Mitigation of Energy Crisis in Pakistan through Energy Conservation in Residential Sector

Farooq. Jan, and Abdul. Mutalib

***Abstract*—**Substantial widening gap between electrical energy demand and supply in Pakistan has led to prolonged supply failures to all sectors of energy consumption particularly residential and industrial sectors. The largest contributor of electrical energy consumption is residential sector having a share of 46.5% of the total electrical energy consumed in the year 2010-11. Energy conservation, the only short term remedy of energy crisis of Pakistan focuses on two basic methodologies i.e. improvement in efficiency of devices and/or changing the consumer behavior pattern through public awareness This paper tries to evaluate the energy saving potential in various subsectors of residential sector in order to mitigate the energy crisis of Pakistan. Energy conservation techniques can save approximately 11.8TWh/year. Thus, upon implementing various conservation techniques in above mentioned subsectors can help in bridging the gap between electrical energy demand and supply to a greater extent.

***Keywords*—** Energy Conservation, Fluorescent Lamp, Incandescent Bulbs, Residential Sector.

NOMENCLATURE

KPK	Khyber Pakhtunkhwa
OECD	Organisation of Economic Cooperation and Development
ENERCON	National Energy Conservation Centre of Pakistan
CRCP	Consumer Right Commission of Pakistan
GIS	Geographic Information System

I. INTRODUCTION

Pakistan, sixth most populous country with an estimated population of 180 million is passing through the most critical time throughout its history in matter of its energy needs. The economy of a developing country is strongly related to its sustainable energy supplies at an affordable rate. Pakistan is a developing country and needs tangible solution to meet its energy needs. Energy demand of the country has increased by six folds since 1980, and is predicted to be doubled by 2015 [1].

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Pakistan per capita energy consumption is least among major developed and developing countries and one- twelfth of the energy consumption of countries OECD in 2010[2]. Pakistan per capita electricity consumption decreased to 449KWH in 2009 from 469KWH in 2007, which is less than one-sixth of the world average of 2825.8 kWh per capita [3].

A great potential of energy conservation exists in various sectors including residential sector. There is wastage of electricity in use of domestic appliances such as lighting, heating, cooling, refrigerators, fans, water pumps etc employ induction motors which are the main consumers of energy. This paper focuses on energy conservation potential in residential sector of Pakistan

Installation of new power plants only is not the remedy of energy crisis but it should be accomplished by adopting the principles of energy conservation. In other words, it may be considered as source of energy. Thus conserving energy is much better than generating energy from Pakistan perspective.

II. RELATED WORK

Despite establishment of ENERCON in 1987, nothing has been done practically for energy conservation in residential sector. In this section, experience and research regarding reduction in energy use in various subsectors of residential sector is presented.

Raudel Villaneda [4] in his work has pointed out the achievable energy conservation in any type of building through lighting retrofitting. Taking the University of Texas Medical School as a case of lighting retrofit, he has explained the possible conservation achieved by replacing inefficient lighting sources with new energy efficient lamps having higher efficacy, replacement of high power consuming inductive ballast by hybrid electronic ones and use of reflectors.

Yuanxia Wang, Jhianghonh Wu and Fang Xie [5] in their work predicted that 40% of the total energy in Guangzhou is employed for residential cooling. They found a great difference in relation between the running time of air conditioner unit and outdoor temperature from the curve given by Chinese energy efficiency standards regarding air conditioning use. Thus for setting up of energy efficiency standards for air conditioning, various climatic regions of the country must also taken into account.

Hao Chen, Juan Zhang and Jie Liu [6] discussed that there is an increase in energy demand for heating purposes with the rise in living standard of the people. A reduction in the energy use can be achieved through increase in efficiency which in

turn can be achieved through architectural layout of the buildings.

