Energy Audit to Reduce Energy Consumption and Increase Sustainability

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Energy Audit to Reduce Energy Consumption and Increase Sustainability

Submitted
in partial fulfillment of the requirements for the
Degree of

Bachelor of Science
in
Electrical Engineering

Approval on ________________

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Declaration

We hereby declare that this project report entitled "ENERGY AUDIT TO REDUCE ENERGY CONSUMPTION AND INCREASE SUSTAINABILITY" submitted to the "Department of Electrical Engineering (RCET)", is a record of an original work done by us under the guidance of Supervisor "MUHAMMAD REHAN ARIF" and that no part has been plagiarized without citations. Also, this project work is submitted in the partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical Engineering.

Group Members	**Signature**	**Date**
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Acknowledgment

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We would like to express our deep appreciation to everyone who contributed to the success of this project. First and foremost, the team expresses gratitude to supervisor, Muhammad Rehan Arif, for providing excellent direction, supplying plenty of resources and encouraging an atmosphere beneficial to self-analysis. The team would also like to thank the committee members, Engr Salman Tariq, and Usman Aslam, for providing their help and insight, which was instrumental in expanding our knowledge and seeing the project through to accomplishment.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

EC	Energy consumption
ECC	Energy consumption cost
ES	Energy Saving
PoU	Price of unit
HVAC	Heating, Ventilation and Air Conditioning
HAP	Hourly Analysis Program
EPA	Environmental Protection Agency
DR	Discount Rate
ININ	Initial Investment
PP	Payback Period
ESC	Energy Saving Cost

Abstract

As the modern world is more conscious about power losses, improved power factors, and more efficient systems. So, there was surely a need for a method or process using which one can consume energy more efficiently or could reduce losses. That’s the reason energy audit was introduced this is the process by which one can come to know its negative usage of energy consumption, how to improve power factor, and how to maximize efficiency by using different tools and meters which results in a reduction of electricity charges. As of 2021, Pakistan's energy generation was primarily dependent on fossil fuels, with over 90% of its energy production coming from oil, coal, and natural gas. This information is based on data from the Pakistan Ministry of Energy, which states that oil accounts for the largest share of energy consumption, followed by natural gas and coal. and where industries’ share is about 26-27% of total energy consumption. In this region, the masses have less awareness of smart energy consumption and need some counseling in this regard. So, monthly electricity expenses could be reduced by monitoring daily consumption responsibly. Energy auditing process implemented in several public sectors e.g., educational institutes and associated Halls of residences as well as medical and industrial sectors in which electricity consumption is reduced by turning off unnecessary appliances, replacing inefficient wirings, improving the cooling and heating quality.

Sustainable Development Goals (SDGs) by United Nations are also kept in consideration because they are the principle element of this project and deal with sustainable environment and economic growth as SDGs 07, 08, 11, 12, and 13 address the Affordable and clean energy, Decent work and economic growth, Sustainable cities and communities, Responsible consumption and production, and Climate action respectively.

Chapter 1

Introduction

Energy demand in developed and developing countries is increasing day by day. The main reason is that people are switching their life patterns from lower class to middle class and from middle class to upper class. The same pattern is followed by industries as they are moving to more and more advanced technology that's why there is an increase in energy consumption and so in electricity charges.

The energy audit is a process in which energy consumption is reduced to save electricity, improve power factor, and make our system more efficient. It includes a process in which the amount of input energy is decreased in the system without adversely affecting the output [1].

Its types include:

1. Walk-through energy audit
2. Detail energy audit
3. Target energy audit [2]

In a walk-through energy audit, there is a short visit of the industry or organization, and possibilities for energy conservation are recommended without using any instruments. However, a detailed energy audit is expanded to three phases: [3]

1. Pre-audit phase
2. Audit phase
3. Post-audit phase

The pre-audit phase is carried out by conducting surveys and gathering data. During the audit part, the amount of energy used and how much it costs, as well as energy losses, power factor, and efficiency, are all observed. During the post-audit stage, recommendations are made based on the collected data.

A targeted energy audit points at a certain part of an organization. An industry may focus on particular parts, such as a boiler system, lighting system, or any single machinery, etc. to reduce energy usage in that specific region.

The environmental issue is one of the major challenges which are being faced nowadays. So, the factors which are causing these issues must be resolved to achieve sustainable development goals. Climate changes are one of the outcomes to be faced due to environmental problems and the parts of the globe which will be affected maximum are South Asia which includes countries like Pakistan, India, and China specifically [4].

There are substantial environmental advantages to conducting an energy audit. Greenhouse gas emissions are a major cause of global warming, but with the help of energy audits, this problem can be mitigated. Energy audits also help firms attract consumers and other interested parties who are concerned about ecological problems by lowering the carbon footprint and raising the sustainability profile.

The majority of countries are switching to alternative forms of energy because the use of fossil fuels causes the release of dangerous greenhouse gases like nitrous oxide and carbon monoxide into the atmosphere. According to research, the majority of natural resources, including gas, coal, water, diesel, and petroleum, will run out by the closing of this century [5]. It indicates fossil fuels are extremely limited and that environmental change is also a result of their consumption. As a result, there should be an alternate option that is both environment friendly and capable to recreate it in the same amount as it is being consumed. Moving toward renewable energy sources is the best option since both energy generation and consumption are secure and environment friendly. Energy derived from renewable sources is also referred to as green or clean energy and all of this is made possible through the energy audit method. The instruments that are used in this regard are:

- UT233 Clamp Meter
- UT383 Lux Meter
- eGauge Energy Analyzer
- ET6531C Infrared Thermometer

Energy conservation is critical in today's world, as the energy demand continues to increase while the resources are scarce. This has led to a greater focus on sustainable technology and the development of new methods for conserving energy. Energy audits play a key role in this effort, as they help organizations understand their energy consumption patterns and identify ways to reduce their energy use.

Numerous organizations and governments have established policies and programs to encourage the use of energy audits in order to recognize their value. The United States Environmental Protection Agency's (EPA) Energy Star program is an ideal instance of a strategy that is able to help businesses in saving money and energy through energy audits. Property owners in the European Union are required by the Energy Performance of

Buildings Directive to conduct energy audits and implement energy efficiency measures [6].

In conclusion, energy analyses are useful tools to cut down the carbon footprint, electricity expenditures and increase sustainability. With a growing focus on environment friendly technologies and reducing the production of emitting greenhouse gases, energy audits will continue to play an important role in shaping the energy landscape of the coming decades.

1.1 Motivation

Today's world is technologically more advanced that's why a huge gap between production and utilization occur around the world because everything is likely powered by electricity. In order to bridge this gap, it is essential to reduce electricity consumption and move toward an efficient system. Therefore, energy audit technology could be useful in this regard, as it reduces carbon and nitrous oxide emissions, thereby minimizing environmental concerns.

This thesis seeks to study the present situation of energy audits and create an extensive and applicable framework for conducting energy audits in various kinds of buildings. By doing an in-depth analysis of current procedures and case studies, this thesis will provide helpful insights into the challenges and opportunities related to energy audits, as well as suggestions for enhancing energy efficiency and sustainability in public and industrial buildings.

1.2 Objectives of energy audit

- Focused to improve power factor.
- Focused on improving the efficiency of the system so audited.
- Reduced the COx and Nitrous NOx emissions as per UN's sustainable development goal number 07, according to which clean and affordable energy has fewer negative effects on the environment shall be produced.
- Reduced the consumption of energy, especially from fossil fuels.

1.3 Problem Statement

The growing demand for energy and the limited availability of energy sources have made energy conservation and shortages urgent issues in recent years. The rapid speed of industrialization, urbanization, and population growth cause a tremendous strain on energy sources. The excess demand for energy has caused a shortage in the supply, which in turn has led to blackouts, price rises, and more pollution from power plants.

Energy audits are one of the best ways to deal with the energy shortage and get people to use less energy. An energy audit is a thorough look at how much energy a building or facility uses and exactly how well it uses it. This helps find places where improvements can be made. Energy audits give organizations useful information about how they use electricity, how they could save energy, and how much energy they could save. This lets make smart decisions about energy management [7].

Energy audits have been shown to be beneficial, but plenty of organizations still lack a systematic plan for managing their energy consumption. Energy audits, when conducted in a conventional manner, can be demanding in terms of time and resources, as well as in terms of the need for specialized knowledge and skill. Therefore, numerous corporations may not have the ability or financial resources to conduct a comprehensive energy audit, potentially resulting in lost savings opportunities [8].

Industrial energy waste is generally the result of human error, inefficient machinery, and flawed production procedures, all of which lead to severe penalties for firms. According to the WAPDA Petition-NEPRA Terms and Conditions of the Tariff schedule, a penalty is imposed for power factors below 0.90 [9]. The gap between energy supply and demand is widening as the demand for electricity continues to increase. To reduce the gap, it is necessary to take significant measures, such as encouraging the use of available resources more efficiently and enhancing electricity production.

Major sources of energy wastage include:

- Inefficient insulation for heating & cooling.
- Faulty appliances & gadgets.
- Using energy-inefficient models of devices.
- Vampire electronics & devices etc. [10].

Chapter 2

Literature Review and Problem Definition

A thorough literature review on energy audits demonstrates their value as an effective means for evaluating energy consumption and recognizing areas for energy savings in a variety of industries. Energy audits are proven to help in long-term energy management by assessing existing energy infrastructure, assessing current energy performance, and suggesting practical ways to cut costs without sacrificing results. The reviewed literature highlights the technical, economic, and environmental dimensions of energy audits. Smart metering, data analytics, and simulation models are just a few examples of cutting-edge technologies that researchers say can improve the precision and usefulness of energy audits. Energy audits are widely acknowledged in the literature as a significant initial step toward meeting energy sustainability targets, as it helps people make educated choices and direct energy management approaches.

Energy audits are an important resource for more sustainable living and lower utility bills. The goal of these audits is to systematically examine energy consumption and locate potential improvement areas. An energy audit is conducted to lessen the negative effects that energy production and consumption have on the environment.

In [11], there is a case study discussed which concluded that a building load is dependent on three different combinations of sources i.e., Smart Grid, Solar PV and Diesel Generator. The most efficient and highly yielded combinations are Grid (100%) > Grid (75%) & Solar PV system (25%) > Grid (50%) & Diesel (50%). In another case, energy was saved by replacing incandescent bulbs with LED bulbs as incandescent bulbs are not well for the environment due to presence of mercury and its life cycle is also shorter.

Another energy saving methodology, obtained in [12, 13], is that some defined parameters such as payback period, lifetime cycle of the replaced equipment, initial cost of investment and present worth etc. should be taken under consideration before replacing any of inefficient equipment.

Energy saving opportunities are described in [12, 14] in which industrial loads are categorized into four types as: necessary load, critical load, deferrable load and unnecessary load in doing so it becomes trouble free to judge that which load is running unnecessarily and by turning off which load, survival is possible.

2.1 Energy Conserving Solutions in HVAC Domain

For the sake of awareness about energy waste and conservation, another pattern is being followed in which all types of equipment and loads are distributed in different sections such as: Lighting, HVAC, Motor & Drives, Processes and Other Electrical Equipment. Each section consists of a checklist having different type of questions in it to test the reliability. After answering all the questions, it is possible to clearly diagnose the current status of equipment or load whether it is in good condition or it is about to get any fault nearly or it should be replaced now etc. [12, 15].

An energy audit process performed for reducing a factory's energy consumption. The method incorporates the HVAC system and production line so that the line can be shut down during low demand times. Energy consumption on the assembly line and in the HVAC system can be reduced by as much as 20%, based on simulation studies[16].

The reference [17] highlights a significant amount of energy efficiency improvement opportunities in hospital HVAC systems, which could result in energy savings of up to 30%. These savings result in significant economic and environmental advantages. Retrofitting HVAC systems with high-efficiency apparatus, upgrading insulating material and air tightness, taking advantage of natural light and natural airflow, and establishing demand-side management programs have been identified as the most effective energy efficiency measures. Hospitals may optimize their electricity usage and contribute to a more sustainable healthcare atmosphere by implementing these measures. These results highlight the necessity of targeted HVAC system improvements in attaining significant energy savings while improving hospitals' environmental impact.

The energy consumption could be minimized by deploying green building practices such as incorporating plants, properly installing HVAC systems, using innovative technologies, and constructing buildings to take benefit from natural resources. Sustainable building techniques have been shown to reduce energy consumption in a number of studies. As a case study, a tree can replace a 10,000-watt air conditioner in terms of cooling power. Up to 30 percent of energy can be saved by installing a properly sized HVAC system, and another 10 percent can be saved by using a smart thermostat. Up to 50 percent of energy can be saved through the use of passive solar design[18].

The study in reference [19] explores the application of advanced control techniques to enhance the energy utilization of HVAC systems in smart campuses. Advanced control techniques are capable of lowering the amount of energy used in HVAC systems on smart campuses. Energy savings averaged 30% across all control techniques. PRAC and MPC are two of the advanced control methods that are talked about. MPC (Model Predictive Control) suggests the future condition of the system and processes the forecasting data for controlling the system in a way that uses the least amount of energy. PRAC (Pattern Recognition Adaptive Controller) uses recognize patterns to find changes in the environment and respond to them.

2.2 Energy Conserving Solutions in Lighting and Fans Domain

An energy audit of an institutional building in Dubai, United Arab Emirates revealed that the lighting system accounted for 22% of the building's total energy consumption. The following energy-efficient innovations have been adopted in order to fix this issue: LED lights were installed because they are more energy-efficient than conventional incandescent lights and have a 25-fold longer lifespan. Occupancy sensors: Occupancy sensors were installed to automatically turn off the lights in vacant rooms, resulting in significant energy savings. These energy-efficient technologies led to a twenty percent reduction in the lighting load of the institution's building. The result is equivalent to an annual electricity savings of 100,000 kWh, or approximately USD 12,000. In addition, these technologies effectively reduced the building's annual carbon emissions by 20 tons[20].

An energy audit was conducted at a small manufacturing facility, and the findings indicate that the company could make significant energy savings in its lighting, foundry, and machine shop. They calculated annual savings of Rs. 3,17,952 for the company, or 14% of total consumption[21].

A lighting audit of a Malaysian academic office building revealed that the previous lighting setup was ineffective, which caused poor indoor air quality and energy waste. Researchers recommended several types of lighting preservation strategies, including the implementation of LED lighting, use of occupancy sensors and implementing dimmers to control brightness which can conserve an estimated 30 percent of energy and reduce annual CO_2 emissions by 6.60 tons. Within two months, the cost of the retrofit would be offset by the savings in energy costs[22].

An audit of the lighting in residences hall in Bagalkot, Karnataka, found ways to save energy and make the lighting less wasteful of resources. Some of the suggestions are to replace incandescent lamps with energy-efficient ones like CFL or LED lamps, fix the lighting levels that aren't suitable, and change the lighting system so that a lesser amount of energy is unproductive. If these steps are taken, they could help save up to 50% of energy, which would save expenditures and be beneficial to the environment. Also, switching to CFL lamps or LED lamps may preserve up to 75% and 80% of energy, respectively[23].

According to a study, using energy-efficient fans can increase cost-effectiveness by 50%. The effectiveness of fans may rise by 80% to 100%, in accordance with studies involving blade design. This offers an opportunity to close the gap between demand and supply and create a solid basis for a bright future[24].

An electrical energy audit that took place at Uka Tarsadia University showed that fans could save a lot of energy. The university has managed to use less energy by putting in energy-efficient fans. Using high-efficiency fan motors, like BLDC motors (Blade less DC Motors), was a big part of saving made. Regular Maintenance, smart controls and automation systems helped save energy even more by restricting fans from operating when no one was in the room or when the weather is good. Overall, these measures result in significant economical savings for the university by effectively reducing energy costs[25].

2.3 Energy Conserving Solutions in Motors and Machines Domain

The reference [26] explains how improved motor systems could save energy. By 2040, the world's motor systems could use 7% less electricity if strong policies were put in place. This would lead to a big drop in greenhouse gas emissions. The implementation of variable speed drives, more efficient motor designs for part-load operation, and more advanced control systems are all important technological trends that help save energy.

In reference [27], there is an in-depth review of techniques is mentioned for locating losses and methods for cooling that improve the effectiveness of electric machines. It explores ways to quantify these losses using techniques like mathematical analysis, experimental measuring, and computer simulation. It covers a variety of loss types, including copper, iron, and stray losses. The cooling processes of air, water, and oil cooling are covered. In addition to discussing the potential energy savings of up to 10% that can be achieved by using more energy-efficient electric machines, the paper makes recommendations for future research directions, including improvements in materials and technologies for improving motor efficiency.

The reference [28] divides energy efficiency improvements for electric motor systems into three categories: design, operation, and maintenance. Using high-efficiency motors, variable speed drives, and optimized insulation during design, as well as choosing the right motor speed and keeping it maintained while it is in use, are crucial measures. In the European

Union, energy efficiency measures can reduce the consumption of electric motors by up to 20%. Such actions could cut greenhouse gas emissions by 1.5 billion tons annually and save the US up to USD 100 billion in energy costs. These measures are a cost-effective method for lowering emissions and energy use because they increase reliability and lower maintenance costs.

Three-phase squirrel cage induction motors' efficiency is reduced by an unbalanced voltage supply, which increases energy use and shortens motor life. The paper recommends utilizing voltage regulators, power factor correction devices, and motors with higher efficiency ratings to address this. By putting these measures in place, motor performance can enhance and reduce the financial costs of an unbalanced voltage supply[28].

The investigators conducted an energy audit of the textile industry and discovered that switching from rewound motors to energy-efficient motors would result in savings of 62,727.49 kilowatt hours[29].

Chapter 3

Methodology

3.1 Methodology

This section details the processes followed throughout the energy audit and the analysis of the various measures taken to reduce energy consumption. This chapter's goal is to provide an extensive overview of the methodology used in the study, including its research design, data collection procedures, and statistical analyses. This chapter targets to offer transparency, reproducibility, and reliability in the research process by clarifying the systematic approach adopted for collecting and analyzing necessary information. In addition, it can be used as a reference for researchers who wish to repeat the study or build upon the results. The methodology is explained in detail so that readers can easily understand every step taken to evaluate energy use, identify sources of waste, implement efficiency modifications, and track the results. The necessary steps to follow while an audit are stated below: [3]

3.1.1 Data Collection

Gathering data on energy consumption is the first step in performing an energy audit. This information can be gathered from multiple sources, such as:

1. Utility bills
2. Meter readings
3. Energy surveys

Once the information is gathered, an initial energy consumption profile can be developed for the structure. This breakdown will reveal how much power is being consumed by various home systems and appliances.

3.1.2 Analysis

After creating a profile of typical energy consumption, it is possible to examine it for potential areas of savings. The following factors may be considered in such an evaluation:

1. Figuring out energy inefficient equipment.
2. Discovering energy-saving potential.
3. Potential cost savings from implementing energy efficiency measures.

3.1.3 Recommendations

The suggestions for enhancing energy efficiency can be given depending on the findings of the analysis. Examples of possible suggestions:

1. Putting in place machinery that uses less energy.
2. Altering the way of energy consumption in a building.
3. Introducing energy efficiency measures.

