ENERGY EFFICENCY IMPROVEMENT FOR COMMERCIAL BUILDING IN BANGLADESH THROUGH ENERGY AUDIT

A Thesis submitted in partial fulfilment of the requirements of the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering

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Certification

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The thesis entitled "**ENERGY EFFICIENCY IMPROVEMENT FOR COMMERCIAL BUILDING IN BANGLADESH THROUGH ENERGY AUDIT,"** submitted by **Md. Showkot Hossain,** ID No: 152-33-2682 and **Md. Akib Hasan,** ID No: 152-33-2718, Session: Fall 2019 has been accepted as satisfactory in partial fulfilment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** September 2019.

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Dedicated to,

Our parent, respected teachers, those people who enriches this field by their research and the person we love.

ABSTRACT

Commercial Buildings are the large consumers of energy, which they use in many different ways. In this thesis we have successfully proved that there is a huge potential of energy savings in the commercial utilities by implementing some energy conservation measures on the largest energy consumption equipment's such as Light and AC.

Bangladesh is developing country, is advancing at a quick pace because of the expansion in industries and technologies. However, the country has been confronting a major energy crisis for a long while to meet the growing needs. Day by day, the gap between energy demand and supply is increase. One effecting way to minimize the gap between supply and demand energy audit is need to conduct in commercial sectors in regular basis. Energy audit helps to find the loss, wastage and give space for improvements in utilization. Main objective of our thesis is to improve energy utilization in commercial building for our country by finding energy loss, provide method and techniques through energy audit. The data entries are facilitated by user forms. They are calculated by MS excel sheet and the transferred to the data table. That's help to generates different pie charts to point the highest energy consumed sector and their cost.

This thesis also focuses on the energy saving opportunities and the potential to reduce energy consumption cost. This is done by replacing conventional lighting and other important equipment with more energy efficient appliances to increase the efficiency. The result of our study successfully demonstrated that, a substantial amount of energy and money can be conserved, if energy audit is practice and executed.

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List of Abbreviation

kWh	Kilowatt hour
Bbl	Barrel of oil
bcm	Billion cubic meters
toe	Tons of oil equivalent
MW	Megawatt
HFO	Heavy Fuel Oil
HSD	High Speed Diesel
EPBD	Energy Performance of Buildings Directives
HVAC	Heat, Ventilation, and Air Conditioning
SAP	Standard Assessment Procedure
HER	Heat Energy Rating
ERBM	Energy Rating Mark
EPA	Energy Performance Study
RMS	Root-mean-square
kVA	Kilo-volt-ampere
kW	Kilowatt
PF	Power Factor
kVAR	Kilo Volt Ampere Reactive
FL	Fluorescent Lamp
CFL	Compact Fluorescent Lamp
BDT	Bangladesh Taka
BLDC	Brushless Direct Current (motor)
BNBC	Bangladesh National Building Code
CRT	Cathode Ray Tube
LED	Light Emitting Diode
AC	Air Conditioner
LCD	Liquid Crystal Display

CHAPTER 1

INTRODUCTION

Electric energy is a crucial part of our human life, and it is one of our most widely used forms of energy. Electricity is a second source of energy, from the conversion of energy like coal, natural gas, oil and nuclear power. In our modern life it plays a vital role for economic development of our country. In all economic sectors, like household and commercial, electricity demand is comprehensive, and day by day demand of electric energy is increases extensively. Yearly electric energy consumption in Bangladesh in 2013 was 53.65 billion kWh, per capita this is an average of 326 kWh, oil consumption is 25,526 Bbl and natural gas consumption is 29.53 bcm [1]. Global electrical energy consumption has already reach to 4185.1 ton of oil and 3030.4 tons of natural gas by 2013 which was 1.4% more than the year 2012, and primary energy consumption growth averaged 2.2% in 2017, up from 1.2% more than the year 2016 and the fastest since 2013. This compares with the 10-year average of 1.7% per year. Global oil consumption growth average 1.8% or 1.7 million barrels per day, above its 10-year averaged of 1.2% for the third consecutive year. Natural gas consumption increases 96 bcm or 3% the fastest since 2010. And coal consumption increased by 25 million toe or 1% the fastest growth since 2013 [2]. This statistic shows that the energy consumption is mostly dependent on fossil fuel like coal, oil, natural gas, which are non-renewable. Now days many alternatives are developed as renewable energy sources such as solar, wind, tidal and geothermal. But there is no sustainable solution to reduce dependency on fossil fuel.

In our country we reached maximum daily consumption is 11,387 MW [3]. According to Bangladesh Energy and Mineral Resources Division in the year 2021, the total electricity demand in Bangladesh will be approximately 24,000 MW [4]. Now in Bangladesh installed power generation capacity is about 16,982 MW out of which 524 MW coal-based power plant; 10,001 MW gas-based power plant; 3,597 MW HFO based power plant; 1,690 MW HSD based power plant; 230 MW hydro power plant; and 660 MW are imported as of March 2019 [5], The total installed capacity combining solar is 20,000 MW [10]. By this statistics Bangladesh still far away from generation of electricity to satisfy the daily demand.

Bangladesh electricity generation is mostly depending on gas power plant its capacity is 10,001 MW [5]. Bangladesh is the eighth largest natural gas producer in Asia Pacific region, approximately 26.6 billion cubic meter in 2017 [6], and Bangladesh reserved capacity of natural gas is 2,33,000 million cubic meters [7]. For power generation and fertilizer production consumes 80% of natural gas at present. Total gas consumption stands as follow: power (45%), fertilizer (35%), industrial, commercial and domestic (20%). Annually the demand of natural gas is increasing at a rate of 13.4%, According to energy experts the reserve of natural gas may last for nearly next two decades and after that Bangladesh need to look for substitutes in terms of non-renewable energy sources [8].

Energy user is increased day by day, currently 90% of the population has access to electricity [9], and the government is also kept to provide the entire country with electricity coverage by 2021. Bangladesh will need an estimated 34,000 MW of power by 2030 to sustain its economic growth of over 7% [10].

In this situation, the cheapest and fastest solution to overcome all the energy demand is energy conservation and improvement of energy efficiency. Energy conservation stand for reduction in energy uses by less energy service and energy efficiency improvement stand for uses of less energy for a constant output. These two-concept merged together by energy audit [11]. In energy audit all types of energy conservation in a building is survey and analysis for reduce the amount of energy consumption in the system with more efficient way without effect the output of the system.

1.1 Energy Audit

Energy audit refers to identifying, investigate and analyse energy efficiency potential, an energy is an important method for identifying such potential for energy efficiency measures and help to reduce their cost [12]. Simply the purpose of energy audit is to analyse or investigate whether it is possible to reduce one system energy consumption or improving the system efficiency without affecting the system final output. According to the energy conservation Act, 2001 of India, the term energy audit is defined as “the verification, monitoring and analysis of use of energy including submission of technical report containing recommendation for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption”. If the object under audit is a commercial building in use, the main purpose of audit is to reduce the energy consumption and improve the comfort of residence and also improve the health and security at the same time. Main objective of energy audit is to optimize the overall energy consumption, to achieve high performance with low cost, and save energy.

Preliminary or level one energy audit based on the historical data on use of energy and visual inspection of the facility and operating equipment and also finding the broad energy input output of a system, identifies the low-cost energy saving opportunities [12]. Level two or medium level audit include an in-details analysis of energy cost, energy uses and characteristics of the system along with on-site energy demand measurement to identify energy measures which are more capital intensive and need to be aligned with the financial budget of the site [12]. I would be interesting to seek the probable reason behind the energy balance. Most sophisticated or level three energy audit is referred to as an investment grade audit, in which it is necessary to give the result when some measures are applied to achieve these results. Also includes an additional continuous monitoring of system data and process characteristics [12].

Using energy audit, it can be possible to optimize the use of energy and the greatest opportunities to cost effective for energy saved.

1.2 Problem Statement

The accessibility of energy has turned into a significant part of our society. In this and related problems, we will talk about the issues of energy utilization, energy reserves, and energy related outflows. Moreover, we will analyse conventional and substitute energy frameworks.

Commercial sector is one of the greatest purchaser portions of power/energy in Bangladesh. Right now, there is a noteworthy contrast in energy demand among urban and rural households. Anyway, such contrast will be decreased one day, when households in the entire nation will enjoy a decent way of life. But they don't follow efficiency measures.

Our pioneers can possibly configuration substitute apparatuses for conventional ones which will be efficient with respect to energy utilization. It will encourage consumers to make perpetual and reasonable behavioural changes to reduce energy use. Besides, the innovation can also encourage the consumers to improve their capacity to monitor, track and deal with one's energy consumption. This will help increase mindfulness on energy issues and keeping everybody informed about the effect of their energy consumption. Energy Audit is the way to find the way of improvement in energy consumption for existing equipment’s in commercial sector.

1.3 Thesis Objectives

The objectives of this thesis paper are to study the energy consumption in commercial building, get reliable knowledge of energy consumption and how to improve the efficiency by reduces energy use to have constant output. Also eliminate energy loss, and detect the access savings opportunities and improving energy efficiency. Also, analyse the possibility of cost reduction. However due to innumerable limitations and shortcomings of instruments, in this paper we will focus the major energy consume equipments and the way of improvement of efficiency, which will be discussed in the following chapter.

1.4 Scopes

Developing country like Bangladesh, where energy production and transmission cost is higher than developed country, energy saving in commercial or household buildings is important for saving money for country and individual consumers. In this paper we find a better energy saving way for consumers. It will help to reduces energy consumption cost and extra pressure on national energy production. Also help to improve operational efficiency of the building. By minimizing energy consumption through this research will help to reduces greenhouse gas which impact on global warming. This will play vital role in our overall economy.

1.5 Research Methodology

The methodology is as follow

- The preliminary phase involved information gathering from library online portal, through interviews and discussion with various operating personnel.

- Current operating data for key parameters influencing energy efficiency were obtained from control panels and through random, on-site measurements.
- Precisely identify the energy conservation options which would affect cost and energy saving.
- Collecting water and electricity bill from office stuff.

1.6 Thesis Organization

This thesis is organized as follows:

Chapter 1 have discussed the scenarios of overall energy crisis and also defined energy audit and subsequent energy studies.

Chapter 2 of this thesis paper will mainly discuss the significance of energy audit and the basic steps to perform an energy audit for a building.

Chapter 3 is based on the presentation of data for DIU library building, after energy audit is performed.

Chapter 4 is discussing all the possible retrofits and savings that can be achieved after a complete energy audit.

Chapter 5 discusses all the possible way to improve energy efficiency.

Chapter 6 is the conclusion part where further research topics and development are stated.

CHAPTER 2

SIGNIFICANCE OF ENERGY AUDIT

2.1 Introduction

For saving energy bills and to conserve national energy resources of a country energy audit is considered to be one of the fundamental and necessary process. Country like Bangladesh are mainly depending upon natural resources for power generation, which has a population over 180 million, Energy audit can be an effective way to find the way to use the energy efficiently. This chapter focus on basic energy audit level, concept about lighting, Electrical equipment and envelope audit.

2.2 Basics of Energy Audit

Energy audit is one of the important ways to find the possible way to, reduces energy use, and reduce the operational cost of electrical appliances, to cut down the electrical bill and save our money and electricity. Quality of energy audit is totally depended on the experiences of the auditor and how much money owner will spent. Simple energy audit provides building owner a list of no cost or low-cost recommendation which can be implemented by operations and maintenance staff. Advance energy audit is a part of the large energy management program. Energy auditing service are provided by energy services companies, energy consultant and engineering farms. Energy auditing process is mainly divided into three levels. They are as follows,

Level 1: Walk-through or Preliminary Audit

The preliminary audit is the simplest type of audit. It consists simple interviews with site operating personnel, review utility bills and other operating data briefly. Walk-through audit is physical site inspection and become familiar with the building operation. Also finding the areas of energy waste and energy efficiency improvement. By these auditors find the areas where the energy is used properly and the areas where the saving opportunities can be applied. It’s not provided details analysis.

Level 2: Standard or General Energy Audit

Standard or general energy audit provide expansion of preliminary audit. Collecting more detailed information about operation, it includes depth analysis of energy cost, usage and analysis equipment, system and characteristics of the building. To evaluate the facilities energy demand rate structures and energy usages profile, auditor need to collect utility for a 12 to 36-month period. In depth interview conducted with operation personnel to understand of major energy consumption system, and knowing the variation in short-term and long-term energy consumption and demand like daily and annual. This type of audit covered detailed financial analysis for cost estimate, site specific operating cost saving, and investment criteria. Also provide sufficient detail to justify project implementation. This type of audit is helpful for energy and cost saving of the building by using energy engineering calculations based on the data collected from the site.

Level 3: Detailed or Investment-grade Energy Audit

Detailed energy audit is the most comprehensive and complete energy audit, it estimates the energy input for different process and collecting of fast data on specific energy consumption. It provides detail energy use characteristics of both the existing facility and energy conservation measures identified. Level 3 energy audit provides detailed calculations of cost and saving with the high level of confidence required for major investment decisions. An actual utility data is provided to making a realistic baseline against which to compare. Extensive attention is given to understanding operating characteristics of all energy consuming systems. Finally, auditors need to prepare details energy audit report, including all the data, energy savings, also including a list of recommendations to save energy.

From above these levels, the auditing can be summarized in table 2.1

Table 2. 1: Audit Phase

Auditing Level	Activities
Level 1: Preliminary Energy Audit	1. Site survey and collect utility data 2. Analysis low cost/no cost energy conservation measures 3. Identify energy efficiency improvement potential
Level 2: Standard Energy Audit	1. Detailed building survey 2. In-depth interview with building staff 3. Analyze the energy and cost savings 4. Breakdown of energy use
Level 3: Detailed Energy Audit	1. More detailed field analysis 2. Calculating cost and saving with a high level of accuracy 3. Making professional report including recommendation

2.3 Literature Review

World energy crisis is one of the major problems. In developing countries like Bangladesh, where electrical energy resources are scare and production of electricity is very costly, energy conservation studies are of great importance. In order to reduce energy consumptions for sustainable and energy efficient manufacturing, continuous energy audit and process tracking of electrical equipment are essential. The main objectives of energy audit are, to minimize energy cost without affecting production and quality, minimize environmental effect, optimize utilization and procurement of energy for all organization.

Energy audits initially became popular in response to the energy crisis of 1973 and later years. Interest in energy audits has recently increased as a result of growing understanding of human impact upon global warming and climate change. Energy audits are also popular due to financial incentives for homeowners [13].

The Primary objective of energy audit is to recommending appropriate policies for bringing down consumption per unit of product output or to lower operating costs. Energy provides a “bench-mark” for managing energy in the organization and also provide the basis for planning a more effective use of energy throughout the organization [14].

European Union Directive Building Conduct

On 16th December, 2002 European Union Directive on Energy Performance of Buildings Directives was proposed. After, this became major areas for future studies on energy performance on buildings. The main purpose of EPBD was to improve the energy performances on the building considering indoor and outdoor conditions. It also mentioned some requirement such as an outline of integrated energy performance of a building, minimum use of appliances, minimum requirements of energy performance in major buildings that are subjected to renovation, regular inspection of boilers and heaters also provide energy efficiency certificates for the buildings. One noticeable upturn of EPBD is the inevitable national energy performance calculation procedure on buildings, for both new and existing buildings. Performance analysis is followed by improvement techniques, certification and assessment on HAVC installations [15].

After the release of EU directive on performance of buildings, in terms of energy, many countries follow the rules such as UK, Denmark, Ireland, Netherland, France, Belgium and Germany [16].

Since 1995, for energy conservation, Standard Assessment Procedure and building regulations-Part L (a section which states energy conservation of houses) are compulsory for new buildings in United Kingdom. SAP is mainly concerned on annual cost of heating, lighting, building envelope insulation, efficiency of heating and domestic hot water system, the fuel prices affect the SAP ratting, which ranges from 1-100. SAP does not include location, consumption on domestic appliances and does not suggest for making buildings more energy efficient. Statics shows that, applying SAP on 17,000 houses per year, almost three million buildings can be audited [17].

