Government of Nepal

Water and Energy Commission Secretariat

Singhadurbar, Kathmandu

Energy Audit Guidelines for Commercial Sectors

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Ashwin, 2077

PREFACE

The Water and Energy Commission Secretariat (WECS) works in the field of collection and analysis of the energy related data in Nepal. The Energy Division of the secretariat, in particular, has been doing such data collection, analysis and future planning of the energy sector. With immense efforts and resources, WECS prepared National Energy Strategy in April 2013, Energy Sector Vision 2050 A.D. in November 2013 and Energy Sector Synopsis report. In both of these documents, energy demand has been forecasted. The energy demand forecast is necessary for the future energy planning of the Country.

In order to meet the energy requirement, efficient use of energy in all sectors of economy should be ensured. Keeping this in mind, WECS has prepared “Energy Audit Guidelines of Commercial sectors”. This is expected to help all sectors covered under this program to reduce their energy demand by adopting energy efficient methods in their activities.

Various studies in different countries have shown that significant energy efficiency improvement opportunities exist in the commercial sector, many of which are cost-effective. These energy efficiency options include both cross-cutting as well as sector-specific measures. However, commercial infrastructures are not always aware of energy efficiency improvement potentials. Conducting an energy audit is one of the first steps in identifying these potentials. Even so, many commercial sectors do not have the capacity to conduct an effective energy audit. The government of Nepal policies and programs aim to assist commercial sectors to improve competitiveness through increased energy efficiency. However, usually only limited technical and financial resources for improving energy efficiency are available, especially for small and medium-sized commercial entities.

This Energy Audit Guideline is intended to provide guidelines for energy auditors, energy managers and all stakeholders involved in energy conservation activities in commercial sector, regarding the key elements for preparing for an energy audit, conducting an inventory and measuring energy use, analyzing energy bills, benchmarking, analyzing energy use patterns, identifying energy efficiency opportunities, conducting cost-benefit analysis, preparing energy audit reports and undertaking post-audit activities. The guideline will assist energy auditors to follow systematic ways to conduct energy audit of commercial sectors without any difficulties.

SUMMARY

Energy Audit Guidelines for commercial sectors is intended to guide the process of identifying and implementing energy saving opportunities that may exist in commercial sectors. It also aims to raise awareness of owners/managers and general public along with providing useful inputs about energy efficient appliances and available technologies. The adoption of guideline will help to achieve reduction in energy use in systematic way, identifying and implementing energy savings opportunities and achieving energy efficiency as well as make better use of energy consuming assets. The guideline provides step by step advice for commercial entities to develop strategy to identify energy efficiency opportunities and development of action plans to implement the options. The Energy Audit Guidelines may also be used by national institutions to recommend strategies, policies, and measures to strengthen the institutional arrangements and capacities of the national institutions working in the development, implementation and promotion of energy efficiency.

For preparation of guidelines, first of all baseline of energy consumption of commercial enterprises were established followed by energy audit in the selected units. 19 commercial enterprises i.e., 4 hospitals/nursing home, 4 commercial bank “A” class, 4 hotels, 4 commercial high rise building/shopping mall and 3 medical stores were selected for conducting baseline study. The energy consumption of selected enterprises was obtained and the specific energy consumption details for each sector were calculated. Review of national, regional and global practices were done along with review of the best available energy efficient technologies. During the process, areas for improvement and energy efficiency options were identified.

There are significant opportunities for improvement of energy efficiency through implementation of low and no cost measures. Some recommendations for specific commercial sectors have also been provided based on the observation during the field visit. With the adoption of the provided measures, the commercial entities can move towards achieving energy efficiency. The guideline also includes the information sheets, formulae for calculation and outline on preparing energy audit report.

ACKNOWLEDGEMENT

Water and Energy Commission Secretariat is thankful to related commercial sectors for their involvement in the preparation of “Energy Audit Guidelines for Commercial Sectors”. The preparation of this guidelines wouldn’t have been possible without their cooperation.

The Secretariat is also thankful to all the team members for their contribution during field visit and preparation of this report. The Secretariat is grateful to the organizations, experts and individuals for their feedbacks and suggestions during the report preparation. Besides these, the Secretariat is also more thankful to the experts from different organizations and authors of various documents, who have been consulted during the work.

Water and Energy Commission Secretariat would like to express its sincere gratitude to GIEF Consultancy Pvt. Ltd. and the experts involved in the preparation of “Energy Audit Guidelines for Commercial Sectors”.

Water and Energy Commission Secretariat

Singhadurbar, Kathmandu

Ashwin, 2077 B.S.

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ABBREVIATIONS

%	:	Percent
AC &s DC	:	Alternating Current & Direct Current
APFC	:	Automatic Power factor Controls
APO	:	Asian Productivity Organization
ASME	:	American Society for Mechanical Engineer
BBSM	:	Bhat-Bhateni Super Market
BEE	:	Bureau of Energy Efficiency
BEP	:	Break Even Point
CEO	:	Chief Executive Officer
CIPEC	:	Canadian Industry Program for Energy Conservation
CO	:	Carbon Monoxide
CO_2	:	Carbon dioxide
COP	:	Coefficient of Performance
DANIDA	:	Danish International Development Agency
DG	:	Diesel Generator
DoHS	:	Department of Health Services
EA	:	Energy Audit
EE	:	Energy Efficiency
ENCON	:	Energy Conservation
EnMS	:	Energy Management System
ENT	:	Ear Nose Throat
FAD	:	Free Air Delivery
FRP	:	Fiberglass Reinforced Plastic
FTLs	:	Fluorescent Tube Lamps
GCV	:	Gross Calorific Value
GHG	:	Green House Gas
GON	:	Government of Nepal
H_2	:	Hydrogen
HF	:	High Frequency
HID	:	High Intensity Discharge
HVAC	:	Heating, Ventilating and Air Conditioning
Hz	:	Hertz
IGEA	:	International Guideline for Energy Audit
IRR	:	Internal Rate of Return
ISO	:	International Organization for Standardization
k Cal	:	Kilo Calorie