J. Kidhen, S. Chirarattananon and P. Chaiwiwatworakul [7] in their work discussed the energy consumption aspect of both residential and commercial sector buildings in Thailand. They presumed a two fold increase in energy demand of the above mentioned two category buildings by the year 2030 i.e. in twenty years. They predicted a significant increase in heating and cooling load since the energy consumption for other subsectors will reach a point of saturation. They concluded that a 23% of the electricity saving can be achieved provided effective energy conservation measures are applied to both, residential and commercial sectors.

Yie-Ru Chiu, Chao-Hsien Liaw and others [8] have focused on the energy consumption on water processing such as collection of water, chemical treatment and distribution in urban population. Taking hilly areas of Taipei as a case study where energy consumption on water supply is sufficiently high, they have devised a GIS based rainwater harvesting scheme in these areas since the collected water of rain could be used for various purposes. The results show an improvement in economic feasibility of their proposed system when energy and water conservation are considered simultaneously.

III. Methodology

Pakistan has a great potential of energy conservation in all sectors that needs to be exploited fully in order to mitigate the current energy crisis. This work focuses on the current energy consumption and possible saving potential in residential sector of the country.

The research work is carried in the following steps.

Data Collection

Field visits were made in order to obtain the required data regarding energy use in residential sector to Hydro Carbon development Institute of Pakistan. Technical data regarding lighting sources was obtained from ENERCON. Data regarding maximum electricity generation and demand was obtained from NPCC, Islamabad. In order to obtain peak load of various districts in summer and winter, visits were made to seven 132kv grid stations in KPK.

Analysis

Fig.1 represents the maximum achieved electric power generation and maximum demand of Pakistan in summer (13-08-2012) and winter (14-12-2011) which shows that the gap between electricity supply and demand reaches 4500MW in summer and 1000-2000 MW in winter [9].

Residential sector consumed 35.88 TWh in the year 2010-11 with a share of 46.5% of the total electric energy consumption [10], the energy consumption is further divided into various sub sectors. Fig. 2 represents the percentage share of electrical energy consumption of various subsectors of residential sectors [11].

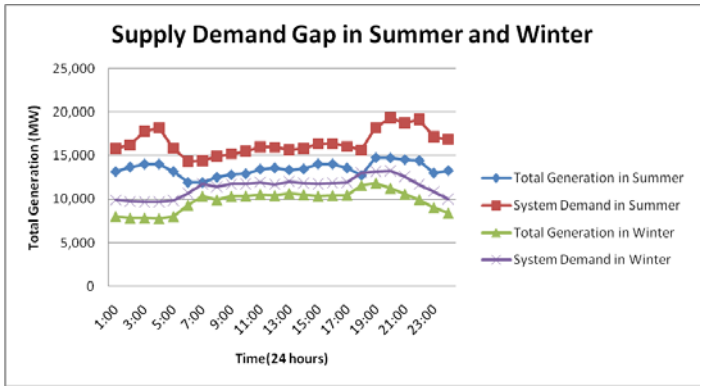

Fig. 1 Supply demand gap in summer and winter

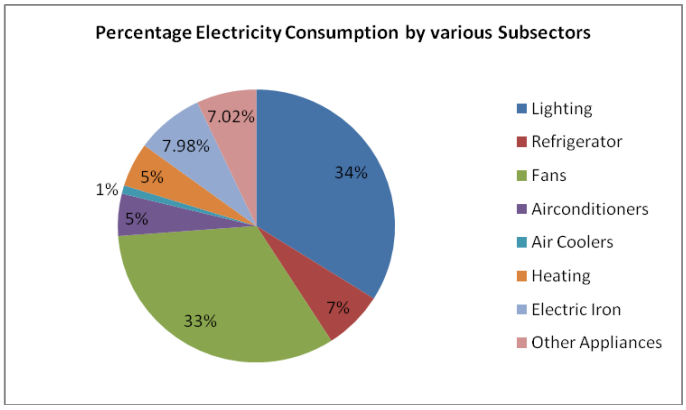

Fig. 2 Percentage electricity consumption by various subsectors

The collected data was then analyzed in terms of various factors to asses to possible energy conservation potential in various subsectors of residential sector.