3.1.4 Spread Awareness

To get the desired results from energy auditing there must be some sort of awareness throughout the educational institutes, industries and any other organization where it is carried out. The awareness could be spread by:

Social media: The internet is a powerful tool that can be adopted to quickly and easily reach a wide range of people. Awareness could be raised by create and share social media messages, videos, and information graphics to the people.

Verbal Talk: Inform your friends, relatives, and coworkers about goal. Encourage them to share the information with their personal networks.

Awareness sessions: Some sort of awareness sessions could be held by inviting any concerned person in educational institute or in the industry for the students and workers.

Awareness pamphlets: Design the pamphlets with writing a message on it regarding energy conservation and display it on the notice boards, walls and work area.

3.1.5 Implementations

The recommended energy conservation measures (ECMs) are put into action in the energy audit's implementation section, which outlines the necessary resources, timeframes, and steps. Actual savings are compared with projected savings to assess how well-implemented ECMs are performing.

3.1.6 Monitoring

After the suggestions have been executed, it they must be tracked to see if the expected energy savings are being realized. This could include:

1. Monitoring energy use.
2. Analysis of energy use in relation to a reference profile.
3. Locating any remaining possibilities for improvement.

3.2 Load Measurement and Analysis Device

3.2.1 Clamp Meter Uni-T 233

The Uni-T 233 meter is a versatile device that is widely used in various industries for measuring electrical parameters. It is a handheld, digital multi-meter that can measure voltage, current, resistance, capacitance, frequency, temperature, and continuity. The meter is designed to be portable, durable, and user-friendly, making it an essential tool for technicians and engineers[30].

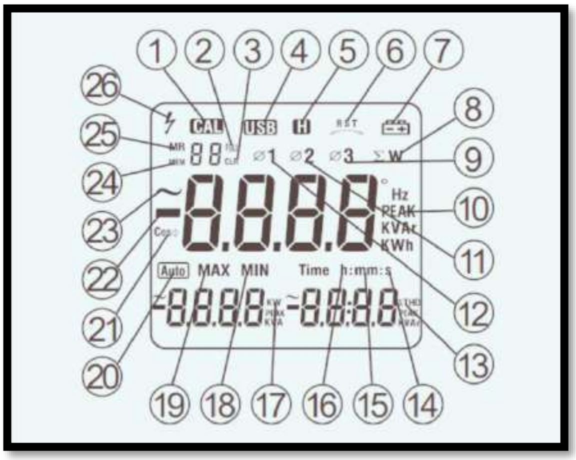
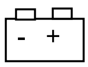


Figure 3.1: Display symbols

Table 3.1: Symbols of clamp meter UT233 with their meanings

Number	Symbol	Meaning
1	**CAL**	Symbol for Calibration
2	**FUL**	Indication for data is full
3	**CLR**	Indication that stored reading is cleared
4	**USB**	Output data is progressing
5	**H**	Active data hold
6	**RST**	Phase Sequence
7		Low battery
8	**∑W**	Watts's sum
9	**Φ3**	Symbol for third phase
10	**PEAK**	Symbol for primary reading unit
11	**Φ2**	Symbol for second phase
12	**Φ1**	Symbol for first phase

13	**S**	Second Unit
14	**Mm**	Minute Unit
15	**H**	Hour unit
16	**MIN**	Minimum Reading
17	**MAX**	Maximum Reading
18	**MEN**	Data store indicator
19	**MR**	Indication to recall the stored reading
20	⚡	Symbol for High Voltage

3.2.1.1 Working

In single-phase system

1. Turn off the power to the circuit or equipment you want to measure first.
2. Connect the voltage input leads to the appropriate points in the circuit, taking care to ensure proper polarity.
3. Connect the current input leads to the appropriate points in the circuit, making sure that the current is flowing in the correct direction.
4. Turn on the circuit or equipment's power supply.

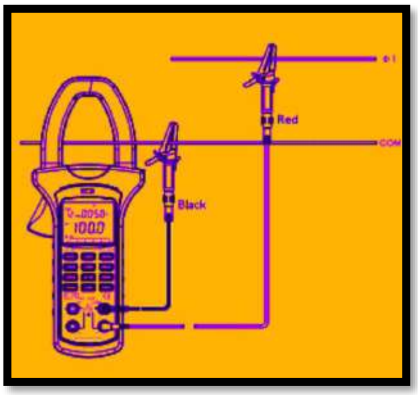


Figure 3.2: Measuring single phase double wire system

In three-phase three-wire system

1. Adjust the UT233 to the proper measurement mode, most likely AC current.
2. Turn off the power to the circuit you'll be measuring.
3. Place the clamp on the UT233 around one of the phase conductors.
4. Reconnect the circuit to the power source.

5. Examine the UT233's display for the measurement.
6. Steps 3-5 must be repeated for the other two-phase conductors.
7. Total current is calculated by adding the readings from all three phases.
8. Remove the UT233 clamp meter and turn off the circuit.

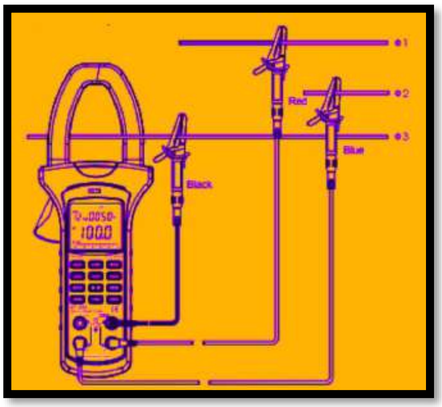


Figure 3.3: Measuring three phase three wire system

In three-phase four-wire system

A three-phase four-wire system is measured in the same way as a three-phase three-wire system. The only difference is that one more step is required and that step is about measuring the neutral current:

- ➢ To measure the neutral current, wrap the clamp around the neutral conducting material. This will yield the neutral current measurement.

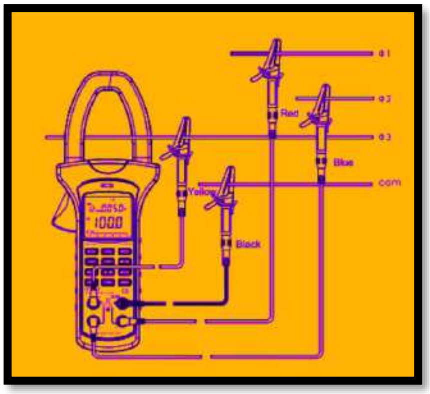


Figure 3.4: Measuring three-phase four wire system

3.2.1.2 Uses of UT233 Meter

The Uni-T 233 meter is used for a wide range of applications in different industries. Some of the most common uses of the meter include:

1. **Voltage measurement:** The Uni-T 233 meter can measure AC voltages up to 600V. It is used to check the voltage of batteries, electricity sources, and electronic devices.
2. **Current measurement:** The meter can measure AC and DC current up to 10 amps. It is used to determine the continuation of wires and test the current draw of electronic devices.
3. **Frequency measurement:** The Uni-T 233 meter can measure frequencies up to 10MHz. It is used to test the frequency of electronic signals as well as troubleshoot problems in electronic circuits.
4. **Power Factor:** The UT233 meter can measure power factor, which indicates an electrical system's efficiency in delivering real power to the load.
5. **Phase Angle:** The meter can also measure phase angle, which is important for analyzing AC circuits because it indicates the time difference among voltage and current waveforms.
6. **Active Power:** The UT233 is capable of measuring active power, which is the actual power used by a load and is crucial for figuring out how much energy is used and how much it costs.
7. **Apparent Power:** The meter may determine apparent power, which is the sum of the real and reactive power used by a load and is calculated by multiplying the voltage by the current.
8. **Reactive Power:** The UT233 can gauge reactive power, which is the power that circulates back and forth between the source and the load without being used up. Reactive power is crucial for figuring out how much capacitance or inductance is needed in a circuit.

3.2.1.3 Principle of Operation

The Uni-T 233 meter operates on the electrical measurement principle. It is made up of several parts, including the display, selector switch, test leads, and function buttons. When connected to a circuit, the meter measures the parameters of electricity and displays the results on the screen.

The voltage is measured by passing a small current through the circuit and measuring the voltage drop. It measures current by connecting the meter to the circuit and measuring the flow of current. Resistance is measured by passing a small current through the circuit and measuring the voltage drop across the component. Capacitance is measured by charging the capacitor with a known voltage and then measuring the time it takes to discharge. It counts the number of cycles per second of the input signal to determine frequency. It converts the voltage generated by the thermocouple probe to a temperature reading to measure temperature.

3.2.2 Lux Meter UT383

3.2.2.1 Introduction

The Lux Meter UT383 is a device that measures the amount of light in an environment. Its purpose is to measure the amount of light present in a specific area, which is measured in "lux" or "foot-candles" (Fc).

3.2.2.2 Working

The UT383 Lux Meter detects the amount of light that enters its sensor and converts that signal into a readable measurement. The sensor is typically a photodiode that is sensitive to visible light. As the amount of light entering the sensor increases, so does the voltage output of the photodiode. The Lux Meter's internal circuitry then processes this voltage output to calculate the corresponding level of illumination in lux or foot-candles[31].

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Figure 3.5: Lux meter UT383

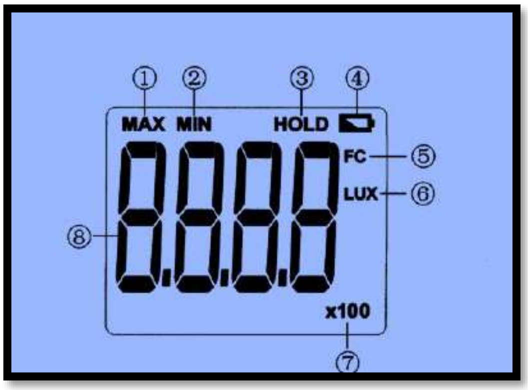


Figure 3.6: Labeled display interface

Table 3.2: Explanation of labeled diagram

Label #	Explanation	Label #	Explanation
1	Extreme Measurement	**5**	Foot Candle
2	Least Measurement	**6**	Lux
3	Hold Reading	**7**	Value*10 or Value*100
4	Battery is Low	**8**	Luminance Value

3.2.2.3 Required Lux in different areas

It's crucial to keep an eye on lighting levels and make necessary adjustments to make workplaces as energy-efficient and environmentally sustainable as possible. One can find opportunities to cut energy use and advance a more sustainable future by regularly checking lux levels. Table 3.3 represents the different kind of sufficient lux according to the requirements of work type there[32].

Table 3.3: Recommended lux for different kind of work places

Area Type	Recommended Illumination (Lux)	Average Room Size (Square Feet)
Living Room	100-300	200-400
Dining Room	200-500	150-250
Kitchen	300-750	150-300
Study/Office	300-750	75-150
Bedroom	100-300	100-200

Hallway	100-300	Varies
Classroom	300-500	500-1000
Hospital	300-500	Varies
Manufacturing Industry	Inspection Task: 1000 or higher	Varies
	General Task:300-500	Varies

3.2.3 Infrared thermometer ET 6531C

The ET 6531C is an infrared thermometer that enables temperature measurement without making contact. It has a laser targeting system for precise targeting and an illuminating LCD display. With a temperature range of -50°C to 650°C, it can be used in a variety of situations, including troubleshooting electrical systems, HVAC systems etc.

3.2.3.1 Working Principle

The ET 6531C infrared thermometer operates on the principle of detecting thermal radiation emitted from a surface. The thermometer's lens gathers infrared radiation when it is pointed at an object and concentrates it onto a detector. The radiation is transformed by the detector into an electrical signal, which is then processed to determine the object's temperature.

3.2.3.2 Uses

1. **Electrical equipment temperature measurement:** The ET 6531C can be utilized for measuring the temperature of electrical components like transformers, circuit breakers, and motors. This is useful in spotting potential overheating issues and avoiding equipment failure.
2. **Energy Audit:** The ET 6531C can be used in an energy audit to locate heat loss points in a building, such as those near windows, doors, and HVAC channels. As a result, energy cost reduction and upgrades to energy efficiency can be given priority.
3. **HVAC system performance:** The ET 6531C can be used for measuring the temperature of air that is emitted by HVAC vents. This can be helpful for identifying potential HVAC system performance issues, such as blocked pipes or jammed filters.
4. **Solar panel inspection:** It is possible to detect the temperature of solar panels using the ET 6531C. This is useful in locating potential panel performance issues like shading or damaged cells that may impact energy output.

Table3.4: Infrared thermometer (ET6531C) specifications

Factors	Specifications
Work Temperature	0°C ~ 40°C
Storage Temperature	-10°C ~60°C
Power Supply	2*1.5VAAA batteries
Infrared Temperature	Range: -50°C ~600°C
	Accuracy: -50°C ~0°C: +-3% ; 0°C ~600°C: +-(1.5%+2°C)
Ambient Temperature	Range: -10°C ~60°C
	Accuracy: 0°C ~40°C: +-1.0°C
Response Time	<0.5S
Radiance	0.10~1.0

3.2.4 EGauge Meter

The eGauge is a modern energy metering tool that offers analytics and real-time monitoring for electrical energy consumption. It is intended to assist people, companies, and organizations in better understanding and controlling their use of electricity. Voltage, current, power, energy consumption, and power factor are the electrical parameters that it is capable of measuring. The eGauge Model EG4xxx's capacity to deliver real-time data and analytics is one of its key characteristics. The gadget has integrated web-based software that enables users to access and view information about their energy usage from any internet-connected device. This makes it possible for users to keep an eye on their consumption patterns, spot energy waste, and decide how best to use their energy[33].

3.2.4.1 Required Tools for Installation

1. If the length of the CT wires needs to be adjusted, a #0 slotted screwdriver is required.
2. A circuit-breaker locater (if power-line communication over HomePlug is being used).
3. Clamp-on AC current meter
4. Laptop with Ethernet cable
5. Voltage Meter

Equipment Outline:

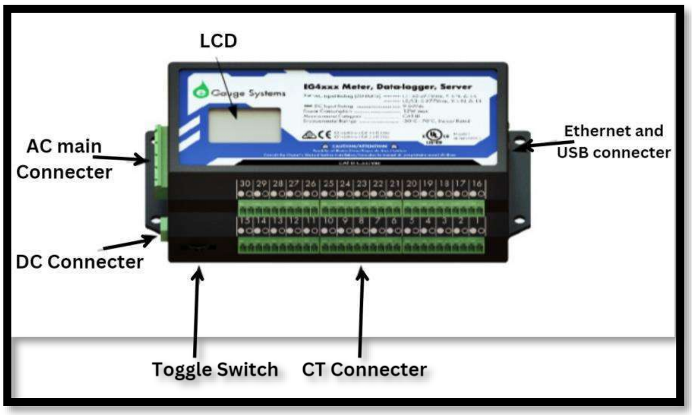


Figure 3.7: Overview of device

The eGauge has three different types of input connectors. The AC Mains connector, which is a 5-pin connector, is used for connecting the device to the power supply. The DC Connector, on the other hand, is a two-pin connector used for monitoring or powering the device with a direct current voltage source. The CT Connector connects current transformers (CTs) and other types of sensors. The eGauge involves an LCD screen and a multi-switch as a user interface. The device has an Ethernet port (RJ45 connector) for connecting via cable to a Local Area Network (LAN), as well as two USB ports (Type-A Female) for interfacing with various IT devices.

Table 3.5: Explanation of pins and their connections

Pin	Name	Explanation
1	L1	Wire connected to Phase 1 of supply
2	N	Wire connected to Neutral terminal
3	L2	Wire connected to the Phase 2 of the power supply for three-phase and split-phase installations.
4		Unused
5	L3	Wire connected to Phase 3 of supply for installation of three-phase.

3.2.4.2 Split Phase Diagram

Figure 3.8 shows a schematic wiring diagram of a typical split-phase setup. In this scenario, an eGauge device is used for monitoring the utility company's electrical consumption (CTs 1-2).

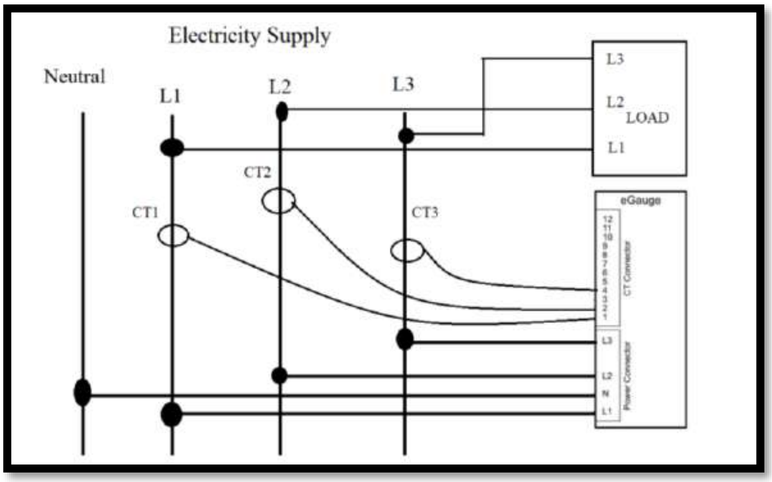


Figure 3.8: Standard split-phase setup wiring diagram

3.2.4.3 Phasing Diagrams

Split-Phase

There are typically two "hot" lines and one neutral line in split-phase panels. Figure 3.9 represents the phasing diagram of split-phase.

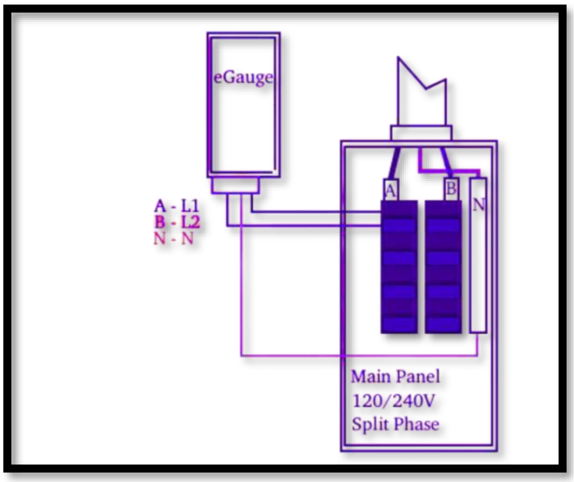


Figure 3.9: Panel for split phase

Three-Phase, Four wires

A three-phase, four-wire system is typically formed by three-phase panels that have separate conductors for each phase and a separate neutral line. The installation of such a system is shown in Figure 3.10, where it is significant to note that each breaker associated to the eGauge is placed on a separate phase.