In Europe, energy audit and the ratting assessment were first initiated by Denmark and they have provided a benchmark for other states to continue. They introduced a mandatory energy analysis in 1985 and “Act on Promotion of energy and Water Conservation in Buildings” is published in 1996, which officially approved on 1997. This act promoted different types of audit, EM/EK and certifications on mainly industrial buildings. Around 45,000 to 50,000 audits are performed per year, and energy consumption is estimated to drop near 20% for 70% single family residence.[17]

In 1997 and later on in 1992, HER and ERBM were introduced in Ireland and was mandatory for all newly constructed buildings. ERBM is broadly used by fuel suppliers and house builders to provide low energy consumption in the buildings. It accounts for annual CO_2 emission and consumption of energy while considering the outputs of HVAC appliances that are the buildings. It also provides suggestion and improvement on building envelope, heating process and also estimates savings [18].

The current regulations for the buildings of Netherlands are EPA. Standard Energy Performance is introduced for new buildings. This encourages on energy conservations and savings. It focuses on energy consumption for heating, lighting system, water pumps and fans [17].

For new non-industrial buildings, Decree 2000-1153 is set-up by the Ministry of Housing and Transport of France so that all the new buildings comply with regulations. While the buildings follow the rules and regulations, two methods are introduced for calculation purpose. First one is a precise, intricate process, developed for expertise and the second one is for amateur, non-experts or for common people [19].

Since 1987, NBN B62-002 and NBN B62-004 regulations have commenced in Belgium and are obligatory for all buildings in residential areas. It is also compulsory for non-industrial in some region such as Brussels and Walloon. They are mainly concerned with the heat transfer coefficient for a building, and the legislation limited to 0.55 W/m2 degree Celsius. However, the legislation varies for the newly build non-industrial buildings [20].

From 1982, Germany has started to work on energy efficiency and a legislation named "Energy Saving Decree" was approve in the year 2001. The two important consequences from this legislation was yearly energy consumption limited to 7 liters of oil equivalent fuel for every m^2 and mandatory replacement of old boilers. The latter one started from 1978 [17].

Energy Conduct Studies

Since the concept developed around 1970, many surveys and assessment has been conducted to find different parametric solutions.

According to Mungwititikul and Mohanty (1996), an energy audit on the consumption of office, performance pattern revealed that 25% of electricity can be saved by controlling sleep modes idle times of the office appliances [21]. Aktacir (2008), investigated on air conditioners and various operation pattern for different designs. Thus, a sample building was chosen somewhere near Adana (a geographically hot region) for developing cooling loads relationships with capacity of air conditioners. Using simplified version of ASHRAE heat balance method the results were concluded that outdoor conditions are very important for the size selection of air conditioners [22].

Also, as per Di Stefano (2000), a study was conducted on lighting system at Melbourne University, Australia. The study replaced conventional lights by 1.2 meter of fluorescent with different ballast. The study showed that up to 64% energy can be saved CO_2 emission could be reduced to 10%. However high cost instalments of light and ballast were the mail problem to deal with and much further investigations are required [23]. Wang, Huang and Cao, audited commercial buildings in Shanghai presented the findings of energy consumption, focusing mainly on electrical equipment such as air conditioner, elevators and also on lighting system. According to this study, climate and occupancy rate were the predominant factors for total energy consumption. They also deduced that air conditioner consumes around 45% and lighting system consumes 10% of the net energy usage [24].

In USA, Mauriello, Norooz and Froehlich studies that 41% of their primary energy is consumed by the building sectors. The paper presented the idea of using thermography infrared (IR cameras) to uncover the thermal defects and inspect building efficiency. Two cases were studied: one with five automated with 10 professional auditors and other one included a case study of a simple residential audit. The paper suggested incorporating automated thermography tool designers' robots and computer science for energy analysis [25]

Aue and Pierce from china uncovered the savings by energy auditing in a paper mill. Several comprehensive steps were followed in their study and an estimation of 4,000 pounds savings per hour steam, improvements in sheet quality and machine efficiency was observed. If energy auditing is done in such type of mills then, $100,000 to over $1 million per year can be saved. Machine efficiency is also expected to rise by 20% [26]. Another study in china showed one of the technical instruments of energy saving in energy audit. A steel plant of china was chosen as a sample site and analysis was done for energy consumption and substantial amount of energy was seed by their activities for example in management sector and using intelligent methods [27].

2.4 Energy Audit Instruments

To Analyse energy consumption and estimate the cost-effectiveness of energy conservation measures, an auditor can use myriad calculation methods and simulation tools. The Auditors must make some measurement during the audit visit, the amount of equipment needed depends on the type of energy consuming equipment used at the facility. Portable instruments are generally used by energy auditors to measure various operating parameters like electrical power, pressure, flow, temperature, flow gas consumption etc.

Some commonly used instruments are mentioned below:

2.4.1 Clamp on Ammeter

These are very useful instruments for measuring current in a wire without having to make any live electrical connections. The clamp is opened up and put around one insulated conductor, and the meter reads the current in that conductor. New clamp on ammeters can be purchased inexpensively that read true RMS value.

2.4.2 Electrical Power Analyzer

These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAR, Amps and Volts. In addition to this, some of these instruments also measure harmonics. It can be able to record the real online data.

2.4.3 Infrared Camera

Infrared cameras are still rather expensive piece of equipment. However, these are very versatile piece of equipment and can be used to find overheated electrical wires, connections, neutrals, circuit breaker, transformers, motors and others pieces of electrical equipment. They can also be used to find wet insulation, missing insulation, roof leaks and cold spots.

2.4.4 IR Thermometer

This instrument is used to measure the temperature, it consists a lens to focus on the detector which converts the energy to an electrical signal that can show in units of temperature.

2.4.5 Light Meter

One simple and useful instrument is the light meter which is used to measure illumination levels in facilities. A light meter that reads in foot-candles allows direct analysis of lighting systems and comparison with recommended light levels specified by the Illuminating Engineering Society.

2.4.6 Power Factor Meter

A portable hand held power factor meter is very handy for determining the power consumption and power factor of individual motors and other inductive devices. This meter typically has a clam on feature which allows an easy connection to the current carrying conductor.

2.4.7 Ultrasonic Flow Meter

This is non-contact flow measurement instrument. The ultrasonic signal travelling with the flow travels faster than a signal travelling against the flow. Ultrasonic flow meter measures the transmit time of both signals.

2.4.8 Airflow Measurement Devices

Measuring air flow from heating, ventilating ducts or from other sources of air flow is one of the energy auditors' tasks. Airflow measurement devices can be used to identify problems with air flows, such as whether the combustion air flow into a gas heater is correct.

2.4.9 Safety Equipment

A good pair of safety glasses is an absolute necessity for almost any audit visit. Hearing protectors may also be required on audit visits to noise plants and high-power industrial equipment. Electrical insulated gloves should be use when electrical measurements will be taken. Due to numerous limitations and lack of availability of instruments. We used some of instrument for measuring temperature, power consumption area and lighting level in this audit.

2.5 Lighting Audit

According to information of power division, electricity consumption per capita 464 kWh in Bangladesh which is one of the lowest in the world. Now in Bangladesh 93% of the total population has the access to electricity [28]. Lighting load takes a large portion of generated power. It consumes about 25% to 35% of the total generated power in the world [29]. The occupied energy for lighting is 15% and 30% for residential buildings and commercial buildings respectively [29]. Nowadays, people prefer Fluorescent Lamps and Compact Fluorescent Lamps to Incandescent Lamps due to higher efficiency and higher lifetime for getting same luminous level [29]. FLs and CFLs are discharged lamps and they require ballast. Ballast generates high initial voltage across lamp tube for required lamp ignition and to limit the lamp current [30]. Magnetic ballast using iron-core transformer and it causes extra heat losses across the ballast [30]. Electronic ballast is much more efficient than Magnetic ballast through lifetime of Electronic ballast is lower than the Magnetic ballast [31]. By energy auditing auditors can find the ways for efficient use of electricity. Auditors can easily come up with some fruitful recommendations based on the findings during energy audit. Lighting energy usage can be reduced by 75% to 90% compared to the conventional practice [32]. This will help us to save our cost and electrical energy. It will also enlarge the community of people getting access in electricity.

2.6 Electrical Audit

It is necessary to audit the electrical equipment which means that equipment that we use in our daily life and which are directly related to the electrical energy consumption. Lights, different types of fan, computer, air conditioner, refrigerator, elevators etc. are the common electrical appliances used in any type of building such as residential, commercials and in industries. In our work we have separated the lighting section from the electrical equipment. Electrical audit means auditing any equipment powered by the electricity or electrical appliances. Some factor which influence these audits are number of equipment, wattage ratings and operation time.

It is defined that the electrical equipment will consume more electricity than other two factors which are lighting and envelope. Electrical equipment is the reason of most of our electricity bills, there is more opportunities for us to save electricity from this sector of the energy audit. So, it is determined that the electrical equipment audit is the most significant part of the energy audit.

Nowadays, our life is completely depended upon the latest technologies. All the latest technologies, gadgets and equipment consume electricity, in short, we are depending on the electricity for our daily life. In offices and industries there are more electricity consuming equipment are increase day by day. This increasing equipment results in increase in the amount of energy consumption. This is one of the main reasons to initiate energy saving and thus electrical equipment auditing is very important.

Sometimes the appliances we use in our buildings consume extra electricity which leads to the wastage of electrical energy. While electrical appliances get older it takes much energy than it used to at the start. As a result, the consumer does not get the desired output. Instead, they get the amplified electricity bills. By electrical equipment audit, we can find out the areas where we need to focus and improve the quality of the equipment so that the owners get benefit from the electrical appliances and save the energy bill at the same time.

Humans tend to commit mistake and also to be forgetful. Sometimes the electrical equipment is switched on for long time and people forget to switch off even after they are done with the use. The electricity bills depend on how long use the appliances. We need to be self-conscious, so that we can use the appliances when it is necessary. Even some specified appliances need to be well maintained to reduce the operational hour. Which helps to reduce electricity bill.

One of the burning and most widely discussed topic is global warming and CO_2 emission. Unfortunately, the appliances we use emit CO_2 and other harmful gases. In addition to that, if the appliances are not maintained properly then there is a chance pollute the climate. Thus, to reduce the impact of this harmful gas and to make our world or workplace safer and better, electrical equipment audit is very essential.

2.7 Envelope Audit

The building envelope consists of those elements of a buildings that enclose conditioned spaces through which thermal energy may be transferred. Energy is saved when the heat exchange between the building and the outside environment is reduced, solar and internal heat gains are controlled [33]. The building envelope audit generally requires gathering the following data:

- Building characteristics and construction
- Window and door Characteristics
- Insulation status

For some buildings, the envelope like walls, roofs, floors, windows and doors can have an important impact on the energy used to condition the facility. The energy auditor should determine the actual characteristics of the building envelope. During the survey, a descriptive sheet for the building envelope should be established to induce information such as construction materials for instance, the level of insulation in walls, floors, roofs and areas, and the number of building envelope assemblies for instance, the type and the number of panes for the windows [34].

The energy audit of the envelope is especially important for residential buildings. Indeed, the energy use from direct condition of heat or from air infiltration or exfiltration through building surfaces accounts for a major portion (50% to 80%) of the energy consumption. For commercial buildings, improvements to the building envelope are often not cost-effective due to the fact that modification to the building envelope like replacing windows, adding thermal insulation in walls are typically considerably expensive. However, it is recommended to audit the envelope components systematically not only to determine the potential for energy savings but also to ensure the integrity of its overall condition. The moisture condensation is often more damaging and costly than the increase in heat transfer because it can affect the structural integrity of the building envelope.

Building envelope is not directly related to the electricity bill or energy consumption but it plays a vital role for lights and the cooling equipment to work hard. These factors are added in the electricity bills and we have to pay some unnecessary money. About 40% of worldwide energy consumption is related to the buildings [35]. As a matter of great regret, most of the energy losses related to the envelope are invisible to us. By energy audit, we can find out the cracks and gaps that cause us to pay more.

Building orientation and geographical location Is the most important factor in case of envelope audit. The heating and cooling capability of the building is the prime factor for our comfort. We invest a lot of money into our heating and cooling appliances, but still maximum efficiency cannot be obtained. One of the biggest reasons behind this is the roof, walls surrounded the room, windows and doors are not well insulated or the envelope of the building is not appropriate to get the desired output and ultimately there is a loss of energy. The solution of this problem can be founded by envelope audit. Thus, it is clear to us the building envelope audit has much significance to save the energy consumption as well as the energy bill.

2.8 Summary

This chapter mainly focused on basic three level of energy audit, difference between them. Then discuss about the instruments which are important for energy audit. Basic concept about lighting audit how it can be done, electrical equipment audit which process need to follow for electrical equipment audit and finally concept about envelop audit. This chapter mainly focused on the major part of energy audit and the details about it.

CHAPTER 3

AUDITING DAFFODIL UNIVERSITY LIBRARY BUILDING

3.1 Introduction

After developing the idea about energy efficiency improvement in commercial building our next step is to examine and check the building energy consumption and its output, also any scope available for improvement. As part of our thesis we surveyed several commercial buildings. In this chapter we will show the process of auditing, data collection and energy consumption for Daffodil university library building.

3.2 Daffodil University Library Building Audit

As we have discussed the audit processes, we have audited in similar fashion. To star the audit, we need some specification about the building. It operates 12 hours and average students' study daily 600 to 800. The sunlight is used more in the daytime most of the floor. On the other hand, electric lights are used in more in night time. During summer time cooling loads like AC fan are running most of the time cooling purposes, and winter time this type of load used lightly.

Table 3. 1: Electricity Bill

Month	Monthly usage (kWh)	Demand Charge	Cost/Unit	Total Bill
Jan	21,745.25	15000	10.81	250,066.15
Feb	22,230.21	15000	10.81	255,308.57
Mar	22,685.45	15000	10.81	260,229.71
Apr	22,595.85	15000	10.81	259,261.13
May	23,478.15	15000	10.81	268,798.80

Month	Monthly usage (kWh)	Demand Charge	Cost/Unit	Total Bill
Jun	23,284.26	15000	10.81	266,702.85
Jul	22,749.95	15000	10.81	260,926.96
Aug	22,875.35	15000	10.81	262,282.53
Sep	21,942.31	15000	10.81	252,196.37
Oct	22,125.85	15000	10.81	254,180.43
Nov	21,564.95	15000	10.81	248,117.11
Dec	20,968.74	15000	10.81	241,672.07

At first, we collected the electricity bill of Daffodil university library building. Electricity bill from January to December 2018 shown in table 3.1, which is collected from official personnel.

From the electricity bill, we have a precise idea about the building energy consumption.

This table shows total energy bill with demand charge and per-unit charge from January 2018 to December 2018. This value helps to determine the monthly electric energy use, and gives an idea about overall electricity use per month and helps to setting achievable benchmarks for the electricity use in library building for low electricity bill.

In December 2018 electricity consumption is very low that’s why amount of bill 241,672.07TK, compared to bill 266,702.85TK from June 2018. Audit team fined the reason behind the difference between the bill of December and June 2018. In Bangladesh December to February is a winter season in this period less amount of electricity is used, because of less use of AC. As corresponding electricity bill is less than another month. On the other hand, during summer season temperature is high, and AC load use continuously that’s why electricity bill in June is much high.

After that, we need the floor plan of this building to get idea about the building orientation and the envelope system. Figure 3.1 show us the 2nd and 3rd floor plan of the library building.

Daffodil university library building located at Sukrabad and the building is west facing. From the floor plan we get the actual length and size of the rooms, windows and doors which are necessary for calculation of our envelope losses.

Next comes data collection, where we used lighting and envelope audit manual forms, figure 3.1 and 3.2 shows the lighting audit form and envelope audit form respectively. These forms are hand written and to fill the form we take help of the floor in charge, security guards and other official personnel related to the building.