KG	:	Kilo Gram
KL	:	Kiloliter
kVA	:	Kilo Volt Ampere
kWh	:	Kilowatt hour
LED	:	Light Emitting Diode
LMD	:	Logistic Management Division
M^3	:	Cubic Meter
MD	:	Maximum Demand
MJ	:	Mega joule
MMWC	:	Millimeter Per Water Column
NEA	:	Nepal Electricity Authority
NM^3	:	Cubic Nanometer
NPR	:	Nepalese Rupees
NPV	:	Net Present Value
NS	:	Nepal Standard
O_2	:	Oxygen
PF	:	Power Factor
pH	:	Potential of Hydrogen
PPM	:	Parts Per Million
PV	:	Solar Photovoltaic
PVC	:	Poly Vinyl Chloride
RE	:	Renewable Energy
RMS	:	Root Mean Square
RoI	:	Return of Interest
RPM	:	Revolution Per Minutes
RTD	:	Resistance Thermometer Detectors
SEC	:	Specific Energy Consumption
TB	:	Tuberculosis
TPH	:	Ton Per Hour
TR	:	Ton of Refrigeration
VFD	:	Variable Frequency Drive
VSD	:	Variable Speed Drive
WECS	:	Water and Energy Commission Secretariat

CHAPTER 1: INTRODUCTION

1.1 Background of the Project

The basic purpose of the Energy Audit Guideline is to impart knowledge to commercial sectors of Nepal on the benchmarking/energy audit/assessment process, and also to guide them on the process of identifying and implementing energy saving opportunities that may exist in the commercial sectors. The guideline also aims to provide useful inputs about energy efficient equipment and technology relevant to commercial sectors.

In general, the key features of Energy Audit Guidelines for commercial sector include:

- Ways to achieve reduction in energy use and carbon emissions in a systematic way
- Providing guidance on how to benchmark, measure, document and report energy use
- Creating a clear picture of current energy use status, based on which new goals and targets can be set
- Evaluating and prioritizing the implementation of new energy-efficient technologies and measures
- Providing a framework to promote energy efficiency throughout the supply chain
- Making better use of energy consuming assets, thus identifying potentials to reduce maintenance costs or expand capacity
- Demonstrating the stakeholders of the corporate commitment to comply with their best practice to protect the environment and,
- Fulfilling the associated regulatory requirements and responding with confidence to green trade barriers in the global market
- Provide useful inputs about available energy efficient equipment and technologies
- Identifying and implementing energy saving opportunities

The guideline provides step by step advice for commercial entities to develop strategy to identify energy efficiency opportunities and development of action plans to implement the options. The Energy Audit Guidelines may also be used by national institutions to recommend strategies, policies, and measures to strengthen the institutional arrangements and capacities of the national institutions promoting energy efficiency. These guidelines provide inputs to concerned decision makers of national energy efficiency organizations on the path to be charted, the process to be followed, and the synergy to be created among the various stakeholders in order to realize the energy efficiency goals set by the respective governments.

The guideline intends to present an analytical framework which can be pursued to achieve energy efficiency goals. It highlights the fact that energy efficiency promotion is a cyclic process. Irrespective of whatever level of success a country/organization may have achieved, there is always scope for further improvement as traditional barriers to energy efficiency are lifted, and there are further technological innovations as energy price keeps rising.

1.2 Types of Energy Used in Commercial Sectors

Commercial sectors mainly use electrical energy while some five star hotels also use thermal energy. Electricity is supplied by the Nepal Electricity Authority (NEA), a government owned organization whereas major source of thermal energy is imported from India and third countries. The petroleum products are imported and distributed by Nepal Oil Corporation (NOC). The NOC is under Ministry of Industry, Commerce and Supplies (MOICS). Mainly used liquid thermal fuel is diesel, LPG and furnace oil, which is imported from India.

1.3 Past and Ongoing Energy Efficiency Activities in Nepal

In Nepal, study related to energy efficiency was found to be started since 1985 but the dedicated works started only from 1999 to 2005 A.D. In these years, works such as energy audits of commercial entity, energy efficiency related trainings and increase in public awareness as well as management of loans for energy efficiency in industries were carried out. Later, from 2009 to 2011, some effective works such as demand side management of electricity, energy audit, study of electricity load profile, preparation of policy suggestions for promotion of energy efficiency as well as replacement of traditional bulbs with energy efficient bulbs were done under Nepal Electricity Authority.

1.4 Policies and Legislation related to Energy Efficiency in Nepal

Article 51 (f) 3 of the constitution of Nepal has mentioned “to ensure reliable supply of energy in an affordable and easy manner, and make proper use of energy, for the fulfillment of the basic needs of citizens, by generating and developing renewal energy”. Different acts, policies, regulations and strategy related to energy efficiency are as follows:

1.4.1 Industrial Enterprises Act, 2076

Chapter 5, Article 24 (p) of this act states that “an industry is entitled to deduction for the purpose of income tax of all expenses invested in machinery or equipment contributing to reduce consumption of energy by enhancing energy efficiency.” Also 29 (b) of the same act states that “electricity generated by an industry for its own purpose is exempted from any fee or royalty payable on it under the prevailing law” and 29 (c) states that “if an industry intends to sell excess of electricity generated by it for its own purpose, it may be sold at the rate set by mutual consent under the prevailing law.”

1.4.2 Industrial Policy, 2067

The objective 7.3 of Industrial policy, 2067 states that “To establish industrial entrepreneurship as a sustainable and reliable sector by utilizing latest technology and environmental friendly production process”. The policies concerning to achieve the objective 7.3 are the technical and financial assistance to the industries that use environment friendly and energy saving technology on their own costs along with the special measures for the enhancement of the green industry and make the established industries free from pollution and carbon. The policy 17.11 states that “The expenses made by any industry in the machine or instrument that help to decrease the consumption of energy, the capital expenses, technology and process for the installation of a system for pollution control and less impact in environment may be deducted for the purpose of income tax” and policy 17.32 states that “No royalty shall be charged on the electricity generated by and industry for its own purpose. Moreover, if the industry desires to sell the electricity energy, provision shall be made to allow the excess energy to the national greed at the prevailing market rate.”

1.4.3 National Energy Efficiency Strategy, 2075

Government of Nepal, Ministry of Energy, Water Resources and Irrigation developed and adopted the National Energy Efficiency Strategy, 2075. The average energy efficiency was 0.84% per year from 2000 to 2015 A.D. This strategy aims to double the growth rate to 1.68% by 2030. The objective is to reduce energy efficiency, facilitate energy access and energy security, and improve the balance of the environment and health.

