Energy Efficiency Analysis And Auditing Of Ethiopian University Buildings: Case Of Buildings In Arba Minch Institute Of Technology

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Abstract: In this paper, the results of the energy audit of buildings in Arba Minch Institute of Technology (AMIT) are presented. The objective of the study was to identify the energy lossy applications, activities and traditions and to suggest the least costly energy conservation mechanisms. All functional lighting systems, office equipment, desktop computers and water fixtures (showerheads, dishwashers, toilet flushers and hand washers) are taken into consideration for the study. Increased energy consumption due to daytime operation of lighting systems, inactive mode operation office equipment and desktop computers and poor water management practices were the focus of the study. Based on the audit results, poor water management practice in the campus contributes the most to the total energy loss followed by the inactive mode energy consumption of desktop computers and daytime operation of outdoor lighting systems. Therefore, a significant amount of energy can be saved by practicing regular maintenance of water fixtures and pipes in the campus. Moreover, awareness creation campaign can help a lot in reducing the energy loss, which could be resulted from inactive mode energy consumption of computers and daytime operation of lamps. Installation of electronic day light control and motion detection systems can be potentially used to reduce the energy consumption of lighting systems operating in the daytime and in class rooms and halls both in the day and night time respectively.

Keywords: energy auditing, lighting systems, office equipment, desktop computers, water management, energy conservation measures, awareness creation

1 INTRODUCTION

Electrical energy is the necessity for the economic development of any country. Many functions in our present day living will stop when the supply of energy stops. The energy used per person has a close relationship with the standard of ones living. In Ethiopia, energy consumption has increased very rapidly in the past few years due to the economic development of the country and the increasing population. In order to meet the ever-increasing demand for electric energy, the government of Ethiopia is constructing huge hydroelectric power plants and alternative energy sources; however, part of the energy generated is lost on not only the transmission and distribution systems but also at the utilization level. As the present industries and public institutions are still using high-energy consuming obsolete equipment, a significant portion of energy is lost at the utilization level. System losses are calculated to be 23%. This figure represents both technical and nontechnical losses and a major share is attributable to the poor design of the distribution network [1]. Ethiopia does not have legislation or mandates in place to incentivize utilities or public entities to invest in energy efficiency, however, the Ethiopian Electric Utility (EEU) has made an effort to increase energy efficiency among its consumers.

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Through its demand side management program, EEU required industries to raise their power factors to 0.95 to avoid being penalized and distributed about ten million compact fluorescent lamps (CFLs) in the last three years replacing inefficient incandescent lamps. In fact, at present incandescent lamps are completely banned from import in Ethiopia [1]. In addition, a number of financial, behavioral, technical and organizational barriers to energy efficiency prevent companies from undertaking investments and actions [1].On the other hand, the culture and technology of energy utilization in the country is poor as the awareness towards energy loss during utilization is insufficient. Because of lack of awareness in the community and low economic level, the cheapest but energy intensive electric/electronic, appliances are purchased for home or office uses. Arba Minch Institute of Technology is one of the six campuses of Arba Minch University located in Arba Minch town, Ethiopia. The Institute hosts more than 11,000 engineering students. The campus gets electrical power from Arba Minch Substation via 15kV MV line. More than 95% of campus activities rely on electricity. Electricity is used for lighting, cooking, water pumping, air conditioning and supplying office appliances like printer, copy machine, scanners, computers, etc. In offices, employees are reluctant in the utilization of energy. Office appliances (computers, printers, photocopy machines, scanners, etc.), fans, lamps or air conditioners are left operating or plugged in to the power supply during the night even sometimes for weekends, which greatly contributes to the inactive mode energy consumption of office equipment. Moreover, there is a significant amount of water leakage here and there associated with broken water fixtures (showerheads, dishwashers, hand washers and toilet flushers) in student and staff residences and pipes; which in turn brings about unintentional additional energy consumption by the pumps. These activities and traditions increase the wastage of energy, the energy that is spent for doing nothing, which results in extra energy bills against the institution. In recent days, campus energy audit has been conducted in several