Building Energy Audit

Lighting

Building Identification: Library Floor No: 01

Please use a new sheet for each area, location or room in the facility.

Existing lights and controls

	Type 1	**Type 2**	**Type 3**	**Type 4**
Type of fixtures:	L	M		
Number of fixtures:				
Number of lamps ~~per fixture:~~	06	1		
If fluorescent indicate length of lamps (2ft, 3ft,4ft, 8ft):	4ft			
Watts per fixture:(Include ballast wattage if known)	23	12		
Fixture height from work surface (ft/m)	9ft	8ft		
Present operation of lights - hours/day	12	12		
Present operation of lights - days/week	06	06		
Present operation of lights – weeks/year	46	46		

Present light levels: Bright______ Adequate ✓ Dim______

Reflectance of walls and ceilings: Good______ Average ✓ Poor______

Can lights be switched on and off as desired? Yes ✗ No ✓ Comment: ______

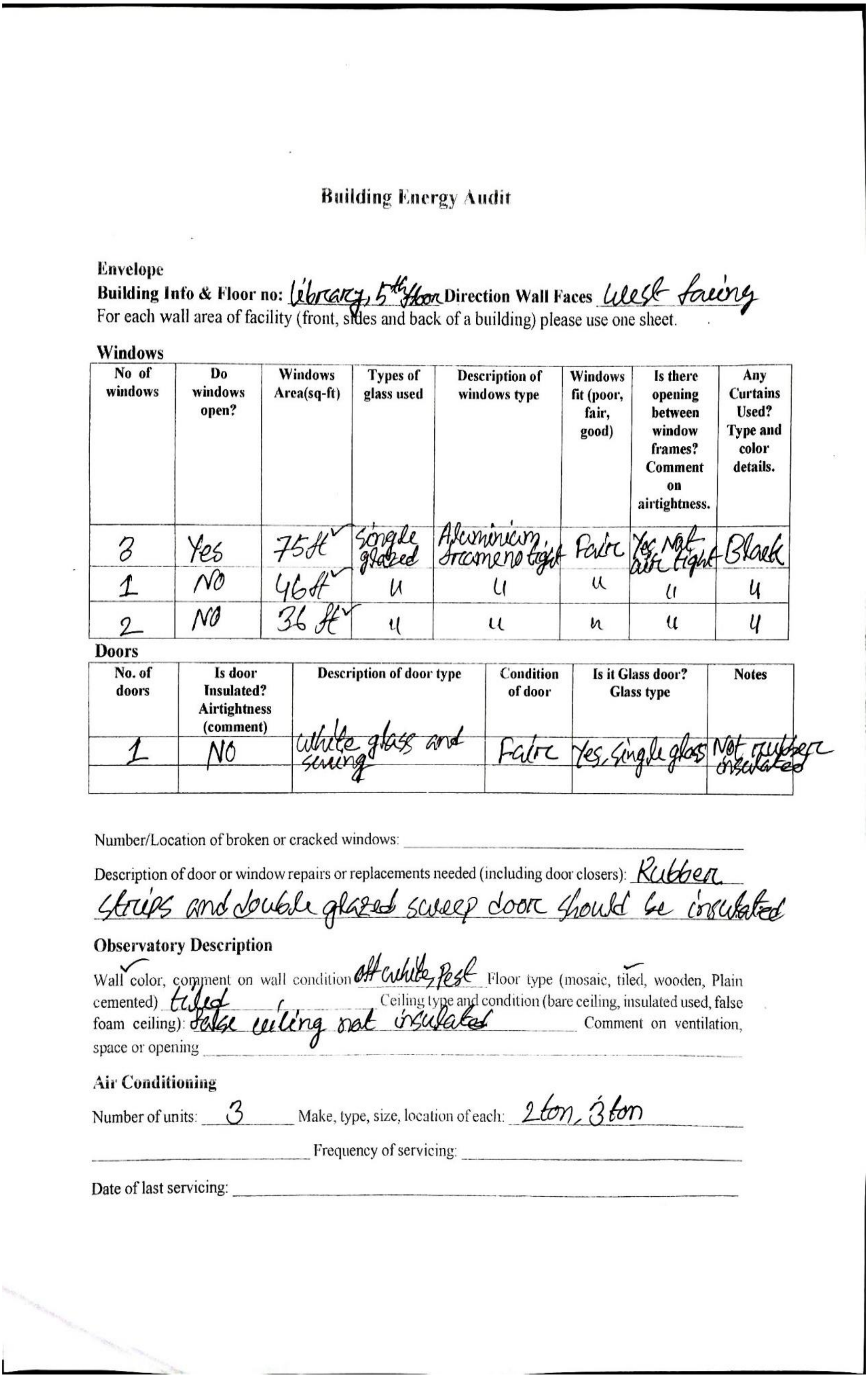
Can lower wattage lamps be installed? Yes ✗ No ✓ Comment: ______

Notes: ______

Lighting Legend

A.- Incandescent B.- Fluorescent T-12 C.- Fluorescent T-12 HO (High Output) D.- Compact Fluorescent E.- Mercury Vapour F.- Fluorescent T-12VHO (VH Output) G.- High Pressure Sodium H.- Low Pressure Sodium I.-Metal Halide (White Light) J.-Fluorescent T-8 K.-Quartz Halogen L.-LED ✓ M.- Other-specify LED Bulb.

Figure 3. 1: Lighting audit manual form



Building Energy Audit

Envelope

Building Info & Floor no: library, 5th floor **Direction Wall Faces** West facing

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows

No of windows	Do windows open?	Windows Area(sq-ft)	Types of glass used	Description of windows type	Windows fit (poor, fair, good)	Is there opening between window frames? Comment on airtightness.	Any Curtains Used? Type and color details.
3	Yes	75 ft	Single glazed	Aluminium frame no tight	Fair	Yes Not air tight	Black
1	NO	46 ft	"	"	"	"	"
2	NO	36 ft	"	"	"	"	"

Doors

No. of doors	Is door Insulated? Airtightness (comment)	Description of door type	Condition of door	Is it Glass door? Glass type	Notes
1	NO	white glass and swing	Fair	Yes, single glass	Not rubber insulated

Number/Location of broken or cracked windows:

Description of door or window repairs or replacements needed (including door closers): Rubber strips and double glazed sweep door should be insulated

Observatory Description

Wall color, comment on wall condition Off white, Pest Floor type (mosaic, tiled, wooden, Plain cemented) tiled Ceiling type and condition (bare ceiling, insulated used, false foam ceiling): false ceiling not insulated Comment on ventilation, space or opening

Air Conditioning

Number of units: 3 Make, type, size, location of each: 2 ton, 3 ton

Frequency of servicing:

Date of last servicing:

Figure 3. 2: Envelope audit manual form

Library building is six storeys building. Ground floor contains a start-up shop, first floor for student's bag keeping room, second floor is for library office, third floor for student study room, fourth floor for book collection and fifth floor for group study room.

Ground. 1st, 2nd and 5th floor are same design and 3rd & 4th floor are same.

Figure 3. 3: Floor plan of DIU library building 2nd and 3rd

3.3 Electrical Energy Utilization Systems

Daffodil library building receives electricity supply from DPDC distribution line. This building has its own generator which only operate during load shedding. Total connected electric load 82,322 watt, where AC contains 63,000-watt, Fan load 4,300-watt, Lighting load 4,196-watt, Water pump load 3,730 watt. Server load 1500 watt, and 96-watt load for CCTV.

Table 3. 2: Connected load

<table>
<tr><th>Sl. No.</th><th colspan="2">Name of Appliance</th><th>Number of Appliances</th><th>Watts</th><th>Total Watts (Number of Appliance*Watts)</th></tr>
<tr><td rowspan="6">1</td><td rowspan="6">Light</td><td>Compact Fluorescent Lamp (CFL)</td><td>13</td><td>23</td><td>299</td></tr>
<tr><td>Compact Fluorescent Lamp (CFL)</td><td>10</td><td>15</td><td>150</td></tr>
<tr><td>Fluorescent Lamp (T12)</td><td>53</td><td>36</td><td>1908</td></tr>
<tr><td>LED Tube</td><td>63</td><td>23</td><td>1449</td></tr>
<tr><td>LED Tube (Mini)</td><td>18</td><td>15</td><td>270</td></tr>
<tr><td>LED Bulb</td><td>10</td><td>12</td><td>120</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">AC</td><td>AC (3 ton)</td><td>4</td><td>4500</td><td>18000</td></tr>
<tr><td>AC (2 ton)</td><td>12</td><td>3000</td><td>36000</td></tr>
<tr><td>AC(1.5ton)</td><td>4</td><td>2250</td><td>9000</td></tr>
<tr><td>3</td><td colspan="2">Computer</td><td>22</td><td>250</td><td>5500</td></tr>
<tr><td rowspan="4">4</td><td rowspan="4">Fan</td><td>56”</td><td>30</td><td>75</td><td>2250</td></tr>
<tr><td>36”</td><td>3</td><td>55</td><td>165</td></tr>
<tr><td>Wall Fan</td><td>19</td><td>65</td><td>1235</td></tr>
<tr><td>Exhaust Fan</td><td>13</td><td>13</td><td>650</td></tr>
<tr><td>5</td><td colspan="2">CCTV</td><td>16</td><td>6</td><td>96</td></tr>
<tr><td>6</td><td colspan="2">Server Box</td><td>3</td><td>500</td><td>1500</td></tr>
<tr><td>7</td><td colspan="2">Water Pump</td><td>1</td><td>3730</td><td>3730</td></tr>
<tr><td colspan="5">Total connected electric load</td><td>82,322</td></tr>
</table>

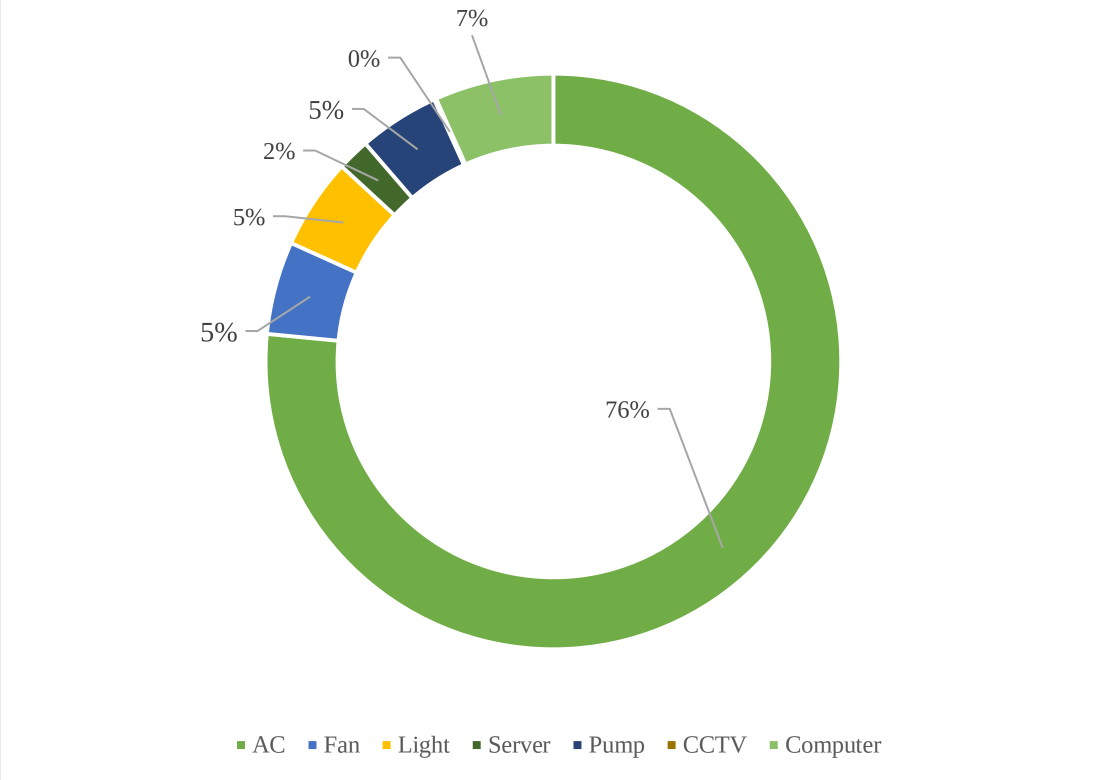


Figure 3. 4: Electricity consumption by different connecter load

Here AC load contains 76% of total load, Computer contains 7%, Fan and light both 5%, Server 2%, Pump 5%, and CCTV Contains less than 1%.

3.4 Energy Use Index

Audit team used the values related to monthly energy consumption this value helps to determining the monthly/annually energy usage. It gives an idea of overall energy usages, energy intensity and helps to setting achievable benchmarks for existing equipment's. EUI is very important for proper use of energy.

EUI have been calculated based on monthly consumption of electricity of different months. EUI shown in figure 3.5.

This is calculated by this formula,

$$\text{EUI} = \frac{Total\ Energy\ Consumption\ \ (kWh)}{Total\ Area\ (sq.ft)}$$

From EUI chart we found EUI 1.86 in June and 1.18 in December.

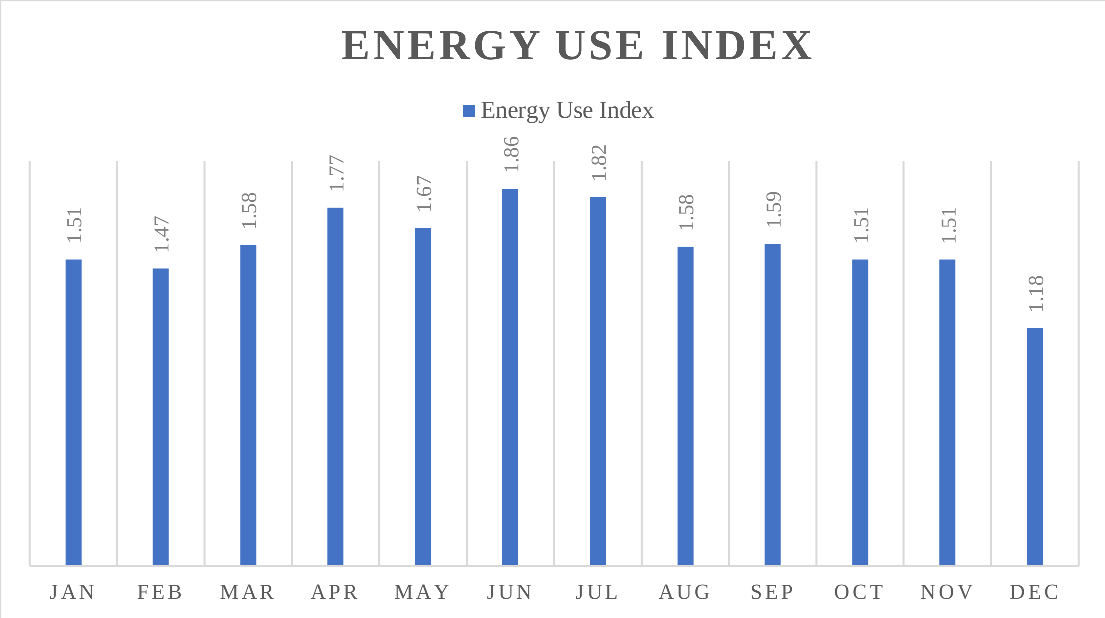


Figure 3. 5: Energy use index per month

3.5 Calculation of Daffodil University Library Building

The data we have collected from the building, we put them into data sheet to get calculations for the building.

Starting the process with lights, Table 3.3 shows the concise lighting information of the library building.