National Energy Efficiency Strategy emphasizes the following:

- Generate awareness on energy efficiency from the consumer level to policy maker level

- Establish policy, legal and institutional frameworks for resource management, resource mobilization, infrastructure development and human resource development required for energy efficiency
- Develop national standards for energy efficiency based on the established international and regional standards as well as to develop equipment and means for measuring energy efficiency
- Make services and production cost effective and competitive by reducing energy consumption needed for production of goods and services
- Reduce energy import by energy conservation

1.4.4 Biomass Energy Strategy, 2073

The strategy aims to contribute to the sustainable development and protection of the environment by developing bioenergy, which has been used in the traditional way, as a modern, sustainable and clean energy. The following strategies are mentioned to increase the efficiency and effectiveness of the production and use of bioenergy:

- To provide technical and financial assistance for research and study on modern efficient, and affordable biomass energy technologies (biogas, ICS, gasifier, briquettes, pellets, industrial boiler, cogeneration, waste to energy etc.) for determining their feasibility, goals, quality control, emission standards, technology development and improvements.
- To carry out public awareness and promotional activities with the participation of local stakeholders for effective and efficient use of biomass energy and for expansion of modern, efficient and affordable technologies.
- To develop appropriate system and market for commercialization of biomass energy and to ensure the sales and distribution of sales of the produced biomass energy and hence benefit.

CHAPTER 2: ENERGY AUDIT AND ENERGY AUDIT METHODOLOGY

2.1 Energy Audit

An energy audit is a systematic identification of energy flow for energy conservation of any energy using entity through survey and analysis. It helps the entity/facilities in understanding their energy use, recognize the areas of high energy use, and identify opportunities in reducing the high energy input/use without negatively affecting the output as well the quality of the output. In other words, energy audit also helps in identification of potential energy saving opportunities.

An energy audit is an important tool or method for finding such potentials for energy efficiency measures and for assessing their financial viability, which can be carried out at different levels. Energy audit can also verify the effectiveness of energy management opportunities after they have been implemented.

Energy audit is also regarded as one of the tools of energy management system to attain the objective of improved energy performance of the organization. It may be used in conjunction with the EnMS or may be used independently. Energy audit has been defined by different institutions in different ways with more or less the common view.

- In ISO 50002:2014, Energy audit requirements with guidance for use, ISO has defined energy audit as a systematic analysis of energy use and energy consumption of audited objects in order to identify, quantify and report on the opportunities for improved energy performance (ISO 2014).
- As per the National Energy Efficiency Strategy, 2075, Energy efficiency is the efficient use of energy by using appropriate means, technology or equipment's related to energy consumption. The state of energy efficiency can be measured by the energy required to produce each good or service. The reduction of the amount of energy required per product or service by using different methods, technologies or equipment's is to increase energy efficiency. The measurement of the declining rate of energy efficiency is the average state of optical energy efficiency; which refers to the declining energy consumption required to produce per national gross domestic product.

The energy audit needs to be carried out under the supervision of experts, with better understanding of energy audit making the audit more effective.

2.2 Benefit of Energy Audit

Several studies around the world have shown three major operating costs in any commercial entity as energy, labor and materials. As the cost of energy has been constantly on the rise, it is also the area for highest potential towards cost reduction. Such an audit will review variations in energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, energy audit is the translation of conservation ideas into realities by evolving technically feasible solutions with economic and other organizational considerations within the specified time frame.

Improving energy efficiency and conservation are essential to achieve economic and environmental sustainability, especially in a developing economy like Nepal. The energy consuming facilities are not always aware of energy-efficiency improvement potentials. Following some set of rules and principles are essential to arrive at a systematic approach towards realization of energy savings. Conducting an energy audit is one of the prime requisites in identifying these potentials. Despite being aware of the usefulness of the energy efficiency, not all commercial entities are financially and technically capable of undertaking the energy audit process in a systematic way and therefore it requires to have guideline to assist the facilities towards effective's way of reducing energy use, increase energy efficiency.

The National Energy Efficiency Strategy, 2075 for Nepal has been approved by the cabinet meeting of GON on 19th Nov 2018. In the section 9.3 of the strategy, development of national standards for energy efficiency based on established international and regional standards as well as development of equipment and means for measuring energy efficiency is clearly outlined. This guideline may also serve as a tool for conducting the energy audit as envisaged in the National Energy Efficiency Strategy, 2075. Understanding all these contexts, WECS has initiated a program titled "Preparation of Energy Audit Guidelines for Industrial, Commercial and Domestic Sectors". This initiative is expected to help different sectors covered under this program to reduce their energy demand by adopting energy efficient methods in their activities.

2.3 Types of Energy Audit

Energy audit can be different depending upon the types of industry, size, technology used, detail to which energy audit is required. It also varies upon the requirement of cost reduction desired along with potential & magnitude of energy savings required. Depending on these criteria, an energy audit can be classified into two types: a preliminary audit and a detailed audit.

a) Preliminary Audit

This is a simple analysis of energy use and performance of energy consuming utilities. It is mostly done using easily available data and does not involve a lot of data collection and measurements. Due its simple type, it requires very less time. Hence, the obtained energy audit results are more general with common identified energy efficiency opportunities. The payback period in this type is done through simple method of calculation with realized energy savings. This type of audit is also known as walk through audit.

b) Detailed Audit

This a more detailed type of energy audit which requires detailed data collection of different energy utilities (Pump, Fan, Induction Motors, Compressed Air, HVAC, Furnace, Boiler System etc.) and its energy consumption measurements. Due to its detailed nature, it requires longer time than the preliminary audit. Hence, the obtained results are more specific with actual picture of energy use, performance of utilities and with more specific recommendations on energy efficiency opportunities. These energy opportunities are discussed with concerned officials of any organization and then recommended for sustainability of savings. Along with these, vendors and energy efficient equipment suppliers are also consulted while identifying energy saving opportunities. It includes detailed financial analysis of cost demanding opportunities with cost benefit analysis. This type of audit is also known as diagnostic audit.

Besides these, the detailed energy audit also involves post audit phase. In post audit phase, energy auditor assists in implementation of recommended energy saving measures and monitors the performance. The energy auditor also helps the organization in identification of barriers and overcome them, if any, in implementing the recommended action plan. Furthermore, the energy auditor ensures energy saving realization from the organization through follow up and periodic review.

2.4 Energy Audit Methodology

Energy Audit Methodology provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems. This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost. In detailed energy audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared with utility bill charges.

2.4.1 Preliminary Energy Audit Methodology

Walkthrough Audit is done under this methodology:

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely and the easiest areas for attention
- Identify immediate (especially no-/low-cost) improvements/savings
- Set a ‘reference point’
- Identify areas for more detailed study/measurement
- Preliminary energy audit uses existing, or easily obtained data

2.4.2 Detailed Energy Audit Method

Energy audit is carried out in three phases: Phase I, II and III and ten steps energy audit flow chart as presented below:

Phase I -Pre Audit Phase

In the pre audit phase, energy auditor starts the initial planning for the carry out audit in structured and systematic way. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is the most important. An initial site visit before the detailed audit is necessary as it provides the energy auditor with an overview of the organization and helps in planning the necessary actions to be conducted in a systematic way. This also helps the energy auditor to familiarize with the organization, its concerned officials and the site itself.