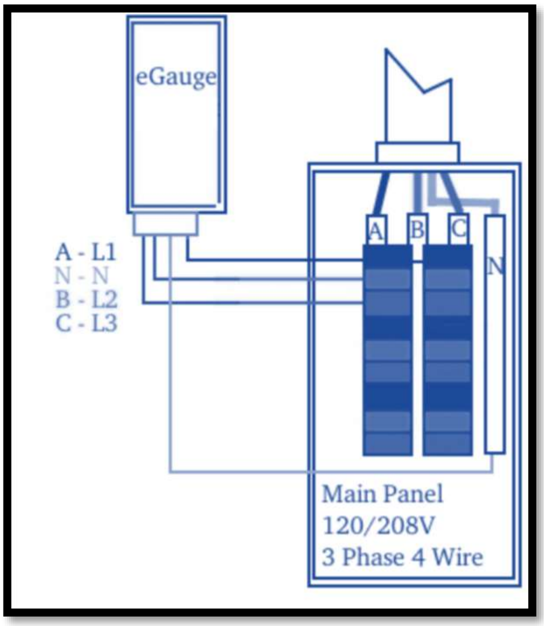


Figure 3.10: Three-phase, four wire panel

Three-phase, three wires

Some three-phase systems are built without a neutral line. Figure 3.11 shows a three-phase, three-wire installation, with the third phase acting as a voltage reference in the eGauge N terminal (Phase CN). It should also be noted that the eGauge's L3 connection is currently unused.

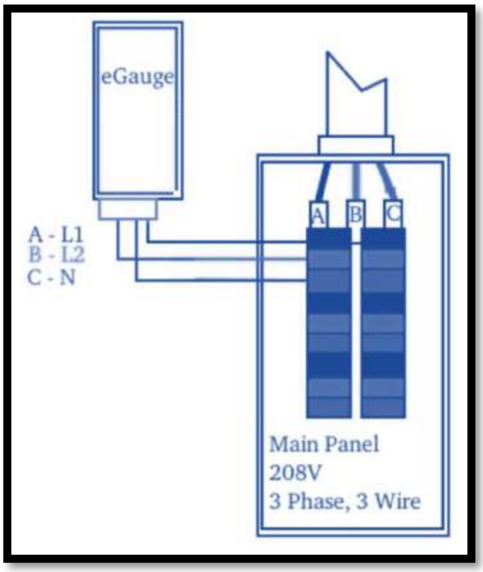


Figure 3.11: Three-phase, three wire panel

3.2.4.4 Steps for Installation

1. Select a location that is convenient for LAN access and is close to a power source and an Ethernet port.
2. Insert the HomePlug AV connector into the outlet.
3. Using the provided Ethernet cable, join the HomePlug AV adapter to the Ethernet port.
4. Locate the circuit breaker for the outlet where the HomePlug AV adapter is plugged in using a circuit-breaker finder. Call it the "L1" phase.
5. If the installation is divided into two phases, identify the second phase as "L2." Label the second and third phases of a three-phase installation "L2" and "L3."
6. Install new breakers to allow access to all phases in the power distribution panel.
7. Check that there is no power on the breaker contacts by opening the breakers.
8. Install the eGauge close to the power distribution panel inside a suitable enclosure.
9. Connect the 5-position plug as shown here:
   i. Attach the black wire (L1) to the phase L1 breaker.
   ii. The white wire (N) should be connected to the neutral.
   iii. Attach the red wire (L2) to the phase L2 breaker.
   iv. For 3-phase installations only, attach the blue wire (L3) to Phase L3's breaker.
10. Connect the 2-pin CT plugs to the eGauge's CT Connector. Note the amperage, phase, and object being measured.
11. Switch off the new breakers. When the eGauge is turned on, the LCD will light up. The measurements begin when the first register readout appears on the screen. To confirm a network connection, you can also look at the screen.

When installing the eGauge meter, keep the following safety advice in mind:

1. Each time you start an installation, turn off the power to the electrical panel.
2. Exercise caution when handling high-voltage electrical parts.
3. Ensure that every connection is safe and properly insulated.
4. If working with electrical components makes you uncomfortable, seek the advice of a licensed electrician.

Chapter 4

Detailed Design and Architecture

The design stage of an energy audit has great potential to minimize electricity consumption and improve sustainability in the context of an environment friendly future. In this chapter, it is described how design can act as an accelerator for energy efficiency. Significant energy savings can be accessed through the use of energy-efficient design principles, the adoption of sustainable materials and systems, all of which pave the way for a more sustainable world. The water heater load automation using a timer circuit and the computer lab cooling system design using Hap 4.90 software are the particular design areas of this chapter. These changes in design show potential for considerable energy costs, lower emissions, and a more sustainable future.

4.1 Design of water heater load automation

The process of automating the operation of water heater using an electronic timer circuit is referred to as water heater load automation using a timer circuit. The timer circuit is used to turn on and off the geyser at predetermined intervals, which can help save energy and lower electricity costs. The main component of the timer circuit is ESP 32.

The water heater can be configured to turn on at appointed hours each day by using a timer switch. It enables the geyser, which typically runs continuously for whole day, to be turn off for 12 hours at a predefined time of day. An energy meter was installed to record the electricity consumption before and after the installation of timer circuit which is 114480kWh and 57240 kWh respectively.

The design of water heater load automation includes following components:

- ESP 32
- RTC DS32311
- L type relay (30A)
- 16*2 LCD
- I2C Module

4.1.1 Functions of these components

4.1.1.1 ESP 32

The microcontroller known as ESP32 is a high-performance device typically found in IoT settings. It has numerous expanding ports, wireless networking (Wi-Fi and Bluetooth), and dual-core processing. It facilitates tasks like data collection from sensors collection, wireless communication, and the implementation of control systems in a wide range of embedded projects while using very low power consumption.

4.1.1.2 RTC DS3231

The DS3231, produced by Maxim Integrated, is a widely used chip for controlling Real-Time Clocks (RTCs). It was made to supply precise timing for use in microcontrollers, PCs, and embedded systems, among other things. The DS3231 is a great option for keeping track of time because it has a number of useful features and functions and communicates with other devices via an I2C (Inter-Integrated Circuit) interface.

4.1.1.3 L-Type Relay (30A)

An L-type relay is a type of relay that is used to control high current loads. It can be used to protect loads from excessive current, switch loads on and off, signal events, and automate processes. L-type relays are typically used in applications such as inverters, motors, welding equipment, lighting control systems, security systems, and industrial automation systems.

*4.1.1.4 LCD (16*2)*

A display module known as an LCD (16x2) (Liquid Crystal Display) is capable of showing 16 characters across each of its two lines. Electronic equipment frequently use it for displaying visual information, such as text, numbers, or simple graphics for user interaction or status updates.

4.1.1.5 I 2 C Module

The Inter-Integrated Circuit (I2C) module enables serial, synchronous, and bidirectional interaction across integrated circuits. It enables multi-master communication, letting multiple devices share a single data bus, and providing mechanisms for sending data, receiving data, and controlling device addressing.

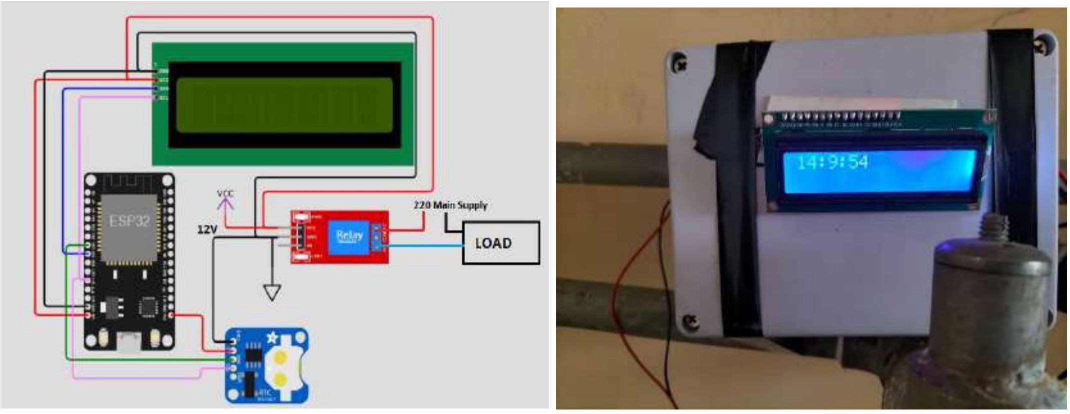


Figure 4.1: Circuit diagram of geyser automation & Implementation

Section 5.1 outlines the implementation details and cost reductions achieved by deploying the designed model.

4.2 Designing Cooling System for Computer Lab by using Hap 4.90 software

There are 20 CPUs in the computer lab, which is on the first floor of the building. However, the CPUs are exposed to direct sunlight because of the lab's position to the south-facing windows, which poses a serious risk to their performance and durability. Sunlight exposure can result in overheating, decreased performance, and probable malfunctions of parts, which could cause expensive repairs and disruptions to the lab's operations. In order to ensure the CPUs' best performance and durability in the computer lab setting, a solution is required to reduce the negative effects of direct sunlight on them. For this purpose, HAP (Hourly Analysis Program) software is used. Designing a cooling system with HAP normally involves entering building data such as size, orientation, and location. The software then analyses the data and calculates the cooling load for the space. The user can then select and size the appropriate HVAC equipment and components, such as chillers, air handlers, and ductwork, and configure the system to meet the required cooling load while minimizing energy consumption. HAP also includes tools for evaluating system performance and optimizing controls for maximum efficiency and comfort. So, to design an economical cooling system for the computer lab, the accurate knowledge of factors is necessary as the Hap 4.90 software asks about the multiple factors values according to the location and then designs cooling system for that specific area; the audit team suggests two possible solutions for this problem [34].

Solution one: It is the design of a temperature control system for the lab on the first floor, which will require a 4-ton air conditioner due to direct sunlight on the roof and heat from the windows.

Solution two: Relocate the lab to the ground floor and replace it with a classroom because there is no direct sunlight on the roof and sunlight cannot enter from any side.

4.2.1 Computer Lab Details

Table 4.1: Information about computer lab

Parameters	Values
Total Area	600 ft sq.
Roof Height	12 ft
No. of windows	03
Size of each window	36 ft sq.

4.2.2 Hap 4.90 software required input data

Table 4.2: Hap 4.90 software required input data

Parameters	Values
Region	Middle East
Location	Pakistan
City	Gujranwala
Latitude	32.2°
Longitude	72.2°
Elevation	757.9 ft
Designed cooling load operational months	March - June

By considering these factors, the efficient cooling load for the computer lab is designed. The solutions and their results are mentioned in next chapter in detail. Section 5.2 provides a comprehensive overview of the results achieved and the cost savings generated as a direct result of implementing this design.

Chapter 5

Implementation and Testing

This section links the earlier design phase, where measures to improve energy efficiency originated, with the later implementation and testing phases. The next steps involve putting the design work for an energy-efficient cooling system for a computer lab and the automation of water heater load through Hap 4.90 software into practice and putting them through a test drive in everyday life. This chapter specifies the process of putting these energy-saving measures into practice, from conceptualization to actualization, demonstrating the actual-life advantages that resulted from their implementation. These efforts, when carried out with precision and tested thoroughly, have been shown to yield significant energy savings and facilitate the route for a more energy-conscious and sustainable future.

5.1 Energy Saving Water Heater Load Automation; Implementation

The implementation of the water heater load is discussed in this chapter. The Table 5.1 provides information on the quantity and rating of geysers. The current geysers operate 24 hours a day and consume 114480kWh energy annually. The energy consumption and its cost (USD 18660.24) are calculated by using the equation (1) and (2) respectively.

$$EC\left(\frac{kWh}{year}\right)=Rating(W)\times\frac{hour}{year}\times Quantity \tag{1}$$

$$ECC(\$)=EC\left(\frac{kWh}{year}\right)\times PoU \tag{2}$$

$$ES\left(\frac{kWh}{year}\right)=EC_{Existing}\left(\frac{kWh}{year}\right)-EC_{New}\left(\frac{kWh}{year}\right) \tag{3}$$

$$ESC(\$)=ES\left(\frac{kWh}{year}\right)\times PoU(\$) \tag{4}$$

$$PP(Days)=\frac{-\ln\left(1-\frac{(ININ\times DR)}{ESC}\right)}{\ln(1+DR)} \tag{5}$$

Table 5.1: Description of Water Heater Load Before and After Implementation of Timer Circuit

Geyser		
Name of Appliances	***Geyser A***	***Geyser B***
Quantity	15	2
Rating(W)	1500	2000
Operational hours	24	24
Days of Operation	180	180
Annul Energy Consumption(kWh)	97200	17280
After installation of timer circuit		
Operational hours (after installation)	12	12
Annual Energy Savings (kWh)	48600	8640
Payback period (hours).	24	48

Before implementing the timer circuit, the operating hours of the geyser are 4320 hours per year. Its initial investment is USD 15. After Implementation the operating hours reduced to 2160 hours per year after implementing it hence 57,240kWh energy could be saved annually. The annual energy savings, cost in results of net savings (USD 9330.12) and payback period is determined by the help of equation (3), (4) and (5) respectively. In this case, a total of 48.36 metric tons of carbon footprints were effectively reduced.

5.1.1 Future Modifications

In addition to the successful implementation of the geyser automation system, future modifications could be made to improve its usability and accessibility to the general public. This can be accomplished by designing a more user-friendly body, introducing an easy-to-use button for modifying its operating and non-operating hours, and enabling modern technologies such as voice assistants or mobile apps for remote control. Proposed changes to the geyser automation system can enhance its adoption and effectiveness in reducing energy consumption, aligning with SDG#7. Automation features optimize energy usage and contribute to a sustainable approach to hot water supply.

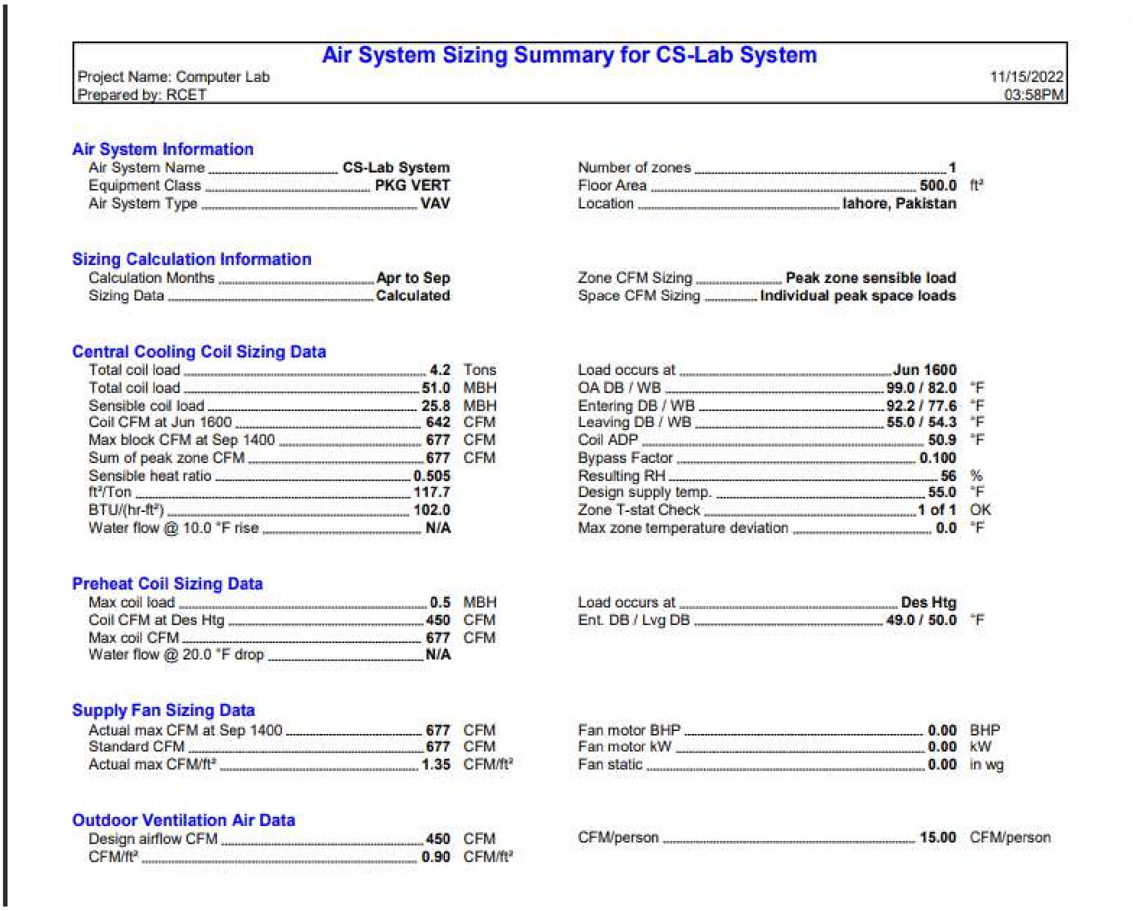
5.2 Cooling System for Computer Lab

There were two different proposals put forth for the computer lab. As means to save money on cooling, the auditing team recommended shifting the computer lab to the first floor as this option was cot efficient for cooling load.

Table 5.3: Designed Cooling System for Computer Lab along with the savings

	Solution one	***Solution two***
Required cooling load (kWh)	4 Ton	2.5 Ton
Total energy consumption (kWh)	2565 kWh/year	1125 kWh/year

The total energy consumption and total annual energy savings are calculated by using equations (1) and (3) respectively.