Table 3. 3: Data of connected lighting load

Type of light	Number of Light Load	Watt rating	Monthly Lighting Energy Consumption (kwh)	Annual Lighting Energy Consumption (kwh)	Rate Per KWh (BDT)	Monthly Lighting Cost (BDT/Month)	Annual Lighting Cost (BDT/yr)
Compact Fluorescent Lamp (CFL)	13	23	13×23×12 ×26=93.28	13×23×12 ×275=986.7	10.81	1008.35tk	10666.22
Compact Fluorescent Lamp (CFL)	10	15	10×15×12 ×26=46.8	10×15×12 ×275=495	10.81	505.9tk	5350.95

Type of light	**Number of Light Load**	**Watt rating**	**Monthly Lighting Energy Consumption (kwh)**	**Annual Lighting Energy Consumption (kwh)**	**Rate Per KWh (BDT)**	**Monthly Lighting Cost (BDT/Month)**	**Annual Lighting Cost (BDT/yr)**
Fluorescent Lamp (T12)	53	36	53×36×12 ×26=595.2	53×36×12 ×275=6563.	10.81	6435.15tk	70951.43
LED Tube	63	23	63×23×12 ×26=452	63×23×12 ×275=4781. 7	10.81	4886.12	51690.17
LED Tube (Mini)	18	15	18×15×12 ×26=84.24	18×15×12 ×275=891	10.81	910.63	9631.71
LED Bulb	10	12	10×12×12 ×26=37.44	10×12×12 ×275=396	10.81	404.72	4280.76
Total Cost						14,150.87	152,571.24

From the table we get monthly lighting cost of 1008.35 BDT for CFL 23W, 505.9 BDT for CFL 15W, 6435.15 BDT for FL T-12 and 4888.12 BDT for LED Tube 23W, 910.63 BDT for LED tube mini 15W, 404.72 BDT for LED bulb 12W. The monthly energy consumption of CFLs 23W, CFLs 15W, FL T-12 and LED Tube/Tube mini/Bulb are 93.28 kWh, 46.8 kWh, 595.29 kWh, 452 kWh, 84.24 kWh and 37.44kWh respectively. Moreover, the total monthly lighting cost is 14,150.87 BDT, and annual lighting cost is 152,571.24 BDT. From lighting summery, we get two pie charts, shown in figure 3.6 and 3.7

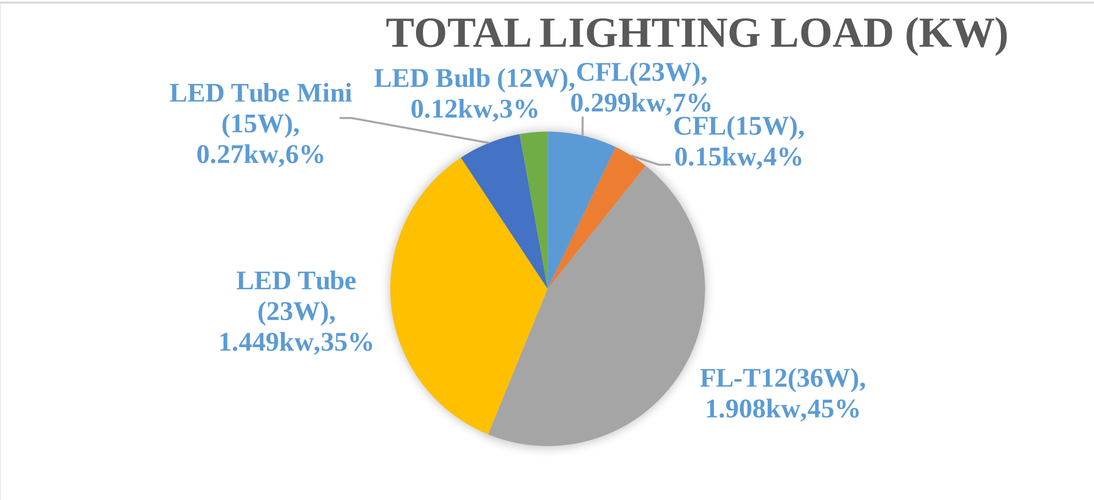


Figure 3. 6: Total lighting load of DIU library building

In this figure we can see the total lighting load of DIU Library building, where FL T-12 consume 1.908 kW which is 45% of the total lighting energy consumption, CFL (15W) consume 0.15 kW which is 4% of the lighting energy consumption, CFL (23W) consume 0.299 kW which is 7% of lighting energy consumption, LED bulb (12W) consume 0.12 kW which is 3% of the lighting energy consumption, LED Tube (15W) consume 0.27 kW which is 6% of the lighting energy consumption, LED Tube (23W) consume 1.449 kW which is 35% of the lighting energy consumption. During our study we observed that, LED tube and LED bulb are better in quality than FL T-12 and CFLs. But still FL T-12 and CFLs are used in the most of the cases.

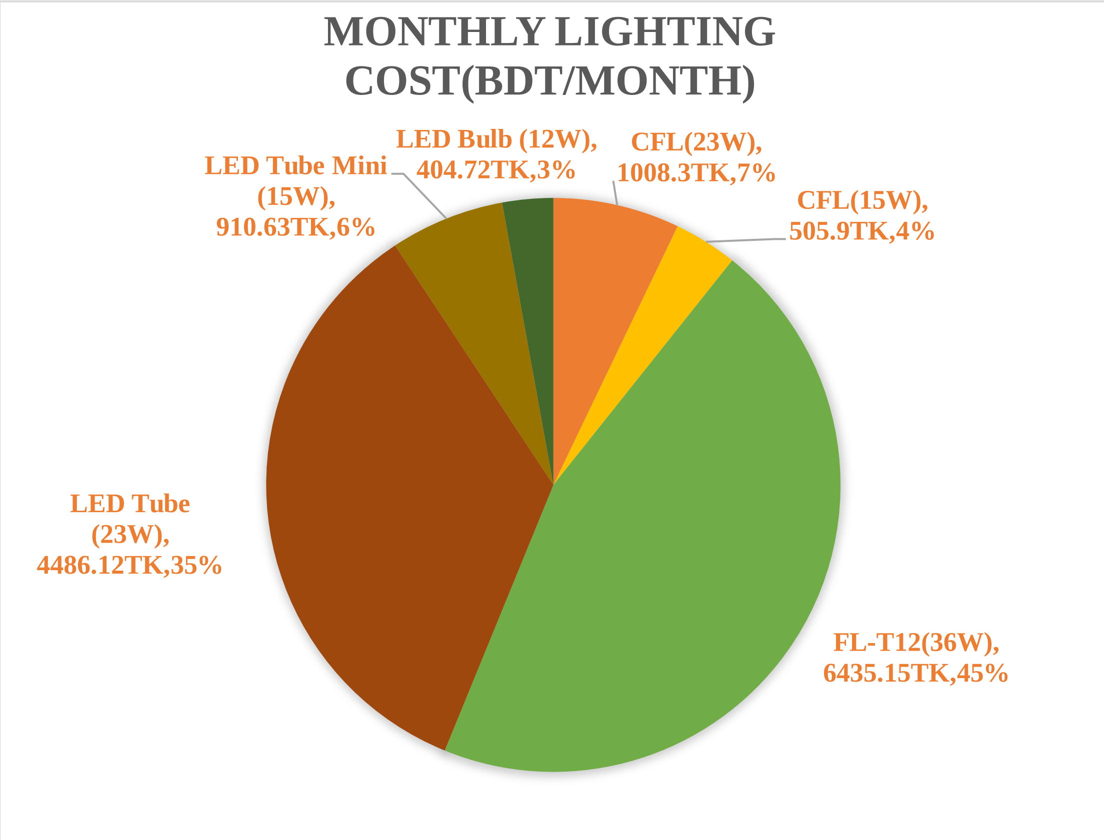


Figure 3. 7: Monthly lighting cost of DIU library building

From this figure, we can see FL t-12, CFLs and LED are responsible for 45%, 11%, and 44% lighting cost respectively. Although FL T-12 consumes more electricity than CFLs.

Next we move to electrical equipment calculations; Table 3.4 shows the concise information about electrical equipment.

Table 3. 4: Data of connected electric equipments

Equipment Type		No. of Equipment	Total Equipment Load (kW)	Monthly Equipment Energy Consumption (kWh)	Monthly Equipment cost (BDT/Month)
Air Conditioner	AC (3 ton)	4×4500	18	5,616	60,708.96
	AC (2 ton)	12×3000	36	11,232	121,417.92
	AC(1.5ton)	4×2250	9	2,808	30,354.48
Computer		22×250	5.5	1716	18,549.96
Fan	56”	30×75	2.25	702	7,588.62
	36”	3×55	0.165	51.48	556.5
	Wall Fan	19×65	1.235	390	4,215.9
	Exhaust Fan	13×50	0.65	202.8	2,192.26
CCTV		16×6	0.096	69.12	747.18
Server Box		3×500	1.5	1080	11,674.8
Water Pump		1×3730	3.73	193.96	2096.7
Total Cost					260,103.28

From the above data table, we can see air conditioner consume 19,656 kWh which costs 212,481.36 BDT per month. Computer consume 1,716 kWh which costs 18,549.96 BDT per month. Different types of Fan consume 1,346.28 kWh, which costs 14,553.28 BDT per month. Server Board consumes 1080 kWh and costs 11,674.8 BDT per month.

Figure 3.8 shows the pie charts of the electric equipment consumption summery And figure 3.9 shows the pie charts of the electrical equipment cost summery.

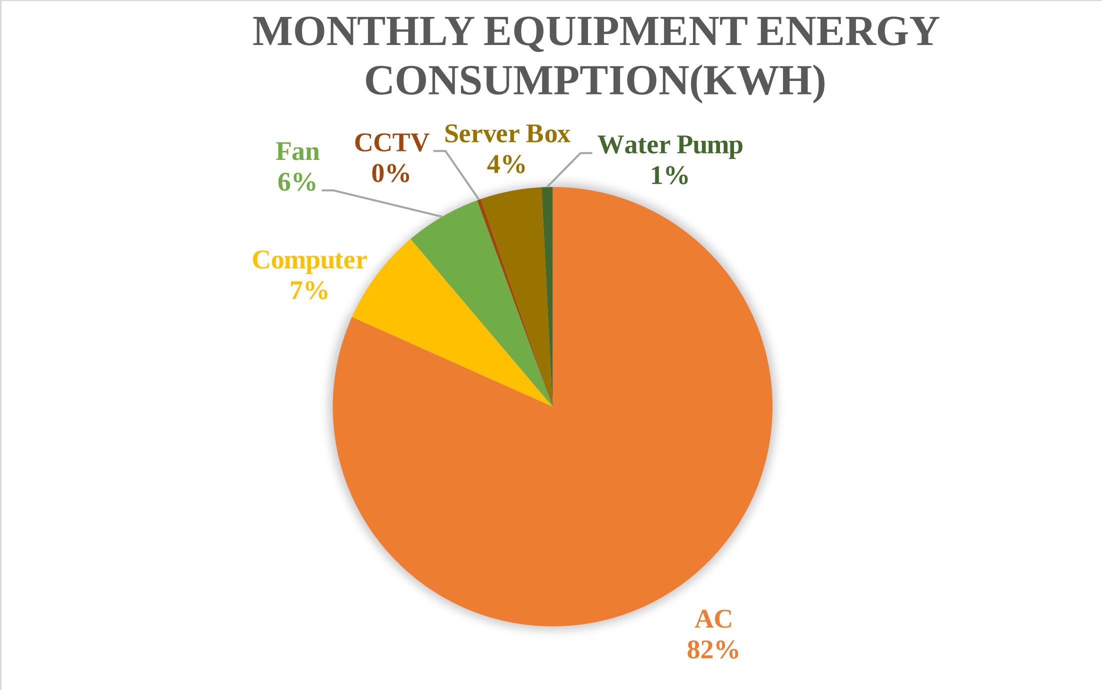


Figure 3. 8: Monthly equipment energy consumption

From the above pie charts, we can see air conditioner consumes most of the electricity and which is 82% of total electricity consumptions. Then computer which consumes 7% of electricity, Fan consumes 6%, Server board and water pump consumes 4% and 1% respectively.

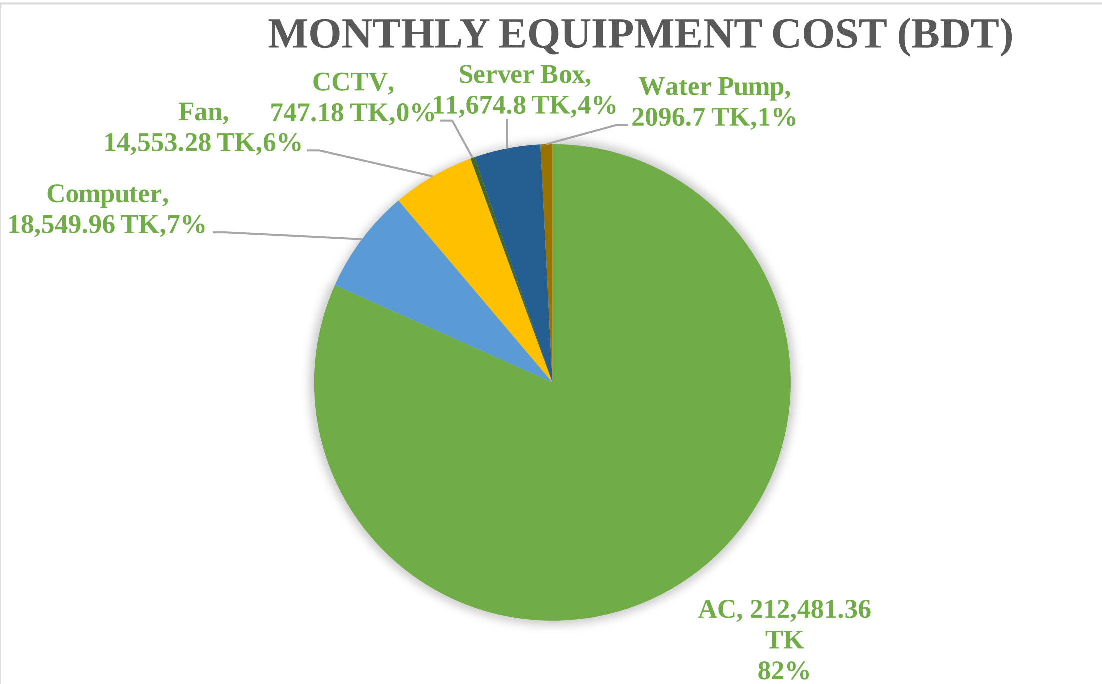


Figure 3. 9: Monthly equipment cost

From the above pie charts, we can see air conditioner consumes most of the electricity and causes large electrical equipment cost which is 212,481.36 BDT of total electrical equipment cost. Then computer electricity cost is 18,549.96 BDT, Fan cost 14,553.28 BDT, server Board and Water pump cost 11,674.8 BDT and 2096.7 BDT respectively.

After that we comes, envelope audit calculation. Table 3.5 shows leakage loss due to envelope audit.

Table 3. 5: Data of building envelope audit

Floor no.	**Total Area of Window (sq-ft)**	**Ambient Temperature (in F)**	**Room Temperature (in F)**	**R value of Glass**	**A.C operation Hours**	**Rate Per kWh**	**Leakage transfer loss**	**Total (BDT)**
Floor -1	101.5	91	75	0.91	12	10.81	1763.99	14468.23
Floor -2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Floor -3	121	91	75	0.91	12	10.81	2102.89	
Floor -4	286	91	75	0.91	12	10.81	4970.47	
Floor -5	178	91	75	0.91	12	10.81	3093.51	
Floor -6	146	91	75	0.91	12	10.81	2537.37	

From the table, we get the calculation of DIU library building leakage loss. The Leakage loss we get is 14,468.23 BDT per month. This is the extra money we have to pay without any service.