During the site visit the energy auditor should carry out the following:

- Discuss the aims and agendas of energy audit with senior management
- Obtain drawings of the building layout, steam distribution, compressed air distribution, electricity distribution etc. accompanied by engineering/production department officials
- Analyze the major energy consumption data with the relevant personnel.

Energy Auditor should focus the following aims during the site visit:

- To finalize energy audit team of the organization.
- To identify the Significant Energy Use (SEU) areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/additional metering required.
- To decide whether any measuring devices/instruments will have to be installed prior to the audit.
- To identify the instrumentation required for carrying out the audit.
- To collect macro data on plant energy resources, major energy consuming areas.
- To create awareness among the technical team of organization through meetings

Phase II- Detailed Energy Audit

In this phase, detail energy audit is carried out based on the planning from the pre audit phase. In this phase, energy survey and monitoring to establish, and investigate, energy/material balances for specific plant departments or items of process equipment are carried out. Detailed trials/experiments for selected energy guzzlers are done. Sometimes, plant operations are checked over an extended period of time, at nights and at the weekends and daytime working hours to ensure nothing or no parts are missed out. The time required during this phase depends on the nature and complexity of the site/organization.

Collection of information during the detailed audit:

- Energy consumption by type of energy, by department, by major items of process equipment, by end-use
- Energy cost and tariff data
- Process and material flow diagrams
- Generation and distribution of site services (e.g. compressed air, steam)
- Sources of energy supply (e.g. electricity from the grid or self-generation)
- Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation)
- Energy management procedures and energy awareness training programs within the organization

Information on existing baseline is important and hence it should be collected with existing reports to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs.

The audit team should collect the following baseline data:

- Capacity utilization
- Amount & type of input materials used
- Water consumption
- Fuel consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc.
- Quantity & type of wastes generated
- Percentage rejection / reprocessing
- Efficiencies

Based on all the data/information collected from the organization/site, the analysis of energy use is conducted and Energy Conservation Opportunities (ECO) are identified and developed. The cost benefit analysis of high cost opportunities is calculated.

After all these steps, the audit report is prepared. The audit report includes a description of energy inputs and product outputs by major department or by major processing functions. List of means of improving these efficiencies will be listed. Preliminary assessment of the cost of energy opportunities/improvements are made along with the expected payback on any capital investment required. The report also includes specific recommendations for which detailed engineering studies and feasibility analyses must be performed to justify the implementation of those conservation measures that require high investments.

Phase III: Post Audit

This phase is required to provide sustainability to the energy audit carried out to the overall purpose of energy audit. During this, the energy auditor assists in implementation of recommended energy saving measures and monitors the performance, helps the organization in identification of barriers and overcome them, if any, in implementing the recommended action plan. It also ensures energy saving realization from the organization through follow up and periodic review.

2.5 Specific Energy Consumption Calculation

It is the measure of amount of energy consumed to the amount of product produced or service provided. It is one of the energy performance indicators and reflects the energy efficiency of the commercial enterprises. SEC is calculated as a ratio of energy used for producing a product or service:

SEC=Energy used/Product or Service amount

Detail Energy Audit Flow Chart:

Phase	Steps
Pre-Audit	Plan and Organize & Walkthrough Survey
	↓
	Meetings and Awareness
	↓
Audit	Data Collection, Process Flow & Energy Utility Diagram Preparation
	↓
	Energy Survey and Monitoring
	↓
	Detailed experiments for selected SEU area
	↓
	Analyze of Energy Use
	↓
	Recommendations of Energy Conservation Opportunities (ECO)
	↓
	Cost Benefit Analysis
	↓
	Reporting
	↓
Post Audit	Implementation and Follow up

CHAPETER 3: GUIDELINES OF COMMERCIAL SECTORS

The Guidelines consists total five most energy intensive commercial sectors. These five commercial sectors are commercial bank "A" class, high rise building (shopping malls), hospital/nursing home, five star hotel and medical store.

3.1 Commercial Bank "A" Class

In the 1980s, Nepal opened the commercial banking sector to foreign participation. Since then, 28 commercial banks, including foreign joint-venture banks have been in operation. Currently, there are 36 development banks and 25 finance companies in operation. There are five types of banks in Nepal (Source NRB, 2019).

3.1.1 Energy Use in A-Class Bank's

A-Class Banks consume mainly electrical energy. Main source of electricity is the national grid, whereas diesel generator is used in case of load shedding. Electrical energy is mainly consumed by lighting, air conditioner, pumps and electronic equipment. The major electricity consuming equipment is lighting electronic device and air conditioner.

3.1.2 Specific Energy Consumption (SEC) in A-Class Bank

SEC is calculated as a ratio of energy used for area or rendering any service:

SEC = Energy used/Area or Service

According to the present study findings, the specific energy consumption of the commercial A-Class Bank in Nepal is given below. Figures derived are based on the energy audit carried out in four A class banks of Nepal.

Table 3.1: Specific Energy Consumption in Commercial Bank

Specific Energy Consumption	
	Electrical (kWh/M^2/Year)
WECS 2019/20	137.83

3.1.3 Significant energy used area and equipment in commercial bank "A" class

The following area and equipment consume significant amount of energy:

- AC system
- Lighting
- Diesel generator
- Computers
- Other electronic appliances

3.1.4 Sampling and Measurement for energy audit

The following electrical parameters are needed to be measured for energy audit of electrical system in a commercial bank:

Data Logging: 24 hours of data logging at main electrical pannel with the help of Three Phase Data Logger. It shows power factor, total load in kW & kVA, peak demand, voltage, current, harmonics.

Load Measurement: Load measurement in all individual induction motors with the help of handheld power analyzer. It shows kW, kVA, ampere and power factor.

Lighting Load Measurement: Load measurement at main lighting pannel with the help of handheld power analyzer.

Lighting details: Collection of lighting types with wattages, running hours and installed location.

Diesel Generator: Calculate kilowatt hour generation in per litre of fuel.

Air Conditioner: Measure the electrical load.