Air System Sizing Summary for CS-Lab System

Project Name: Computer Lab — 11/15/2022
Prepared by: RCET — 03:58PM

Air System Information

Air System Name: CS-Lab System
Equipment Class: PKG VERT
Air System Type: VAV
Number of zones: 1
Floor Area: 500.0 ft²
Location: lahore, Pakistan

Sizing Calculation Information

Calculation Months: Apr to Sep
Sizing Data: Calculated
Zone CFM Sizing: Peak zone sensible load
Space CFM Sizing: Individual peak space loads

Central Cooling Coil Sizing Data

Total coil load: 4.2 Tons
Total coil load: 51.0 MBH
Sensible coil load: 25.8 MBH
Coil CFM at Jun 1600: 642 CFM
Max block CFM at Sep 1400: 677 CFM
Sum of peak zone CFM: 677 CFM
Sensible heat ratio: 0.505
ft²/Ton: 117.7
BTU/(hr-ft²): 102.0
Water flow @ 10.0 °F rise: N/A
Load occurs at: Jun 1600
OA DB / WB: 99.0 / 82.0 °F
Entering DB / WB: 92.2 / 77.6 °F
Leaving DB / WB: 55.0 / 54.3 °F
Coil ADP: 50.9 °F
Bypass Factor: 0.100
Resulting RH: 56 %
Design supply temp.: 55.0 °F
Zone T-stat Check: 1 of 1 OK
Max zone temperature deviation: 0.0 °F

Preheat Coil Sizing Data

Max coil load: 0.5 MBH
Coil CFM at Des Htg: 450 CFM
Max coil CFM: 677 CFM
Water flow @ 20.0 °F drop: N/A
Load occurs at: Des Htg
Ent. DB / Lvg DB: 49.0 / 50.0 °F

Supply Fan Sizing Data

Actual max CFM at Sep 1400: 677 CFM
Standard CFM: 677 CFM
Actual max CFM/ft²: 1.35 CFM/ft²
Fan motor BHP: 0.00 BHP
Fan motor kW: 0.00 kW
Fan static: 0.00 in wg

Outdoor Ventilation Air Data

Design airflow CFM: 450 CFM
CFM/ft²: 0.90 CFM/ft²
CFM/person: 15.00 CFM/person

Figure 5.1: Interference of Hap 4.90 software (A)

Air System Sizing Summary for CS-Lab System

Project Name: Computer Lab
Prepared by: RCET

01/24/2023
05:00PM

Air System Information

Air System Name	**CS-Lab System**	Number of zones	**1**
Equipment Class	**PKG VERT**	Floor Area	**600.0** ft²
Air System Type	**VAV**	Location	**Gujranwala, Pakistan**

Sizing Calculation Information

Calculation Months	**Apr to Sep**	Zone CFM Sizing	**Peak zone sensible load**
Sizing Data	**Calculated**	Space CFM Sizing	**Individual peak space loads**

Central Cooling Coil Sizing Data

Total coil load	**2.8** Tons	Load occurs at	**Jun 1600**
Total coil load	**36.0** MBH	OA DB / WB	**94.6 / 79.6** °F
Sensible coil load	**25.8** MBH	Entering DB / WB	**78.4 / 65.6** °F
Coil CFM at Jun 1600	**642** CFM	Leaving DB / WB	**55.0 / 54.3** °F
Max block CFM at Sep 1400	**677** CFM	Coil ADP	**51.9** °F
Sum of peak zone CFM	**677** CFM	Bypass Factor	**0.100**
Sensible heat ratio	**0.505** ft²/Ton	Resulting RH	**46** %
	117.7	Design supply temp.	**55.0** °F
BTU/(hr-ft²)	**102.0**	Zone T-stat Check	**1 of 1** OK
Water flow @ 10.0 °F rise	**N/A**	Max zone temperature deviation	**0.0** °F

Preheat Coil Sizing Data

Max coil load	**0.5** MBH	Load occurs at	**Des Htg**
Coil CFM at Des Htg	**450** CFM	Ent. DB / Lvg DB	**49.0 / 50.0** °F
Max coil CFM	**677** CFM		
Water flow @ 20.0 °F drop	**N/A**		

Supply Fan Sizing Data

Actual max CFM at Sep 1400	**677** CFM	Fan motor BHP	**0.00** BHP
Standard CFM	**677** CFM	Fan motor kW	**0.00** kW
Actual max CFM/ft²	**1.35** CFM/ft²	Fan static	**0.00** in wg

Outdoor Ventilation Air Data

Design airflow CFM	**250** CFM	CFM/person	**15.00** CFM/person

Figure 5.2: Interference of Hap 4.90 software (B)

Chapter 6

Results and Discussion

This section of Results and Discussion explores the findings of the energy audit performed in order to reduce back on power usage. Based on the groundwork established in Design and Implementation, the next steps involve assessing the effectiveness and consequences of the adopted measures and strategies. A thorough evaluation of the energy-saving initiatives and their effects is provided by analyzing the data gathered during the energy audit and taking into account the insights gained during the design and implementation stages. This discussion highlights the importance of the results in achieving the goals while also pointing out areas that may need improvement and require additional study.

6.1 Energy Audit at RCET Academic Block

Energy Audit was performed at campus building of University of Engineering and Technology Lahore, RCET Campus. For this purpose, a survey was conducted (mentioned in Appendix D, Figure D.1) to identify personal opinions as well as daily habits of students and faculty regarding the wastage or conservation of electricity. A significant quantity of energy could potentially be saved by taking various energy-efficient actions, it was discovered after the survey's data analysis.

The total load of the Campus building is mainly consisting of lighting load, cooling load, electric geysers and electronic information system. The lighting load includes Incandescent bulbs, CFLs, Fluorescent tube and LED bulbs. While the cooling load consists of ceiling fans and air conditioners. On the other hand, Computers, Printers and WIFI devices represents the information system load.

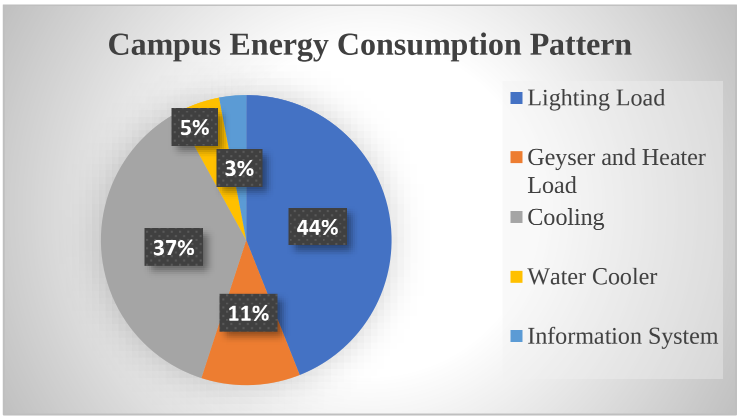


Figure 6.1: Annual energy consumption pattern of Academic block

The Energy savings can be achieved through the replacement of inefficient lighting, cooling systems (fans and air conditioners), and the implementation of efficient alternatives. Furthermore, addressing CPU overheating issues can be accomplished by utilizing HVAC (Heating, Ventilation, and Air Conditioning) analysis to optimize the lab's temperature and airflow management, resulting in improved energy efficiency and reduced equipment damage.

6.1.1 Survey Questionnaire and its Findings

A survey was conducted among teachers and students, and the obtained results were analyzed using Minitab software to examine correlations. Weak correlation values were identified and eliminated to focus on significant factors. Finally, a graphical representation was created to illustrate the remaining strong correlations between variables. A connection identified by using the statistical software, Minitab 19 [35], to look into the connection between faculty's practices. Minitab is statistical software which includes tools for calculating correlations and graphical representation of data to identify relationships and patterns among the different variables.

The strength and direction of the linear relationship between two variables are assessed using correlation values. The range of correlation values is -1 to 1, where a value of -1 denotes a perfect inverse relationship (perfect negative correlation), a value of 0 denotes no correlation, and a value of 1 denotes a perfect positive correlation (direct relationship)[36].

$$r_{xy}=\frac{\sum(xi-\bar{x})(yi-\bar{y})}{\sqrt{(\sum(xi-\bar{x})^2)(\sum(yi-\bar{y})^2)}} \quad \text{(A)}$$

Equation (A) could also be used to find out the correlation values.

Table 6.1: Correlation among the habits of university's faculty

Correlation among the habits of university's faculty		
Variable 1	***Variable 2***	***Correlation***
Habit to turn off appliances before leaving the office	Habit to properly shutdown the laptop	0.912
	Habit to utilize sunlight	0.426
	Have opinion that university is not getting free of cost electricity	0.535
Habit to properly shutdown the laptop	Habit to utilize sunlight	0.960
	Have opinion that individual wastes electricity effects.	0.597
	Habit to turn off appliances at home	0.815
Habit to utilize sunlight	Habit to turn off corridors' lights	0.618
	Have opinion that university is not getting free of cost electricity	0.713
	Waste energy because they are not answerable	0.546
	Have opinion that excess power consumption effects environment	0.975
Habit to turn off corridors' lights	Have opinion that university is not getting free of cost electricity	0.969
	Have opinion that excess power consumption effects environment	0.704
Have opinion that university is not getting free of cost electricity	Waste energy because they are not answerable	0.811

The Table 6.1 represents that there is a strong correlation (0.912) between the persons who have habit to turn off appliances before leaving the office and habit to properly shutdown the laptops and there are very weak relationships between the individuals who have habit to turn off appliances before leaving the office and habit to turn off the corridors' lights. The faculty members have been observed to switch off their appliances before leaving, however, they do not seem to follow the same practice when it comes to turning off the lights in the corridors. In the same a very strong correlation (0.975) is found between the members who have habit to utilize sunlight and who have opinion that excess power consumption results in negative impacts on the environment. Another strong correlation (0.969) is observed between the persons who have habit to turn off corridors' lights and who have opinion that university is not getting free of cost electricity. The details of the survey questions are mentioned in appendix section.

Table 6.2: Correlation among the habits of university students

Correlation among the habits of university students		
Variable 1	***Variable 2***	***Correlation***
Habit to use sunlight	Noticed energy saving initiatives in the university	0.827
	Get the awareness on energy conservation from university	0.573
Habit to properly shutdown the laptop	Habit to use sunlight	0.681
	Have knowledge about energy audit	0.722
Avoid to charge laptops/mobiles in class	Habit to turn off appliances before leaving the class	0.627
	Habit to turn off corridors' lights	0.853
	Noticed energy saving initiatives in the university	0.506
Have knowledge about energy audit	Habit to use sunlight	0.547
	Habit to shut down the laptop	0.722

In Table 6.2 it is described that the students who notice energy saving initiatives also have habit to use sunlight (0.827). A strong correlation (0.722) was found between students who possess knowledge about energy audits and their tendency to consistently shut down their laptops. Similarly, it was observed that students who actively turn off corridor lights during the daytime also tend to avoid charging their laptops or mobile phones in classrooms.

6.1.2 Lighting Load

The inefficient lighting consists of incandescent bulbs, fluorescent tubes, and compact fluorescent lamps. LED bulbs and tubes have been included in the category of load, but their proportion is very low. The operational hours are 1560 (time of use per day=6.5hours and 240 days per year) in a year. Figure 6.2 lists all types of lighting loads that are currently in use on campus, including LEDs, Incandescent Lamps, CFLs, and Fluorescent Tubes, in addition to their percentage usage.

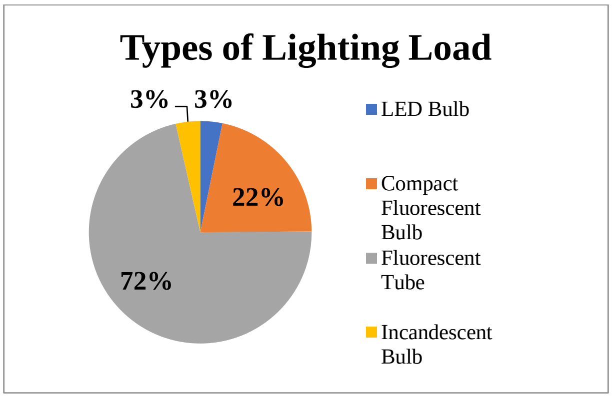


Figure 6.2: Type of lighting load in university building

6.1.2.1 Suggested Replacements of the inefficient lighting load

The existing inefficient lighting loads such as CFLs, fluorescent tubes and incandescent tubes could be replaced by energy efficient LED tubes and bulbs [34]. Table 6.3 mentions the inefficient lighting load in the campus building and represents the replacement along with the investment and payback period. The energy consumption and it's cost for incandescent bulbs, CFLs and fluorescent tubes are 561kWh/year, 9548 kWh/year, 35696 kWh/year and \$91.443, \$1556.324, \$5818.448 respectively, which are calculated by using (1) and (2) by taking 1unit = 1kWh at a unit price of USD 0.163. The discount rate defined for Pakistan is 17.

Table 6.3: Replacing Inefficient lighting with energy-efficient solutions

Lighting Load			
Name of Appliances	***CFL***	***Incandescent Bulb***	***Fluorescent Tube***
Quantity	204	30	673
Rating(W)	60	100	60
Annul Energy Consumption(kWh/yr.)	19095	4680	62993
Implementation	***LED Bulb***	***LED Bulb***	***LED Tube***
Rating(W)	30	12	34
Potential Energy Savings (kWh/yr.)	9547	4119	27297
Payback Period (Days)	50	14	73

Equation (6) is used to calculate the payback period by using initial investment, discount rate and cost saving**.** The energy and cost savings for replacing incandescent bulbs, CFLs and fluorescent tubes are $213.61, $31.41, $1174.52, 9547kWh/year, 4119 kWh/year, 27297 kWh/year and $671.397, $1556.161, $4449.411 respectively, find out by utilizing (3) and (4). The equation (5) is used to calculate the payback period.

6.1.3 Fans

The majority of existing fans are aged fifteen to twenty years old, contributing to significant energy waste. The investigation revealed an issue with motors excessive heat due to their frail state, multiple times rewinding, and worn-out bearings, all of which reduce their efficiency and cause them to waste energy. The annual energy consumption of existing fan load is 40435 kWh per year while electricity consumption cost (ECC) is of $6590.9 which are calculated by (2) and (3). The operational hours are 1080(time of use per day=6 hours and 180 days per year) per year.

Table 6.4: Replacing Inefficient cooling load with energy-efficient solutions

Cooling Load	
Name of Appliances	***Fan***
Quantity	312
Rating(W)	120
Annul Energy Consumption(kWh/yr.)	40435
Suggested Energy Efficient Fans	
Rating(W)	75
Expected Energy Savings (kWh/yr.)	15163
Payback Period (Year)	2.658

6.1.3.1 Suggested Replacements of the inefficient cooling load

Inefficient old fan load could be upgraded by switching to modern, energy-efficient models [35]. The salvage price for inefficient fan and price for a new efficient fan is $8.52 and $24.39 respectively. While the net initial investment is $4960. Table 6.4 shows that if this is executed, annual energy savings of 15163 kWh and energy saving cost of $2471 would be possible as calculated by (3) and (4). On the other hand, (5) is used to calculate the payback period.

6.1.4 Electronic Information System

The information system of the campus consists of Computers, Printers and Wi-Fi Devices. The Table 6.5 represents the quantity, ratings and annual energy consumption of such kind of informational loads. The table also describes that computer systems and printing press machines remains on idle and standby mode respectively. The (1) is used to calculate the energy consumption by informational system load.

Table 6.5: Replacing Information system with energy-efficient solutions

Information System Load			
Name of Appliances	***Computers***	***Printers***	***Wi-Fi Devices***
Quantity	150	40	70
Rating(W)	***While in idle mode=80W***	***While in standby mode=5W***	5W
Annul Energy Consumption(kWh)	3600	300	2520
Energy Saving Measures	Reduce the screen time (1/4)	By properly turning OFF	By switching OFF in off-timings (8hours)
Annual Energy savings (kWh)	2700	300	1680

While in Table 6.5 it is mentioned that a significant amount of energy could be saved by reducing the screen timer of the computer systems, by properly turning off the printing press machines when not in use and by switching off the Wi-Fi devices university off timings. To calculate energy savings and the payback period, (3) and (5) are used.

6.1.5 Air Conditioning Load

There are number of air-conditioners in the campus building and most of them are energy inefficient as they are non-inverter type. Table 6.6 shows that these inefficient air conditioners consume 9450 kWh in a year as calculated by (1). The operational hours for air conditioners are 630 (time of use per day=7 hours and 90 days per year) hours per year.

Table 6.6: Replacing Inefficient air conditioning load with energy-efficient solutions

Air conditioning load	
Name of Appliances	***Air conditioners (non-inverter)***
Quantity	10
Rating(W)	1500
Annul Energy Consumption(kWh)	9450
Suggested Air Conditioners (Inverter)	
Rating(W)	800
Annual Energy Savings kWh	4410
Payback Period	5.68 years

The Table 6.6 suggests the replacement of the inefficient air conditioning load (non-inverters) with the efficient one (inverters) by implementing it 4410 kWh of energy could be saved annually and these savings are finding out by using (3). While for getting payback period (5) is used.

6.1.6 Energy Conservation by Removing Surplus Loads

During the audit, it was observed that numerous locations had an excess of lights and fans that were either unnecessary or in excess of what was needed. Removing these could result in significant energy savings. The corridors of the university have the highest concentration of these types of loads, while there are relatively fewer in classrooms, offices, and labs throughout the university. The Table 6.7 and 6.8 displays the expected energy savings (calculated by (3)) that could be achieved by eliminating these loads. The operating hours for lighting and fan load are 1560(time of use per day=6.5hours and 240 days per year) and 1080(time of use per day=6 hours and 180 days per year) hours per year.

Table 6.7: Annual energy savings by removing surplus cooling load

Annual energy savings by removing surplus cooling load	
Number of fans	62
Power rating of each fan	0.120 kW
Daily working hours	5 hours
Number of working days in a year	135 days
Annual Energy savings	5022 kWh

Table 6.8: Annual energy savings by removing surplus lighting load

Annual energy savings by removing surplus lighting load	
Number of lights	96
Power rating of each light	0.06 kW
Daily working hours	5 hours
Number of working days in a year	300 days
Annual Energy savings	8550kWh

6.1.7 Energy Audit for Water Pump

The water pump is installed at the residential area of the university which serves the water requirements of the Halls of residences and the campus building. The size of the earth bore mentioned, 450 feet.

Motor Plate Details:

Table 6.9: Motor name plate

IP 44		**SIEMENS**	
No. LPK			
3∅Motor	TYPE 1PM3	166 ---- 4 AA 74	Frame 160L
Voltage 380V	**Conn** Δ	**A** 22	**PF** 0.88
RPM 1460	**Ambient Temp** 40℃	**Weight** 185Kg	**Manuf. Year** 2000
MADE IN PKISTAN			

Table 6.10: Physical inspection

General cleanliness	Bad
Bearing Condition	Not Noisy
Alignment of Motor	Not Proper
Motor Surface Temperature	110℃
Motor winding	Not Proper

6.1.7.1 Problem Statement

The three phases of the motor are out of balance, with only two of them working properly and putting out 22A each. But the third phase is having issues, as the current is only 11A.

Data Collection

Table 6.11: Data collected using eGauge

Date & Time	3∅ load [kW]
4/13/2023 15:31	14.421
4/13/2023 15:32	10.488
4/13/2023 15:33	9.169
4/13/2023 15:34	9.057
4/13/2023 15:35	8.993
4/13/2023 15:36	9.001
4/13/2023 15:37	9.029
4/13/2023 15:38	9.005
4/13/2023 15:39	8.974
4/13/2023 15:40	8.94

Reason of the problem: This is because in a balanced three-phase system, the current should be evenly distributed between all three phases. If the current in one phase is significantly lower than the current in the other two phases, it could indicate an issue with that phase.

Calculation:

Current Imbalance (%) $=\frac{\text{Imax}-\text{Imin}}{\text{Imax}+\text{Imin}} \times 100$

Current Imbalance (%) $=\frac{22-11}{22+11} \times 100$

Current Imbalance (%) =33%

Reason of the problem: When there is a current imbalance in a motor, with one phase having a higher or lower current compared to the other two phases, it can indicate a potential issue with the motor windings.

Effect of unbalance current: Unbalanced currents in motors can have several adverse effects. Let's discuss some of the key consequences of unbalanced currents in motors [37].

1. Overheating of the motor: The unbalanced current draw can cause the motor to operate with an increased current, leading to overheating of the motor, which may result in insulation breakdown, short circuit, or other motor failures.

2. Uneven mechanical stress on the motor: The unbalancing of the current draw can cause uneven mechanical stress on the motor's bearings, which may result in damage or premature failure of the motor.

3. Electrical issues: The unbalancing of the current draw can also result in electrical issues such as increased harmonics, voltage fluctuations, and unbalanced currents, which can cause problems with other equipment connected to the same power supply.