colleges and Universities. The energy audit of the IIT-Kanpure Hostels area was conducted [2]. They looked forward with optimism that the institute authorities, staff and students shall ensure the maximum execution of the recommendations and the success of their work. In IIT Roorke an energy audit has been conducted to seek opportunities to improve the energy efficiency in the campus [3]. Reduction of energy consumption while maintaining or improving human comfort, health and safety were of primary concern. Moreover, some daily practices relating common appliances have been provided which may help reducing the energy consumption. A sincere attempt has been made to conduct the energy audit at Nandi Institute of Technology & Management Sciences, Bangalore, to estimate the energy consumed in a day, week and month [4]. Identification of areas of energy wastage and estimation of energy saving potential in the canteen, all departments and institute central facilities has been made by walk-through energy audit. The steps of an electrical audit have been shown by investigating the electricity consumption at University campus [5]. The results showed that significant electricity savings can be achieved if the current lighting system is replaced by an energy efficient light emitting diode (LED) type fixtures. Energy cost meter is used to measure the standby power for various domestic appliances [6]. The energy cost meter is used to determine how much electricity a household product consumes. Energy cost meter is a device programmed to measure 24 hours and it can also be reprogrammed to measure for 7 or 30 days or a period by ones choice. However, no one has yet considered the effect of poor water management in the campuses on the energy loss and associated expenditure. Therefore, in this study, in addition to others, the effect of water leakage on the energy consumption of institutes having own water pumping system is considered. This study can be used as a reference in locating energy wastage areas in public higher institutions of Ethiopia. It is expected to reduce energy losses and energy expenditure in Arba Minch Institute of Technology and bring breakthrough in energy utilization trend.

2 METHODOLOGY

Energy auditing is a complex and lengthy process that needs to apply a lot of effort and time. To finish the auditing, the researcher has accomplished the following tasks.

- Audit preparation-selection of major electricity applications in the campus
- Survey and collection of data-collect data regarding the type, location and number of energy consuming appliances and problematic water fixtures in the campus.
- Data analysis-analysis of collected data to calculate the energy losses and related expenses.
- Identification of Energy conservation Measures(ECMs)-identify least costly ECMs and analyze them how they can contribute for energy saving for the campus

For data collection,the following tools have been used. Power Quality Analyzer- is used to measuere the power consumption of appliances at different conditions of the appliance. Plastic bottles- different sizes like 1 liter, 0.5 liter, 0.25 liter and 0.125 liter plastic bottles are used to measure the discharge rate of water leakage from different damaged water fixtures (dish washer, toilet, shower heads,etc).

2.1 Lighting system energy consumption

The lifetime energy consumption of a lamp with power rating of P and operating for t hours of its lifetime is calculated by the expression

$$EC = \frac{P\,x\,t}{1000}\text{[kWh]}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Similarly, the energy loss of the same lamp operating for td hours/day unintentionally can be calculated by:

$$EL = \frac{P\,x\ td}{1000}\ \text{[KWh/day]}\ \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

If in average, n number of the same lamps are operating unnecessarily for td hours/day, and if this happens for d days/year, the annual total energy loss can be calculated as:

$$ELT = \frac{n\,x\,P\,x\ td\,x\,d}{1000}\ \text{[KWh/year]}\ \ldots\ldots\ldots\ldots\ldots(3)$$

2.2 Office equipment energy consumption

The energy consumption of an office equipment with active power consumption of Pa operating for ta hours/day, being idle for ti hours/day, being in sleep mode for ts hours/day and shut down for tsh hours/day is:

$$EC = \frac{Pa\,x\ tn+Pi\,x\,ti+Ps\,x\,ts+Pshxtsh}{1000}\ \text{[kWh/day]}\ldots\ldots\ldots(4)$$

Where Pi=the power consumption (in watts) of the equipment when it is idle, Ps= power consumption during the sleep mode, Psh=power consumption during shut down mode(zero if it is unplugged)

EC=energy consumption in kwh/day

The annual energy consumption of the same equipment working for d days/year will be

$$ECY = d\,x\,EC\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where: ECY is the energy consumption in kwh/year. Out of the total energy consumption, the contribution of idle, sleep and shut down modes is taken as energy loss, which can be calculated as follows:

$$ELA = d\,x\,[EC - \left(\frac{Pn\,x\,tn}{1000}\right)]\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

where: ELA is the annual energy loss(kWh/year) by the office equipment due to the power consumption of the equipment when it is not operating.

2.3 Energy consumption of water pumps

In simple terms, the energy consumed by a water pump to deliver 1 million liter (ML) of water at total dynamic head (TDH in meters) can be calculated by:

$$kWh\ to\ pump\ 1ML = \frac{2.725xTDH}{\eta}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where η is the efficiency of the pump system.

Therefore, the energy consumption of the pump (ECP in kWh) to pump V(in ML) liters of water by TDH (in meters) is

$$ECP = 2.725\frac{TDHxV}{\eta}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

In this research, the main concern is to calculate the energy loss due to the water management problems. Therefore, whenever water leaks unintentionally, it results not only water wastage but also energy wastage.

3 RESULTS

3.1 Connected Electrical Loads

TABLE 1
SUMMARY OF CONNECTED LOADS

Description of load	Power consumption (kW)	contribution
Lighting	418	56.2%
Office equipment	105	14.1%
Desktop computers	100	13.4%
Pumps	90	12.1%
Fans	10.9	1.5%
Refrigerator	15	2.0%
Others	5.3	0.7%
Total	744.2	100%

Since more than 95% of the connected load consists of lighting system, office equipment, desktop computers and pumps, the energy audit focuses on only these loads.