3.1.5 Potential Energy Conservation Opportunity in Commercial Banks

The following energy conservation opportunities can be found in commercial banks:

Table 3.2: Energy Focus Area in Commercial Banks

S.N.	Energy Conservation Opportunities	Types of investment
1	Demand Management (Load Balance)	No Cost
2	Regular cleaning of lighting sources	
3	Cleaning of AC filter in regular basis	
4	Develop a culture to get turn off AC, Fan and Light when not in use	
5	Power Factor Improvement by installation of capacitor bank with APFC units	Low Cost
6	Replace conventional lamp with LED	
7	Revision of Contract Demand with NEA and fixed with as per actual demand	
8	Replace inefficent fan with super fan.	
9	Use air Curtain at main entrance to save air exchange.	
10	Install AC controllers in all AC. Ensure star rated AC during installation of new AC	Cost Demanding
11	Install Solar PV at Terrace for lighting	

3.1.6 Some General Energy Saving Opportunities

- Use light sensor for automatic controlling.
- Use motion sensor at public area for automatic lighting control.
- Close doors and windows while using air-condition.
- Establish routine maintenance procedure.
- Conduct internal energy audit regularly.
- As a good practice, it is strongly recommended to implement Energy Management System ISO 50001.

3.2 High Rise Building (Shopping Mall)

Shopping Malls first emerged in the early 1920s in the United States, but they didn't grow into today's gigantic mega-mall units in the 1980s. They filtered into Asia following the meteoric growth of the East Asian economies in 1990s and gave rise to a generation of hip youngsters who indulged in a new "Mall Culture". Malls have caused a stir in Kathmandu having redefined not only lifestyles but shopping itself. Kathmandu malls are far smaller than their international counterparts but like them they have sparked a new lifestyle.

Shopping complex is a marketplace providing a wide range of products and services under the same building. The main advantage of shopping in a Shopping (commercial) complex is that you can find a wide range of products, compare different products in different shops, save your time and effort and also get a quality service at the same time.

3.2.1 Energy Use in Commercial High Rise Buildings (Shopping Complexes)

Commercial high rise buildings (Shopping Complex) consume both electrical and thermal energy. Main source of electricity is the national grid, whereas diesel generator is used in case of load shedding. Electrical energy is mainly consumed by lighting, air conditioner, pumps, lifts and escalators. The major electricity consuming equipment is lighting and air conditioner.

3.2.2 Specific Energy Consumption (SEC) in Commercial High Rise Buildings (Shopping Complex)

SEC is calculated as a ratio of energy used for area or rendering any service:

SEC = Energy used/Area or Service

According to the present study findings, the specific energy consumption of the commercial high rise building (Shopping Complex) in Nepal is given below. Figures derived are based on the energy audit carried out in four commercial high rise building/shopping complex units of Nepal.

Table 3.3: Specific Energy Consumption in High Rise Building (Shopping Mall)

Description	Specific Energy Consumption
	kWh/M^2/Year
WECS 2019/20	65.67
Regional (India) [1]	158
International Benchmark [2]	258

3.2.3 Significant energy used area and equipment in shopping malls

The following area and equipment consume significant amount of energy:

- HVAC system
- Lighting
- Cooling tower
- Diesel generator

[1] BEE-ECO III Benchmarking Study, 2009
[2] BEE-ECO III Benchmarking Study, 2009

- Induction motor
- Pumps

3.2.4 Sampling and Measurement for energy audit

The following electrical parameters are needed to be measured for electrical energy audit in shopping malls:

Data Logging: 24 hours of data logging at main electrical pannel with the help of Three Phase Data Logger. It shows power factor, total load in kW & kVA, peak demand, voltage, current, harmonics.

Load Measurement: Load measurement in all individual induction motors with the help of handheld power analyzer. It shows kW, kVA, ampere and power factor.

Lighting Load Measurement: Load measurement at main lighting pannel with the help of handheld power analyzer.

Lighting details: Collection of lighting types with wattages, running hours and installed location.

Diesel Generator: Calculate kilowatt hour generation in per litre of fuel.

The following thermal parameters are needed to be measured for thermal energy audit in shopping malls:

HVAC: Measure inlet & outlet temperature, flow rate, area and electrical load for COP and performance evaluation.

Cooling Tower: Measure inlet and outlet temperature.

3.2.5 Potential Energy Conservation Opportunity in Shopping Malls

The following energy conservation opportunities can be found in shopping malls:

Table 3.4: Energy Focus Area in High Rise Building (Shopping Mall)

S.N.	Energy Conservation Opportunities	Types of investment
1	Demand Management (Load Balance)	No Cost
2	Regular cleaning of lighting sources	
3	Use efficient reflector in lighting sources	
4	Turning off AC, Fan and Light while not in use	
5	Power Factor Improvement by installation of capacitor bank with APFC units	Low Cost
6	Replace conventional lamp with LED	
7	Revision of Contract Demand with NEA	
8	Install VFD for Pump	
9	Replace inefficient fan with super fan	
10	Install AC controllers	Cost Demanding
11	Install Solar PV at Terrace for lighting	

3.2.6 Some General Energy Saving Opportunities

- Install energy meter for every section of the unit and energy log book for individual section.
- Mall technicians should have Portable clamp on power analyzer for electrical measurements.
- Use light sensor for automatic controlling.
- Replacement all outdoor light with LED type.
- The running utility section must be done in off peak timing.
- As a good practice, it is strongly recommended to implement Energy Management System ISO 50001.

3.3 Hospital/Nursing Home

Most of the hospitals in Nepal are general hospitals, with an emergency department to treat urgent health problems to a sudden illness. The government of Nepal started providing health services to common people by establishing hospitals in the country since 1889 AD. At present, the Ministry of Health and Population has provided for a provision of four categories of government-run hospitals as per the federal set-up. According to the Nepal Health Infrastructure Development Standard, 2017 endorsed by the Cabinet on May 4, 2017 there shall be hospitals of first, second, third, and specialised category at the rural municipality, municipality, provincial, and central levels respectively.

3.3.1 Energy Use in Hospital

Most of the hospitals consume both electrical and thermal energy. Main source of electricity is the national grid, whereas diesel generator is used in case of load shedding. Electrical energy is mainly consumed by lighting, air conditioner, water treatment plant, HVAC, medical equipment, laundry and lifts.

3.3.2 Specific Energy Consumption (SEC) in a Hospital

SEC is calculated as the ratio of energy used for area or rendering any service:

SEC = Energy used/Number of Bed/Area or Service

According to the present study findings, the specific energy consumption of the commercial hospitals in Nepal is given below. Figures derived are based on the energy audit carried out in four hospitals of Nepal.

