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Auditing and Analysis of Energy Consumption of a Hostel Building

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Authors' contributions

This work was carried out in collaboration among all authors. Author BSM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SV and BSN managed the analyses of the study. Author GG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The Energy Auditing is the key to the utilization which balance out the circumstance of energy crisis by providing the conservation schemes. The accompanying paper has been set up so as to encourage our comprehension of the energy consumption pattern of the Residence of hostel building in Agricultural Engineering College and Research Institute, Trichy. In the hostel, most of the energy usage spent on enlightenment and cooking purpose by the means of electricity and Liquefied Petroleum Gas (LPG). The accompanying paper presents the identification of zones of energy wastage and estimation of energy sparing potential in the hostel which has been made by walk-through energy Audit. Likewise, a detailed examination of data gathered is done by recommending cost-effective measures to improve the efficiency of energy use. Estimation of implementation costs and payback periods for each recommended action has been made. Based on the analysis of auditing exercise, some recommendations were suggested to reduce the electric energy consumptions which can reach up to 49.8%. The LPG for cooking can be partially reduced by implementing a steam cooking system in the hostel. The results will be beneficial for the operation and maintenance team to manage electrical and LPG usage and reduce the hostel overall expenditure.

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Keywords: Energy audit; energy utilization; energy conservation; payback period.

1. INTRODUCTION

The Directive 2010/31/EU indicates that the public sector should lead the way in the field of energy performance of buildings and the national plans should set more ambitious targets for the buildings occupied by public authorities [1]. Energy consumption management is a difficult task and grown a lot of attention throughout the last several decades. In India, the residential and public sectors command the most noteworthy portions of energy consumption, hence, these segments need attention for energy auditing and energy conservation measures [2]. At present 8-10% of the entire electricity generation in India is consumed by commercial building and the demand for electricity in the commercial sector is raising yearly by 11-12% [3]. The schools and university hostel buildings have high energy consumptions and need to be rehabilitated [4]. One significant reason behind this is the decision-makers' lack of knowledge of potential energy saving measures [5]. Because of this lack of knowledge, in many times systems and equipment were chosen regardless of their energy use or effect on the operational expenses. Energy conservation is regarded as an effective measure to cater this problem and is observed to be achievable too [6]. The optimal use and reduction of energy consumption hold more importance as compared to adding more in the generation mix [7]. The optimization of energy is merely impossible without conducting an energy audit. The process of Energy Audit focuses on the overall consumption of energy in the building [8].

Ideal energy management practices, however, improves the energy savings, when applied with precise measurement and verified techniques. The precise estimation and storage of operational data and proper schedule of the different processes are prior actions in energy saving [9]. Investing to improve the energy efficiency of buildings provides an immediate and relatively predictable positive cash flow resulting from lower energy bills [10]. Energy auditing has been found useful in studying building energy performance, and energy consumed by diverse equipment's in the building [11]. The detailed energy audit contains complete recording and analysis of energy consumption, by sector during a long and representative time span [12]. Alajmi, [13] conducted an energy audit in two story building, after audit assessment and proper implementation of recommendation he found that energy saving of up to 49.3% yearly with a simple payback period of fewer than six months. In this study hostel building, namely Agricultural Engineering College and Research Institute located in the Trichy district is investigated to analyze the energy utilization pattern. The detailed energy audit was carried out in equipment wise and possible recommendations with simple payback period are illustrated.

2. MATERIALS AND METHODS

2.1 Building Location

The Agricultural Engineering College and Research Institute, Trichy, hostel spread over an area of 1900 m^2. Which consists of two separate buildings of postgraduate and undergraduate students respectively. The undergraduate hostel is a two-storey building (Fig. 1) accommodating 120 students and located at the western part of campus. It has a total area of 1300 m^2. The hostel having a total of 46 residence rooms. Each room has a 2 tube light & a single ceiling fan and 4 toilets at the corner of the hostel with common mess with dining hall provided at the right corner of the hostel. The postgraduate hostel is a two-storey building (Fig. 2) accommodating 20 students and located at the left corner of the undergraduate hostel. It has a total area of 240 m^2. The ground Flore is used for recreational purpose viz, indoor gaming with attached tv hall.