Lighting

It accounts for the largest energy consumption among all the subsectors and is present throughout the year. It accounts for 34% of the total energy used with a share of 12.2 TWh/year [10]. Among lighting sources, incandescent bulbs contribute for 36%, compact fluorescent lamps 42% and linear fluorescent tube lights 22% of the lighting points with average operating hours 2.9, 2.9 and 3.3 hours per day respectively while there is no use of new energy efficient Light Emitting Diode bulbs[11]-[12].

Table 1 provides a comparison of power consumption of various lighting sources illuminating the same amount of light (lumen) respectively. Energy conservation is possible by the replacement of high power consuming sources with lower ones keeping in view other factors such as color rendition etc.

TABLE I
COMPARISON OF LIGHTING SOURCES

Incandescent bulb(watts)	Fluorescent lamp (watts)	LED bulb (watts)	Light output (lumens)
40	9-13	3-6	450
60	13-15	7	800
75	18-25	8-12	1,100
100	25-40	13	1,600

-Energy Conservation In Lighting

If the 30 million [13] highly inefficient incandescent bulbs are completely replaced, a reduction in energy use will occur. Let's suppose 3/5th of the bulbs are rated as 100 watt and 2/5th at 60 watt, the total energy consumption by IB's comes out to be 2.7594 TWH/year.

-*Replacement Of Incandescent Bulbs*

Considering $3/5^{th}$ and $2/5^{th}$ of the bulbs used for outdoor and indoor purposes and they are replaced by high efficient, high efficacious and having long operating life of 50 thousand hours 13 Watt LED bulbs and 40 watt FL's respectively, the net energy consumed would be 1.215 TWh per year.

Net reduction in energy use = 2.759 TWh – 1.215 TWh
= 1.543 TWh/year

-Replacement Of Inductive Ballasts

A considerable portion of electrical energy in fluorescent lamps is wasted as ballast losses. Old inductive ballast account for 25% of the total input power i.e. 10 watts for a 40 watt fluorescent lamp. Since FL's occupy 25.83 million of the lighting points and an average operating time of 3.3 hours per day, the energy consumption by ballast is 0.311 TWh/year [12]. The replacement of these old inductive ballasts with modern electronic ballasts that use 10% of the input power can save 0.186 TWh/year.

-Use Of Controllers

Use of various types of sensors such as dimmers, photo, occupancy and motion sensors reduce the amount of light resulting in reduction in energy consumption by lighting sources. Overall they can reduce energy consumption by 25-35%, i.e. a further reduction of 3.66 TWh is possible through lighting control.

Heating

Besides other sources such as natural gas and biomass, adequate portion of electrical energy is also used for heating purposes in those areas of Pakistan where distribution losses are higher i.e. in Khyber Pakhtunkhwa and some parts of Sind. The electric energy use for heating is devastating owing to lower efficiency of power plants, transmission and distribution losses. Out of fuel consumed for every 100 kwh of generation, the energy at consumer premises is only 25-27 kwh. Electricity is for two aspects in heating, water and space heating.

The statistical data shown by ENERCON shows that approximately 7% load of any commercial or residential is used for heating purposes cosuming1.794TWh in the year 2010-11 [14]-[16].

Assuming that entire late night load is used for heating purposes, the data obtained from various 132KV grids of KPK show that 418 MW out of 534 MW is consumed for heating purpose which makes 78% of the peak load of these areas. Thus, in order to overcome the electrical energy needs of the country, attention must be given to conserve energy used for heating purposes.

-Conservation Aspects in Heating

A reduction in heating energy use can be achieved by as: Control Over Theft Losses

Control over distribution losses in these areas will have more than 80% reduction in heating load.