3.2 Energy loss due to daytime operation of lamps

The campus has been observed for 10 days from 8:00 to 12:00 AM in the morning and early evening. In average 59 outdoor lamps (53 x36 w fluorescent tubes, 6x HPS(high pressure sodium) lamps) are operating at least for four hours in the morning at different locations; and all 150 outdoor fluorescent tubes and 33 HPS lamps get switched on early in the evening. Since these lamps are providing light during the daytime, the energy used by these lamps in the daytime is taken as a wasted. The energy wasted due to these practice is presented in Table 2. From this table, 9.5 MWh/year of energy is lost due to daytime operation of outdoor lighting systems in the late morning and early evening.

TABLE 2
ENERGY WASTE DUE TO UNINTENTIONAL OPERATION OF LAMPS

Description of lamp	No. of lamps operating in the late morning	No. of lamps switched on early evening	Energy loss(kWh/day)	Energy loss(kWh/day)
36 W fluorescent tubes	53	150	13	4,692
250 w HPS	5	33	13	4,770
			Total	9,462

3.3 Energy loss due to high power consumption nature of lamps

Although, there are recent state of art technologies of lamps, the lamps installed in the institute buildings are obsolete and energy intensive. In Table 3 the comparison of different installed lamps is presented. While comparing different types of lamps based on their light output/watt, the table indicates that 60-watt incandescent lamps are the least efficient lamps ever installed in the campus, where as 250 w sodium lamps are the best in the group. However, 250 w HPS lamps consume the most in 1200 hours of operation. Although HPS lamps consume the largest amount of energy in the group for 1200 hrs (average lifetime of incandescent lamps) of operation, the lumen output/watt is the greatest. However, since 60-watt incandescent lamps consume much energy to bring out a little light, they have to be ignored for future installations.

TABLE 3
ENERGY CONSUMPTION OF INSTALLED LAMPS IN 1,200 HRS AND EFFICACY.

Description of lamp	Energy consumption (kWh/unit/1200 hrs)	Lamp efficacy (lumen/watt)
36 w fluorescent tube	43.2	93
18 w fluorescent tube	21.6	64
40 w fluorescent tube	48	88
60 w incandescent lamp	72	13
40 w incandescent lamp	48	11
250 w HPS lamp	300	104
15 w CFL	30	44

3.4 Energy losses associated with office equipment

The majority (about 41%) of office equipment is hp5200 laser jet printers followed by canon iR2016J copy machines and hp3800 scanners. The most important source of energy waste related to office equipment is idle, sleep mode, and shut down (plugged in) power consumption. Table 4 shows the inactive modes power consumption of the office equipment (printer, copy machine, scanners). Assuming 240 days/year of operation, the three inactive modes of operation of office equipment results in an energy loss of about 2,625 kWh/year. As there are more printers than copy machines and scanners, much of the inactive mode energy consumption comes from the printers.

TABLE 4
ENERGY LOSSES OF OFFICE EQUIPMENT

#	Description of office equipment	Energy loss (kWh/day)	Energy loss (kWh/year)
1	Printer	6.53	1566.38
2	Copy machine	3.56	855.31
3	Scanners	0.85	203.02
	Total	10.94	2624.71

3.5 Energy losses associated with desktop Computers

In this study, only desktop computers with monitors (not laptops) are considered. Similar to office equipment, computers have also a nature of energy consumption when they are idle, sleeping/hibernating, or shut down (plugged in) modes. Table 5 shows the energy consumption of computers for these modes taking 250 days/year of operation.

TABLE 5
INACTIVE MODE ENERGY CONSUMPTION OF COMPUTERS

Item description	Quantity	Energy loss(kWh/day)	Energy loss(kWh/year)
Desktop Computers	1001	160	39,915

3.6 Energy Loss due to poor water management

Based on the ten days survey conducted in the campus, data regarding the damaged water fixtures (toilet flusher, hand washers, shower heads and dish washers, and associated water leakage was collected. Assuming that water is available 250 days/year (which is usually the case), the water and associated energy loss due to the damaged water fixtures(assuming 75% of pump efficiency and 150 meter total dynamic head from the pumps location to the reservoir), is calculated as presented on Table 6. As shown on this table the damaged showerheads contribute 40% of energy loss followed by toilet flushers and hand washers. This indicates that there is an urgent need for repair and replacement of damaged showerheads and toilet flushers to minimize the water loss and the associated energy loss.

