calculations.

3.5 Energy-performance Method

With the energy-performance method, a total requirement for the building is set based on the supply of energy or the resulting environmental impact, for instance, in form of CO_2 emissions. This method requires comprehensive calculations of the energy-performance of a building, with standard values for climate and use in different types of buildings. Constructors are required to use an advanced computer-based model for the calculations, which integrates the values of all the different parts and installations of the building.

Values for energy-performance are set on the basis of an overall value – consumption per square meter or a mixture of the two – for different types of use or different types of buildings. Installations using renewable energy in the building will usually be calculated as improvement in performance. The energy-performance model requires handling multiple factors, such as solar gains, recovery of energy losses, shading and efficiency in installations.

In energy-performance method, comparing the use of different energy forms, such as heating (gas, oil or diesel) with the use of electricity is necessary. Depending on local energy conditions, there may be adjustments where some kWhs or GJ are valued higher than others or the comparison can be based on energy costs. In performance calculations, the maximum value is often set for the use of fossil fuels – primary energy use or as a maximum CO_2 emission. Free trade-offs can be made between insulation and installation of efficient equipment, but this trade-off should be based on the selection of fuels, the use of renewable energy, the primary design (form) of the building, use of daylight, and intelligent installations or automatics. Windows with better thermal values can be used to increase the window area or negative losses can be balanced out with positive gains as passive heating.

Energy-performance standards give optimal freedom to constructors or designers to reduce energy consumption within the frame. If efficient boilers or air conditioners are more cost-effective than improved insulation, the constructors can choose this alternative to improve performance. Similarly, it will be possible to substitute more expensive solutions in the building envelope with efficient renewable energy systems or by heat recovery. The model adapts to a change in prices, technical development and allows new solutions and products. There is a need to develop and maintain sophisticated calculation methods and computer tools that take all these important factors into account.

3.6 Mixed Models (Hybrids)

Some countries use a mix of all the afore-mentioned models. For example, an energy-frame for the building might be combined with prescriptive values for installed products. Another typical mixture is when building codes allow a choice between the simple approach with prescriptive values, an energy-performance or an energy-frame. The designers can, therefore, use a model that is simple to calculate, or choose a more complicated model that offers more freedom and flexibility. Sometimes both performance values and prescriptive values are set, whereby the prescriptive values are tighter than the value for the overall calculation. This ensures that buildings constructed after the prescriptive values, automatically fulfill the energy-frame or energy-performance requirements.

Some countries/states have two or more models that have to be followed at the same time. In this case, energy-efficiency requirements will grow from the prescriptive models over the energy-frame to energy-performance. The target is to ensure that no building part or component of the heating or cooling system is too poor to base the overall calculation on a model that gives more flexibility. The aim may also be to avoid moisture problems if building parts without insulation result in condensation, or to compensate for different lifetimes of components.

4. DEVELOPMENT

Most countries had started with prescriptive values. When energy-efficiency requirements increased and more elements were included, trade-offs or an overall frame allowing adjustments of the individual values was required. Today, energy-performance models and computer tools are being developed in many regions. International standardisation has been introduced with the aim of developing and harmonising models to calculate energy-performance.

At the same time, countries have decided to have several methods for compliance with regulations, which allow builders and constructors the flexibility to choose from a number of options. This is especially the case for small residential buildings where there is a general effort to make simple and comprehensive rules.

5. SCOPE OF BUILDING EFFICIENCY IN PAKISTAN

The biggest consumers of energy in housing are air-conditioning and heating (in extreme weather), while next in importance are refrigeration and water heating. The smallest energy uses in typical dwellings are for lighting, cooking, laundry and running miscellaneous electronics.

Optimization of a building, as per its usage and location, is the most important factor for energy-conservation. Buildings in southern parts of Pakistan, like Multan or Karachi, will require more cooling than heating. Similarly, requirements of lighting of building and most importantly their control (manual or automatic/timer based) will curtail the energy bill.