-Energy Efficient Buildings

Existing residential buildings in Pakistan have no aspect of energy conservation resulting in large amount of energy wastage. A renovation in the existing building by providing insulation in various parts of building such as walls, roofs, windows can reduce the energy consumption for this purpose [15]. National Energy Conservation centre of Pakistan has introduced Building Energy Code of Pakistan (BECP) for all the five climatic zones providing maximum allowable limits for various factors that affect the energy use in buildings such as shading coefficient, solar factor, heat transfer coefficient and equivalent temperature difference [16].

A 50% reduction in energy use i.e. 0.575 TWh can be achieved by energy efficient building employing active/passive solar heating or energy efficient renovation (EER).

Air Conditioning

Air conditioning represents a good proportion of load among residential sub-sectors in summer which goes upto 3000MW [14]. Most of ac units are older, high power consuming window type having rated wattage of 2.2 KW although new energy efficient 1.7 KW split type are replacing them. Consumer pattern for air conditioning shows an average operating time of 6-8 hours for four months and normal setting temperature of $17\text{-}18^0$C. The energy consumption for air conditioning comes out to be 2.78 TWh for the year 2010-11[9].

-Conservation Aspects

Operation At Optimal Temperature

A reduction of 0.677 TWh can be achieved without affecting the comfort if all the ac units are operated at optimal temperature of 230C since a per degree rise in thermostat setting results in reduction of 5-7% of the energy use.

-Use Of Sensors

Sensors or controllers control the cooling output (BTU/hr) of ac units in the absence of occupants or reduction in number of occupants thus controlling the energy consumption. Use of sensors can reduce the energy consumption by 15-20%, i.e. 0.575 TWh/year.

Refrigeration

It consumed a share of 2.511TWh in the year 2010-11 in residential sector. Among various components, compressor units accounts for 90% of the total energy consumption. Thus, any improvement in the design of compressor unit will help in energy conservation.

-Possible Conservation

Energy Standards & Labeling

The government must introduce energy standards & labeling which will save approximately 1% [10] of the energy consumption i.e. 0.025TWh/year.

For economical operation, temperature of thermostat should be set on $36\text{-}40^o$F for refrigerator portion and on $0\text{-}5^o$F for

freezer area. A 20-25% more energy is consumed if thermostat is set 10^oF lower than needed and freezer is set 5^oF below the optimum settings.

Besides other measures such as ventilation and temperature setting, considerable amount of energy can be saved by replacing old inefficient units with energy star @ qualified units that consumes 20% less energy but that requires some investment [17].

Fans and Room Coolers

Fans and room coolers contribute a major share of 33% and 1% of the total electrical energy consumption accounting for 11.8404 TWH/year and 0.358 TWH respectively during the year 2010-11.

Fans used for domestic purposes are only 27% efficient [18]. According to comparative study conducted by CRCP in support with the Global Environment Facility (GEF/UNDP), it was noticed that all the existing fans tested didn't meet the efficiency standards. Moreover, 12.67 watts/8 hours extra energy is consumed by these fans [19].

-Energy Conservation

Since, efficiency of domestic fans is 27 %, which implies that 73% of energy is wasted.

Total wasted energy by fans= E_{W1} = 0.73* 11.8404 TWH
= 8.643492 TWH

According to [21], fans can be made more efficient up to 30% (i.e. 57% more efficient) by energy standard and labeling. So:

The total energy wasted will become:

E_{W2} = 43% of the total energy
= 0.43 * 11.8404 TWH
E_{W2} = 5.091372 TWH

Amount of saved energy = $E_W = E_{W1} - E_{W2}$
= 8.643492 – 5.091372
= 3.55212 TWH

Water Pumps

Per capita water consumption of Pakistan was 1,037m^3/year where the total water consumption was 183.5 Km^3/year in 2008 [20]. Except Karachi, Hyderabad and Islamabad, underground water is used for domestic purposes. Some additional energy is also used to pump this water to home's tanks at some height. Therefore, water conservation is as worth

A net reduction of 11.8TWh/year can be achieved upon implementing various energy conservation measures. In other words, 11.8 TWh of extra energy can be made available to consumers without affecting the socio economic life of the people. This would make availability of additional 1400 MW of power throughout the year which will result in approximately elimination of power outages in winter completely and reduction in duration of power cuts in summer.

as energy conservation [21], lesser the amount of water used, less energy will be consumed and more will be the energy conserved.