TABLE 6
ENERGY LOSS DUE TO WATER POOR WATER MANAGEMENT

#	Description of water fixture	Water leakage (m3/year)	Energy loss (kWh/year)
1	Toilet flusher	39,259.08	21,592
2	Shower head	56,917.73	31,305
3	Hand washer	34,525.44	18,989
4	dishwasher	9,824.98	5,404
	total	140,527.22	77,290

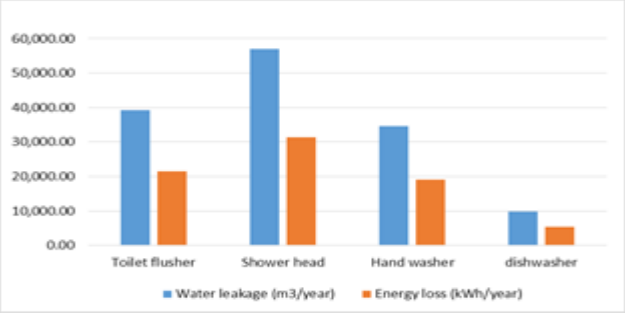

Fig. 1. *Water and energy wastes from poor water management practices*

In total, the annual energy loss in the campus is presented on Table 7. As shown on this table, the estimated amount of energy loss in the campus is about 129.3 MWh/year which results in an additional energy expenditure of $3400/year.

TABLE 7. *ENERGY LOSSES ASSOCIATED WITH MAJOR LOADS*

#	Applications	Energy loss (kWh/day)	Energy loss (kWh/year)
1	lighting	26	9,462
2	Office equipment	11	2,624.71
3	Desktop computers	160	39,915
4	Water pumping	9309	77,290
	total	506	129,292

This can be presented with the pie chart for comparison as shown on Figure 2

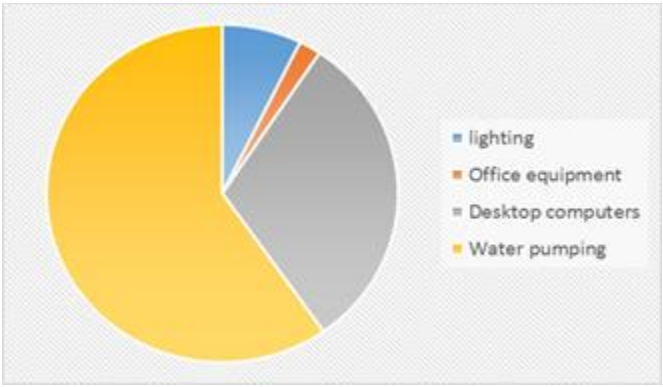

Fig.2. *Comparison of contribution of different applications on energy loss*

From the pie chart on Figure 2, 60% of the energy consumption is due to the poor water management practices and 31% of the energy loss is due to the inactive mode power consumption of the computers.

3.7 Energy Conservation Measures

Since different electronic materials have different functions or roles, their contributions to the energy loss have different nature. Therefore, the energy saving mechanisms applied for each electrical device is different. However, there are also some energy saving measures that might be applied for saving energy in different categories of electronic equipment. The following are some of the technical measures that can be practiced potentially to reduce the energy consumption and waste.

- Regular Maintenance of water infrastructure and fixtures to reduce the water leakage and associated energy loss
- Use of separate socket points (with on/off switches) for computers and office equipment to reduce the energy waste due to idle modes of operation
- Use T8 and T5 Fluorescent tubes when replacing the T12 fluorescent tubes
- Use of CFL and LED lamps instead of incandescent and HPS lamps
- Installation of day light control systems for outdoor lighting
- Installation of motion detectors for classrooms lighting systems

3.8 Awareness creation campaign

Even though most of the people know the benefits of (electrical) energy, only a few realize that energy loss and its effects on the economy and energy sufficiency. Thus, an awareness creation campaign needs to be organized in the campus to make all the community aware of the potential energy loss behavior and practices. There are different mechanisms of awareness creation campaign as listed below.

- Use of energy conservation stickers in office, computers, printers, fan controllers, door, TVs, dormitories, laboratories, bathrooms etc.

- Energy day- when everybody talks about energy conservation
- Hands-on training for installers, purchasers, secretaries, guards and decision makers regarding the benefit of energy conservation.

4 CONCLUSIONS

In this study, effort has been applied to study the potential energy lossy activities and traditions in buildings of Arba Minch Institute of Technology. The audit result shows that the water leakage contributes about 60% of the total energy waste in the campus followed by the inactive mode energy consumption of desktop computers. Therefore, the campus administration has to focus on regular maintenance of water fixtures and create awareness among the employees and students of the institute to practice energy conservation activities. It is also recommended to implement technical solutions like day light control and motion detection systems, which switch off/on the lights in streets and classrooms when necessary.

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