2.2 Energy Audit Methodology

An energy audit is a technique to predict operating difficulties and optimize the energy consumption of resident's buildings without satisfying comfort [14]. As per Energy Conservation Act, 2001 an energy audit is defined as "The authentication, monitoring and examination of the use of energy including a plan of technical report containing a recommendation for improving energy efficiency with a cost-benefit breakdown and action plan to reduce energy consumption" [15].

2.2.1 The proposed energy audit is done in three phases comprising

Finally, some researchers developed tools that support local administrators to assess the energy performance of educational buildings through simple data input and to identify the most convenient energy efficiency measures easily [16]. Jain [17] conducted energy auditing of commercial building by following equipment-wise consumption pattern. The steps followed in energy auditing methodology is described below.

1. Data Collection – In primary data assortment stage, comprehensive data assortment was performed utilizing various apparatuses, for example, perception, talking with key people, and estimations.

2. Data Analysis - Detailed analysis of the data gathered was done. The database generated during analysis was used for producing graphical representations.

3. Recommendation – Based on the results of data analysis and observations, some steps for reducing power consumption without affecting the comfort and satisfaction were recommended along with their cost analysis.

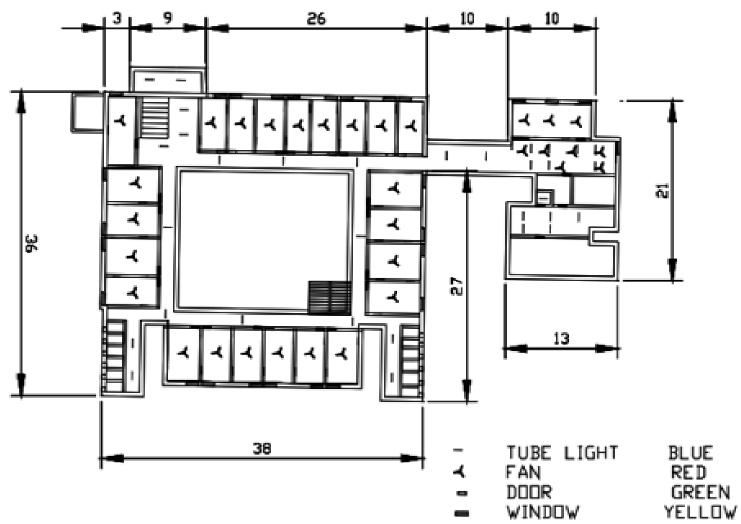

Fig. 1. Layout of an undergraduate hostel

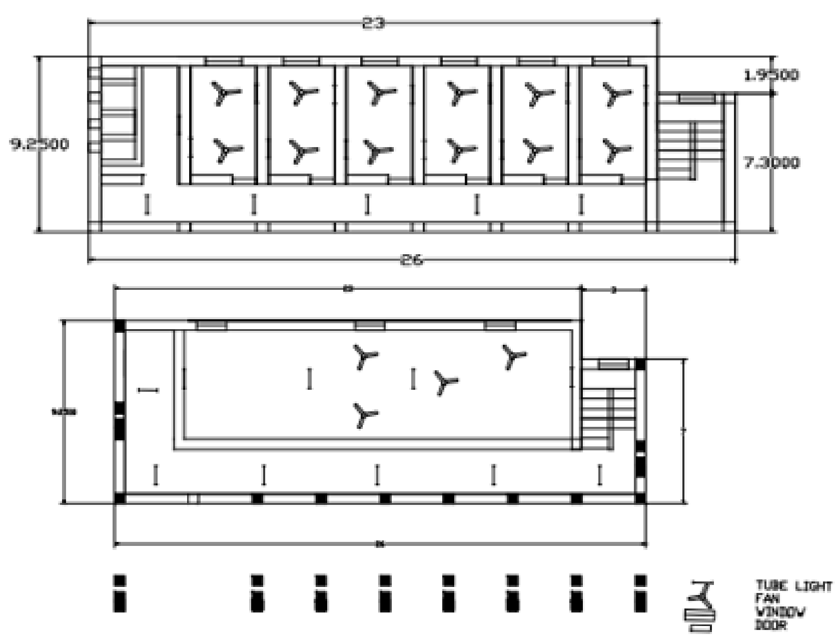

Fig. 2. Layout of postgraduate hostel

2.2.1.1 The methodology adopted for audit

1. Visual survey of specific area
2. Visual inspection and data collection
3. Observations on the general condition of the facility and equipment and quantification
4. Identification/verification of energy consumption and other parameters by measurements
5. Detailed calculations, analyses and assumptions
6. Validation
7. Potential energy saving opportunities
8. Implementation

The audit methodology mainly focuses on recorder data of energy consumption of building service system. The collected data is used to diagnose the weak points of the building energy-usage system, tap latent power and then a detailed energy audit study are presented. By conducting an investigation of the energy consumption, the energy audit focuses mainly on the equipment consumption, especial on lighting system, electronic equipment's, fan and miscellaneous items.

2.2.1.2 Energy audit instruments used

The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. Some of the key instruments used in energy audit are lux meter, Infrared thermometer, Tachometer, Leak detector etc. As per availability and requirement in this audit, researcher used lux meter for measurement of light Illumination levels.

2.2.1.3 Payback period

