Journal of Energy Research and Environmental Technology (JERET)
p-ISSN: 2394-1561; e-ISSN: 2394-157X; Volume 6, Issue 4; October-December, 2019; pp. 295-298

http://www.krishisanskriti.org/Publication.html

A Case Study on Energy Auditing of Residential Hostel Building of a University Campus

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Abstract—*With the growing awareness of the energy crisis, the need to conserve and manage the energy resources in a responsible manner is being increasingly felt by different sectors of the economy. In the present study an attempt has been made to evaluate the high energy consumption in the building sector and the imperative need to design the energy efficient buildings. In Deenbandhu Chhotu Ram University of Science and Technology, Haryana students hostel building has been selected for the present study. The case studies of four hostels of Indian Institute of Technology, Mumbai, Indian Institute of Technology, Kanpur, MLA hostel of Nagpur and of Cross River University of Technology, Nigeria comprising of different climatic zones has also been considered and existing study has been compared with the same. The energy auditing has been conducted by collecting energy consumption data for the last five years. The air-to-air thermal transmittance of the wall and the roof for the hostel room has also been computed and compared with recommendations prescribed by the Energy Conservation Building Code and Bureau of Indian Standard Code number 3792- 1978. Various application pertaining to the use of renewable energy sources has also been explored in the present study. It has been found that the existing solar water heater for the kitchen is saving energy for cooking. From the present study it can be recommended that energy auditing and replacing the normal electrical appliances with energy efficient devices will save 7591.39 kWh of energy per year after replacing with179 FTLs by Electronic ballast is considered to be a best alternative and proves to be cost effective and energy efficient.*

Introduction

Energy has become a critical factor for a nation’s economic progress and hence has become a key issue for all countries. With recent exponential increases in energy pricing, the formerly neglected or underestimated concept of energy conservation has swiftly assumed great significance and potential in cutting costs and promoting economic development, especially in a developing-country scenario. Energy efficiency is the technique of using less energy to provide the same level of energy service. The earliest provisions for energy efficiency for reducing fossil fuel consumption has cascading effects in reducing pollution and global warming. Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy-intensive solutions sought to construct a building and meet its demands for heating, cooling, ventilation, and lighting cause severe depletion of invaluable environmental resources. However, buildings can be designed to meet the occupant’s need for thermal and visual comfort at reduced levels of energy and resources consumption.

The energy conscious design approach helps designers and building owners to economically reduce building operating costs, while improving comfort for the building’s occupants. Appropriate combinations of these parameters lead to savings of energy required for maintaining healthy and comfortable indoor conditions. Investigations and studies being carried out by various researchers and investigators pertaining to energy efficiency has been studied and compared.

The major parameters being consider in various studies related to energy efficiency includes (i) climatic zones comprising of landform, vegetation, Water bodies, Street width with orientation, Open spaces and built form, (ii) Passive solar heating with efficiency or utilizable of 0.5 and 0.7, (iii) Mass effect comprising of summer along with night ventilation and winter seasons, (iv) Air movement includes physiological cooling effect (1 and 1.5 m/s), Evaporative cooling (direct and indirect), various design variables (solar control, glazing systems, insulating value, emittance value, frames and spacer, fenestration design and shading devices), ventilation (stack effect, induced ventilation effect) and day light. Similar studies has been carried out in the hostels of IIT Kanpur, Member of Legislature Assembly Nagpur, IIT Bombay, Cross River University of Technology Nigeria at different climatic zones, from the study it has been interpreted that energy consumption is increasing rapidly and this objective of making use of renewable source of energy as first preference and to conserve and efficiently utilize our scarce resources for identifying their savings potential. Based on available case studies and documents, various circumstances are taken to adopt renewable sources of energy in all aspects.

Moreover, the global energy scenario has undergone a drastic change in the last two decades. Due to ever growing demand

and shortage of supply, the cost of fossil fuel (coal, oil and natural gas) is increasing day by day. Increasing consumption has led to environmental pollution resulting in global warming and ozone layer depletion. Consequently, the era of fossil fuel is gradually coming to an end and the attention is focused on the conservation of energy and search for renewable sources of energy, which are environmentally benign. Buildings are major consumers of energy insofar as their construction, operation and maintenance are concerned. Building typology selected for the study is hostel because there is ample scope for energy savings.