Out of the total electrified households of approximately 16 million, only 27% of households use motor pumps [22]. So:

Total number of pumps = 4.32 million (approximately)

Let's consider that all pumps used are of 0.5hp (i.e. 370 watts), and their minimum operating time is 1 hour per day, then energy consumption comes to be 0.583 TWh/year in 2010-11.

-Energy Conservation

Adoption of the following measures will help in reduction in energy use.

Energy Standards and Labeling

Current standard motors have an efficiency of 84.7% (US standard efficiency) and the best is 91.7% (US premier efficiency). Since all the motors in our country are below standard, let's consider they are 75% efficient. Then,

Losses, L_1 = 0.25 * 0.583 TWh
= 0.145Wh

If all the motor are made according to Energy Standards & Labeling having efficiency of 84.7%, the energy loss will be:

Losses, L_2 = 0.153 * 0.583 TWH
=0.089 TWh

Net energy conservation = L_1-L_2
= 0.145 – 0.089
= 0.0596 TWh/year

Sensor Based Water Devices

Automatic sensor based water taps, showers, etc. should be employed to meet water needs efficiently. These devices have already been employed in domestic sector of developed countries.

Rain Water Harvesting System

In rapid growing of population, water energy issue can be solved to some level by harvesting rain water at some reasonable sites and can be used for potable purposes like flushing toilets and gardening etc., bypassing complicated treatments and transportation processes [23].

IV. CONCLUSION

Besides helping in mitigation of electrical energy crisis and thus reducing load shedding to a greater extent, it will help in decreasing our dependence on furnace oil as well as help in reducing the amount of green house emitted from burning of fossil fuels in power plants.

Fig.3 represents the results regarding current energy use in various sections of residential sector, possible conservation and the energy requirement after implementation conservation techniques.

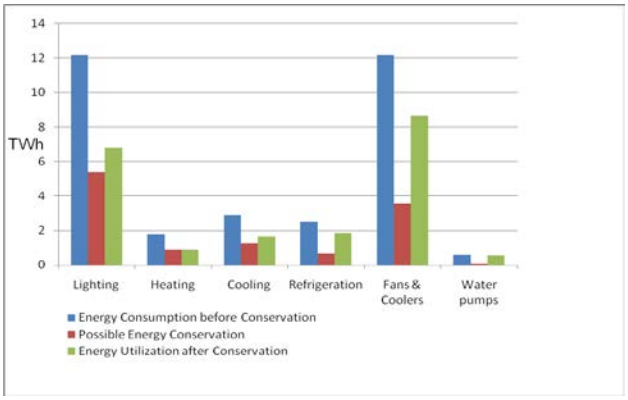

Fig. 3 Energy use, possible conservation and actual requirement

V. RECOMMENDATIONS

Besides installation of new power plants, the government must take the initative for energy conservation in all the subsectors with particular in residential sector since largest consumer of electricity.

- Complete phase out of the incandescent bulbs should be carried with immediate effect.
- Energy Standards & Labeling should be introduced and strickly followed.
- All the government buildings should be constructed according to Building Energy Code of Pakistan (BECP) to minimize energy use and the existing buildings should be renovated accordingly.
- A graeter portion of energy can be saved by creating awareness should among the people regarding energy use through media.
- People should make use of controllers with lighting fixtures and air conditioner rooms to reduce consumer bill as well as save energy.
- The use of air conditioners should be minimized or they be operated at moderate temperature to save energy.
- All electrical equipments should be switched off when not in use.

ACKNOWLEDGMENT

The author would like to thank to Managing Director ENERCON and staff members of Hydrocarbon Development Institute of Pakistan, Ministry of Environment, for extending their technical support throughout the research work.

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