Todate, there is no Building Energy Efficiency Code in practice in Pakistan. Some suggestions and recommendations from different case studies, existing building codes and research for energy-conservation are given below:

6. THE LAYOUT AND STRUCTURE OF BUILDINGS

According to Donald (2003), the following measures can help make buildings energy-efficient:

6.1 Design a Layout Tailored to Energy-Usage

The primary purpose of a building layout is to provide pleasant living environment. A good layout allows convenient movement between rooms/ compartments, provides easy access to outside areas, exploits views, isolates noise, keeps one comfortable under all conditions, and does all this with elegance. For example, orientation of the living-room windows toward the waterfront or the mountains, and putting bedrooms on the quiet side of the house. At the same time, the layout should be used to minimize the energy requirements. One should create a core area that consists of the cluster of rooms more often used. Rooms that are occupied less frequently should be located outside the daily traffic pattern so that they do not need to be heated, cooled, or lighted most of the time. For example, locate guest bedrooms and storage rooms in a separate wing. In general, large spaces should be kept out of the daily traffic pattern.

Large rooms that are used occasionally may be thermally isolated from the rest of the house. For example, big halls that are occasionally used should be parted from the rest of the house with glass doors and partitions, to save cooling and heating costs. These allow to merge the large room with connected spaces when needed. If the temperature in an unoccupied space rises or falls a lot, it should be thermally isolated from the rest of the house by using doors and insulated interior walls.

If the house/building has more than one storey, provide convenient doors at the top or bottom of the stairs. The doors prevent uncomfortable temperature stratification and energy waste. The doors should be made as wide as the stairs to provide ample manoeuvring space near the stairs.

6.2 Installation of Insulation in the Walls, Roof, and Exposed Floors

Insulation is the primary tool to slash two biggest energy costs, heating and cooling. Unfortunately, there is not much awareness on this issue in Pakistan. In typical Pakistani weather, to install 12” of insulation in the walls and 16” to 20” of insulation in ceilings will be of good use. The contemporary building structure made of concrete and cement or baked clay blocks has no place to accommodate the above-mentioned insulation techniques. This calls for a big change in construction practices. Walls that are thick enough to accommodate adequate insulation require studs of the same width, which should be rigid and strong. Increasing the wall thickness does not greatly increase materials cost. Generally, conventional non-flammable glass or mineral fibre insulation is used for the walls, roof, and floors.

6.3 Rationalization of Windows and Skylight Areas

Windows and skylights create a large fraction of the total heating and cooling costs. Unfortunately, glazing remains a weak link in the energy-performance of the houses. Even the best windows have poor insulation value compared to insulated walls. Also, windows and skylights account for most cooling cost by allowing sunlight to enter the house directly. If the house has too much glass, no other improvement to the structure can compensate for this. It is like a boat that has a big hole in the hull. So, the use of glass should be planned wisely. The sight lines from inside the daytime rooms should be planned to get the best view in relation to the glass area. In bedrooms and bathrooms, the window sills should be high enough to provide privacy, as well as allowing the use of windows for lighting.

Glass allows good use of daylighting, which is pleasant if it is well-planned. However, lighting cost in houses is small, whereas heating and cooling costs are large. For commercial buildings, on the other hand, lighting may cost more than heating or cooling. Windows and skylights are light fixtures that cost a lot of money to install and operate, and should be planned accordingly.

6.4 Installation of Windows/Doors with Good Insulation and Excellent Weather Sealing

The insulation value of windows depends mainly on number of panes. For the windows that can be opened the models that close very tightly should be selected and stay tight for as long as the house stands. Slider and hinged windows are available in tight-sealing models. Windows also serve as the inlet for outside ventilation air that could be used for cooling.

Daylighting uses relatively small skylights and clerestories to provide daylight in addition to the light that comes through regular windows. Well-designed daylighting provides a pleasant ambiance while also saving a relatively small amount of energy. Passive solar heating is the use of direct sunlight through large windows and skylights to provide heating. In many locations, passive solar heating could eliminate the cost of heating energy almost completely, e.g. in northern areas of Khyber Pakhtunkhwa and Balochistan provinces of Pakistan. However, it is expensive to build and is much more complex in use than it appears to be. Most passive solar installations have generally been failures, wasting energy, causing discomfort and moisture problems, and ruining the appearance of the house.

6.5 Shading Windows to Minimize Air-Conditioning Cost

Most home air-conditioning cost is due to sunlight that enters through windows. Entrance of direct sunlight from windows during warm weather should be contained. Deep roof overhangs are a great feature for this purpose. They also prevent basement moisture problems and extend the life of exterior wall surfaces. Where roof overhangs are not sufficient, soffits and other architectural features should be considered for shading. Awnings are an effective alternative, but they tend to become shabby with age. All exterior shading requires careful orientation with respect to the Sun's motion. Interior shading is inexpensive, but it is less effective and it interferes with views. Ordinary venetian blinds and roller shades work well, but only if used properly.