The payback period is characterized as the amount of time required to recover the original investment [18]. If all components being held steady, project with a shorter payback period is considering as better project since the investor can recoup the capital invested in a shorter period of time [19]. The payback period is calculated by using formula 1 [20].

$$T = \frac{\Delta K}{\Delta \text{э}} \tag{1}$$

Where,

T = payback period (years)
ΔK = capital investment (Rs)
Δ э = net annual cash inflow (Rs)

3. RESULTS AND DISCUSSION

3.1 Energy Consumption Pattern

The detailed energy consumption pattern of hostel building is measured thoroughly, by using reference bills and measuring instruments. Each measurement is described below.

3.1.1 Annual electricity consumption pattern of hostel

Annual electricity consumption pattern of the hostel is shown in Fig 3. The total yearly energy consumption is 41.2 MWh with an average per capita energy consumption is 380 KWh. Electricity is used for meeting the requirements of lighting, fans, water coolers, pumps, computers, and other specific requirements hostel mess. The monthly electricity consumption details for the past 12 months were collected to study the variation in energy consumption over a period of one year. It can be summarized in Table. 1.

The average annual electricity consumption between May 2016 and April 2017 period has to be 41.2 MWh. From Fig. 3. it is evident that electricity requirement is substantially increased during the summer due to the increased need for running cooling devices such as fans and water coolers.

3.1.2 Location wise power consumption analysis

The location wise distribution of power consumption in the hostel has been illustrated below Fig. 4. From the Fig. 4, it is evident that major power consuming areas are residence rooms and mess. Residence rooms with 50% share in power consumption are a very important area to focus on improving the energy efficiency of the hostel.

3.1.3 Equipment wise analysis of power consumption

Equipment wise analysis has been done in order to identify the equipment's, energy consumption pattern within the same application area, which consumes more power as compared to others.

The Table. 2 summarizes the results of equipment wise analysis of power consumption of hostel in kW/h.

3.1.4 Energy usage in hostel kitchen

The hostel having common mess system for both undergraduate and postgraduate students. The hostel has a demand of approx. 20 – 23 LPG cylinders per month, each cylinder weighing 19 kg, approx. 418 kg of LPG gas required per month with an annual demand of approx 5016 kg.

3.2 Audit Energy Load

3.2.1 Audit of lighting load

To determine the total lighting load, a physical count of the number of light fixtures provided in different floors and sections of the building was carried out. It was found during the survey that mainly 40 W T12 tube light, 36 W T8 tube light and 20 W compact fluorescent lamps have been used in the building. An accurate digital Lux Meter was used to measure the illumination level at various sections of the building. The measured data are summarized in Table 3.