The energy audit of the IIT-Kanpur hostels area was carried out by the members [1]. This report is just one step, a mere mile marker toward destination of achieving energy efficiency and have emphasize that an energy audit is a continuous process. This project is the vision to make IIT Kanpur hostels energy efficient. It is a fact that hostels of IIT Kanpur community uses a huge amount of energy. IIT Kanpur's energy bill keeps up around INR 9-10 crore per year. This amount is huge and thus naturally attracts attention that quite a lot of energy is being wasted, which in turn would mean that huge amount of financial resources is being wasted.

Also, energy audit assumes significance due to the fact that the IIT-Bombay electricity bill had crossed Rs. 10 crores during 2007, and it was aimed at obtaining a detailed idea about the various end use energy consumption activities and identifying, enumerating and evaluating the possible energy savings opportunities [2]. The target is to achieve savings in the electrical energy consumption to the extent of 20%. The audit was also aimed at giving the students a feel of the practical problems and difficulties in carrying out energy audits. As energy engineers, the students of the department enthusiastically participated in the endeavor. The energy consumption on campus is mainly in the form of electricity, apart from the use of LPG as cooking fuel in the hostels. MLA Hostel carried out detailed energy audit, during the month of June – July (2004) [3]. They carried out very, very elaborate measurements for the various areas like main transformers, pumps, streetlights, etc. and analyzed very critical the effectiveness of energy consumption, in each area.

Methods and Methodology

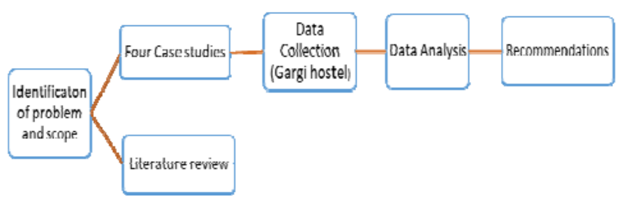


Fig. 1: Schematic representation of methodology used in present study

The proposed study has been carried out in the student's hostel of Deenbandhu Chhotu Ram University of Science and Technology, Haryana for data analysis of various electric appliances and for replacing them with energy efficient devices to neglect wastage of energy. Therefore, various parameters are considered to make the place energy efficient and schematic representation for the same is shown in Fig.1.

Various parameters determined in the present study includes climate analysis, thermal transmittance value using the data acquired in terms of energy usage or utilization in the selected hostel. The requirement of renewable appliances as an alternative has also been computed.

In climate analysis weather represent the state of the atmospheric environment over a brief period of time which helps the designer to build a house that filters out adverse climatic effects, while simultaneously allowing those that are beneficial. After studying the sun path of New Delhi, it has been found that region of student's hostel lies in composite zone as shown in Fig. (2).

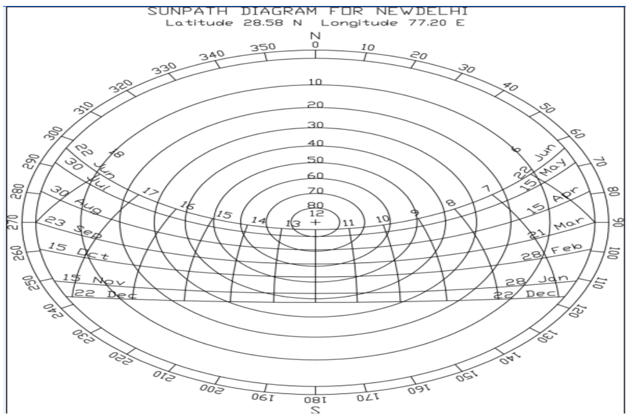


Fig. 2: Sun path Diagram of New Delhi

Thermal transmittance incorporates the thermal conductance of a structure along with heat transfer due to convection and radiation. The value of thermal transmittance can be calculated by using a U-Value factor that measures the rate of heat loss through a material [4].

For walls the U -value as shown in fig. 3(a) can be calculated by using Eq. (1).

$U=1/R=1/0.415=2.409 W/m^2K$ (1)

where, U= thermal conductivity of a given material, R= resistance to heat flow through a given thickness of material For roof section the U-value as shown in fig. 3(b) can be calculated by Eq. (2).