4. Reduced Efficiency: Unbalanced currents lead to an imbalance in the magnetic fields within the motor. This causes the motor to operate at a lower efficiency level than intended. The motor may experience increased losses, higher operating temperatures, and reduced overall performance.

5. Voltage Unbalance: Unbalanced currents are often accompanied by voltage unbalance. Voltage unbalance can further exacerbate the effects of unbalanced currents, leading to additional heating and torque imbalances. It can also cause increased power consumption, reduced power factor, and can impact the overall stability of the electrical system.

6. Reduced Power Factor: Unbalanced currents contribute to a lower power factor. A low power factor results in increased reactive power consumption, leading to higher energy costs and potential penalties from utility companies.

7. Uneven Load Sharing: In multi-motor systems, unbalanced currents can lead to uneven load sharing among the motors. This imbalance in load sharing can cause certain motors to operate at higher loads while others are underutilized. Over time, this can cause premature wear on the overloaded motors and may lead to cascading failures in the system.

Figure 6.3: Installed motor

6.2 Energy Audit at RCET halls of residences

Energy audit at Halls of residences of the university performed in the same pattern as the institutional building. A questionnaire-based survey (mentioned in Appendix D, Figure D.2) was conducted to get to know about the factors that are causing energy wastage. Another reason for conducting the survey is to get know about the common habits among residents who waste electricity and who do not waste. To find these correlations Minitab Software is used. The energy efficient measures which could result in savings of electricity and hence cost is described below:

A connection identified by using the statistical software, Minitab 19[35], to look into the connection between the residents' practices. The introduction of Minitab software is mentioned in previous section of audit at university.

Table 6.12: Correlation among the habits of residents

Correlation among the habits of residents		
Variable 1	***Variable 2***	***Correlation***
Habit to turn off appliances before leaving the room	Believed to have paid for all the electricity	0.967
	Waste energy because they are not answerable	0.753
Believed that university is getting free of cost electricity	Believed they have paid for all the electricity.	0.85
	Waste energy because they are not answerable	0.773
	Have opinion they waste electricity single handedly.	0.773
	Habit to keep laptop on standby mode.	0.850

The Table 6.12 describes the strong relationship among the students who believe that university gets free of cost electricity from the government. The residents who believe so also believe that they have paid for all the electricity after paying their Hall of Residences dues, they waste energy because they are not answerable, have opinion that they waste electricity single handedly and they keep their laptops on standby mode also.

6.2.1 Installing Prepaid meters-A Case Study

i) Problem Statement: From the findings of survey, it was observed that almost 75% of the students are wasting electricity because they assume they have paid for all the electricity after paying their Hall of Residences fees. To minimize the wastage the team suggested installing the prepaid meters in every room.

ii) Prepaid Meters: Prepaid meters are electronics devices that are used to measure and monitor utility consumption such as electricity. Prepaid meters, as opposed to traditional postpaid meters, require users to pay in advance for the amount of utility they intend to consume.

iii) Properties:

- Improved billing accuracy and transparency: By installing prepaid meters, consumers can track the consumption status in real-time, allowing to adjust the usage and avoid unexpected bills.
- Significant control over utility usage: Prepaid meters allow consumers to monitor the usage and manage the utilization accordingly, which can help in saving money as well as minimizing wastage [38].

In Table 6.13 it is described that each room pays USD 28.00 for one year of electricity while each room actually consumes the energy of USD 254.28 and each room consumes almost 1560kWh/year while they just pay for the 172kWh/year energy. Each unit equals to USD 0.163 and per room pays USD 28 for 172kWh energy consumption.

$$Each\ room\ \ actually\ pays\ = \frac{USD28}{USD0.163} \cong 172\frac{kWh}{year}$$

An energy meter was installed to check the energy requirements of each room for the good practices of energy consumption, and it is estimated that 1080kWh energy is sufficient for each room for one year. As per good practices, lighting loads, fan loads, water heater load and electronic gadgets (laptops and mobiles chargers) operate for 3600 hour/year, 2000hour/year, 2160 hour/year and 900 hour/year and consume 150kWh, 240kWh, 480kWh and 216kWh energy per year respectively. It is noted that the sufficient average energy for these best practices is 1080-kWh per year.

Table 6.13: Actual energy consumption and actual payment in halls of residences

Analysis of actual energy consumption and actual payment in residential area	
Number of rooms	100
Annual energy consumption	156000 kWh
Duration	12 months
Each room consumes energy (Annually)	1560 kWh

Each room actually pays for energy (per year)	172 kWh
Each room pays for one year	USD 28.00
Each room actually consume energy of	USD 254.28
Estimated annual energy required per room (As per good practice)	1080 kWh

In Table 6.14 it is mentioned that if the university's management install prepaid meters, the initial investment for the 100 meters is USD 2450. Moreover, the annual energy savings will be of 48000 kWh which results in the reduction of USD 7824 annually. The payback period is of 4.2 months. While the DR for calculating the payback period in Pakistan is 17% [39, 40] .

Table 6.14: Installation of prepaid meters

Installation of prepaid meters	
Number of meters required	100
Cost of each meter	USD 24.50
Total initial investment	USD 2450
Annual energy savings (kWh)	48,000
Annual savings	USD 7824
Payback Period (months)	4.2

6.2.2 Lighting Load

The major portion of lighting in the halls of residences is still old, consisting of compact fluorescent lamps, fluorescent tubes and Incandescent bulbs. However, the type of load also consists of LED bulbs and tubes but their percentage is very small. The annual energy consumption of existing inefficient lighting load is 21384 kWh per year while ECC is of USD 3485.59 and the operational hours are 3600 (time of use per day=12 hours and 300 days per year) per year. The Fig. 6.5 shows the percentage of efficient and inefficient lighting loads running in the halls of residences.

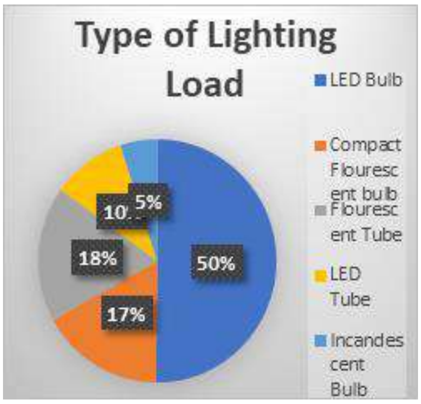


Figure 6.4: Types of lighting load

6.2.2.1 Suggested Replacements of inefficient lighting load

Inefficient fluorescent tubes, incandescent bulbs and CFLs could be replaced by LED tubes and LED bulbs. The initial investment is USD 52.28, USD 15.68 and USD 94.10 while the cost savings are USD 352.08, USD 774.25 and USD 903.835 for fluorescent tubes, incandescent bulbs and CFLs respectively. In Table 6.15, it is mentioned that an amount of energy could be saved by doing so. The energy consumption (kWh/yr.) is calculated using (1) while (2) is used to calculate the energy consumption cost by taking product of energy consumption with unit price. (1 Unit = 1kWh). The energy savings and payback period are calculated by using (3) and (5) respectively.

Table 6.15: Inefficient lighting load with efficient replacements

Lighting Load			
Name of Appliances	***CFL***	***Incandescent Bulb***	***Fluorescent Tube***
Quantity	50	15	54
Rating(W)	24	100	60
Annul Energy Consumption(kWh/yr.)	4320	5400	11664
Suggested Efficient Lighting Load			
Rating (W)	12	12	34
Potential Energy Savings (kWh/yr.)	2160	4750	5545
Payback Period (Days)	50	7	34.2

6.2.3 Fans

During audit it is noticed that existing old fans are the cause of energy wastage as there are some sources such as poor-winding material, mechanical wear and tear and multiple times rewinding. The inefficient old fans consume 24000kWh energy per year and the ECC is of

USD 3912 while the operating hours are 2000hours (time of use per day=10 hours and 200 days per year) per year. Table 6.16 shows the existing fan load and its annual energy consumption in the Halls of residences. The annual energy consumption calculated using (1). Whereas (2) is used to determine the cost of energy consumption.

6.2.3.1 Suggested Replacements of inefficient cooling load

The inefficient existing fans could be replaced by energy-efficient fans. These energy efficient fans consume 15000kWh energy per year. The salvage price of a fan is USD 8.52 while the cost for the brand-new energy efficient fan is USD 24.39. The net initial investment and cash flow (ESC) are USD 1587.66 and USD 1467 respectively. These efficient fans could result in the savings which are described in Table 6.16.

Table 6.16: Existing cooling load with replacements

Existing inefficient old fans	
Quantity	100
Rating(W)	120
Annual Energy Consumption(kWh/yr.)	24000
Suggested efficient 5-star fans	
Rating(W)	75
Potential Energy Savings (kWh/yr.)	9000
Payback Period (years)	1.3

6.3 Energy Audit at Govt. Mozzang Teaching Hospital Lahore

The Government Mozzang Hospital, situated on 37-Temple Road in Lahore, Pakistan, was previously a metropolitan corporation dispensary and was established in 1992 with 25 beds. Initially, it was under the jurisdiction of the District Government Lahore but later was declared a teaching hospital affiliated with Fatima Jinnah Medical University Lahore on 19th November 2014. Recently, the district government constructed a new 20-bed Gynae unit, increasing the total bed capacity to 45. The current Medical Superintendent of the hospital is Dr. M. Riaz, and the hospital has functional departments of Gynae, Radiology, Anesthesia, Dentistry, Pediatrics, Surgery, Emergency, and Pathology. Hospital receives an 11kV line from WAPDA and there is a placement of a transformer according to the 240kW sanctioned load.

After doing audit in the hospital some of the points were noted out at where energy could be conserved. The percentage load of the offices in hospital is as follows:

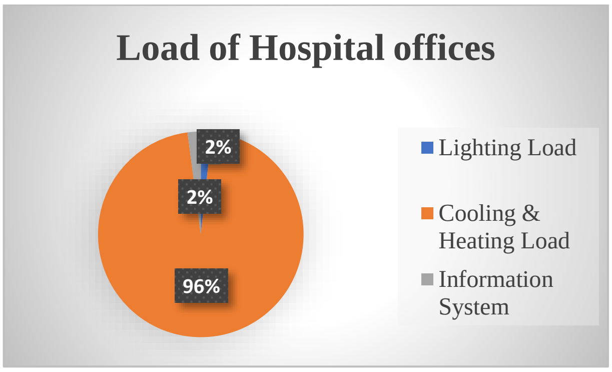


Figure 6.5: Load of hospital offices

The savings from different areas are here:

6.3.1 Lighting Load

The portion of the lighting load belongs to inefficient category such as compact fluorescent tubes and bulbs. These could be replaced by efficient lighting loads such as LED bulbs and lights. The final results of the savings from the replacements are following:

Table 6.17: Suggested efficient lighting Load

Quantity	Rating (W)	Daily consumption (kWh)	Annual consumption(kWh)	Annual savings(kWh)
42	918	12.32	3886	2761

6.3.2 Air Conditioners

The air conditioners installed there are of non-inverter type and that are cause of energy wastage. A huge amount of energy could be saved if these inefficient air conditioners are replaced by the efficient i.e. Inverter type. Table 6.18 illustrates the annual savings (kWh/year).

Table 6.18: Suggested efficient air conditioning load

Quantity	Rating (W)	Daily Consumption(kWh)	Annual Consumption(kWh)	Annual Savings(kWh)
25	23200	294.9	58980	56800

6.3.3 Fans

Majority of the fans are outdated and consume more energy and hence they are energy inefficient ones. The suggestion is to replace them with 5-star fans. Table 6.19 describes the details of savings which could be get by implementing suggested efficient measures.

Table 6.19: Suggested efficient replacement of fans

Quantity	Rating (W)	Daily Consumption(kWh)	Annual Consumption(kWh)	Annually Savings(kWh)
52	3900	66.14	13230	6840

6.3.4 Electric Heaters

The current heating loads are of old versions and consume more energy. These electric heaters could be replaced by up-to-date latest ones and by doing so the conserved energy is mentioned in Table 6.20.

Table 6.20: Suggested efficient heating load

Quantity	Rating (W)	Daily Consumption(kWh)	Annual Consumption(kWh)	Annual Savings(kWh)
26	26000	320	38280	37140

6.3.5 Medical Machinery

There is a variety of medical machines for different purposes. Some of them are energy inefficient. The substitute energy efficient machinery could import from foreign only and will be not feasible to replace due to the high cost. Table 6.21 and 6.22 shows the details of the machines installed in the hospital.

Table 6.21: Operational machines

Types of Machinery	Quantity	Rating (W)	Duration (hr.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Human Count 60 TS	01	60	08	0.48	153.6
Medonic	01	200	08	1.6	512
Humalyzer 3500	01	300	08	2.4	768
Centrifuge Machine	01	200	08	1.6	512

Electronic Microscope Olympus CX23	01	1500	07	10.5	3360
X-Ray Machine	01	50	02		

Table 6.22: Associated machines to operation theatre

Types of Machinery	Quantity	Rating (W)	Duration (hr.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Anesthesia Machine	01	500	14	7.0	2240
Ventilator	01	400	24	9.6	3072
Auto-Clave	01	1500	14	21	6720
Washing Machine	01	400	04	1.6	512
Spinning Dryer	01	300	04	1.2	384
Baby warmer Machine	01	500	12	6.0	1920

6.3.6 Energy Efficient Measures on X-Ray Machine and Dental Chair

It was observed that X-Ray machines are active all the time even when not in use and same happen to dental chair as it kept on stand-by mode. So, amount of energy could be saved by properly turning off these machineries when they are not in operational mode.

Table 6.23: Suggested energy efficient measures on medical machines

Types of Loads	Quantity	Rating (W)	Duration (hr.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
X-Ray Machine	01	50	02	0.1	32
Dental Chair	02	40	02	0.08	25.6

6.3.7 Recommendations for medical machines

Anesthesia machine

1. Turn off the machine when not in use to avoid unnecessary energy consumption.
2. Use low-flow anesthesia techniques to reduce the amount of gas used, which can lower the energy required to vaporize the gas.
3. Choose an anesthesia machine with electronic control systems, as they tend to be more energy-efficient than pneumatic systems.

Ventilator (observation)

1. Use ventilators with energy-saving modes that automatically adjust settings based on patient needs and ventilation requirements.
2. Replace filters and other components regularly to ensure that the machine is operating at peak efficiency.

Ultrasound machine

1. Use the machine's power-saving settings when not actively imaging patients.
2. Opt for a machine with an LED display, which typically uses less energy than other types of displays.
3. Choose a machine with a smaller, more energy-efficient power supply.

Hematology analyzer

1. Use automated sample preparation techniques to reduce the amount of energy needed to process samples.
2. Select a machine with a low-power, efficient design and features such as sleep modes to reduce energy consumption when not in use.
3. Avoid overfilling reagents, which can waste energy and increase costs.

Centrifuge machine

1. Use the machine's timer settings to avoid over-spinning and reduce energy consumption.
2. Opt for a machine with a brushless motor, which is typically more energy-efficient than other types of motors.
3. Choose a machine with a smaller, more energy-efficient power supply.

Electronic Microscope

1. Turn off the microscope when not in use to avoid unnecessary energy consumption.
2. Choose a microscope with LED illumination, which typically uses less energy than other types of lighting.
3. Opt for a microscope with a high-efficiency power supply and energy-saving features such as sleep modes

6.4 Energy Audit at Capital Sports Corporation

Capital Sports Corporation is a football manufacturing sports industry located at Village Kopra, Wazirabad-Sialkot Road. This industry receives an 11kV line from WAPDA and there is a placement of a transformer according to the 160kW sanctioned load that transformer steps down the 11kV to 440V. The factory uses various halls, each of which is assigned a specific task, to manufacture products in stages. These halls include Rubber-Sheet Hall, Cutting Section, Printing and Stitching Hall, Research and Development Department, and Packing Hall.

6.4.1 Generator

The installed generator in the industry is 360 kVA which is used to supply power to the whole industry in case of any interruption from WAPDA.

Maximum generator capacity (kW)

P=kVA*P. F

P =360*(.8)

P=288KW

Load factor (LF)

LF=Actual Power used by Load/Maximum Power that generator can supply

LF =180/288

LF=0.625

Current generator capacity (kW)

P=KVA*P. F

P =360*(.496)

P=178.56kW

Figure 6.6: Installed generator

Table 6.24: Initial details of the generator

Generator details	
Log Sheet	Not Available
Physical Condition	Mediate
Load Factor	0.62
Power Factor	0.496
Fuel Consumption rate	40 Liter/hour
Maintenance	In case of any malfunction
Control System Review	Manual

6.4.1.1 Recommendations

The energy efficient measures for the generator are: [41]

1. Prepare proper log sheet of generator which includes oil consumption rate, running time of generator, and maintenance schedule of generator.
2. The load factor (LF=Actual Power used by Load/Maximum Power that generator can supply) of the generator is 0.62 which shows that the generator is in under loading condition. Operate the generator at full load. Under loading reduces the efficiency of the generator.
3. Operate the generator at its rated power factor (PF=0.8), which is possible if it is run at full load, connect equal loads on all three phases, and use Capacitor banks.
4. Regularize the maintenance at least once in two months to minimize wear and tear, reduce fuel consumption and extend the life of the generator.

Implementation: Implementing the recommended changes to improve the generator's energy efficiency.

Monitoring: Monitoring of the generator's energy consumption and performance to ensure the recommended changes have the desired effects.

6.4.2 Solar Generated Electricity System

There is a solar system having four inverters each of 50 kW and a total of 200 kW. The generated electricity is used to feed back the grid by net metering which results in deduction in electricity cost from the electricity bill.

Figure 6.7 Installed solar system

Table 6.25: Basic data for solar energy audit

Basic data for solar energy audit	
Latitude & Longitude	Lat 32.55°, Lng 74.55°
Tilt Angle	20°
Solar Radiation	3.64kWh/m^2/day
Inverter type & Capacity	Solis,50kW
Number of Inverter	4
Cleanliness	Negligible
Control System Review	Manual
Previous Solar Generation Record	Not Available

6.4.2.1 Observation & Recommendations

The team discovered shortcomings in the solar system throughout the evaluation, which compromised its total energy efficiency. The team presented a set of recommendations to address the matter and improve the system's performance: [42]

Table 6.26: Observations and Recommendations regarding solar system

Observations	Recommendations
The audit team observed that there is no cleaning there which results in reduced power efficiency.	Solar panels should have a regular system of cleaning, which enhances its Power efficiency.
The audit team discovered that the solar system falls short of a monitoring device for recording the energy it generates. As a result, there is no record of the sector's utilization of solar energy or the surplus energy given to WAPDA.	To ensure effective monitoring and management of the solar system, it is imperative for the industry to maintain a comprehensive data sheet that records the power generation over time, maintenance history, and export of surplus electricity to WAPDA through a green meter.
It is noticed that sometimes solar panel's breaker is switched off by generator operator when WAPDA cut off its supply and then generator provide the supply to industry after that when electricity is turned on from WAPDA generator supply is cut off, the generator operator switched on the breaker of solar panel after some delay. Maybe generator operator forgets to turn on the breaker. Solar generated electricity is wasted in this way. It is advised to automate the breaker using a timer or instruct your generator operator to activate the breaker as soon as electricity is turn on.	To ensure an uninterrupted power supply from renewable sources, an automated switch capable of detecting the presence of WAPDA (Water and Power Development Authority) electricity and switching the connection from the generator to the PV source should be put on the generator.