3.2.2 Audit of fan

It was found during the survey that, the hostel having total 71 number of fans with a rated power consumption of each fan is 60 W. Further it is found that there is two number of inefficient exhaust fans used in the kitchen. The innventory of fans are shown in Table 4.

3.2.3 Audit of gadgets and laptop load

After a complete examination of all the rooms, it was found that approximately 95 students using a laptop and almost all students using mobiles, during the survey it was found that 123 mobiles are used in the hostel. Approximate duration of using laptop comes out to be in between 3-4 hours/day, but most of them don't switch off the laptop when there is no need.

3.3 Cost Benefit Analysis and Payback Period

After a complete analysis of audit data, it was found that there are a number of ways in which the present situation may be improved. By following cost benefit analysis and payback period.

3.3.1 Replacing Fluorescent Tube Light (FTL) with Light Emitting Diodes (LED) tube light

The dominant light source at most places in the hostel is traditional 40 W FTLs with conventional Ballast (Choke) which consumes 40 W/h. If this conventional Ballast (Choke) is replaced by T8 LED tube light 16 -18 W power can be saved per tube light.

3.3.2 Replacing existing fans into energy efficient DU bush less superfan

Another important energy consuming equipment in the hostel is the fans installed for cooling and ventilation needs. At present, there are 71 inefficient fans used in hostels. Most of the fans are installed with resistance regulators. After the measurement, it was found that each existing fan consuming 60 W/h power. Energy efficiency can be improved by replacing the existing ceiling fan with 5 star rating (BEE) energy efficient DU Bush less super fan. A saving of 27-30 W/h per fan can be obtained by replacing the existing ceiling fan with 5 star rating (BEE) energy efficient super fan.

Table 1. Month wise energy consumption at hostel

Sl. No	Month	Energy consumption (kWh)	Electricity consumption charges (Rs)
1	May - Jun - 2016	6440	38339
2	Jul - Aug - 2016	6410	38167
3	Sep - Oct - 2016	6040	36039
4	Nov - Dec - 2016	7580	45115
5	Jan - Feb - 2017	6830	40803
6	Mar - Apr - 2017	7980	50115
	Total	41280	248578
	Average	6880	41430