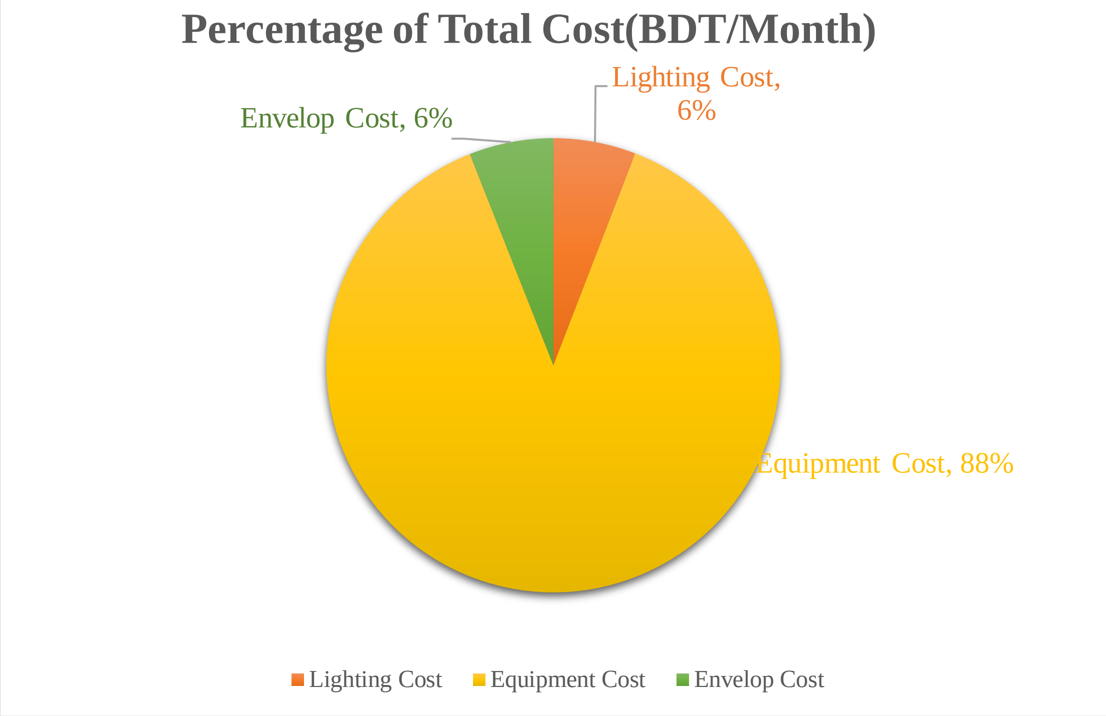


Figure 3. 10: Percentage of total cost

The pie charts show lighting cost is 6% of the total cost. Most of the part are covered by the electrical equipment's, which is 88% of the total cost and the envelope loss is 6% of total cost.

3.6 Analysis in Terms of Actual Bill

Our data was collected in the month of January. In Bangladesh January is a winter season. So, the cooling load used less than another season. As most of the electricity bills are consumed by the cooling equipment, in this season we have less electricity bills compared to the other seasons. We have found 260,103.28 BDT electricity bills from our data table for the DIU library building. Which is pretty much close to the actual bill.

3.7 Comments

There is much electrical equipment for which electricity consumption cannot be measured. These types are categorized as miscellaneous in terms of energy consumption. For example, laptop chargers this is used on daily basis to charge our laptops. The energy consumption of this charger is difficult to calculate. But still this use of electricity is increasing our bills. In spite of this, our calculated value is closed to original energy bills and we can assume an error percentage of our calculation to be approximately +10% to -10% due to the above-mentioned problems. All data collection forms can be found on Appendix Part A.

3.8 Summary

For energy audit huge data are need for calculation, in this chapter we show the electric bill we collected from responsible office personnel, also the floor plan to understand about the building structure. We calculated EUI in terms of energy use based on area. Daffodil library building data are collected and shown in this chapter, also we show some pie charts for showing the connected load, energy consumption and energy consumption cost for different electric equipment's. Identify cost for different types of load based on their individual energy consumption. We try to show the impact of different types of load, on the energy bill. Also try to analysis in terms of energy bill, and the limitations of work.

CHAPER 4

ECONOMIC FEASIBILITY STUDY

4.1 Introduction

Main goal of our energy audit is to save the energy and money. By saving energy our national overall demand also reduced and increase the energy efficiency which help to use those energy in different energy consumption sector. It's helpful for our country and its developments. In this chapter we focused on lighting equipment's, electrical equipment's, and envelope consideration. Where energy savings and the recommendation for efficient energy equipment's are discussed.

4.2 Lighting Consideration

In Bangladesh, lighting system consumes more energy compared to other electricity consuming equipment's. Lighting accounts for approximately 20% to 30 % of the electricity consumption worldwide [36]. The lighting system varies from place to place and from sector to sector but it needs to provide a suitable condition with desired level of illumination. Simultaneously, the system needs to be designed illumination level that is maintaining the required level of output. As a developing country we need to look towards energy efficient technology due to many factors [36].

The factors are on the following:

1. Due to the high expense in constructing new power plant
2. Due to the increasing population which increase the power demand
3. Lack of capital for investment in alternatives
4. Increases energy consumption leads to contribution of carbon emission

Thus, switching toward energy saving light technologies can save substantial amount of energy [37]. In Bangladesh, mostly incandescent and fluorescent light are used [38]. Nowadays, Compact Fluorescent light (CFLs) are taken the place of Incandescent light bulbs. These CFLs are available in different watts with different colour and lumen. The usage of CFLs can be seen in the most of the commercial buildings, such as shopping malls, Industries, Universities, Office and also in residential areas. Amongst other types of lamp are High Intensity Discharge lamps (HIDs) such as, Low Pressure Sodium Lamps (LPSLs), High Pressure Sodium lamps (HPSL), Halogen Lamps (HL) which are readily available in Markets. Research has now come up with energy efficient bulbs known as Light Emitting Diode (LED), which claims to reduce energy consumption by 50% [39, 40].

4.2.1 Incandescent Lights

Incandescent light bulbs have been the most commonly used light sources over the past one and half decade also called the 'Edison Bulb' [36]. When current passed through a thin filament of tungsten wire, its gates heated up and emits the light. Due to the good proportion of heat, the lights have low efficiencies. Incandescent lights convert 5% of its input energy to useful output as visible light. The gasses, however collect the tungsten particles and send them back to the filament. However, almost 90% of the energy generated by an incandescent bulb is released as heat, not light [36]. This is the cheapest of all lights and nowadays it is commonly used in the rural areas of Bangladesh.

4.2.2 Fluorescent Lamps

In the past few years, incandescent bulb starts to give way to more efficient fluorescent (FL), Compact fluorescent (CFL) and light emitting diode (LED) lighting system. FL bulbs are one of the most successful innovations in the light industry. They consume far less energy to produce the same amount of light. For instance, a 15W FL lamp emits the same amount of light as 60W incandescent bulb [36]. Inside the lamp, vapours of mercury are inflamed by the alternating current. The gas helps to emit light which hits the fluorescent material, found inside the inner part of the tube. This causes a soft glow of light and their efficiencies are quite good [38]. Fluorescent lamps are mostly available in long cylinders ranging 5W to 40W. 'Parallel length' or PL tubes are obtainable in the markets. Fluorescent lights are also one of the extensively used light in the commercial buildings and industries. Both 36W and 40W of fluorescent lamps are available in the market which provide same lumen output [38].

4.2.3 Compact Fluorescent Lamps

For the last few years, usage of CFLs has been flourished in our country. In the urban areas, CFLs has already replaced many fluorescents and the traditional incandescent lights. It is considered to be one of the best technological innovations in the lighting industries. The lifetime of CFLs in 10 times longer than incandescent bulb [36]. The energy consumption of CFL in terms of watt is also very less compared to incandescent and fluorescent.

4.2.4 High Density Discharge Lamps

HIDs are mainly suitable for all types of outdoor and external uses, where lamps need to operate at extended period of time. HPLS are considered to be source of lights. They produce amber colour and are used in street lighting [38]. LPSL are also used for outdoor applications and they produce copper golden colour.

4.2.5 LED

The LED is what is called a "solid-state lighting" technology or SSL. It radiates light from a part of semiconductor made of positively and negatively charged component. The light is radiated as the electrons transfers inside the semiconductor from negative to positive layer [36]. Studies showed that retrofitting the traditional CFLs, FLs and all other lights by LED can save a considerable amount of energy. There are basically two types of LEDs, the 5mm LED chips and the high-output chip on board (COB). The 5 mm LED has low light output and lacks proper thermal path that is essential for maintaining the LEDs junction temperature. Normally the luminous of the 5 mm LED would reduce to half of its original value after 6000 hours. The COB is known as the current choice for lighting since it offers far superior luminous output as well as having proper thermal path for regulating the LEDs junction temperature. Figure 4.1 shows the Incandescent, CFL, and LED light bulb [36].

A comparison table for different types of bulbs is on the following [41].

Table 4. 1: Comparison of features for different type of lights

Feature of Light	**Incandescent**	**CFLs**	**LED**
Life span of a typical bulb	1,200 hours	10,000 hours	50,000 hours
Watts per bulb (60W equivalent)	60	14	10
Cost per Bulb	30-50 BDT	350-650 BDT	600-1500 BDT
Turns on instantly?	Yes	Slight delay	Yes
Durability	Fragile	Fragile	Durable
Heat Emission	High (85 BTU’s/hr)		Low (3 BTU’s/hr)
Hazardous Material	None	5mg	None
Replacement Frequency (over 50 kWh)	40+	5	1

Figure 4. 2: Fluorescent lamp

Figure 4. 1: Incandescent lamp

Figure 4. 4: Compact fluorescent lamp

Figure 4. 3: LED lamp

A survey was conducted in several building in Daffodil International University, the capital city of Bangladesh to obtain the types of the light used in the commercial purposes. Table 4.2 shows the information of different types of lights used in buildings that we have audited.

Table 4. 2: Data of light in commercial building

Building Name	**Total Number of CFLs (W)**	**Total Number of Fluorescent T(12W)**	**LED Tube (W)**	**LED Tube Mini (W)**	**LED Bulb**
DIU Central Library	13-(23W) 10-(15W)	53-(36W)	63-(23W)	18-(15W)	10-(12W)

The illumination levels of corresponding building are also measured by digital lux meter which can measure up to a range of 200000 Lux.

Table 4.3 represent the data of luminous level in lux collected from our field visit.

Table 4. 3: Average luminous level measured by light meter

Name of the Building	**Average Luminous level in working Space of per Room (in lux)**
DIU Central Library	744.35

One of the main problems that were identified during our visit was quality of the lighting products. The lighting companies of Bangladesh do not maintain standard quality control over the manufactured lighting products. As a result, cheap and low-quality ballasts are provided which causes the lighting system inefficient and losses in terms of money.

4.3 Retrofits

Retrofit is the process of replacing inefficient light systems with more advanced and higher efficiencies system. This also depends upon various parameters such as policies and regulations, occupant’s expectations, building specification and human factors [42]. However, considering above factors, we have observed that by replacing all types of bulbs by LED, the output efficiency of the lights can be improved.

Table 4.4 shows an equivalent replacement of conventional light bulbs by energy efficient LED lamps

Table 4. 4: Replacement of typical lamps by LED lamps

Type of Light	Replacement
Fluorescents T-12 (36W)	LED tube lights (16W)
Compact Fluorescent (23W)	LED lamps (14W)
Compact Fluorescent (15W)	LED lamps (9W)

The data we have accumulated are mostly for the classrooms and laboratories of University Building (DIU library building).

Table 4.5 below exhibits the actual recommended illumination level for these buildings. According to Bangladesh National Building Code, BNBC (2011), the illumination level [44].

Of our site should be,

Table 4. 5: Recommended illumination level by BNBC

Name of the Building	Recommended illumination level (Lux)
DIU central Library	300 (per room)

The unit Lux is defined as lumens per square meter. Thus, the recommended values stated by BNBC already considered the floor area for every classroom.

The quality of light should be improved by the manufacturer. Electronic ballast could be used where FL are used. This draws fewer current causes less loss than the conventional magnetic ballasts.

Smart switching sensors can be used to automatic switch off when there are no occupants in the room. A new type of light known as T5 improved and modified version of FL is now claiming that it has less heat dissipation, cheaper and has higher efficiencies than LEDs [43]. Future replacements can be done with T5 if it proves to be efficient. In that case payback period might reduce significantly.

4.4 Electrical Equipment Consideration

Electric bills become heavy in amount due to electrical appliances other than lighting because most of the appliances consume high electric power. The common electrical appliances used in commercial areas are air conditioner, Ceiling fan, Stand fan, Computer, Elevator, CC camera, Refrigerator etc. For the technological advancement most of these have been updated to a new version which consumes less power without degrading service quality in comparison to conventional ones. To save electrical power consumption in commercial areas we have to retrofit energy efficient appliances over older ones.

4.4.1 Replacement of Air Conditioner

As an equipment to modify the natural environment, air conditioning has very broad application. Its operation is based on the temperature, humidity, cleanliness, freshness and air flow in a room of enclosed space to maintain the comfort zone for humans or requirements of a technical process. If anyone buys a bigger air conditioner than the actual sized unit it will cool less efficiently than the properly sized unit. Several types of air conditioner include window type, split type air conditioner.

The key parameters for choosing air conditioners include [45]:

- Cooling capacity
- Power consumption
- EER & SEER
- Air flow
- Noise
- Dehumidification

From the point of view of establishing energy efficiency the main parameters are:

4.4.1.1 Cooling Capacity

The cooling capacity of an air conditioning system is expressed in BTU's or tons. Cooling capacity is defined as the heat load in a room that has to be removed to attain a certain room temperature and humidity. The typical design is to set 24ºC and 55% relative humidity which are most conducive to human body [46]. One ton of cooling capacity equals 12,000 BTU's/hour of cooling capacity. The higher the rate of

BTU/hour, the greater the cooling capacity is. Before replacing the air conditioner, cooling capacity need for a room should be measured to be more efficient. Step to calculate cooling capacity [46].

Step 1

Find the volume of the room in cubic feet

Volume = Width × Length × Height (cubic feet)

Step 2

Multiply this volume by 6

C1 = Volume × 6

Step 3

Estimating the number of people (N) that will usually occupy this room. Each Person produces about 500 BTU/hour of heat for normal office-related activity. Multiply these two figures together

C2 = N × 500 BTU/hour

Step 4

Add C1 and C2 together and you will get a very simplified cooling capacity needed for the room.

Estimated cooling capacity needed = C1 + C2 (BTU/hour)

4.4.1.2 Power Consumption

The total amount of power consumed while operating in cooling or heating mode specified in electrical watts. The lower the power consumption, the higher is the efficiency of the air conditioner.

4.4.1.3 EER & SEER

EER (Energy efficiency ratio) is the ratio between the cooling capacity and the total power input and is denoted by EER (rated cooling capacity/input power). The larger the value of EER, the more efficient the air conditioner is. SEER (Seasonal Energy Efficiency Ratio) is obtained by dividing the total cooling that the equipment is able to provide over the entire season (in BTU) over the total energy in watt-hour it will consume. For more efficient equipment SEER will be higher.

4.4.1.4 Air Flow

Under rated conditions in cooling mode, the volume of air flow into an enclosed room within a specified period of time.

4.4.1.5 Noise and Dehumidification

These two items are directly related to the comfort of the consumer. The main source of noise in an air conditioner is the fan and the compressor, the dehumidification capacity measures the amount of latent heat removed from the enclosed space.

Beside the specified specifications above, energy star rating sir conditioner has implemented inverter technology to achieve better efficiency.

4.4.2 Inverter Technology in Air Conditioner

An inverter model means that the compressor is powered by a variable speed drive or 'inverter', which enables the compressor to run at a range of speeds from slow to fast, to match the output required. Most conventional compressors run at a constant speed and these types of units vary their capacity by switching on and off at different intervals.

Inverter are a sophisticated piece of technology which improve performance and energy efficiency of air conditioners under normal use.