During outages of electricity, solar-generated energy is wasted since it is not directed to WAPDA.	Installing a PV DG synchronization device for a solar system can improve the efficiency and reliability of the system. This device facilitates the synchronization between the solar PV system and the diesel generator, ensuring that the power supply is always available and stable.

6.4.3 Transformer

The capacity of the installed transformer is of 200 kVA and a net meter is connected to it which takes the electricity from the WAPDA as well as feeds back to the grid through the solar electricity system while the sanctioned load of the industry is 160 kW.

kVA Rating: 200 kVA

Manufacturer: PEL

Pole/Pad Mounted: Pad Mounted

6.4.3.1 Inspection

A transformer that is not grounded is at risk of damage from lightning strikes, power surges, and other electrical disturbances. This can lead to a number of problems, including:

1. **Phase-to-Ground Faults:** Phase-to-ground faults in ungrounded systems can escalate into phase-to-phase faults if not promptly detected and cleared. This can lead to more severe fault conditions and potentially larger fault currents.
2. **Ground Faults in Ungrounded Systems:** When a ground fault occurs in an ungrounded system, it may not immediately cause a significant fault current. Instead, it can evolve over time, potentially leading to insulation breakdown and more severe faults if not detected and cleared.
3. **Voltage Unbalance:** Unbalanced loads or faults can lead to voltage unbalance between phases in an ungrounded system, affecting the performance of connected equipment and potentially causing operational issues.

4. **Reduced lifespan:** Transformers that are not grounded are more likely to overheat and fail prematurely.

5. **Electric shock hazard:** The absence of a grounding path can contribute to the buildup of static charges and increased risk of arcing faults, which could lead to fire hazards.

6.4.3.2 Recommendations

1. Connect the grounding wire to the transformer's grounding terminal.
2. Install a surge arrester on the transformer's primary side.
3. Inspect the grounding system regularly for signs of damage [43].

Implementation

Earthing of the transformer is implemented and 2.6 ohm is obtained which is sufficient.

Problem Statement

The information obtained from electricity bill of this industry is that the maximum demand of industry is 160 kW but MDI shows that the maximum demand of industry is greater than registered demand in WAPDA. Industry faces the problem of MDI and pay penalty accordingly.

Solution

The industry should manage their load that does not exceed 160 kW. If their load is greater than 160 kW, they should increase their electricity demand from WAPDA or shift some lighting and cooling load on solar.

6.4.4 Boiler

Background: The boiler of this company plays a very important role in production. Capital sports unit consists of a boiler which is use to generate steam for various applications including heating process, press machine etc. The operating time of the boiler depends on the production demand. Heat is supplied to the boiler by burning wood.

Figure 6.8: Installed boiler in the industry

Table 6.27: General details of boiler

Item/Equipment	Comments
Nameplate Data	Not Available
Manufacturer	Not Available
Type	Water tube package
No of Burners	1
Operating Pressure	Pressure Sensor (Not Available)
Operating Temperature	160℃
Fuel Control System	Manual
Physical Appearance	Unsatisfactory
Boiler House	Not Proper
Burner	Coil Burner
Fed Water Temperature	20℃
Heat Medium Distribution	Rubber Sheet Hall

6.4.4.1 Inspection

1. It was noted that the boiler's physical condition is poor and that it requires maintenance work frequently. For instance, the wood being burned was wasting away because the furnace or firebox was broken.
2. Due to the impurities in the supplied water, the boiler experiences scaling issues [44].

3. The team observed the absence of pressure and temperature gauges. The temperature and pressure of a boiler have an effect on the production and efficiency of steam. Proper levels enable safe and efficient operation, while high levels result in improved steam generation and energy transfer efficiency. It is an alarming situation and question mark on the industry having quality verified certificate.
4. It was noticed that the steam transmission pipelines are displaced at several locations, which causes steam to be wasted.
5. The boiler system in the sector does not contain a smart thermostat. Inefficient heating schedules, manual control, and missed potential for energy savings result from the absence of a smart thermostat in the boiler system.

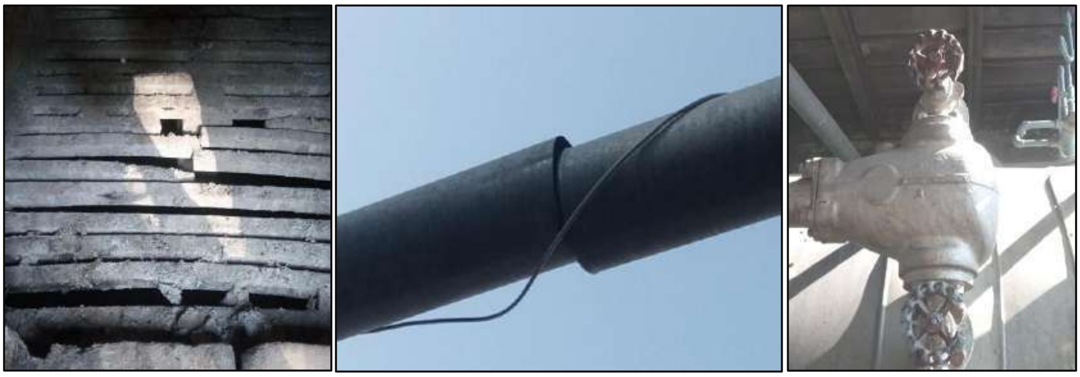


Figure 6.9: Broken components of Boiler

6.4.4.2 Recommendations

1. Maintenance work is required in order to consume less burning material i.e., woods.
2. To resolve the scaling issues, it is recommended to use the chemicals to purify the water.
3. Install the temperature sensor as it would be helpful in detecting the temperature of the burning fuel and can detect that whether it is on the standard or below the standards.
4. Place the steam transferring pipes correctly in order to use the maximum generated steam.
5. Repair or replace the broken parts and properly insulate them.
6. The steam produced during boiling does not remove all the impurities present in the water, leading to a higher concentration of these contaminants in the boiler. So, it is advisable to periodically flush the steam drum.
7. To increase energy efficiency and reduce energy consumption, the use of a smart thermostat can be beneficial in optimizing heating schedules.

8. In a boiler system, increasing the feed water temperature can lead to several efficiency improvements reduced fuel consumption, increased fuel efficiency, fast steam generation see in figure 6.9.

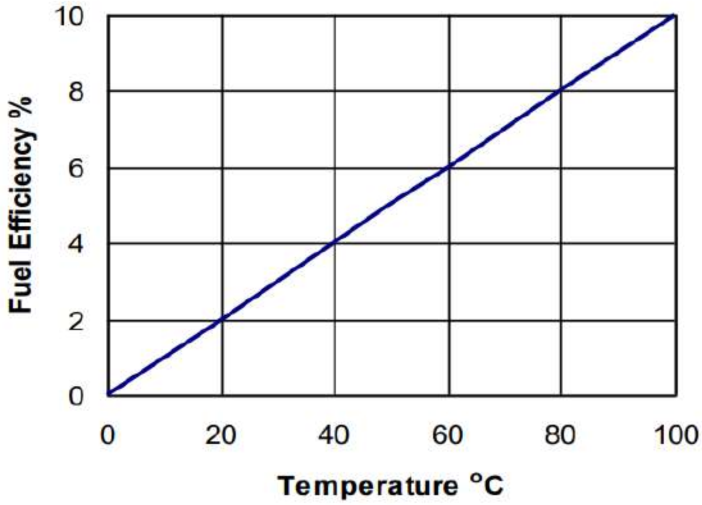


Figure 6.10: Efficiency Improvement from feed water temperature in boiler

6.4.5 Compressor

The industry has five compressors that are used to inflate footballs, soccer balls and basketballs. Compressors are also used in the process of testing and quality assurance Furthermore, compressors are used to provide the air to machinery for example bladder inflation machine, conveyor machine, etc.

Figure 6.11: Compressor's rating measured by clamp meter.

A Compressor energy audit typically involves several steps, including:

Inspection: There is no regular maintenance of the compressor, the air leakage is happening from multiple places, which reduces the efficiency of the compressor.

Operating parameters:

Pressure =130psi

(Compressor A) Rated Power = 1HP =0.746kW

(Compressor B) Rated Power =2HP =1.492kW

6.4.5.1 Recommendations

1. Compressors can be equipped with Variable Frequency Drives (VFDs) to control their speed and make them use less energy, which is a considerable advantage.
2. Routine maintenance of the compressor is required to ensure long-term efficiency.
3. It is advised to correctly install fittings with the required sealants as loose connections have been found to be a source of fuel waste.
4. Identifying and repairing leaks in air systems is essential for minimizing energy losses. The presence of leaks in the air system wastes a significant amount of energy. Fixing these leaks not only will improve the system's energy efficiency, but will also result in cost savings and increased productivity.
5. The temperature of the intake air has a significant impact on compressor performance. An increase in intake temperature can cause the compressor's efficiency to decrease. For every 5 degrees Celsius that the intake air temperature exceeds the ambient temperature, efficiency is reduced by 1%. This relationship shows the importance of maintaining optimal compressor performance by controlling the intake air temperature.
6. When it is feasible, looped systems should be configured and the distribution system should have the proper pipe diameter size. (Sufficient access to equipment is not provided)

6.4.6 Savings from Lighting and Cooling Loads

Table 6.28: Savings from Lighting and Cooling Load

Energy Efficient Measurements	Saved Energy (kWh/year)
By Replacing Inefficient Lights	5482
By Replacing Inefficient Fans	8448

An extensive energy audit report created at the industry is included in the Appendix C. It contains thorough details on operational loads, their associated energy usage, and the replacement of inefficient devices with energy-efficient ones. The energy usage of the industry is thoroughly examined in this report, with areas for improvement and the successful integration of energy-efficient appliances into the operational framework highlighted.

6.4.7 Recommendations for Cooling load and Electric Heaters

1. Ensure that air coolers and air conditioners are cleaned and serviced regularly to increase their efficiency and life span.
2. Make sure that the room or space is properly insulated to reduce the cooling loads and energy consumption.
3. Reduce the cooling demand by implementing measures such as shading windows, using fans, and reducing heat sources in the space.
4. Use natural ventilation where possible to reduce energy consumption.
5. Use the air-conditioners on 25C-26 C which would be helpful in reducing 8-10% of total energy consumed by an air conditioner if it runs on 16 C to 18 C.
6. Use a programmable thermostat to regulate the heater’s temperature.
7. Consider using alternative heat sources such as solar.
8. The number of hours the heater is used could be decreased to 5 from 8 (don’t use from 11:00 am – 2:00 pm) as by doing this 65 kWh of energy could be saved per month.
9. Regular maintenance and cleaning can help the fan run efficiently and prolong its life.
10. Unplug the fan when not in use to reduce standby power consumption.

Whenever possible open the windows and doors to allow natural ventilation instead of using the fan.

6.4.8 Recommendations for Lighting Loads

1. Ask the employees to turn off the appliances during break time.
2. Raise awareness among laborers about the importance of using power wisely.
3. In the workspace when there isn't any work being done, the lights could be turned off.
4. In the daytime sunlight could be utilized.
5. The 4 fluorescent tubes (4*80=320W) must be replaced by 3 LED lights (3*40W = 120W) which means 26 kWh could be saved monthly.

6.5 Energy Audit at Govt. Technical Training Institute Lahore

The Government Technical Training Institute located in Gulberg, Lahore is a vocational training institute that operates under the Technical Education and Vocational Training Authority (TEVTA) of the Government of Punjab, Pakistan. It was established in 1936, consists on total area of 12 acres and have total load of 600kW. It aims to provide quality technical and vocational education to meet the skill requirements of various industries and promote employment opportunities.

The college has 15 departments which offer a range of technical and vocational courses to students, equipping them with practical skills and knowledge necessary for the job market. The institute focuses on hands-on training and practical experience to ensure that students gain proficiency in their chosen fields.

The institute offers programs in various disciplines, including but not limited to electrical technology, mechanical technology, civil technology, computer science, and information technology. These programs cover both theoretical and practical aspects, preparing students for the challenges of the industry.

6.5.1 Savings

Table 6.29: Annual Energy Savings

Energy Efficient Measurements	Saved Energy (kWh/year)
By Replacing Inefficient Lights	10273
By Replacing Inefficient Fans	7706
By Replacing Inefficient Air Conditioner	13200

An extensive energy audit report created at the college is included in the Appendix A. It contains thorough details on operational loads, their associated energy usage, and the replacement of inefficient devices with energy-efficient ones. The energy usage of the college is thoroughly examined in this report, with areas for improvement and the successful integration of energy-efficient appliances into the operational framework highlighted.

Chapter 7

Conclusion and Future Work

7.1 Conclusion

In conclusion, the study examined energy audits as a tool for cutting energy use and advancing sustainability. The primary focus was on performing energy audits in a variety of public sectors, such as educational institutes and associated Halls of residences as well as medical and industrial sectors in which electricity consumption is reduced by turning off unnecessary appliances, replacing inefficient wirings, improving the cooling and heating quality. The goal was to pinpoint sources of energy waste and then take corrective action.

Several widely used energy-saving techniques were identified throughout the work as successful methods for lowering energy use. Some examples are the installation of energy-efficient light bulbs, the replacement of inefficient fans with energy-efficient ones, the elimination of surplus lights and fans, the improvement of system operations, and the introduction of automation. The findings of the energy audits showed significant rises in energy conservation and a reduction in consumption across all of the investigated settings. Reduced energy costs, improved operational efficiency, and a lesser ecological impact were just some of the obvious advantages experienced by each setting after adopting the suggested measures. These results illustrate the value and significance of conducting energy audits for the purpose of discovering and fixing energy ineffectiveness.

In addition, the study pointed out how energy audits can have extensive impacts on the protection of the environment. The information obtained from the energy audits is useful not only as a tool for immediate consumption cuts but also as a roadmap for the future of energy management. It is important to understand that energy audits are a continuous process rather than a one-time fix. Maintaining energy efficiency gains and ensuring long-term sustainability requires constant monitoring, evaluation, and analysis of energy usage patterns. It has been determined that human behavior is a source of energy waste. The audit found that building residents are not aware of energy efficiency measures or taking proper measures to implement them. Energy efficiency can be encouraged by implementing conservation measures, educating residents in energy-saving techniques, and presenting rules and regulations.

It is suggested that one approach to lowering long-term costs and reducing dependability on traditional energy sources is to investigate the possibility of involving renewable energy sources. In addition, the energy audit highlighted the significance of developing an energy management plan that encourages regular evaluation, maintenance, and employee participation. The audited facility or framework can develop a culture of environmental sustainability and continuous improvement by tracking energy consumption, establishing attainable goals, and providing training for staff.

In conclusion, the work demonstrates the important role of energy audits in achieving frequent reductions in energy consumption and increases in sustainability. Organizations can save significant amounts of funds and energy and make significant contributions to environmental preservation by identifying energy inefficiencies, carrying out targeted measures, and promoting a culture of energy-conscious behavior. In order to make real progress toward a greener future, it is crucial to keep highlighting the importance of energy audits as a key component to achieving sustainable and efficient energy consumption.

7.2 Relevant SDGs

This research corresponds to several Sustainable Development Goals (SDGs) of the United Nations, including SDGs 07, 08, 12, and 13. It encourages the supply of affordable and clean energy, the promotion of economic growth; support the adoption of responsible consumption and production practices, and climate action for addressing climate change. The research addresses these essential global goals, highlighting its dedication to promoting sustainable development and having a positive impact in these areas.

7.3 Future Work

7.3.1 Integration of Smart Technologies

Integrating smart technologies like the Internet of Things (IoT) and modern sensors that enable real-time monitoring of energy consumption is an area that needs more attention in future work. Energy auditing professionals as well as building occupants can benefit from this integration because it can improve the precision of data collection, automate energy-efficient processes, and reveal previously undiscovered insights.

7.3.2 Artificial Intelligence (AI)

Energy audits can be more precise with the help of AI, which can examine massive amounts of data to locate potential areas for energy savings. The auditing process can be simplified and proactively energy management can be achieved through the development of artificial intelligence-powered calculations and algorithms that are able to recognize abnormalities, trends, and deficiencies in utilization of energy.

7.3.3 Advanced Building Energy Simulation

In order to accurately forecast energy performance and locate possible electricity savings initiatives, future research should refine building energy simulation models. Simulation software can provide more precise insights through the integration of real-time data and machine learning algorithms, allowing auditors to recommend distinctive measures to improve energy efficiency and sustainability.

7.3.4 Renewable Energy Sources

Future energy audits must consider the economic feasibility of integrating renewable energy sources into current systems in light of the rising importance of renewable energy. In order to significantly reduce dependence on fossil fuels and increase the sustainability of energy systems, it is important to evaluate the potential benefits of solar, wind, geothermal, and other renewable energy technologies.

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Appendix A

Energy Audit at Technical Training Institute, Gulberg Lahore.