Reference: Tamil Nadu Electricity Board (TNEB), 2016-17

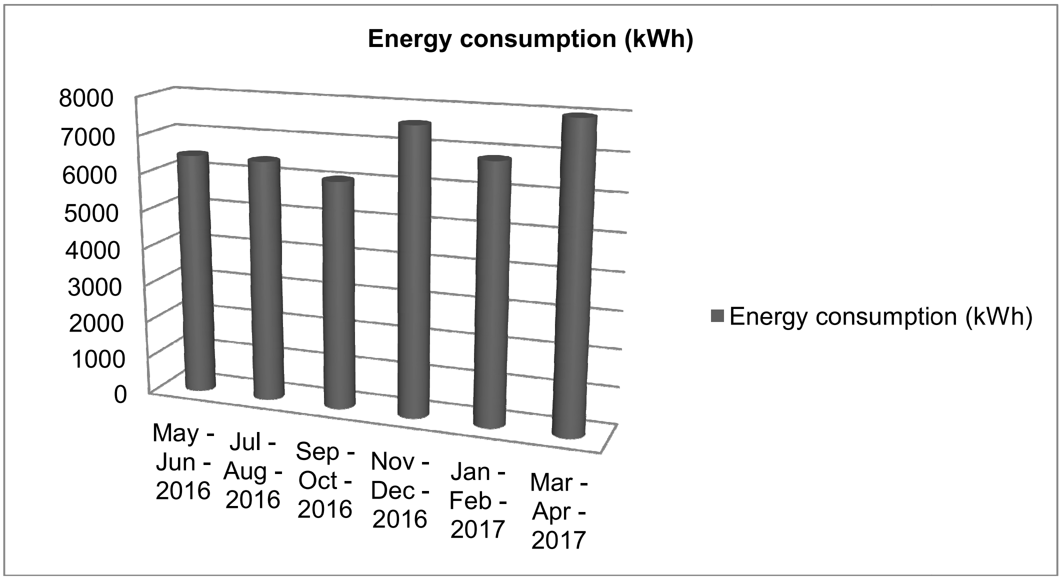

Fig. 3. Month wise electricity consumption at hostel

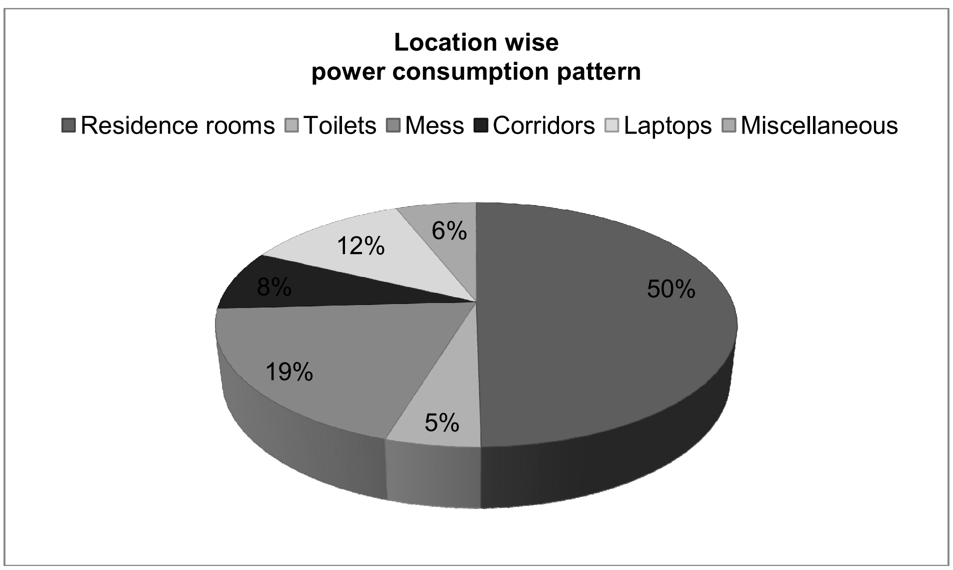

Fig. 4. Location wise power consumption pattern of hostel

3.3.3 Installation of solar PV power system at hostel

Since last 25 years, the hostel mainly depends on electrical energy for all the energy need. The average annual electricity consumption is to be 41.2 MWh, which is billed at an average of Rs. 250000/Annum. The best possible way to reduce or completely eliminate the use of electricity is to be installing solar PV power system.

3.3.4 Implementation of motion sensors in toilets and corridors

The large quantity of energy could be saved by using an automation system in toilets and corridors. According to the movement in the corridors and toilets, motion sensors should switch on or switch off the light. This can greatly reduce the total load in corridors and toilets.

Table 2. Equipment wise analysis of load

Sl. no	Item	Quantity (No)	Load per item (Watts)	Total load (kW/h)
1	Lighting			
	1.T 8	95	36	3.42
	2.T12	79	40	3.16
	3.CFL	36	20	0.72
2	Fan	70	60	4.20
	Laptops	95	50	4.75
3	Mobiles	123	04	0.49
4	Kitchen appliances			
	1. Grinder- 10 L	1	746	0.746
	2. Grinder- 5 L	1	373	0.373
	3. Mixer grinder	1	550	0.55
	4. Exhaust fan	2	60	0.12
5	Refrigerator	1	200	0.2
6	Water purifier	1	70	0.07
7	Miscellaneous			
	1.TV	1	110	0.11
	2.Wifi box	1	20	0.02
	3.Pesto flash	1	15	0.015
	Total connected load			18.95