Finally, we can reduce air conditioning energy use by 26%-45% [45] by switching to high efficiency air conditioners of various brands keeping the adobe specification in mind. Another electrical appliance which is responsible for consuming a significant amount of electricity is circulating fans. Circulating fan include ceiling fan, table fan, floor fan, window fan and poles or wall mounted fans. Both the power consumption and can be reduced by using energy efficient fans, maintaining proper installation rules from the user's point of view and using energy efficient components in making fans from producer's point of view. In the summer, a running ceiling fan raise your thermostat setting by 4ºF [48] without hampering your comfort which can cut out cooling cost by at least 4%-6% and in some eases by 8% [49]. Therefore, choosing appropriate fans in important to save energy.

Several factors to keep in mind to buy and install ceiling fans in order to make them more efficient

4.4.3 Fan Size and Blade Angle

Fan size refers the diameter of the circle that rotating blades make. The larger the room the larger the fan size is. It is best practice to follow the followings [50]:

- Room less than 80 sq. ft.: 24-42” blades
- Room which is 100-150 sq. ft.: 44-50” blade
- Room which is 150-300 sq. ft.: 52-60” blade
- Room greater than 300 sq. ft.: 62” blade span

Choose blade angle of 12-14^{o} otherwise it will be flat and reduce air flow [50].

4.4.3.1 Fan Installation

Installing the proper sized fans in proper position we can make the fans more efficient. Table 4.6 represent the suggested lengths of drop rod for fan installation for different ceiling heights [51].

Table 4. 6: Length of drop rod for different heights

Ceiling Height (feet)	Drop Rod
9	12
10	18
11	24
12	36
13	48

4.4.3.2 Noise Levels

The lesser the noise produced by the fan the more comfort we feel. Fans rated with their noise levels. Very quiet fans are rated at 0.5 to 1.5 tones [49].

4.4.3.3 CFM

It measures the air flow in cubic per minute. We should select higher CFM to reduce the cooling cost which should be at least 6000-7000 CFM [15] for the best results. The required CFM for a room is calculated in the following way [49]:

Volume of the room, V = Square feet of the floor × room height in feet.

Then multiply it by 30 or 60 air charges per hour and divided by 60 to get the required CFM.

CFM required = $\frac{V \times 30\ or\ 60}{60}$

4.4.3.4 Motors

Fans with BLDC (Brushless DC) motor are more efficient than the fans with split phase inductor motor. The reason is that inductor motor does not maintain synchronous speed with the generated magnetic field whereas BLDC motor maintain synchronous speed by reducing the friction of the rotor. A ceiling fan with BLDC motor consumes power about 50% that of a fan with split phase inductor motor [52]. At high speeds, power consumption can be reduced from 70-75W to 45-50W [52].

Table 4.7 shows the criteria for ceiling fan in order to be ENERGY STA* certified [54].

Table 4. 7: Specification of ENERGY STAR rated ceiling fan

Equipment	Specification
Ceiling Fans	1. Specification defines residential ceiling fan airflow efficiency on performance basis: CFM* of air flow per watt of power consumed by the motor and controls. Efficiency is measured on each of three speeds. 2. At low speed, fans must have a minimum air flow of 1250 CFM* and an efficiency of 155 CFM/Watt. 3. Qualifying ceiling fan models must come with a Minimum 30-year motor warranty; one-year components warranty and a 2-year light kits warranty. 4. At high speed, fan must have a minimum airflow of 5000 CFM* and an efficiency of 75 CFM/Watt.

Finally, if we can implement energy efficient technique in all fans sold by 2020 globally and install them properly, we can save 70 terawatt hours per year (TWh/Year) and can reduce 25 million tons of CO2 emission [48].

For other appliance like computer monitor, refrigerator etc. try to get the energy star rated appliances because it will cut your electricity bill to some extent. Think about computer monitor. CRT (cathode ray tube) monitors consume about 100W or more depending on the size of the monitors and LCD monitors consume less power than CRT [54]. LED monitors are more efficient than CRT and LCD because it consumes lesser power. ENERGY STAR* rated computer monitors consume power depending on their resolutions or megapixels and the maximum consumed power in on mode for different resolution is determined by the two criteria specified in ENERGY STAR* site [55]. The two criteria are the follows.

Criterion 1

In order to be ENERGY STAR* certified maximum active mode power must not exceed the equation: $Y= 38X + 30$, where X is the number of megapixels in decimal from and Y is rounded up to the nearest whole number and expressed in watt.

Criterion 2

If $X<1$ then $Y=23$ and if $X>1$ then $Y=28X$, where X is the number of megapixels in decimal from and Y is rounded up to the nearest whole number and expressed in watts.

This power will obviously be lesser than the power used in conventional monitor. Therefore, using ENERGY STAR* rated appliances we can save our money as well as electricity.

In addition to this, installing automated sensor-based fans and setting timers in air conditioner and setting the monitor in optimum brightness level which is about 15-30 percent for each LCD [56] monitors can effectively reduce power.

4.5 Building Envelope Consideration

Starting with the windows, windows are the most important part of a building envelope. Window is the great source of day lighting, ventilation and the heat from the sun in the winter. On the other hand, in summer air conditioners must work harder to cool from sunny window. Unfortunately, window is responsible for 10%-25% of heating bill by letting heat out [57]. In our country most of the glasses are single glazed with low insulation which contributes a lot in energy leakage. Moreover, doors also can contribute significantly to air leakage and can also waste energy through conduction. Specially, when it is old, not insulated, improperly installed or improperly air sealed. Sliding glass doors lose much more heat than other types of doors because glass is very insulator. It is almost impossible to stop all the air leakage around the weather stripping on a sliding glass door [58]. In this case swinging doors can offer tighter seal than sliding doors are single glazed and problems with this type of doors because most of the swinging doors are single glazed and not properly insulated. It is very obvious that the south facing buildings can have much air which actually decrease the demand of the cooling energy. Buildings location is an important factor in case of lighting energy consumption if daylight can enter in the building then we can reduce the light energy by 40%-50%. Lastly, any kind of crack in the wall or ceiling is the reason to air leakage.

There are many factors upon which envelope audit depends on such as U-factor, R-factor, fenestration rate etc. As our calculation is based on the R-factor so we emphasized on the R-factor. Unfortunately, we have limitation on our equipment so we ignore the other factors.

There are different types of operable windows available but we usually use horizontal slider. In some cases, we also use tilt and turn window. Anyway, the point is that all the windows that we use are single glazed and not properly insulated which is causing our air condition to work hard to leak the cold air as well as we cannot have our desirable temperature in our room or it takes longer to cool down. Now, in market there are some available window which can actually increase its efficiency which are multiple glazed windows. As the glazes of the window increases the R-value also increase as a result the leakage decreases. As for the doors there are two operable style: swinging and sliding. The swinging doors are more efficient that the sliding doors but there is energy star rated efficient doors and windows are available in the market. One of the sophisticated ways to save the energy bill is using insulated curtains. Insulated curtains are very useful in a way that they are not only energy saver but also improve the comfort and beauty of the rooms. To prevent air leakage there are four separate layers in the insulated curtains [59]. First, a core layer of high-density foam that insulates windows form exchange heat. Secondly, a vapour barrier blocks the foam's absorption of moisture. Thirdly, a layer of reflective film that deflects heat back into the room. Fourth, an outer layer with a decorative fabric. There are some different kinds of insulated curtains like roman shades, hobbled shades, side draw shades, and classic curtains [59]. Next, one the significant factor is reflectance of the wall. If wall painting or colour has low LRV (Light Reflection Value) then it must be absorbing your light [60]. As a result, you need more lights which are not efficient at all.

From our surveys, we found some typical areas of building envelope which must be replaced to improve the energy efficiency. First of all, we need to replace the windows which are very low quality and single glazed. Even, they are not properly insulated. Thus, we have replaced them by energy efficient multiple glazed windows which are available on the market. Furthermore, there are ENERGY STAR* rated windows are available in the market. Same goes for the doors, especially the sliding doors must be replaced by the new swinging energy efficient doors and as for the existing swinging doors they are not properly insulated. So, proper insulation will increase the efficiency. Replacing the windows and the door could save about 16% of the total energy bills [58].

The biggest reason of the air leakage is the cracks or holes in the walls or ceiling. So, we have to repair any kind of cracks and holes available in the building. Besides, the crack in the wall, the paint of the wall is also a factor to save energy bills. White paints reflect 80% of the light while black reflects only 5%, cool colours, such as blues and greens, to be 6-10 degrees Fahrenheit cooler than the actual temperature and worm colours, such as red and oranges, will result in a 6-10 degrees Fahrenheit warmer [61]. So, keeping this mind we have to choose our wall paint colour. Lastly, replacing old curtains with new energy efficient insulated curtains can be useful. According to the U.S. Department of Energy, white plastic curtains backing could reduce home heat in take by 33%. Addition to that, closing curtains could save up to 10% in heat loss [62].

Overall, we can save up to 50% of lighting and heat energy depending on area where the energy efficient product is use including insulation of the building, efficient windows, door and curtains, colour used, type of the construction amount of ventilation etc. [63].

4.6 Saving on Lighting

As we discussed on our previous chapters, our study was confined to two academic building of Daffodil University. Among them, full assessment and energy losses were calculated for Daffodil University building.

Fluorescent tubes are to be replaced by LED tubes available in 8 and 16 watt which can replace all traditional 36-watt T-12, 23 W and 15W CFLs respectively.

After inspection of DIU library building, we seen fluorescent T-12, CFLs types is available.

Thus, we calculated the saving by replacing the most efficient lamps that are available now and our calculation method is [64].

- Considering wattage of FL T12 lights = 36 W
- Wattage of LED tube lights = 16 W
- The wattage difference we get = 36-16 W = 20 W
- Number of tube lights = 53
- Wattage Saving = $\frac{53 \times 20}{1000}$ = 1.06 kW
- Average working hours = 12 hours
- Total number of days the lights are active = 275 days
- Saving in unit = 1.06 × 12 × 275 = 3,498 kWh
- Cost of electricity@ BDT = 10.81 × 3,498 kWh = **37,813.38 BDT**

Compact Fluorescent lamps (CFLs) are to be replaced by LED bulbs available in 14W and 9W, which can be replace 23 watt and 15watt of CFL respectively to get 1450 lumens.

- Considering wattage of a CFL = 23 W

- Wattage of LED lamps = 14 W
- The wattage difference we get = 23-14 = 9 W
- Number of CFLs lights = 13
- Wattage Saving = 13×9/1000 = 0.117 kWh
- Working hours = 12
- Total number of days the lights are active = 275 days
- Saving in unit = 0.117 × 12 × 275 = 386.1 kWh
- Cost of electricity@ BDT = (10.81×386.1) kWh = **4,173.74 BDT**
- Considering wattage of a CFL = 15 W
- Wattage of LED lamps = 9 W
- The wattage difference we get = 15-9 = 6 W
- Number of CFLs lights = 10
- Wattage Saving = $\frac{10 \times 6}{1000}$ = 0.06 kWh
- Working hours = 12
- Total number of days the lights are active = 275 days
- Saving in unit = 0.06 × 12 × 275 = 198 kWh
- Cost of electricity@ BDT = 10.81 × 198 kWh = **2,140.38 BDT**

After replacement with above mentioned types, total annual saving for Library building would be = 37,813.38+4,173.74+2,140.38 = **44,172.5 BDT**

From our worksheet, the total annual cost for FL T-12 and CFLs lighting was calculated = **87,008.6 BDT**

Therefore, after replacements with LED we can annually save,

$$=\frac{44{,}172.5}{87{,}008.6} \times 100 = \mathbf{50.76\ \%}$$

Table 4. 8: Savings from lighting audit

Name of the buildings	**Types of lights used and corresponding Wattage**	**Replacement lights and corresponding Wattage**	**Savings after retrofits**
Daffodil Library Building	CFL- 13 (23W)	LED Lamp (14W)	50.76 %
	CFL- 10 (15 W)	LED Lamp (9W)	
	FL- 53 (36)	LED Tube (16W)	

4.7 Saving from Electrical Equipment

Terminologies used for calculation of saving from electrical equipment

Q_a= Quantity of air conditioner

Q_f= Quantity of fan

Q_m = Quantity of fan

WH_d= Working hours per day

WD_m= Working days per month

U_c = Unit cost of electricity for commercial building

P_{exist} = Power rating of existing appliance

P_{star} = Power rating of ENERGY STAR* rated appliance

P_{con}^{exist}= Power consumption of existing appliance

P_{con}^{*}= Power consumption of ENERGY STAR* rated appliance

P = Saving in Power consumption

Saving calculation for Daffodil Library Building for electrical appliances

Saving from the replacement of conventional air conditioner by ENERGY STAR rated air conditioner:

Q_a = 12

WH_d = 12 hours

WD_m = 26 day

P_{exist} = 3000 W

P_{star} = 2650 W (Source: [65])

P_{con}^{*}= Q_a ×P_{star}

= 12 × 2650

= 31.8 kW

P_{con}^{exist}= Q_a ×P_{exist}

= 12 × 3000

= 36 kW

U_c= 10.81 BDT

P = P_{con}^{exist} - P_{con}^{*}

= 36 – 31.8

= 4.2 kW

Saving in BDT/Month = P × WH_d × WD_m × U_c

= 4.2 × 12 × 26 × 10.81

= **14,165.42 BDT/Month**

Saving from the replacement of conventional fan by ENERGY STAR* rated fan:

Q_f = 30

WH_d = 3 hours

WD_m = 26 day

P_{exist} = 75 W

P_{star} = 55 W (Source: [66])

$P_{con}^{*}= Q_f \times P_{star}$

= 30 × 55

=1.65 kW

$P_{con}^{exist}= Q_f \times P_{exist}$

= 30×75

= 2.25 kW

U_c = 10.81 BDT

P = P_{con}^{exist} - P_{con}^{*}

= 2.25 – 1.65

= 0.6 kW

Saving in BDT/Month

= P × WH_d × WD_m × U_c

= 0.6 × 3 × 26 × 10.81

= **506 BDT/Month**

Saving from the replacement of conventional computer monitor by ENERGY STAR* rated computer monitor:

Q_m = 22

WH_d = 12 hours

WD_m = 26 day

P_{exist} = 50 W

P_{star} = 25 W (Source: [66])

P_{con}^{*}= Q_m ×P_{star}

= 22 × 25

= 0.55 kw

P_{con}^{exist}= Q_m ×P_{exist}

= 22 × 50

= 1.1 kW

U_c = 10.81 BDT

P = P_{con}^{exist} - P_{con}^{*}

=1.1 – 0.55

= 0.55 kW

Saving in BDT/Month

= P × WH_d × WD_m × U_c

= 0.55 × 12 × 26 × 10.81

= **1,855 BDT/Month**

Total cost for electrical appliances for Daffodil Library building= **127,025 BDT/Month**

This value is calculated based on major electrical equipment which we recommended to replace in above calculation section.

Total saving for electrical appliances for DIU library building.

= 14,165.4 + 506 + 1,855

=16,526.4 BDT/Month

It is 12.7% of the total cost of electrical appliances.

Annual saving would be,

= 16,165.4 × 12

=**193,984.8 BDT/year**

Table 4.9 summarizes the saving of power consumption per month for electrical appliances for DIU library building.

Table 4. 9: Savings of power consumption for DIU Library Building

Electrical Appliances	**Q**	P_{star} **(W)**	P_{exist} **(W)**	P_{con}^{*} **(kW)**	P_{con}^{exist}**(kW)**	**P(kW)**
Air Conditioner	12	2650	3000	31.8	36	4.2
Fan	30	55	75	1.65	2.25	0.6
Computer Monitor	22	25	50	0.55	1.1	0.55

Table 4.10 summarizes the saving of money in BDT/month for the electrical appliances for DIU library building.

Table 4. 10: Summarizes the savings of money in BDT/month for the electrical appliances for DIU Library Building

Electrical Appliances	WH_d	WD_m	U_c	**Saving in BDT/month**
Air Conditioner	12			14,165.4
Fan	3	26	10.81	506
Computer Monitor	12			1855
Total Savings:				**16,526.4**

Total cost for electrical appliances for DIU library building = 127,025 BDT/Month

Saving 12.7% for electrical appliances for DIU library building.