Table 3.5: Specific Energy Consumption in Hospitals/Nursing Homes

Description	Specific Energy Consumption	
	kWh/M^2/Year	kWh/Bed/Year
WECS 2019/20	83.4	5553.6
[3]Regional (India)	281	-
[4]International Benchmarking Indices	378	13,890

[3] *Source: BEE-ECO-III Benchmarking Study, 2009*

[4] *Source: BEE-ECO-III Benchmarking Study, 2009*

3.3.3 Significant Energy used area and equipment in Hospital

The following area and equipment consume significant amount of energy:

- HVAC system
- Lighting
- Water treatment plant
- Pumping system
- Cooling tower
- Diesel generator
- Laundry
- Medical appliances

3.3.4 Sampling and measurement for energy audit

The following electrical parameters are needed to be measured for electrical energy audit in hospitals:

Data Logging: 24 hours of data logging at main electrical pannel with the help of Three Phase Data Logger. It shows power factor, total load in kW & kVA, peak demand, voltage, current, harmonics.

Load Measurement: Load measurement in all individual induction motors with the help of handheld power analyzer. It shows kW, kVA, ampere and power factor.

Lighting Load Measurement: Load measurement at main lighting pannel with the help of handheld power analyzer.

Lighting details: Collection of lighting types with wattages, running hours and installed location.

Pumping Load Measurement: Measure power consumption and head discharge for performance evaluation.

Diesel Generator: Calculate kilowatt hour generation in per litre of fuel.

The following thermal parameters are needed to be measured for thermal energy audit in hospitals:

HVAC: Measure inlet & outlet temperature, flow rate, area and electrical load for COP and performance evaluation.

Cooling Tower: Measure inlet and outlet temperature of water and coolant.

3.3.5 Potential Energy Conservation Opportunity in Hospitals

The following energy conservation opportunities can be found in hospital:

Table 3.6: Energy Focus Area in Hospitals/Nursing Homes

S.N.	Energy Conservation Opportunities	Types of investment
1	Demand Management (Load Balance)	No Cost
2	Painting of light colour in wall	

S.N.	Energy Conservation Opportunities	Types of investment
3	Regularly clean lights for maximum illumination	
4	Turning off AC, Fan and Light while not in use	
5	Power Factor Improvement by installing capacitor bank with APFC units	Low Cost
6	Replace conventional lamp with LED	
7	Revision of Contract Demand with NEA	
8	Installation of VFD for Pump	
9	Replace inefficient fan with super fan	
10	Replace old pump with energy efficient pump	
11	Insulation of Autoclave	
10	Install AC controllers. Ensure to install star rated AC.	Cost Demanding
11	Purchase star rated refrigerators	
12	Install Solar PV at Terrace	

3.3.6 Some General Energy Saving Opportunities

- Install energy meter for every section of the unit and monitor regularly.
- The planning schedules may be fine-tuned to benefit from lower billing rates during 11 PM to 5 AM (Off-peak time). The options could include water pumping for storage, use of autoclave for sterilization, laundry and water filtration etc.
- Use light sensor for automatic controlling.
- Use motion sensor at public area for automatic lighting control.
- Regularly clean for maximum illumination as well as replacement of burnt fluorescent lamps.
- Close doors and windows while using air-condition.
- Establish routine maintenance procedure.
- Conduct internal audit regularly. As a good practice, it is strongly recommended to implement Energy Management System ISO 50001.

3.4 Five Star Hotel

Hotels in Nepal were established only after it was opened to outsiders for expedition purpose since 1941. Himalayan Inn, the first hotel of Nepal was established in 1950. It was followed by Hotel Paras in 1951 which started providing its service in New Road Kathmandu and at the same time in 1952. “Hotel Royal” was established in 1953, which was the first international standard hotel in Nepal. The first five star hotel of Nepal “Del’ Annapurna” was introduced in 1965. As tourism sector started slowly growing in Nepal, amenities related to the sector were also eventually introduced. However, it took eight more years for another five star hotel to be established in Nepal. It came under the name “Hotel Yak & Yeti” in 1973. As of March 2020, there are 16 five star hotels with 2,705 rooms and 607 international standard hotels (NTB, 2020). Due to the fact that tourism is one of the fastest growing sectors and the sector that has the capability to revive the economy, more and more five star hotels are likely to be established in the future.

3.4.1 Energy Use Five Star Hotel

Five star hotels consume both electrical and thermal energy in their processes. Main source of electricity is the national grid, whereas diesel generator is used in case of load shedding. Electrical energy is mainly consumed by motors, drives, compressors (both air and refrigeration), pumps and lighting. The major electricity consuming processes are cold storage, homogenization and chilling of water. Thermal energy is required for the operation of boilers that generate steam for the laundry and other processes. Fuel used for the boiler operation is mainly diesel. Others sources such as light diesel oil and furnace oil are also used in some five star hotels.

3.4.2 Specific Energy Consumption (SEC) in Five Star Hotels

SEC is calculated as a ratio of energy used for producing a product or rendering any service:

SEC=Energy used/Room or Area Service amount

According to the present study findings, the specific energy consumption of the commercial five star hotels in Nepal is given below. Figures derived are based on the energy audit carried out in four 5 star hotel units of Nepal.

Table 3.7: Specific Energy Consumption in Hotels

Description	Specific Energy Consumption			
	kWh/M^2/Year	kWh/Room/Year	MJ/M^2/Year	MJ/Room/Year
WECS 2019/20	224.72	15647.45	653.26	54220.14
EEC-FNCCI 2015 (Nepal) [5]	-	17,326	-	45,367
Regional (India) [6]	254	-	-	

[5] *EEC-FNCCI, 2015*

[6] *BEE-ECO-III Benchmarking Study, 2009*

Description	Specific Energy Consumption			
	kWh/M^2/Year	kWh/Room/Year	MJ/M^2/Year	MJ/Room/Year
International Benchmarking Indices [7]	279	24,110		

3.4.3 Significant energy used area and equipment in five star hotels

The following area and equipment consume significant amount of energy:

- HVAC system
- Lighting
- Water treatment plant
- Pumping system
- Cooling tower
- Compressor
- Diesel generator
- Laundry
- Boiler
- Heat exchanger
- Kitchen appliances

3.4.4 Sampling and measurement for energy audit

The following electrical parameters are needed to be measured for electrical energy audit in five star hotels:

Data Logging: 24 hours of data logging at main electrical pannel with the help of Three Phase Data Logger. It shows power factor, total load in kW & kVA, peak demand, voltage, current, harmonics.

Load Measurement: Load measurement in all individual induction motors with the help of handheld power analyzer. It shows kW, kVA, ampere and power factor.

Lighting Load Measurement: Load measurement at main lighting pannel with the help of handheld power analyzer.

Lighting details: Collection of lighting types with wattages, running hours and installed location.

Pumping Load Measurement: Measure power consumption and head discharge for performance evaluation.