Table A.1: Existing Lighting Load of Electronics Department

Lighting Load		
Name of Appliances	***Compact Fluorescent Lamp***	***Fluorescent Tube***
Quantity	08	64
Rating(W)	280	3200
Hours of Operation	12	12
Days of Operation	300	300
Annul Energy Consumption(kWh)	1008	11520

Table A.2: Suggested Efficient Lighting Load of Electronics Department

Lighting Load		
Name of Appliances	***LED Bulb***	***LED Tube***
Quantity	08	64
Rating(W)	144	1920
Hours of Operation	12	12
Days of Operation	300	300
Annul Energy Consumption(kWh)	518.4	6912
Annual Energy Saving(kWh)	489.6	4608

Table A.3: Existing Cooling Load of Electronics Department

Cooling Load		
Name of Appliances	***Fans***	***Air Conditioners (Non-Inverter)***
Quantity	24	04
Rating(W)	2880	8000
Hours of Operation	12	04
Days of Operation	120	120
Annul Energy Consumption(kWh)	4147.2	3840

Table A.4: Suggested Efficient Cooling Load of Electronics Department

Cooling Load		
Name of Appliances	***5-Star Fans***	***Air Conditioners (Inverter)***
Quantity	24	04
Rating(W)	1800	4000
Hours of Operation	12	04
Days of Operation	120	120
Annul Energy Consumption(kWh)	2592	1920
Annual Energy Saving(kWh)	1555.2	1920

Table A.5: Existing Informational System of Electronics Department

Informational Systems			
Name of Appliances	***Computer Systems***	***LED TV***	***Projector***
Quantity	04	01	04
Rating(W)	480	70	2600
Hours of Operation	03	03	06
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	432	63	4680

Table A.6: Suggested Efficient Measures for Informational Systems of Electronics Department

Informational Systems	
Name of Appliances	***Latest Projector (Energy Efficient)***
Quantity	04
Rating(W)	600
Hours of Operation	06
Days of Operation	300
Annul Energy Consumption(kWh)	1080
Annul Energy Savings (kWh)	3600

Table A.7: Existing Lighting Load of Electronics Lab

Lighting Load		
Name of Appliances	***LED Bulbs***	***Table Lamps***
Quantity	10	15
Rating(W)	500	900
Hours of Operation	12	06
Days of Operation	300	300
Annul Energy Consumption(kWh)	1800	1620

Table A.8: Suggested Efficient Lighting Load of Electronics Lab

Lighting Load		
Name of Appliances	***LED Bulbs***	***Table Lamps (LED)***
Quantity	10	15
Rating(W)	500	270
Hours of Operation	12	06
Days of Operation	300	300
Annul Energy Consumption(kWh)	1800	486
Annul Energy Saving(kWh)	***Already Efficient***	**1134**

Table A.9: Existing Cooling Load of Electronics Lab

Cooling Load		
Name of Appliances	***Fans***	***Air Conditioners***
Quantity	06	02
Rating(W)	720	4000
Hours of Operation	12	06
Days of Operation	120	120
Annul Energy Consumption(kWh)	1036.8	2880

Table A.10: Suggested Efficient Cooling Load of Electronics Lab

Cooling Load		
Name of Appliances	***5-Star Fans***	***Air Conditioners (Inverter)***
Quantity	06	02
Rating(W)	450	2000
Hours of Operation	12	06
Days of Operation	120	120
Annul Energy Consumption(kWh)	648	1440
Annual Energy Saving (kWh)	388.8	1440

Table A.11: Existing Informational System of Electronics Lab

Informational Systems			
Name of Appliances	***Computer Systems***	***Laptop***	***Projector***
Quantity	08	01	01
Rating(W)	960	90	650
Hours of Operation	03	03	03
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	864	81	585

Table A.12: Suggested Efficient Measures for Informational System of Electronics Lab

Informational Systems	
Name of Appliances	***Latest Model Projector***
Quantity	01
Rating(W)	150
Hours of Operation	03
Days of Operation	300
Annul Energy Consumption(kWh)	135
Annual Energy Saving(kWh)	450

Table A.13: Lab Equipment of Electronics Lab

Lab Equipment			
Name of Appliances	***Soldering Iron***	***Drill Machine***	***Hot air gun***
Quantity	28	02	15
Rating(W)	1680	200	22500
Hours of Operation	06	02	02
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	3024	120	13500

Table A.14: Lighting Load of Electrical Department

Lighting Load			
Name of Appliances	***LED Bulbs***	***Compact Fluorescent Lamp***	***Fluorescent Tube***
Quantity	10	08	28
Rating(W)	500	280	1400
Hours of Operation	12	12	12
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	1800	1008	5040

Table A.15: Suggested Efficient Lighting of Electrical Department

Lighting Load			
Name of Appliances	***LED Bulbs***	***Compact Fluorescent Lamp***	***Fluorescent Tube***
Quantity	10	08	28
Rating(W)	500	144	840
Hours of Operation	12	12	12
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	1800	518.4	3024
Annual Energy Saving(kWh)	*Already Efficient*	489.6	2016

Table A.16: Cooling Load of Electrical Department

Cooling Load		
Name of Appliances	***Ceiling Fans***	***Bracket Fans***
Quantity	10	04
Rating(W)	1200	240
Hours of Operation	12	12
Days of Operation	120	120
Annul Energy Consumption(kWh)	1728	345.6

Table A.17: Suggested Efficient Cooling Load of Electrical Department

Cooling Load		
Name of Appliances	***Ceiling Fans***	***Bracket Fans***
Quantity	10	04
Rating(W)	750	240
Hours of Operation	12	12
Days of Operation	120	120
Annul Energy Consumption(kWh)	1080	345.6
Annual Energy Saving(kWh)	648	***Already Efficient***

Table A.18: Existing Lighting and Cooling Load of Electrical Lab

Lighting and Cooling Load Loads		
Name of Appliances	***Fluorescent Tube***	***Fan***
Quantity	10	06
Rating(W)	500	720
Hours of Operation	06	06
Days of Operation	300	300
Annul Energy Consumption(kWh)	900	1296

Table A.19: Suggested Efficient Energy Measures of Electrical Lab

Lighting and Cooling Load Loads		
Name of Appliances	***Fluorescent Tube***	***Fan***
Quantity	10	06
Rating(W)	300	450
Hours of Operation	06	06
Days of Operation	300	300
Annul Energy Consumption(kWh)	540	810
Annual Energy Saving(kWh)	***360***	***486***

Table A.20: Existing Lighting and Cooling Load of Main Store

Lighting and Cooling Load		
Name of Appliances	***Ceiling Fans***	***CFLs***
Quantity	15	23
Rating(W)	1800	805
Hours of Operation	07	07
Days of Operation	300	300
Annul Energy Consumption(kWh)	3780	1690.5

Table A.21: Suggested Energy Efficiency Measures of Main Store

Lighting and Cooling Load		
Name of Appliances	***Ceiling Fans***	***CFLs***
Quantity	15	23
Rating(W)	1125	414
Hours of Operation	07	07
Days of Operation	300	300
Annul Energy Consumption(kWh)	2362.5	869.4
Annual Energy Saving(kWh)	1417.5	821.1

Table A.22: Lighting and Informational System Load of Welding Workshop

Lighting and Informational System Load		
Name of Appliances	***Compact Fluorescent Lamp***	***Projector***
Quantity	13	01
Rating(W)	455	650
Hours of Operation	12	03
Days of Operation	300	300
Annul Energy Consumption(kWh)	1638	585

Table A.23: Suggested Efficient Lighting and Informational System Load of Welding Workshop

Lighting and Informational System Load		
Name of Appliances	***LED Bulb***	***Projector (Latest)***
Quantity	13	01
Rating(W)	234	150
Hours of Operation	12	03
Days of Operation	300	300
Annul Energy Consumption(kWh)	842.4	135
Annual Energy Saving(kWh)	**795.6**	**450**

Table A.24: Cooling and Heating Load of Welding Workshop

Cooling and Heating Load			
Name of Appliances	***Ceiling Fans***	***Exhaust fans***	***Electric Oven***
Quantity	06	03	01
Rating(W)	720	120	2000
Hours of Operation	12	12	01
Days of Operation	120	300	300
Annul Energy Consumption(kWh)	1036.8	432	600

Table A.25: Suggested Energy Efficient Measures on Cooling and Heating Load of Welding Workshop

Cooling and Heating Load		
Name of Appliances	***Ceiling Fans***	***Exhaust fans***
Quantity	06	03
Rating(W)	450	120
Hours of Operation	12	12
Days of Operation	120	300
Annul Energy Consumption(kWh)	648	432
Annual Energy Saving(kWh)	**388.8**	**86.4**

Table A.26: Lighting Load of Luban Workshop

Lighting Load		
Name of Appliances	***Spot Lights***	***Ceiling Lights***
Quantity	16	30
Rating(W)	800	1200
Hours of Operation	12	12
Days of Operation	250	250
Annul Energy Consumption(kWh)	2400	3600

Table A.27: Suggested Energy Efficient Measures for Lighting Load of Luban Workshop

Replacement with Efficient Lighting Load		
Name of Appliances	***Led Lights***	***Led Ceiling Lights***
Quantity	16	30
Rating(W)	480	900
Hours of Operation	12	12
Days of Operation	250	250
Annul Energy Consumption(kWh)	1440	2700
Annual Energy Saving (kWh)	960	900

Table A.28: Cooling Load of Luban Workshop

Cooling Load			
Name of Appliances	***Ceiling Fans***	***Chillers***	***Water Dispenser***
Quantity	14	05	01
Rating(W)	1050	6000	100
Hours of Operation	12	12	20
Days of Operation	180	180	320
Annul Energy Consumption(kWh)	2268	12960	640

Table A.29: Informational System and Other Loads of Luban Workshop

Informational Systems				
Name of Appliances	***Computer Systems***	***Projector***	***LED TV 108"***	***Automatic Production Level***
Quantity	25	01	01	01
Rating(W)	2500	650	250	5.1
Hours of Operation	10	04	03	24
Days of Operation	300	300	300	300
Annul Energy Consumption(kWh)	7500	780	225	36.72

Table A.30: Lighting and Cooling Load of Cooking Department

Lighting and Cooling Load				
Name of Appliances	***LED Bulbs***	***Fans***	***Refrigerator Buraq (R-1)***	***Refrigerator***
Quantity	06	04	01	01
Rating(W)	108	480	400	400
Hours of Operation	12	12	12	12
Days of Operation	300	180	250	250
Annul Energy Consumption(kWh)	388.8	1036.8	1200	1200

Table A.31: Suggested Energy Efficient Measures in Lighting and Cooling Load of Cooking Department

Lighting and Cooling Load			
Name of Appliances	***LED Bulbs***	***Fans***	***Refrigerator***
Quantity	06	04	01
Rating(W)	108	300	200
Hours of Operation	12	12	10
Days of Operation	300	180	250
Annul Energy Consumption(kWh)	388.8	648	547.5
Annual Energy Saving(kWh)	***Already Efficient***	388.8	12

Table A.32: Other Kitchen Accessories of Cooking Department

Welding Workshop Equipment						
Name of Appliances	***Juicer***	***Blinder***	***Hand Dryer***	***Oven***	***Meat Grinder Machine***	***Aqua Water Filter***
Quantity	01	04	03	01	01	01
Rating(W)	600	1400	600	1500	750	60
Hours of Operation	04	04	03	05	02	12
Days of Operation	250	250	250	250	250	250
Annul Energy Consumption(kWh)	600	1400	450	1875	375	180

Table A.33: Lighting, Cooling and Heating Load of Machinist Workshop

Lighting, Cooling and Heating Load			
Name of Appliances	***LED Bulbs***	***CF Tubes***	***Fans***
Quantity	04	03	04
Rating(W)	72	150	480
Hours of Operation	12	12	12
Days of Operation	300	300	120
Annul Energy Consumption(kWh)	259.2	540	691.2

Table A.34: Suggested Energy Efficient Measures in Lighting, Cooling and Heating Load of Machinist Workshop

Lighting, Cooling and Heating Load			
Name of Appliances	***LED Bulbs***	***CF Tubes***	***Fans***
Quantity	04	03	04
Rating(W)	72	90	300
Hours of Operation	12	12	12
Days of Operation	300	300	120
Annul Energy Consumption(kWh)	259.2	324	432
Annual Energy Saving(kWh)	Already efficient	216	259.2

Table A.35: Lighting and Cooling Load of HVAC Department

Lighting and Cooling Load			
Name of Appliances	***Fluorescent Tube***	***Fans***	***Air Conditioners***
Quantity	16	04	01
Rating(W)	800	480	2000
Hours of Operation	12	12	06
Days of Operation	300	120	120
Annul Energy Consumption(kWh)	2880	691.2	1440

Table A.36: Suggested Energy Efficient Measures in Lighting and Cooling Load of HVAC Department

Lighting and Cooling Load			
Name of Appliances	***LED Tube***	***5-Star Fans***	***Air Conditioners (Inverter)***
Quantity	16	04	01
Rating(W)	480	300	1000
Hours of Operation	12	12	06
Days of Operation	300	120	120
Annul Energy Consumption(kWh)	1728	432	720
Annual Energy Saving(kWh)	1152	259.2	720

Table A.37: Lighting and Cooling Load of Draftsman Mechanical Department

Lighting and Cooling Load				
Name of Appliances	***CFL***	***LED Light***	***Fans***	***Air Conditioners***
Quantity	09	01	08	02
Rating(W)	315	50	960	8000
Hours of Operation	12	12	12	06
Days of Operation	300	300	120	120
Annul Energy Consumption(kWh)	1134	180	1382.4	5760

Table A.38: Suggested Energy Efficient Measures in Lighting and Cooling Load of Draftsman Mechanical Department

Lighting and Cooling Load				
Name of Appliances	***LED Bulbs***	***LED Light***	***5-Star Fans***	***Air Conditioners***
Quantity	09	01	08	02
Rating(W)	162	50	600	4000
Hours of Operation	12	12	12	06
Days of Operation	300	300	120	120
Annul Energy Consumption(kWh)	583.2	180	864	2880
Annual Energy Saving(kWh)	550.8	Already Efficient	518.4	2880

Table A.39: Information System of Draftsman Mechanical Department

Informational Systems			
Name of Appliances	***Computer Systems***	***Projector***	***Printing Press***
Quantity	25	01	02
Rating(W)	2500	650	80
Hours of Operation	08	08	02
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	6000	1560	48

Table A.40: Lighting and Cooling Load of Industrial Electronics Department

Associated Loads				
Name of Appliances	***Fluorescent Light***	***Fans***	***Window AC***	***Photocopier Machine***
Quantity	10	06	03	02
Rating(W)	500	720	4500	1600
Hours of Operation	12	12	06	02
Days of Operation	300	120	120	300
Annul Energy Consumption(kWh)	1800	1036.8	3240	960

Table A.41: Suggested Energy Efficient Measures in Lighting and Cooling Load

Associated Loads				
Name of Appliances	***LED Light***	***5-StarFans***	***AC (Inverter)***	***Photocopier Machine***
Quantity	10	06	03	02
Rating(W)	300	450	3000	1600
Hours of Operation	12	12	06	02
Days of Operation	300	120	120	300
Annul Energy Consumption(kWh)	1080	648	2160	960
Annual Energy Saving(kWh)	720	388.8	1080	

Table A.42: Lighting and Cooling Load of Computer Lab-I

Lighting and Cooling Load			
Name of Appliances	***Fluorescent Light***	***Fans***	***Air Conditioner***
Quantity	11	03	02
Rating(W)	550	360	8000
Hours of Operation	12	12	06
Days of Operation	300	120	120
Annul Energy Consumption(kWh)	1980	518.4	5760

Table A.43: Suggested Energy Efficient Measures in Lighting and Cooling Load of Computer Lab-I

Lighting and Cooling Load			
Name of Appliances	***LED Light***	***5-Star Fans***	***Air Conditioner (Inverter)***
Quantity	11	03	02
Rating(W)	330	225	4000
Hours of Operation	12	12	06
Days of Operation	300	120	120
Annul Energy Consumption(kWh)	1188	324	2880
Annual Energy Saving(kWh)	792	194.4	2880

Table A.44: Informational System of Computer Lab-I

Informational Systems			
Name of Appliances	***Computer Systems***	***Projector***	***Printing Press***
Quantity	20	01	01
Rating(W)	2000	650	40
Hours of Operation	08	08	02
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	4800	1560	24

Table A.45: Lighting and Cooling Load of Computer Lab-II

Lighting and Cooling Load			
Name of Appliances	***CFL***	***Fans***	***Air Conditioner***
Quantity	10	07	02
Rating(W)	350	840	8000
Hours of Operation	06	06	06
Days of Operation	300	120	120
Annul Energy Consumption(kWh)	630	604.8	5760

Table A.46: Suggested Energy Efficient Measures in Lighting and Cooling Load of Computer Lab-II

Lighting and Cooling Load			
Name of Appliances	***CFL***	***Fans***	***Air Conditioner***
Quantity	10	07	02
Rating(W)	180	525	4000
Hours of Operation	06	06	06
Days of Operation	300	120	120
Annul Energy Consumption(kWh)	324	378	2880
Annual Energy Saving(kWh)	306	226.8	2880

Table A.47: Information System of Computer Lab-II

Informational Systems			
Name of Appliances	***Computer Systems***	***Projector***	***Printing Press***
Quantity	20	01	02
Rating(W)	2000	650	80
Hours of Operation	08	08	02
Days of Operation	300	300	300
Annul Energy Consumption(kWh)	4800	1560	48

Appendix B

Energy Audit at Capital Sports Corporation

Table B.1: Existing inefficient and suggested efficient lighting load

Lighting Load			
Name of Appliances	***CFL***	***Incandescent Bulb***	***Fluorescent Tube***
Quantity	20	10	26
Rating(W)	25	100	70
Time of Use	2640	2640	2640
Annul Energy Consumption(kWh/yr.)	1320	2640	4805
Suggested Efficient Lighting Load			
Rating (W)	12	12	34
Potential Energy Savings (kWh/yr.)	687	2323	2472
Payback Period (Days)	52	20	109

Table B.2: Existing inefficient and suggested efficient air coolers load

Existing inefficient old air coolers	
Quantity	40
Rating(W)	200
Time of Use	2640
Annual Energy Consumption(kWh/yr.)	21120
Suggested energy efficient air coolers	
Rating(W)	120
Potential Energy Savings (kWh/yr.)	8448
Payback Period (month)	4

Appendix C

Energy Audit at Govt. Mozzang Teaching Hospital, Lahore.