4.8 Savings on Building Envelope Audit

Single glazed windows can be replaced by the ENERGY STAR* rated double or triple glazed windows which we talked about in our previous chapter. Now, this replacement will give us 16% saving on the existing leakage loss by the windows as we said earlier.

From the data table of energy audit, we get envelope leakage loss for DIU library building = 14,468.23 BDT/Month

So, saving by replacing windows of DIU library building

$= 14{,}468.23 \times 16\%$

$= 2{,}314.91$ BDT

We can save **2,314.91 BDT/Month** by replacing windows from library building.

Annual saving for Library building = $2{,}314.91 \times 12 = 27{,}779$ BDT/year

Total monthly cost of electricity consumption for library building of DIU,

$= 260{,}103.28 + 14{,}150.87 = 274{,}254.15$ BDT/Month

Total monthly saving for library building of DIU,

$= \frac{44{,}172.5}{12} + 16{,}526.4 + 2{,}314.91$

= **22,522.35 BDT/Month**

Overall saving for library building of DIU,

$= \frac{22{,}522.35}{274{,}254.15} \times 100 =$ **8.21 %** of the total cost of electricity consumption.

Figure 4.2 and 4.3 show the percentage of cost of DIU library building before saving and after saving respectively.

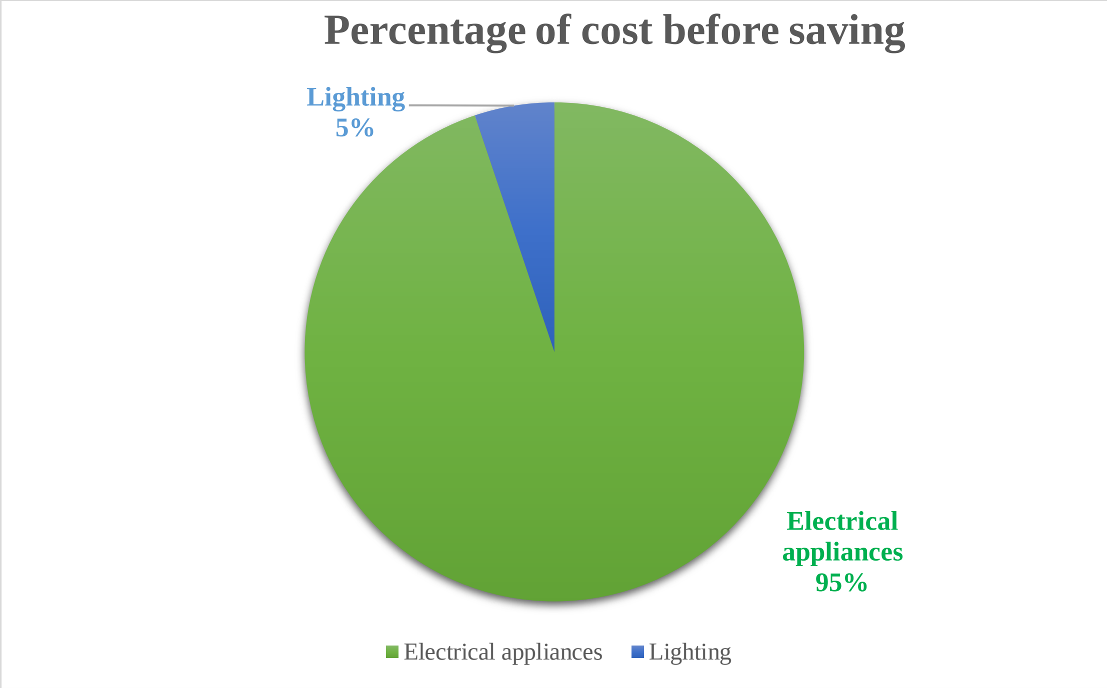


Figure 4. 5: Percentage of cost before saving

Figure 4.2 illustrates that electrical appliances contribute 95% and lighting system contributes 5% to the total cost before saving.

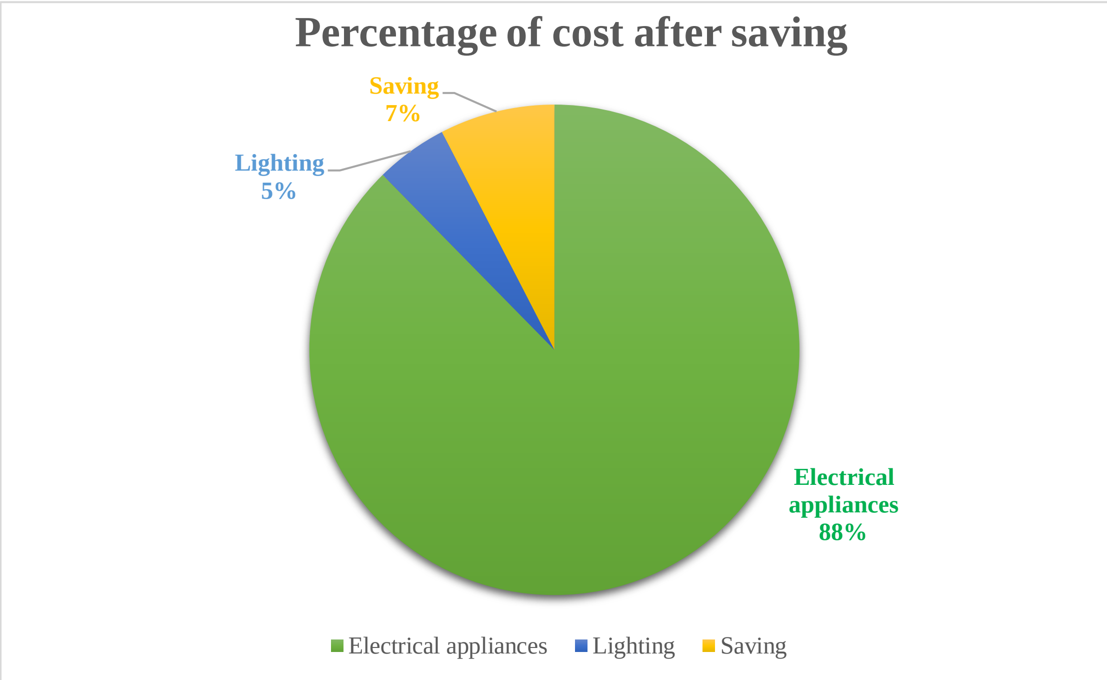


Figure 4. 6: Percentage of cost after saving

Figure 4.3 shows that the contribution of electrical appliances and lighting system to total cost reduces due to saving of 7%.

4.9 Payback Period

We know that, payback period in year = Total annual investment/net annual saving [67]

We will only analyse the payback period for DIU library building.

Table 4. 11: Star rated appliances for DIU Library Building

Name of the components and quantity		**Price in BDT for per piece**	**Investment in BDT**
LED Lamps	14 W (13)	650	(650×13) = 8,450
	16 W (53)	820	(820×53) = 43,460
	9 W (10)	450	(450×10) = 4,500
Air conditioner (Star rated) [84] Quantity- 12		74,999	(74,999×12) =899,988
Fan (Star rated) [84], Quantity-30		4200	(4200×30) = 126,000
Monitor (Star rated) [86] Quantity- 22		17000	(17000×22) = 374,000
Energy Efficient glass for the Windows building (6 storied-one sided) [83]		220 (per sq-ft)	(220×832) = 183,040
Total Investment			16,39,438

Total lighting system investment for Library building = 56,410 BDT/year

So, payback period for lighting system would be

= 56,410//44,172.5

=**1.27 year or 15.32 Month**

Total electrical system investment for library building, = 13,99,988 BDT/Year

Payback period for electrical system would be,

= 13,99,988/193,984.8

= **7.21 year or 86.6 month**

Total envelope investment for library building = 183,040 BDT/year

Payback period for envelope system for library building,

= 183,040/27,779

= **6.5 years or 79.06 month**

4.10 Summary

The objective of an energy audit is to identify energy losses and the way of energy saving opportunities. In this chapter we try to show the savings from different types of light and electrical equipment's. How to replace efficient types of light for existing inefficient light and replace equipment's with STAR rated electrical equipment's. Also, the loss from the envelope leakage. We show some chart to spectacle how energy consumptions change with saving energy. We calculate the payback period for making decision for future investment. Percentage of cost before saving and after saving are calculated on pie chart for better understanding. This chapter mainly based on feasibility of energy savings and the way of the replacement for efficient energy consumptions.

CHAPTER 5
ENERGY EFFICIENCY IMPROVEMENT

5.1 Introduction

Energy consumption is very high in our present world. But what if our devices and homes and businesses could operate exactly as they do today, while using less electricity? That's the promise of energy efficiency, a major clean energy solution. Energy efficiency can bring significant economic, social and environmental benefits. But while energy efficiency is improving around the world, its positive impact on global energy use is overwhelmed by rising economic activity across all sectors. In this chapter we discussed some way to make a building more efficient.

5.2 Installation of Solar System

Daffodil library building only operate by DPDC supply line, all load is operated by national supply. It’s an opportunity to reduce energy consumption cost by installing solar system. It will help to reduce energy consumption by supply power in Peck hour for mandatory load, and also help to operate load like stair light.

5.3 Operation Time

Operation time is important for reducing energy cost for commercial building in Bangladesh. During Our inspection we observed all air-condition and lights are running, in our country peak and off-peak hour energy consumption for commercial building are different, Off-peak hour energy consumption cost is less then peak hour energy consumption. In this case library operating personnel need to know the peak and off-peak hour, and need to operate less load in peak hour. It will help to reduces cost for energy consumption, this practice also reduces energy consumptions.

5.4 Performance of Equipment

Checking Equipment performance is important in energy audit, Due to less performance equipments energy consumption is high comparatively high-performance equipments. Many equipments are still operating in library building, those equipments gives less output in terms of energy they consume. Some window AC and ceiling light are old model and consume large energy, this equipment consume more energy but they are not capable to give high performance. It's necessary to change those less efficient or less performing equipment for saving energy consumption which help to reduces energy consumption cost.

5.5 Improving the Power Factor

Most of the equipment's in library building are inductive load type, which reduce power factor of supply and it increase the energy consumption cost. By improving power factor in commercial building, huge amount of electric bill can be reduced. By installing capacitor bank in supply line, power factor can be improved.

5.6 Energy Efficient Technologies in Commercial Utilities

Day by day Technology are updated, and energy efficiency equipment are manufactured. But still commercial building in our country are use low energy efficient equipment's. We need to upgrade our equipment's to STAR rated equipment's, which are more ECO friendly and energy efficient. Which help to reduce energy consumption in the building, and also reduce energy consumption cost. Using energy efficient technology in commercial utilities is beneficial for county and owner also.

5.7 Best Practice

Library operating personnel need to maintenance electric equipment's regularly for achieve high efficiency and less energy consumption cost, also suggest periodical variation analysis of the high capacity equipment's like AC. Also need to operate heavy energy consumed equipment's in off peak time. And use more sun light to save energy during day time.

5.8 Field Saving Opportunities

Some of the energy saving opportunities in common energy consuming systems are mentions below. This thing is finding out during energy audit. Which will help to reduce energy consumption.

5.8.1 Lighting

- Installing LED to replace fluorescent and Compact fluorescent
- Using sunlight during day time
- Reducing light levels where appropriate
- Using electric ballast

5.8.2 Air Conditioning System

- Reducing unnecessary Air Conditioning system
- Use STAR rated AC for lower energy consumption
- Employing the best monitoring and control technique

5.8.3 Fan

- Installing fan of correct size
- Use energy STAR rated fan
- Co-ordinate with air conditioning system
- Doing the periodic maintenance

5.8.4 Pump

- Optimizing the use of water
- Install correct rating pump
- Optimize the pipeline size
- Operate in off peak period mostly

5.9 Summary

There are lot of way to make a building energy efficient. In this chapter we try to recommend some basic way to make a building more efficient. The way of using the load based on peak and off-peak period. Also recommend solar for reducing energy consumption for various type of load. Some practice can reduce huge amount of energy consumptions and energy consumption cost, for constant output.

CHAPTER 6

CONCLUSION

In today's world, the uses of electrical energy are ascending everyday due to increasing demand in both developing and under developing countries. The price hike of fuel has now become a common phenomenon and this leads to the increase in the generation cost of electricity. Increase in the generation cost proportionally increase the tariff rates and the consequences are reflected in our monthly energy bill. Although, energy auditing does not provide the exact solution to reduce the usage but again it provides several opportunities for improving our usage which may lead to a good proportion of saving. The techniques and calculation method that are used for small scale audit may not be appropriate for large scale industrial audits. In this study, we have discussed the fundamental steps and instruments required to start any scale audit. We have mainly focused on DIU Library Building with the objective of calculating energy loss, designing an actual retrofit scenario, calculating the potential electricity saving in percentage and finally the payback period. Our study depicted that reasonable amount of energy can be saved if the energy audit is performed properly.

6.1 Limitations of the Work

Due to limitations and insufficient measuring equipment we could not consider many factors such as infiltration rate, fenestration factors and others. Water consumption is also one of the important factors for a building which contributes in the electrical bill. Subsequent studies in this area may result in optimistic savings. Also, additional research and data is required to produce better results and can devise an effective method to conserve energy. In this paper we only calculate highest number equipment's for replacement and retrofit due to the lack of data and operation time.

6.2 Future Scopes of the Work

There is much further scope of our work to conduct in future, which may include considering fenestrations, improvements in infiltration and ventilation rate, calculations of heat flow due to conduction of material for windows, increasing motor efficiencies for water pumps, elevators and escalators. It is well known that, conservation of every kilowatt of energy reduces significant amount of carbon emission and carbon footprint. Thus, for a sustainable environment and to contribute towards carbon neutrality, it is very much crucial to introduce energy audit in every sector with few changes in existing system to cut the growing demand in Bangladesh. The government of Bangladesh may decide the policies so that all industries and commercial buildings undergo energy audit and this will definitely enhance our economical standing in world market.

Appendix A

A-1 Lighting Audit Form for Library Building

Building Energy Audit

Lighting

Building Identification: Library Floor No: 01

Please use a new sheet for each area, location or room in the facility.

Existing lights and controls

	Type 1	Type 2	Type 3	Type 4
Type of fixtures:	L	M		
Number of fixtures:				
Number of lamps ~~per fixture:~~	06	1		
If fluorescent indicate length of lamps (2ft, 3ft,4ft, 8ft):	4ft			
Watts per fixture:(Include ballast wattage if known)	23	12		
Fixture height from work surface (ft/m)	9ft	8ft		
Present operation of lights - hours/day	12	12		
Present operation of lights - days/week	06	06		
Present operation of lights – weeks/year	46	46		

Present light levels: Bright____ Adequate ✓ Dim____

Reflectance of walls and ceilings: Good____ Average ✓ Poor____

Can lights be switched on and off as desired? Yes ✗ No ✓ Comment: ____

Can lower wattage lamps be installed? Yes ✗ No ✓ Comment: ____

Notes: ____

Lighting Legend

A.- Incandescent B.- Fluorescent T-12 C.- Fluorescent T-12 HO (High Output) D.- Compact Fluorescent E.- Mercury Vapour F.- Fluorescent T-12VHO (VH Output) G.- High Pressure Sodium H.- Low Pressure Sodium I.-Metal Halide (White Light) J.-Fluorescent T-8 K.-Quartz Halogen L.- LED M.- Other-specify LED Bulb.

Building Energy Audit

Lighting

Building Identification: Library Floor No: 02

Please use a new sheet for each area, location or room in the facility.