Table 3. Lighting inventory and illumination level measurement

Sl. No	Location	T12	T8	CFL	Illumination Levels (Lux)
1	Rooms	43	57		90
2	Cooking Area	5	4		115
3	Dining Hall	6	6		85
4	Toilet	1	8	28	95
5	Verandah	18	15		80
6	Reading Table		03		60

Table 4. Fan inventory

Sl. No	Particulars	Values
1.	Total number of fans (Numbers)	71
2.	Number of fans in residence rooms (Numbers)	55
3.	Number of fans in mess (Numbers)	12
4.	Rated power of each fan (W)	60
5.	Number of exhaust fans in cooking area (Numbers)	2
6.	Rated power of exhaust fan (W)	60

3.3.5 Recommendation for gadgets and laptop load

Energy consumption by gadgets and laptop can be reduced by spreading energy conservation awareness among students and hostel staff. Regular inspection of hostel buildings is required and imposing a fine on defaulters is another effective option.

3.3.6 Replacing LPG gas stove cooking into steam cooking

Energy consumption for cooking in boy's hostel mainly depends on LPG energy source. Hostel mess is working throughout the year. The hostel has a demand of approx 20 - 23 LPG cylinders per month, each cylinder weighing 19 kg, approx 418 kg of LPG gas required per month with an annual demand of approx 5016 kg. At present each cylinder cost about 1515 Rs inclusive of all taxes and delivery charge. So annually 399960 ~ 400000Rs billed for LPG energy.

The best possible way to reduce the use of LPG is to be replacing LPG gas stove cooking into the steam cooking system. The college campus having abounded natural source in the form of firewood. Proper maintenance of trees in the form of pruning is essential for better growing of trees. This pruning parts can be successfully used for steam cooking purpose in the form of intake fuel for steam boiler. By implementing steam cooking we can reduce the use of LPG and also effectively utilize the natural resources available on the campus.

3.3.7 Replacing normal cooking vessels into presser cookers

In the hostel, conventional aluminium vessels are using for cooking purpose. These vessels are inefficient in energy consumption and need more cooking time. It ultimately consumes more energy for cooking, as a result, it's directly affect the cost of energy usage. Energy efficiency can be improved by replacing the existing vessels with efficient pressure cookers.

Table 5. Cost benefit analysis of lighting load

Sl. no	Particulars	Values
1.	Total No. of conventional Ballast FTLs in hostel	174
2.	Average Power consumption of conventional Ballast FTL (W/h)	40
3.	Average Power consumption of LED (W/h)	18
4.	Power saved per FTL (W/h)	(40 - 18)W/h = 22
5.	Total Power consumption of LED (kW/h)	174 × 18 = 3.132
6.	Average Use of LED per day (h)	6.5
7.	Average Use of LED per year (h)	365 × 6.5 = 2375
8.	Total Energy consumption per year (kWh)	3.132 × 2375 = 7438.5
9.	Net annual cash inflow (Total Energy consumption per year × cost per unit of electricity/Local Tariff)	7438.5 × 6 = Rs 44631
10.	Average Cost of Replacing each FTL into LED	Rs 500
11.	Initial investment	174 × 500 = Rs 87000
12.	Payback period in years (years)	87000/(44631) = 1.95

The simple payback period for replacing all conventional Ballast (Choke) FTLs of the hostel into LED tube light is 1.95 years

Table 6. Cost benefit analysis of fan

Sl. no	Particulars	Values
1.	Total number of fans in hostel	71
2.	Average power consumed by each fan (W/h)	60
3.	Average power consumed by each super fan (W/h)	28
4.	Average utilisation of fan in a day (h)	10
5.	Average utilisation of fans in a year (h)	365 × 10 = 3650
6.	Total Power consumption (kW/h)	71 × 28 = 1.988
7.	Total Energy consumption per year (kWh)	3650 × 2.272 = 7256.2
8.	Net annual cash inflow (Total Energy consumption per year × cost per unit of electricity/Local Triff)	7256.2× 6 = Rs 43537.5
9.	Expenses should be spent replacing one fan into super fan	Rs 3500
10.	Total expenditure in replacing all existing fans	71 × 3500 = Rs 248500
11.	Resale value of existing fan	Rs 200/fan
12.	Total Resale value of all existing fans	71 × 200 = Rs 14200
13.	Initial investment	248500-14200 = 234300
	Payback period (years)	(248500 -14200)/43537.5 = 5.38