$U=1/R=1/1.176=0.850 W/m^2K$ (2)

where, U= thermal conductivity of a given material, R= resistance to heat flow through a given thickness of material

Data for energy consumption for various electrical appliances were recorded and five years data were analyzed

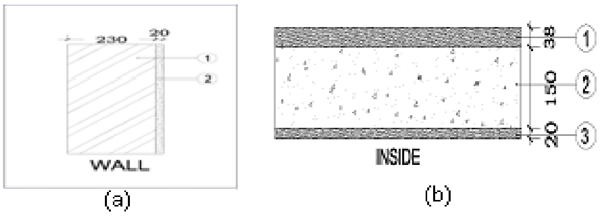


Fig. 3: Value of thermal conductance on (a) Walls (b) Section of roof

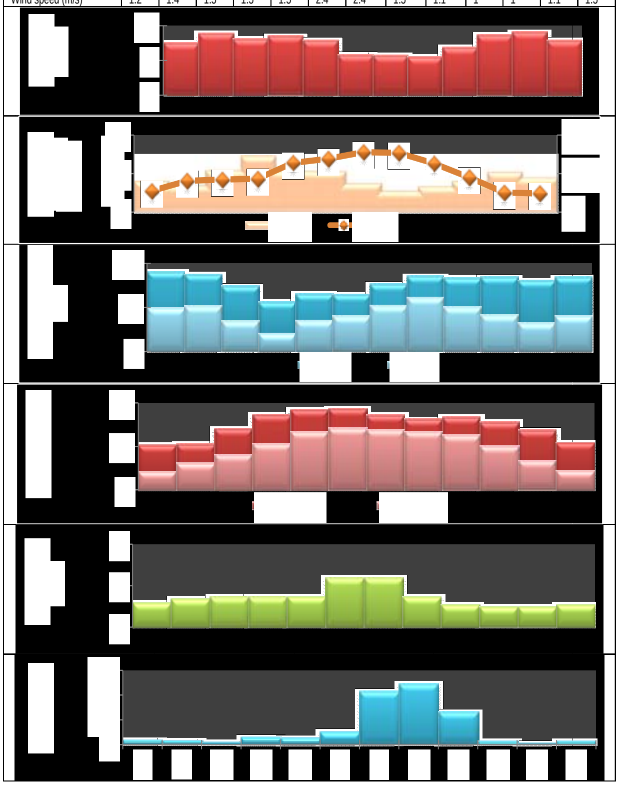
Results and Discussions

From the present study it has been executed that climate plays a pivotal role in determining the design and construction of a building. In the student's hostel of DCRUST, Haryana situated near Delhi has composite climate. After executing the study, it has been computed that intensity of solar radiation is very high in summer with diffuse radiation amounting to a small fraction of the total. In monsoons, the intensity is w with predominantly diffuse radiation. The maximum daytime temperature in summers is in the range of 32 – 43 ºC, and night time values are from 27 to 32 ºC. In winter, the values are between 10 to 25 ºC during the day and 4 to 10 ºC at night. The relative humidity is about 20 – 25 % in dry periods and 55 – 95 % in wet periods.

The presence of high humidity during monsoon months is one of the reasons why places like New Delhi and Nagpur are grouped under the composite and not hot and dry climate. Precipitation in this zone varies between 500 – 1300 mm per year. This region receives strong winds during monsoons from the south-east and dry cold winds from the north-east. In summer, the winds are hot and dusty. The sky is overcast and dull in the monsoon, clear in winter and frequently hazy in summer. Composite regions experience higher humidity levels during monsoons than hot and dry zones. Various data has been analyzed on the instant of every month and various factors have been studied like rainfall, sunshine hours, relative humidity, wind speed, variation in temperature and mean solar radiation. These variations are compared with an instant of a month as shown in Table 1.

Table 1: Monthly variation of climatic data (source)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Mean sunshine hours	7.6	9	8.2	8.6	8	5.9	5.8	5.6	7	8.8	9.2	8	7.6
Cloud cover	28	20	32	33	41	58	57	43	43	23	14	23	34.58
Solar Radiation Daily Avg. (Wh/M²)													
Direct	4059	3528	5501	7363	5396	5350	3780	2778	3361	4040	5263	4540	4580
Diffuse	1100	1621	1684	1729	2563	2764	3117	3082	2529	1802	1012	966	1997
Relative humidity (%)													
Maxm. (RH)	91	88	75	57	66	65	77	86	84	85	81	85	78.3
Minm.(RH)	50	52	35	21	36	41	53	62	51	42	33	41	43.1
Air Temperature (°C)													
Maxm. (DBT)	20.9	21.4	28.4	34.9	37.1	37.7	34.6	32.7	33.7	31.4	27.7	22.1	30.2
Minm (DBT)	8.7	12.5	16.5	21.5	27.1	28.7	27.9	27.1	25.4	20.3	13.8	9.1	19.9
Mean (DBT)	14.8	17	22.5	28.2	32.1	33.2	31.3	29.9	29.6	25.9	20.8	15.6	25.1
Thermal neutrality	22.6	23.4	25.5	27.7	29.2	29.5	28.9	28.4	28.2	26.8	24.9	22.9	25.4
Upper limit	24.6	25.4	27.5	29.7	31.2	31.5	30.9	30.4	30.2	28.8	26.9	24.9	27.4
Lower limit	20.6	21.4	23.5	25.7	27.2	27.5	26.9	26.4	26.2	24.8	22.9	20.9	23.4
Precipitation (mm)	18.9	16.6	10.8	30.4	29	54.3	216.8	247.6	133.8	15.4	6.6	15.2	795.4
Wind speed (m/s)	1.2	1.4	1.5	1.5	1.5	2.4	2.4	1.5	1.1	1	1	1.1	1.5