Existing lights and controls

	Type 1	Type 2	Type 3	Type 4
Type of fixtures:	B	L	M	
Number of fixtures:	8			
Number of lamps/~~per fixture~~:	02	7	1	
If fluorescent indicate length of lamps (2ft, 3ft,4ft, 8ft):	4ft	4ft		
Watts per fixture:(Include ballast wattage if known)	36	23	12	
Fixture height from work surface (ft/m)	9ft	9ft	8ft	
Present operation of lights - hours/day	12	12	12	
Present operation of lights - days/week	6	6	6	
Present operation of lights - weeks/year	46	46	46	

Present light levels: Bright____ Adequate ✓ Dim____

Reflectance of walls and ceilings: Good____ Average ✓ Poor____

Can lights be switched on and off as desired? Yes ✓ No____ Comment: ____

Can lower wattage lamps be installed? Yes ✓ No____ Comment: ____

Notes: ____

Lighting Legend

A.- Incandescent B.- Fluorescent T-12 C.- Fluorescent T-12 HO (High Output) D.- Compact Fluorescent E.- Mercury Vapour F.- Fluorescent T-12VHO (VH Output) G.- High Pressure Sodium H.- Low Pressure Sodium I.-Metal Halide (White Light) J.-Fluorescent T-8 K.-Quartz Halogen L.- LED M.- Other-specify LED Bulb.

Building Energy Audit

Lighting

Building Identification: Library Floor No: 03 .

Please use a new sheet for each area, location or room in the facility.

Existing lights and controls

	Type 1	Type 2	Type 3	Type 4
Type of fixtures:	B	L	D	M
Number of fixtures:	8			
Number of lamps/per fixture:	2	9	3	1
If fluorescent indicate length of lamps (2ft, 3ft,4ft, 8ft):	4ft	4ft		
Watts per fixture:(Include ballast wattage if known)	36	23	23	12
Fixture height from work surface (ft/m)	9ft	9ft	8ft	8ft
Present operation of lights - hours/day	12	12	12	12
Present operation of lights - days/week	6	6	6	6
Present operation of lights – weeks/year	46	46	46	46.

Present light levels: Bright____ Adequate ✓ Dim____

Reflectance of walls and ceilings: Good____ Average ✓ Poor____

Can lights be switched on and off as desired? Yes ✓ No____ Comment: ____

Can lower wattage lamps be installed? Yes ✓ No____ Comment: ____

Notes: ____

Lighting Legend

A.- Incandescent B.- Fluorescent T-12 C.- Fluorescent T-12 HO (High Output) D.- Compact Fluorescent E.- Mercury Vapour F.- Fluorescent T-12VHO (VH Output) G.- High Pressure Sodium H.- Low Pressure Sodium I.-Metal Halide (White Light) J.-Fluorescent T-8 K.-Quartz Halogen L.-LED M.- Other-specify LED Bulb.

Building Energy Audit

Lighting

Building Identification: Library Floor No: 04

Please use a new sheet for each area, location or room in the facility.

Existing lights and controls

	Type 1	Type 2	Type 3	Type 4
Type of fixtures:	B	L	D	M
Number of fixtures:	12			
Number of lamps/per fixture:	2	18	5	3
If fluorescent indicate length of lamps (2ft, 3ft,4ft, 8ft):	4ft	4ft		
Watts per fixture:(Include ballast wattage if known)	36	23	15	12
Fixture height from work surface (ft/m)	9ft	9ft	8ft	8ft
Present operation of lights - hours/day	12	12	12	12
Present operation of lights - days/week	6	6	6	6.
Present operation of lights – weeks/year	46	46	46	46

Present light levels: Bright____ Adequate ✓ Dim____

Reflectance of walls and ceilings: Good____ Average ✓ Poor____

Can lights be switched on and off as desired? Yes ✓ No____ Comment:____

Can lower wattage lamps be installed? Yes ✓ No____ Comment:____

Notes:____

Lighting Legend

A.- Incandescent ✓B.- Fluorescent T-12 C.- Fluorescent T-12 HO (High Output) ✓D.- Compact Fluorescent E.- Mercury Vapour F.- Fluorescent T-12VHO (VH Output) G.- High Pressure Sodium H.- Low Pressure Sodium I.-Metal Halide (White Light) J.-Fluorescent T-8 K.-Quartz Halogen ✓L.- LED M.- Other-specify LED Bulb.

Building Energy Audit

Lighting

Building Identification: Library Floor No: 05

Please use a new sheet for each area, location or room in the facility.

Existing lights and controls

	Type 1	Type 2	Type 3	Type 4
Type of fixtures:	B	D	L	M
Number of fixtures:	12			
Number of lamps/per fixture:	02	5	8	3
If fluorescent indicate length of lamps (2ft, 3ft,4ft, 8ft):	4ft		4ft	
Watts per fixture:(Include ballast wattage if known)	36	23	23	12
Fixture height from work surface (ft/m)	8ft	7ft	8ft	7ft
Present operation of lights - hours/day	12	12	12	12
Present operation of lights - days/week	6	6	6	6
Present operation of lights – weeks/year	46	46	46	46

Present light levels: Bright______ Adequate ✓ Dim______

Reflectance of walls and ceilings: Good______ Average ✓ Poor______

Can lights be switched on and off as desired? Yes ✓ No______ Comment: ______

Can lower wattage lamps be installed? Yes ✓ No______ Comment: ______

Notes: ______

Lighting Legend

A.- Incandescent B.- Fluorescent T-12 C.- Fluorescent T-12 HO (High Output) D.- Compact Fluorescent E.- Mercury Vapour F.- Fluorescent T-12VHO (VH Output) G.- High Pressure Sodium H.- Low Pressure Sodium I.-Metal Halide (White Light) J.-Fluorescent T-8 K.-Quartz Halogen L.- LED M.- Other-specify LED Bulb.

Building Energy Audit

Lighting

Building Identification: library Floor No: 06

Please use a new sheet for each area, location or room in the facility.

Existing lights and controls

	Type 1	Type 2	Type 3	Type 4
Type of fixtures:	B	L	M	D
Number of fixtures:				
Number of lamps ~~per fixture~~:	5	8	1	10
If fluorescent indicate length of lamps (2ft, 3ft, 4ft, 8ft):	4ft	4ft		
Watts per fixture:(Include ballast wattage if known)	36	23	12	15W+23W
Fixture height from work surface (ft/m)	9ft	9ft	8ft	8ft
Present operation of lights - hours/day	12	12	12	12
Present operation of lights - days/week	6	6	6	6
Present operation of lights – weeks/year	46	46	46	46

Present light levels: Bright____ Adequate ✓ Dim____

Reflectance of walls and ceilings: Good____ Average ✓ Poor____

Can lights be switched on and off as desired? Yes ✓ No____ Comment: ____

Can lower wattage lamps be installed? Yes ✓ No____ Comment: ____

Notes: ____

Lighting Legend

A.- Incandescent B.- Fluorescent T-12 C.- Fluorescent T-12 HO (High Output) D.- Compact Fluorescent E.- Mercury Vapour F.- Fluorescent T-12VHO (VH Output) G.- High Pressure Sodium H.- Low Pressure Sodium I.-Metal Halide (White Light) J.-Fluorescent T-8 K.-Quartz Halogen L.-LED M.- Other-specify LED Bulb.

A-2 Envelope Audit Form for Library Building

Building Energy Audit

Envelope

Building Info & Floor no: Library, 1st floor **Direction Wall Faces** West facing

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows

No of windows	Do windows open?	Windows Area(sq-ft)	Types of glass used	Description of windows type	Windows fit (poor, fair, good)	Is there opening between window frames? Comment on airtightness.	Any Curtains Used? Type and color details.
1	NO	59 ft^2					

Doors

No. of doors	Is door Insulated? Airtightness (comment)	Description of door type	Condition of door	Is it Glass door? Glass type	Notes
2	NO	white glass and swing	Fair	Yes, single glass	Not rubber insulated

Number/Location of broken or cracked windows: ______

Description of door or window repairs or replacements needed (including door closers): ______

Observatory Description

Wall color, comment on wall condition Off white, Rest Floor type (mosaic, tiled, wooden, Plain cemented) tiled Ceiling type and condition (bare ceiling, insulated used, false foam ceiling): false ceiling not insulated Comment on ventilation, space or opening ______

Air Conditioning

Number of units: 2 Make, type, size, location of each: 2 ton

______ Frequency of servicing: ______

Date of last servicing: ______

Building Energy Audit

Envelope

Building Info & Floor no: Library, 2nd Floor **Direction Wall Faces** West facing

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows

No of windows	Do windows open?	Windows Area(sq-ft)	Types of glass used	Description of windows type	Windows fit (poor, fair, good)	Is there opening between window frames? Comment on airtightness.	Any Curtains Used? Type and color details.
1	YES	25 ft²	Single glazed	Aluminium frame, No tight	Fair	YES Not air-tight	Black
1	NO	25 ft²	"	"	"	"	"
1	NO	25 ft²	"	"	"	"	"

Doors

No. of doors	Is door Insulated? Airtightness (comment)	Description of door type	Condition of door	Is it Glass door? Glass type	Notes
1	NO	Tinted white glass & swing door	Fair	YES, single glazed	Not Rubber insulated.

Number/Location of broken or cracked windows: ______

Description of door or window repairs or replacements needed (including door closers): Rubber strips and doubled glazed sweep door should be installed.

Observatory Description

Wall color, comment on wall condition White & pest Floor type (mosaic, tiled, wooden, Plain cemented) Tiled Ceiling type and condition (bare ceiling, insulated used, false foam ceiling): False ceiling Not insulated. Comment on ventilation, space or opening ______

Air Conditioning

Number of units: 0 Make, type, size, location of each: ______

______ Frequency of servicing: ______

Date of last servicing: ______

Building Energy Audit

Envelope

Building Info & Floor no: library, 3rd floor **Direction Wall Faces** west facing

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows

No of windows	Do windows open?	Windows Area(sq-ft)	Types of glass used	Description of windows type	Windows fit (poor, fair, good)	Is there opening between window frames? Comment on airtightness.	Any Curtains Used? Type and color details.
2	NO	50 ft²	single glazed	Aluminium frame, not Air tight	fair	Not Air tight	Black
1	NO	25 ft²	"	"	"	"	"
1	NO	46 ft²	"	"	"	"	"

Doors

No. of doors	Is door Insulated? Airtightness (comment)	Description of door type	Condition of door	Is it Glass door? Glass type	Notes
01	not insulated	White glass, swing door	Fair	YES, single glazed	not rubber insulated.

Number/Location of broken or cracked windows: NO

Description of door or window repairs or replacements needed (including door closers): ______

______

Observatory Description

Wall color, comment on wall condition offwhite, pest Floor type (mosaic, tiled, wooden, Plain cemented) tiled Ceiling type and condition (bare ceiling, insulated used, false foam ceiling): Bare ceiling Comment on ventilation, space or opening ______

Air Conditioning

Number of units: 3 Make, type, size, location of each: 1.5 ton and 2 ton

______ Frequency of servicing: ______

Date of last servicing: ______

Building Energy Audit

Envelope

Building Info & Floor no: Library, 4th Floor **Direction Wall Faces** West facing

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows

No of windows	Do windows open?	Windows Area(sq-ft)	Types of glass used	Description of windows type	Windows fit (poor, fair, good)	Is there opening between window frames? Comment on airtightness.	Any Curtains Used? Type and color details.
3	Yes	75 ft²	Single glazed	Aluminium frame No tight	Fair	Yes Not air tight	Black
3	NO	75 ft²	"	"	"	"	"
2	NO	46 ft² + 90 ft²	"	"	"	"	"

Doors

No. of doors	Is door Insulated? Airtightness (comment)	Description of door type	Condition of door	Is it Glass door? Glass type	Notes
1	NO	white glass sweeping door	Fair	Yes, Single glazed	Not rubber insulated

Number/Location of broken or cracked windows: ____________

Description of door or window repairs or replacements needed (including door closers): Rubber strips and doubled glazed sweep door should be insulated

Observatory Description

Wall color, comment on wall condition White & Pest Floor type (mosaic, tiled, wooden, Plain cemented) Tiled Ceiling type and condition (bare ceiling, insulated used, false foam ceiling): False ceiling not insulated Comment on ventilation, space or opening ____________

Air Conditioning

Number of units: 11 Make, type, size, location of each: 1.5 ton, 2 ton, 3 ton

____________ Frequency of servicing: ____________

Date of last servicing: ____________

Building Energy Audit

Envelope

Building Info & Floor no: library, 5th floor **Direction Wall Faces** West facing

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows

No of windows	Do windows open?	Windows Area(sq-ft)	Types of glass used	Description of windows type	Windows fit (poor, fair, good)	Is there opening between window frames? Comment on airtightness.	Any Curtains Used? Type and color details.
3	Yes	75ft	single glazed	Aluminium frame no tight	Fair	Yes Not air tight	Black
1	NO	46ft	"	"	"	"	"
2	NO	36 ft	"	"	"	"	"

Doors

No. of doors	Is door Insulated? Airtightness (comment)	Description of door type	Condition of door	Is it Glass door? Glass type	Notes
1	NO	white glass and swing	Fair	Yes, single glass	Not rubber insulated

Number/Location of broken or cracked windows: ____

Description of door or window repairs or replacements needed (including door closers): Rubber strips and double glazed sweep door should be insulated

Observatory Description

Wall color, comment on wall condition Off white, Pest Floor type (mosaic, tiled, wooden, Plain cemented) tiled Ceiling type and condition (bare ceiling, insulated used, false foam ceiling): false ceiling not insulated Comment on ventilation, space or opening ____

Air Conditioning

Number of units: 3 Make, type, size, location of each: 2ton, 3ton

____ Frequency of servicing: ____

Date of last servicing: ____

Building Energy Audit

Envelope

Building Info & Floor no: library, 6th floor **Direction Wall Faces** West facing

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows

No of windows	Do windows open?	Windows Area(sq-ft)	Types of glass used	Description of windows type	Windows fit (poor, fair, good)	Is there opening between window frames? Comment on airtightness.	Any Curtains Used? Type and color details.
3	Yes	75 ft	single glazed	Aluminium frame no tight	Fair	Yes, Not air tight	Black
1	NO	46 ft	"	"	"	"	"

Doors

No. of doors	Is door Insulated? Airtightness (comment)	Description of door type	Condition of door	Is it Glass door? Glass type	Notes
1	NO	white glass and swing door	Fair	Yes, single glazed	Not rubber insulated

Number/Location of broken or cracked windows: ____

Description of door or window repairs or replacements needed (including door closers): ____

Observatory Description

Wall color, comment on wall condition Off white, Best Floor type (mosaic, tiled, wooden, Plain cemented) tiled, Ceiling type and condition (bare ceiling, insulated used, false foam ceiling): False ceiling not insulated ____ Comment on ventilation, space or opening ____

Air Conditioning

Number of units: 3 Make, type, size, location of each: 1.5 ton, 2 ton

____ Frequency of servicing: ____

Date of last servicing: ____

Appendix B

Figure1: AC (3 Ton)

Figure2: AC (1.5 Ton)

Figure3: Fixture light

Figure 4: AC (2 Ton)

Figure 5: LED Tube

Figure 6: Wall Fan

Figure 7: Water Purifier

Figure 8: Desktop

Figure 9: LED Bulb

Figure 10: Small Fan

Figure 11: Exhaust Fan

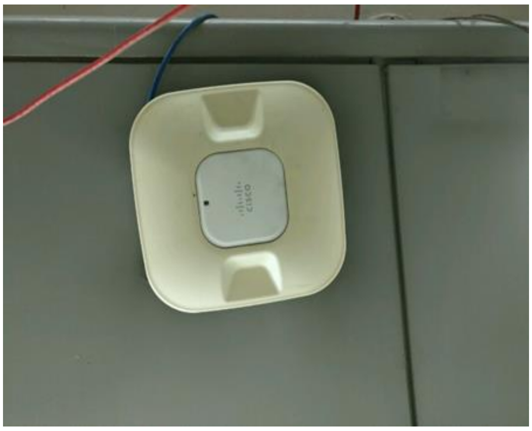


Figure 12: Router

Figure 13: Ceiling Fan

Figure 14: Server box

Figure 15: CFL Bulb

Figure 16: CC Camera

Figure 17: LCD TV

Figure 18: LED Watch

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