The payback period for replacing existing fans into superfan is 5.38 years. Hence, this would reduce the consumption of power in a large portion

Table 7. Cost benefit analysis of solar power installation

Sl. no	Particulars	Values
1.	Total Power load demand (kWh/day)	115 × 1.3(discharge loss) = 150 kWh/day
2.	Total PV module capacity	150 kWh/6 h (Max expected sunny hours per day) = 25 kW
3.	PV module capacity	250 kWp
4.	No. of solar panels need	25 kW/250 W (Max output of each solar panel) = 100
5.	Size of solar inverter (maximum conveyance of load at any instant)	18.95 ~ 20 kW
6.	Batteries (200 Ah × 12V)	Load/ voltage × 0.8 (Battery efficiency) = 150 kW/12V × 0.8 = 15625Ah (40 batteries of 400Ah × 12V capacity required)
7.	Total space required (m^2)	100 m^2
8.	Initial Investment (Rs)	19,50,000
9.	Life span of system (years)	25 - 35
10.	Net annual cash inflow (Rs)	2,50,000
11.	Payback period (years)	19,50,000/2,50,000 = 7.8 Years

The payback period for installing a solar power system in the hostel is 7.8 years. Within 7.4 years the investment should be recovered successfully. After 7.4 years and up to remaining period 17.2 years system will produce power with free of cost with little periodic maintenance

Table 8. Cost benefit analysis of motion sensor installation

Sl. no	Particulars	Values
1.	Average number of tube lights in a corridor & toilets	40
2.	Average power consumption of the tube light (W)	36
3.	Average number of motion sensors required (10 corridors and 4 toilets)	14
4.	Average reduction in usage per day by motion sensor (h)	4
5.	Total energy saved in corridor per year (kWh)	(40 × 4 × 36 × 365)/1000 = 2102
6.	Saving in Rs. Per year	2102 × 6 = Rs 12612
7.	Cost of installation per motion sensor	Rs 2100
8.	Total cost of installing motion sensors in a corridors	2100 × 14 = Rs 29400
9.	Payback period (years)	29400/12612 = 2.33

The payback period for installing motion sensors in corridors & toilets is 2.12 years. It would reduce energy consumption in a considerable quantity

3.3.8 Replacing inefficient kitchen appliances

In hostel, they using old inefficient, manual defrosting type refrigerator, its consuming 4.8 kWh energy per day. So its need to replace existing refrigerator into 5 star rating, energy efficient, self-defrosting refrigerator for saving energy.

3.3.9 Creating awareness among workers & students

Most of the workers in a hostel not aware of the importance of energy and conservation of energy. It is better to create awareness among workers to prevent possible way of energy wastage. For this purpose, proper orientation should be necessary for workers.

4. CONCLUSION

The prime objective of the paper is to put light on the energy saving potential available by taking appropriate measures in the sector of education. The energy audit is an effective technique to measure, evaluate, analyse the building energy consumption pattern and doing retrofitting on the resulting recommendations reduces the energy consumption of the building together with the cost of electricity bill without compromising the comfort. The brief finding of the paper is presented here. The annual electric energy consumption during the period May - 2016 to Apr - 2017 is 41280 kWh. The possible savings by replacing conventional FTL bulbs into LED bulbs are 20551 kWh of electricity which comes to about 49.8% reduction in electricity consumption per year and monetary savings of Rs. 1.245 lakh. If the solar power system is implemented, 100% of electrical energy is saved. The investment required for implementing the proposed solar power system measures is Rs. 19.5 lakh with a simple payback period of 7.8 years. By installing motion sensors in corridors and toilets will reduce the electricity consumption about 2102 kW/year with a simple payback period of 2.33 years.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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