6.6 Ventilating Near Ceiling Air

The space above the roof insulation should be open to air flow. The roof surface should work like an umbrella or a parasol, not like a tight fitting raincoat. Good ventilation of the underside of the roof surface reduces air-conditioning cost, prevents moisture condensation and ice dams during cold weather. A continuous row of large openings should be installed completely around the bottom edges of the roof to feed air to the underside of the roof surface.

6.7 Tree Plantation to Optimize Shading

In a climate that can be warm for extended periods, trees should be made an integral part of building designs.

7. THE ENERGY-USING EQUIPMENT OF THE BUILDING

The most important principles for energy using equipment are discussed below:

7.1 Select High-Efficiency Models of All Energy-Using Equipment

All the equipment in the building that uses energy – including air-conditioners, water heaters, refrigerators, freezers, washing machines, cloth dryers, television sets, computers, light bulbs, etc – is available in a wide range of high-efficiency versions. Select high-efficiency appliances. This requires no special skills, and it adds very little to the cost construction of the house.

7.2 Turn off Heating, Cooling, Lighting, and Other Energy-using Equipment when not Needed

All electric appliances should be turned off when not needed. Electronic equipment that is operating in 'standby' mode uses very little energy.

8. EFFECTIVE HEATING AND COOLING

8.1 Heating and Cooling Systems that are Tailored to Individual Spaces

Equipment that can heat and cool rooms individually only when occupied should be used. Separate systems for heating and cooling should be used. This avoids big compromises in efficiency and comfort. Heating and cooling systems that need ducts for air distribution should be avoided. Ducts leak badly and control temperature unevenly and also collect dirt and cause health problems.

Hydronic heating is a favoured heating method in most advanced countries. Convectors are completely silent. It is easier to install pipes or wiring for convectors than to install ducts. High-efficiency gas boiler may be used to heat water. This system is now being introduced in Pakistan and is economical to install during new constructions. For cooling, one gets the best combination of efficiency and comfort by using a number of split system air-conditioners, each serving an individual room or a group of rooms that are used at the same time.

8.2 Programmable Thermostats

Programmable thermostats turn off heating and cooling automatically and help conserve energy.

8.3 Placement of Condensing Units of Air-conditioning Equipment in Cool and Clean Locations

The condensing unit is the outside metal box that makes all the noise. Its location is critical, and should be installed in a cool location, such as a shaded side of the house. It needs wide open air flow and should be installed somewhere it is not fouled by debris, such as leaves and dirt.

8.4 Quiet, High-volume Ventilation Fan fo Provide Outside Air Cooling

A quiet whole-house ventilation fan should be installed for use when it is cool outside and air-conditioning is not needed. The fan exhausts warm air from the house and cool air enters through windows. This works well for cooling bedrooms at night. In houses, the most common method is to install the fan above an opening near the ceiling.

8.5 Management of Windows and Ventilation

Opening a window very slightly will provide enough ventilation to avoid indoor air quality problems in a room. Even a small window opening admits a lot of air.

8.6 Energy Efficient Cooking Area

- Refrigerators and freezers should be installed in cool areas that isolate them from heat producing equipment, including the cooking range, water heater, and dishwasher.
- Keeping lids on pots and pans while cooking saves cooking time and energy.
- Frozen food should be thawed in the refrigerator.

8.7 Saving Water and Water Heating Energy

- Separate hot and cold water faucets should be installed for all basins, tubs, and showers.
- Efficient flushing toilets should be installed .
- Efficient washing machines should be uised.
- Geysers should be turned off if the house is being vacated for longer period.

8.8 Efficient Lighting

- Reflective interior colours should be used to reduce lighting costs.
- Fluorescent lighting should be installed in rooms where lights stay on for long periods.
- All light fixtures should be made as efficient as possible.
- Motion sensors can help control lighting in appropriate locations.

9. CONCLUSIONS

Energy-conservation is a long and time-taking process but is very beneficial in the long run. It is the right time for Pakistan to adopt energy-conservation techniques and equipment like developed world has. Fast development of energy-efficient buildings is, therefore, necessary to deal with growing energy-crisis and related environmental impacts in Pakistan. Innovations in the prevailing building-design will help the country in reducing the energy crisis.

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