Air Compressor: Conduct FAD test, identify leakage in distribution system.

Diesel Generator: Calculate kilowatt hour generation in per litre of fuel.

[7] *BEE-ECO-III Benchmarking Study, 2009*

The following thermal parameters are needed to be measured for electrical energy audit:

In Boiler:

Flue Gas Analysis: Measure oxygen, carbondioxide, carbonmonoxide, stack & ambient temperature.

Surface Heat Loss Measurement: Measure surface temperature of boiler body and steam pipelines.

Feed Water Analysis: Measure pH, TDS, hardness and temperature.

Blow Down Water Analysis: Measure pH & TDS.

Economizer & Air Preheater: Measure inlet and outlet temperature of water and air.

HVAC: Measure inlet & outlet temperature, flow rate, area and electrical load for COP and performance evaluation.

Heat Exchanger: Measure inlet and outlet temperature.

Cooling Tower: Measure inlet and outlet temperature of water and coolant.

3.4.5 Potential Energy Conservation Opportunity in Five Star Hotel

The following energy conservation opportunities can be found in five star hotels:

Table 3.8: Energy Focus Area in Hotels

S.N.	Energy Conservation Opportunities	Types of investment
1	Demand Management (Load Balance)	No Cost
2	Phase balance	
3	Regularly clean lights for maximum illumination	
4	Measure oxygen or carbondioxide in stack and control excess Air in Boiler	
5	Maintain boiler loogbook	
6	Turning off AC, Fan and Light while not in use	
7	Power Factor Improvement by installing capacitor bank with APFC units	Low Cost
8	Replace conventional lamp with LED	
9	Revision of Contract Demand	
10	Install VFD for Pump and Motor	
11	Replace old pump and motor with energy efficient pump & motor	
12	Insulation of bare pipes and fittings in steam distribution	
13	Condensate Recovery	
14	Install Solar PV at Terrace or Solar Grid Tie System	Cost Demanding
15	Install Economiser and air preheater in boiler	

3.4.6 Some General Energy Saving Opportunities

- Install energy meter for every section of the unit and monitor regularly.
- Use light sensor for automatic controlling.
- Make a culture to shutdown electrical appliances while not in use.
- Use motion sensor at guest areas for automatic lighting control.
- Close doors and windows while using air-condition.
- Conduct internal audit regularly. As a good practice, it is strongly recommended to implement Energy Management System ISO 50001.

3.5 Medical Stores

An efficient management of logistics is crucial for effective and efficient delivery of health services as well as ensuring rights of citizens of having quality of health care services. Logistics Management Division (LMD) was established under Department of Health Services (DoHS) in 1993, with its major function being procuring, storing and distributing health commodities for the health facilities of the government of Nepal.

Medical stores are the facilities where mostly vaccines, reagents and test samples are stored. It requires electrical energy for cooling and refrigeration for the longevity of the items stored. All kinds of health care centers (private and government owned both) require a medical store for storing such vaccines and other items to preserve them and make them readily available for use in the future.

In the past, there was one central and five regional medical stores as well as district level stores in all 75 districts of the country. After Nepal has gone under the federal restructuring process, this structure has been transformed into the network of one central, seven provincial and 77 district level medical stores. The central level medical store is located in Kathmandu. All the provincial medical stores are located in the provincial headquarters except for the store in Province no. 2, which is located in Pathalaiya of Bara district.

3.5.1 Energy Use in Medical Stores

Medical stores consume mainly electrical energy. Main source of electricity is the national grid, whereas diesel generator is used in case of load shedding. Electrical energy is mainly consumed by lighting, cold storage room and fridge. The major electricity consuming equipment is lighting, air conditioner and fridge.

3.5.2 Specific Energy Consumption (SEC) in Medical Store

SEC is calculated as a ratio of energy used for area or rendering any service:

SEC = Energy used/ Area or Service

According to the present study findings, the specific energy consumption of the commercial medical store in Nepal is given below. Figures derived are based on the energy audit carried out in three medical stores of Nepal.

Table 3.9: Specific Energy Consumption in Medical Stores

Specific Energy Consumption	
	Electrical (kWh/M^2)
WECS 2019/20	89.86

3.5.3 Significant energy used area and equipment in medical stores

The following area and equipment consume significant amount of energy:

- HVAC system
- Lighting
- Diesel Generator
- Deep Fridger and Fridge

3.5.4 Sampling and Measurement for energy audit

The following electrical parameters are needed to be measured for electrical energy audit in medical stores:

Data Logging: 24 hours of data logging at main electrical pannel with the help of Three Phase Data Logger. It shows power factor, total load in kW & kVA, peak demand, voltage, current, harmonics.

Load Measurement: Load measurement in all individual induction motors with the help of handheld power analyzer. It shows kW, kVA, ampere and power factor.

Lighting Load Measurement: Load measurement at main lighting pannel with the help of handheld power analyzer.

Lighting details: Collection of lighting types with wattages, running hours and installed location.

Pumping Load Measurement: Measure power consumption and head discharge for performance evaluation.

Diesel Generator: Calculate kilowatt hour generation in per litre of fuel.

HVAC: Measure inlet & outlet temperature, flow rate, area and electrical load for COP and performance evaluation.

3.5.5 Potential Energy Conservation Opportunity in Medical Stores

The following energy conservation opportunities can be found in medical stores:

Table 3.10: Energy Focus Area in Medical Stores

S.N.	Energy Conservation Opportunities	Types of investment
1	Make sure to clean refrigeration, deep fridge and lighting fixtures on the regular basis	No Cost
2	Use of optimum capapcity of freezer	
3	Turning off refrigerators while not in use for long time	
4	Power Factor Improvement by installing capacitor bank	Low Cost
5	Replace conventional lamp with LED	
6	Replace the old refrigerator with star rated refrigerator	Cost Demanding

3.5.6 Some General Energy Saving Opportunities

- Make air exchange provision in refrigerator room.
- Establish routine maintenance procedure of all appliances.
- Conduct internal energy audit regularly.
- Implement Energy Management System ISO 50001.

CHAPTER 4: ENERGY CONSERVATION OPPORTUNITIES IN COMMERCIAL SECTORS

4.1 Electrical Load and Demand Management

In Nepal, electricity billing adopted for commercial sectors has two parts where a consumer pays for two components:

- For the maximum demand (kVA) recorded during the billing duration; and
- For the energy (kWh) consumed during the billing duration.

Maximum demand charge is related to the fixed cost of capacity blocked for serving a consumer's needs. A tri-vector meter installed at the consumer's end records the maximum demand registered by a consumer during billing duration, apart from other important consumption features such as active power (kW), reactive power (kVAR), apparent power (VA) and power factor (PF).