U-values for walls have been compared for brick, plaster and inside film of the wall with their physical and electrical properties as shown in Table 2.

Table 2: U-values for wall

Element	Thickness (m)	Conductivity (W/mk)	Resistance(m²k/W)
Outside Film			0.1
(i) Brick	0.23	1.21	0.165
(ii) Plaster	0.02	2.721	0.027
Inside Film			0.123
		Total	0.415

Also, U-values for the roof of the hostel has been calculated and compared with their physical and electrical properties from which resistance has been calculated to provide a hostel building energy efficient as shown in Table 3.

Table 3: U-values for section of roof

Element	Thickness	Conductivity(W/mk)	Resistance (m^2k/W)
Outside Film			0.44
1.Concrete	0.15	1.44	0.104
2.Plaster	0.38	0.721	0.522
Inside Film			0.105
		Total	1.176

Now, the U-values for the section of roof and wall have been compared with the standard energy and building codes (EBC and BIS) as shown in Table 4.

Table 4: Comparison of U- values

	ECBC (2010)	BIS 3792 (1978)	GARGI
MAX. U- Factor (Roof)	0.261	2.33	0.850
Max.U- Factor (Wall)	0.440	2.56	2.409

*ECBC [5] (Energy and Building codes), BIS [6,7] (Bureau of Indian standard)

The energy used in buildings can vary greatly depending on the behavior of its occupants. It is therefore necessary to understand the various types of loads on a building in order to design an energy efficient building. Replacing electromagnetic ballast of 179 FTLs by Electronic ballast in all the rooms can save 7591.39 kWh of energy per year. The electronic ballast provides proper starting and gets on very fast than the electromagnetic ballast. Because of the higher efficiency of the ballast itself and the improvement of lamp efficacy by operating at a higher frequency, electronic ballasts offer higher system efficacy for low pressure lamps like the fluorescent lamp.

Further it can be recommended that replacing incandescent bulbs in the bathrooms by CFL and replacing rheostatic speed regulators of 174 fans in the student rooms and mess with electronic speed regulators will save around 2596.08 kWh of energy per year. With electronic speed regulators not only, the fan rotates smoothly but also there is negligible heat dissipation. Normal fan speed regulators use resistance for controlling the speed whereas the electronic speed regulator uses the voltage regulator which changes the input voltage to the fan thereby changing the speed of the fan.

However, installing solar water heaters in all hostels and installation of biogas plant for food waste processing of 21.2 kg and horticulture waste of 14.56 kg per day will reduce consumption of LPG cylinders. Looking for natural lighting opportunities through windows a committee should be set by the University whose terms of reference will be solely on energy management. Purchasing energy at the most economical price through fuel selection and altering schedules to take advantage of our utility's rate structure and assess the scope for more energy efficient lamps and luminaries. Involvement of training staff and teaching all employees to identify ways to save energy through maintenance, optimum usage of day lighting should be adopted and various operational improvements throughout the university can be done. Energy saving accessories can be installed to replace the old high energy consuming ones.

Conclusions

From the present study, it can be concluded this proves to be a mere mile marker towards the destination of achieving energy efficiency of a hostel. Energy auditing on regular basis should be done for university and educational institutes that helps in maintaining the proper energy usage and maintenance of energy equipments. The study further confirms that primary source and secondary sources are required to be controlled in order to improve the energy efficiency of a hostel. The compiled possible actions indicate to conserve and efficiently utilize our scarce resources and identified their savings excessive energy usage. This energy saving usage will be advantageous in terms of economy as well as saving of energy will be helpful in reducing the burden on environment.

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