Table C.1: Existing lighting load of hospital offices

Number of offices=15	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
LED Bulbs	14	700	10	7	2100
Compact Fluorescent Bulb	16	384	10	3.84	1152

Table C.2: Suggested efficient lighting load of hospital offices

Number of offices=15	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annually Saving (kWh)
LED Bulbs	16	288	10	2.88	864	288

Table C.3: Existing heating and cooling load of hospital offices

Number of offices=15	Air Conditioners (non-inverter)	Fans	Electric Heaters	Freezer
Quantity	15	15	15	01
Rating (W)	28500	1730	30000	500
Duration (hrs.)	12	12	12	24
Days of Operation	200	200	120	365
Daily Energy Consumption (kWh)	342	20.76	360	12
Annual Energy Consumption (kWh)	68400	4152	43200	4380

Table C.4: Suggested energy efficient measures for cooling load

Quantity	Rating (W)	Total Rating (W)	Hours	Days	Daily energy consumption(kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
15	900	13500	12	200	162	32400	36000

Table C.5: Suggested energy efficient measures for fans

Quantity	Rating (W)	Hours	Days	Daily energy consumption(kwh)	Annual Energy Consumption (kWh)	Annually Saving(kWh)
15	75	12	200	13.5	2700	1452

Table C.6: Suggested energy efficient measures for heating load

Quantity	Rating (W)	Hours	Days	Daily energy consumption(kwh)	Annual Energy Consumption (kWh)	Annually Saving (kWh)
15	1000	12	120	180	21600	21600

Table C.7: Existing information system of hospital offices

Number of offices=15	Printing System	Computing Devices	Laptops	LCD
Quantity	06	03	07	01
Rating (W)	300	360	490	80
Duration (hr.)	12	12	04	24
Days of Operation	350	350	300	350
Daily Energy Consumption (kWh)	3.6	4.32	1.96	1.92
Annual Energy Consumption (kWh)	1260	1512	588	672

Table C.8: Existing load analysis of X-ray department

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Compact Fluorescent Lamp	04	96	07	0.672	215.04
Fan	03	330	07	2.31	462
Air Conditioner	01	1400	07	9.8	1960
Water Dispenser	01	80	07	0.56	179.2
X-Ray Machine	01	1500	07	10.5	3360
Electric Heater	01	2000	07	14	1680

Table C.9: Suggested energy efficient measures for lighting load of X-ray department

Quantity	Rating(W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
4	72	7	320	0.288	92.16	123

Table C.10: Suggested energy efficient measures for cooling load of X-ray department

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
1	900	7	200	6.3	1260	700

Table C.11: Suggested energy efficient measures for fans of X-ray department

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
3	225	7	200	1.5755	315	147

Table C.12: Suggested energy efficient measures in heating load of X-ray department

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
1	1000	7	120	7	840	840

Table C.13: Existing load analysis of dental department

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
LED Bulbs	03	150	06	0.9	288
Fan	02	220	06	1.32	264
Air Conditioner	01	1500	06	9.0	1800
Water Dispenser	01	80	06	0.48	153.6
Auto-clave	01	500	06	3.0	960
Dental Chair	02	800	06	4.8	1536
Electric Kettle	01	1000	06	6.0	1920
Electric Heater	01	2000	06	12	1440

Table C.14: Suggested energy efficient measures for fans of dental department

Quantity	Rating(watt)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
2	150	6	200	0.9	180	84

Table C.15: Suggested energy efficient measures for cooling load of dental department

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
1	900	6	200	5.4	1080	720

Table C.16: Suggested energy efficient measures for heating load of dental department

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
1	1000	6	120	6	720	720

Table C.17: Energy savings in dental chair (by properly turning off)

Types of Load	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Dental Chair	02	40	02	0.08	25.6

Table C.18: Existing load of medicine store

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
LED Bulbs	02	100	07	0.7	224
Fan	01	120	07	0.84	168
Air Conditioner	01	1500	07	10.5	2100
Refrigerator	02	800	24	19.2	7008
Electric Heater	01	2000	07	14	1680

Table C.19: Suggested energy efficient measures for fans of medicine store

Quantity	Rating (watt)	Hours	Days	Daily Consumption	Annual Consumption(kwh)	Annual Savings (kWh)
1	75	7	200	0.525	105	63

Table C.20: Suggested energy efficient measures for cooling load of medicine store

Quantity	Rating (W)	Hours	Days	Daily Consumption(kWh)	Annual Consumption(kWh)	Annual Savings (kWh)
1	900	7	200	6.3	1260	840

Table C.21: Suggested energy efficient measures for heating load

Quantity	Rating (W)	Hours	Days	Daily consumption (kWh)	Annual Consumption (kWh)	Annual Savings (kWh)
1	1000	7	120	7	840	840

Table C.22: Existing load of laboratory

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Compact Fluorescent Lamp	05	120	24	2.88	921.6
Fan	01	120	24	2.88	576
Air Conditioner	01	1500	24	36	7200
Refrigerator	01	300	24	7.2	2628
UPS	01	1200	06	7.2	2628
Informational System	01	120	14	1.68	537.6
Electric Heater	01	2000	16	32	3840

Table C.23: Suggested energy efficient measures for fans of laboratory

Quantity	Rating (W)	Hours	Days	Daily Consumption (kWh)	Annual Consumption (kWh)	Annual Savings (kWh)
1	75	24	200	1.8	360	216

Table C.24: Suggested energy efficient measures for lighting load of laboratory

Quantity	Rating (W)	Hours	Days	Daily Consumption (kWh)	Annual Consumption (kWh)	Annual Savings (kWh)
5	90	24	320	2.16	691.2	230

Table C.25: Suggested energy efficient measures for cooling load of laboratory

Quantity	Rating (W)	Hours	Days	Daily Consumption (kWh)	Annual Consumption (kWh)	Annual Savings (kWh)
1	900	24	200	21.6	4320	2880

Table C.26: Suggested energy efficient measures for heating load of laboratory

Quantity	Rating (w)	Hours	Days	Daily Consumption(kWh)	Annual Consumption(kWh)	Annual Savings (kWh)
1	1000	16	120	16	1920	1920

Table C.27: Load analysis of existing laboratory machinery

Types of Machinery	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Human Count 60 TS	01	60	08	0.48	153.6
Medonic	01	200	08	1.6	512
Humalyzer 3500	01	300	08	2.4	768
Centrifuge Machine	01	200	08	1.6	512
Electronic Microscope Olympus CX23	01	400	08	3.2	1024

Table C.28: Load analysis of existing ultrasound department

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
LED Bulbs	02	100	12	1.2	384
Fan	01	120	12	1.44	288
Air Conditioner	01	1600	12	19.2	3840
Electric Heater	01	1000	12	12	1440
Ultrasound Machine	01	200	12	2.4	768
Electric Heater	01	2000	12	24	2880

Table C.29: Suggested energy efficient measures for fans of ultrasound department

Quantity	Rating (W)	Hours	Days	Daily Consumption(kWh)	Annual Consumption(kWh)	Annually Saving(kWh)
1	75	12	200	0.9	180	108

Table C.30: Suggested energy efficient measures for cooling load of ultrasound department

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption	Annual Savings (kWh)

					(kWh)	
1	900	12	200	10.8	2160	1680

Table C.31: Suggested energy efficient measures for heating load of ultrasound department

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption(kWh)	Annua l Saving (kWh)
1	1000	12	120	12	1440	1440

Table C.32: Savings for ultra sound machine (by properly turning off the appliance).

Type of Load	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Ultra sound Machine	01	20	02	0.04	12.8

Table C.33: Existing load of hepatitis clinic

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Ceiling Lights	06	300	07	2.1	672
Bracket Fan	01	60	07	0.42	84
Air Conditioner	01	2000	07	14	2800
Water Dispenser	01	80	07	0.56	179.2
Printing Press	01	50	07	0.35	112
Computing Device	01	150	07	1.05	336
Electric Heater	01	1500	07	10.5	1260

Table C.34: Suggested energy efficient measures for lighting load of hepatitis clinic

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
6	108	7	320	0.756	241.92	431

Table C.35: Suggested energy efficient measures for cooling load of hepatitis clinic

Quantity	Rating (W)	Hours	Days	Daily Consumption (kWh)	Annual Consumption(kWh)	Annual Savings (kWh)
1	900	7	200	6.3	1260	1540

Table C.36: Suggested energy efficient measures for heating load of hepatitis clinic

Quantity	Rating (W)	Hours	Days	Daily consumption(kWh)	Annual consumption(kWh)	Annual Savings (kWh)
1	1000	7	120	7	840	420

Table C.37: Load analysis of operation theatre and its associated rooms

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Compact Fluorescent Tube	08	480	18	8.64	2764.8
LED and CFL Bulbs	10	550	18	9.9	3168
Fan	04	480	14	6.72	1344
Pedestal Heater	01	1500	14	21	2520
Air Conditioner	03	5600	14	78.4	15680
Refrigerator	01	300	24	7.2	2628
UPS	01	1500	06	9.0	3285
Instant water heater	01	1500	12	18	2160

Electric Kettle	01	1000	06	6.0	1920
Electric Heater	02	3000	06	18	2160

Table C.38: Suggested energy efficient measures for lighting Load of operation theatre

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
8	240	18	320	4.32	1382.4	1382

Table C.39: Suggested energy efficient measures for fans of operation theatre

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
4	300	14	200	4.2	840	504

Table C.40: Suggested energy efficient measures for cooling load of operation theatre

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
3	2700	14	200	37.8	7560	8120

Table C.41: Suggested energy efficient measures for heating load of operation theatre

Quantity	Rating (W)	Hours	Days	Daily Energy consumption(kWh)	Annual Energy consumption(kWh)	Annual Savings (kWh)
2	2000	6	120	12	1440	720

Table C.42: Load analysis of machinery associated to operation theatre

Types of Machinery	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Anesthesia Machine	01	500	14	7.0	2240
Ventilator	01	400	24	9.6	3072
Auto-Clave	01	1500	14	21	6720
Washing Machine	01	400	04	1.6	512
Spinning Dryer	01	300	04	1.2	384
Baby warmer Machine	01	500	12	6.0	1920

Table C.43: Load analysis of male ward

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
LED Bulb	06	300	24	7.2	2628
Fan	05	600	24	14.4	2880
Electric Heater	03	6000	24	144	17280
Air Conditioner	01	2500	24	60	12000
ECG Machine	01	500	08	4.0	1460
Cardiac Monitor	01	200	08	1.6	584

Table C.44: Suggested energy efficient measures for fans of male ward

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual Savings (kWh)
5	375	24	200	9	1800	1080

Table C.45: Suggested energy efficient measures for heating load of male ward

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
3	3000	24	120	72	8640	8640

Table C.46: Suggested energy efficient measures for cooling load of male ward

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
1	1600	24	200	38.4	7680	4320

Table C.47: Load analysis of paediatric ward

Types of Loads	Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
LED Bulb	05	250	24	6.0	2190
Fan	03	360	14	5.04	1008

Table C.48: Suggested energy efficient measures for fans of paediatric ward

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
3	0.225	14	200	3.15	630	378

Table C.49: Load analysis of gynae wards corridors

Types of Loads	Quantity	Rating (W)	Duration (hr.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
LED Bulb	06	300	24	7.2	2304
Fan	06	660	24	15.84	3168

60" LED TV	01	80	12	0.96	307.2
Water Pump	02	3730	08	29.84	9548.8

Table C.50: Suggested energy efficient measures for fans of gynae ward corridors

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption (kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
6	450	24	200	10.8	2160	1008

Table C.51: Load analysis of hospital's other corridors

Types of Loads		Quantity	Rating (W)	Duration (hrs.)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)
Compact Fluorescent Tube	Corridor 01	03	180	24	4.32	1382.4
LED Bulb	Corridor 02	05	250	24	6.0	1920
	Corridor 03	05	250	24	6.0	1920
Fan	Corridor 01	03	360	24	8.64	1728
	Corridor 02	03	360	24	8.64	1728
	Corridor 03	05	480	24	11.52	2304

Table C.52: Suggested energy efficient measures for lighting load of corridors

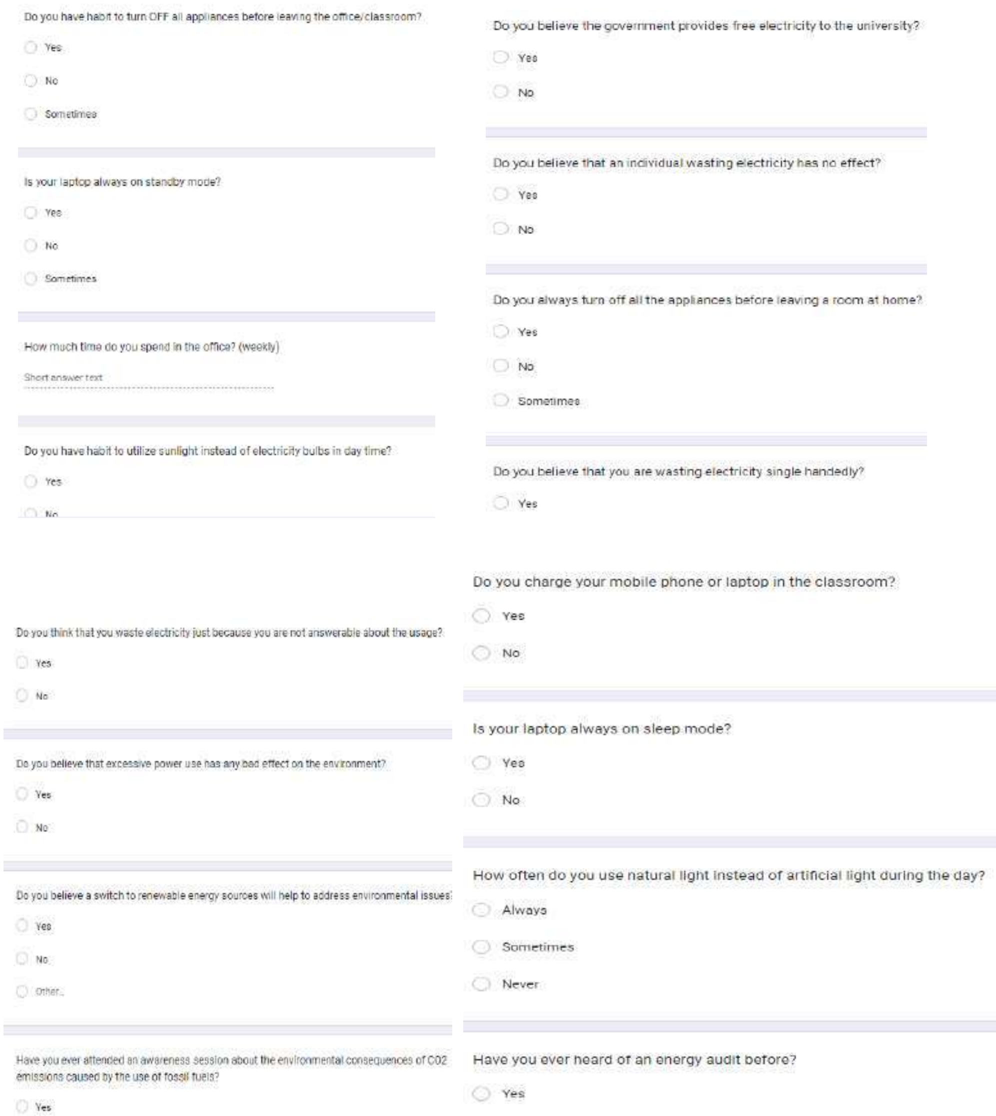
Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
3	150	24	320	3.6	1152	230.4

Table C.53: Suggested energy efficient measures for corridors fans

Quantity	Rating (W)	Hours	Days	Daily Energy Consumption(kWh)	Annual Energy Consumption(kWh)	Annual Savings (kWh)
11	825	24	200	19.8	3960	1800

Appendix D

Designed questionnaire survey for university and halls of residences.



Do you have habit to turn OFF all appliances before leaving the office/classroom?

- Yes
- No
- Sometimes

Is your laptop always on standby mode?

- Yes
- No
- Sometimes

How much time do you spend in the office? (weekly)

Short answer text

Do you have habit to utilize sunlight instead of electricity bulbs in day time?

- Yes
- No

Do you believe the government provides free electricity to the university?

- Yes
- No

Do you believe that an individual wasting electricity has no effect?

- Yes
- No

Do you always turn off all the appliances before leaving a room at home?

- Yes
- No
- Sometimes

Do you believe that you are wasting electricity single handedly?

- Yes

Do you think that you waste electricity just because you are not answerable about the usage?

- Yes
- No

Do you believe that excessive power use has any bad effect on the environment?

- Yes
- No

Do you believe a switch to renewable energy sources will help to address environmental issues?

- Yes
- No
- Other...

Have you ever attended an awareness session about the environmental consequences of CO2 emissions caused by the use of fossil fuels?

- Yes

Do you charge your mobile phone or laptop in the classroom?

- Yes
- No

Is your laptop always on sleep mode?

- Yes
- No

How often do you use natural light instead of artificial light during the day?

- Always
- Sometimes
- Never

Have you ever heard of an energy audit before?

- Yes

Figure D.1: Survey Questions Designed for Campus Faculty

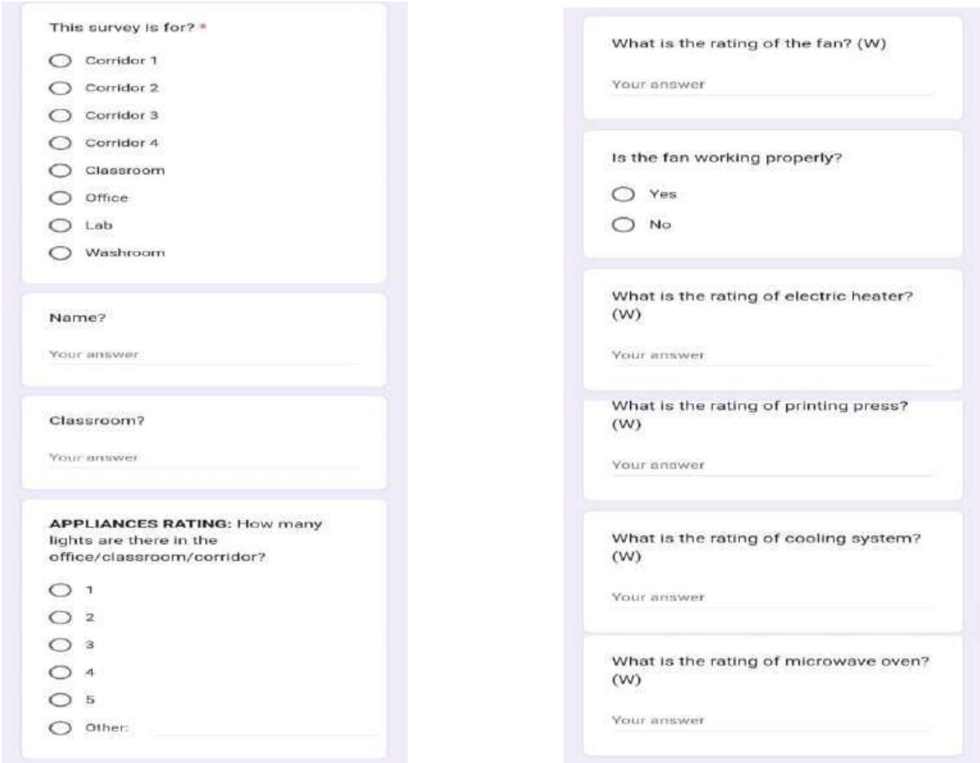


Figure D.2: Survey Questions Designed for Campus students

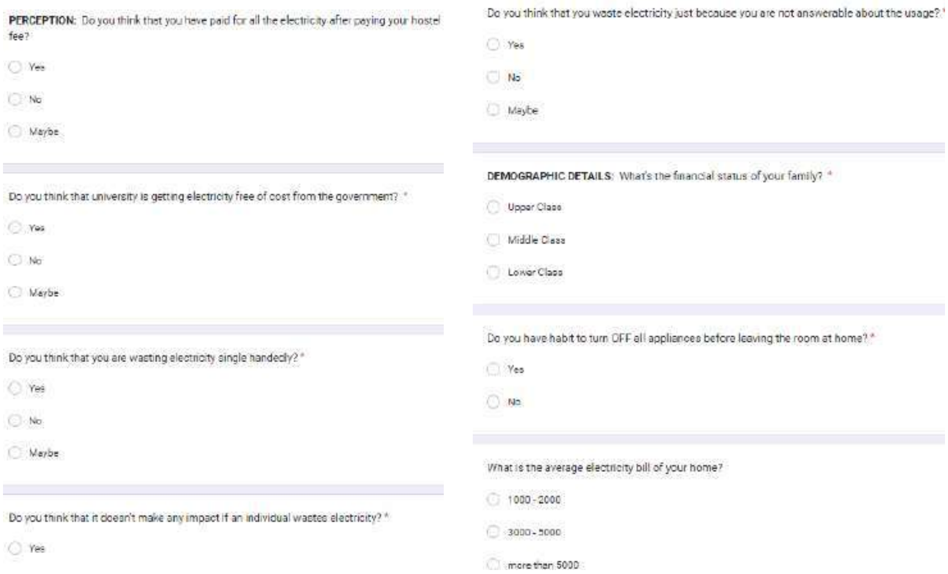


Figure D.3: Survey Questions Designed for Students in Halls of residences