Typical billing pattern by NEA for commercial sectors having 11 kV electricity supply is given below. Tariff scheme for sectors/units with different voltage system is not identical and has to be verified from company's utility. Tariffs are generally subjected to variation over a period of time.

Table 4.1: Electricity tariff (NEA) applicable to commercial sectors reference year 075/76

Period	Price in NPR per kWh
Peak time (5 PM to 11 PM)-T1	12.9
Off peak time (11 PM to 5 AM)-T3	
Other time (5 AM to 5 PM)-T2	
Demand charges per kVA: NPR. 350.00	

Electrical load management is the process of scheduling load usage so as to reduce electricity use during peak load periods. This measure will help in reducing electrical energy cost as the tariff during normal and off peak hours is lower than in peak hours.

Demand management commonly refers to a set of measures taken to reduce the maximum demand of a system without affecting the plant output.

The conventional methods used to achieve this purpose are:

- Staggering of working of sub-plants.
- Shedding (arbitrary) of loads.
- Make use of alternative source of electrical energy, providing cogeneration/captive generating units.
- Storage of products such as water at higher level, components for assembly, fluids at higher/lower temperature etc.,
- Power factor improvement.

Automatic demand controllers could be used to switch off low priority loads to reduce maximum demand.

4.2 Power Factor Management

The power factor (Pf) is the ratio of working power to apparent power. When current lags the voltage like in inductive loads, it is known as lagging power factor and when current leads the voltage like in capacitive loads, it is known as leading power factor.

Power Factor = [Working Power (kW) /Apparent Power (kVA)] = Cos ϕ

PF = [kW/kVA] = Cos ϕ

Where,

If power factor is maintained at close to unity, power drawn by the load is reduced eventually reducing the maximum demand. It also reduces electrical losses resulting from reduced reactive current drawn by the load. This helps in enhancing the system capacity.

Installing and maintaining properly sized capacitors help reduce the reactive power of inductive loads and also improve power factors at the user end. Benefits of improved voltage are also achieved due to this measure.

Advantages of PF improvement by capacitor addition:

- Reactive component of the network is reduced and hence also the total current in the system from the source end.
- I^2R power losses are reduced in the system because of reduction in current.
- Voltage level at the load end is increased.
- A high power factor can help in utilizing the full capacity of your electrical system.

4.3 Improvement of Operational Performance of Electric Motor

Operational performance of electric motor can be achieved in following ways:

4.3.1 Motor System Maintenance

It is vital to ensure that equipment driven by electric motors is kept clean, lubricated and correctly aligned, paying particular attention to drive couplings and gear or belt systems where small changes in shaft alignment can result in excessive wear and energy loss, vibration and premature failure.

Motors should also be maintained regularly including cleaning of ventilation grills and fans to ensure that they do not overheat. As the temperature of the motor conductors rise, the resistance increases and the electrical heating losses increase, leading to a lower efficiency and shorter equipment life.

4.3.1.1 Maintain supply voltage close to rated specification

Efficiency of an electric motor reduces by approximately 2 to 4 points when operating at less than 95 % of design voltage and the service temperatures increase up to 20 ºF greatly reducing life of insulation. Running a motor above its design voltage also reduces power factor and efficiency. Similarly running a motor with unbalanced supply voltage also reduces motor performance.

4.3.1.2 Minimize Rewinding Losses

During a motor failure, or in the stripping of the winding from the stator core prior to rewinding, heating involved causes exposure to high temperatures. These temperatures can, in many cases, affect the electrical characteristics of the stator core steel and result in increased iron losses and lower motor efficiency. Rewinding can thus reduce motor efficiency and reliability. It is always advisable to keep record of no load electrical parameters of any given motor when purchased to compare it later when rewinding or over hauling is done.

4.3.1.3 Optimize transmission efficiency by use of efficient belts and gears

Power transmission equipment plays a crucial role in energy consumption by the electric motor. Motor power transmission equipment, including shafts, belts, chains, and gears, should be properly installed and maintained. Use of flat belts in place of V-belts improves transmission efficiency.

4.3.1.4 Optimize motor loading

Under loading results in lower efficiency and lower power factor, higher first cost for the motor and related control equipment and installation cost. Under loading also results from selecting a large motor for an application requiring high starting torque would have been suitable. Large motors inherent have higher rated efficiencies than smaller motors. Therefore, the replacement of motors operating at 60-70% of capacity or higher is generally not recommended.

For motors, which normally operate at loads below 40-45% of rated capacity, an inexpensive and effective measure might be to employ delta/star switches. A change from the standard delta operation to star operation involves input. Operating in the star mode leads to voltage reduction of √3 per phase. Motor output falls to one-third of the value in delta mode, but performance characteristics as a function of load remain unchanged. Thus, full load operation in star mode gives higher efficiency and power factor than partial load operation in the delta mode. However, motor operation in the star mode is possible only for applications where torque to speed requirement also reduces with reduced load.

4.3.1.5 Speed control of induction motors

An induction motor is an asynchronous motor the speed of which can be varied by changing the supply frequency. The speed can be varied by other means such as varying the input voltage, varying the resistance of the rotor circuit, using multi-speed windings, using mechanical means such as gears and pulleys, eddy current or fluid couplings, or by using rotary or static voltage and frequency converters. A number of factors such as investment cost, load cycle, range of speed control required, maintenance, reliability and any special control requirements will have to be considered before adopting any particular control strategy.

The characteristics of the load are particularly important. Load refers to the torque output and corresponding speed required and can be broadly classified as constant torque, variable torque or constant power. Constant torque loads are those for which the output power requirement may vary with the speed of operation but the torque does not vary as in conveyers, rotary kilns and constant displacement pumps. Variable torque loads are those for which the torque required varies with the speed of operation as in centrifugal pumps and fans. Constant power loads are those for which the torque requirements typically change inversely with speed. Machine tools are typical examples of constant power load.

Variable torque applications account for the largest potential for electricity savings with variable speed drives.

4.4 Improvement of lighting performance

Energy saving in lighting system could be attained by following means:

- Use of appropriate lighting controls
- Optimum usage of day light
- Installation of "exclusive" transformer or lighting voltage controller

- Installation of high frequency (HF) electronic ballasts in place of conventional ballasts
- Replace T-12 FTLS by T-8/T-5 FTLS
- Installation of energy efficient LED lamps in place of “Conventional” lamps

4.5 Opportunities in Compressed Air System

Compressed air is among the most expensive forms of energy available in a plant because of its poor efficiency. Typically, only 10 to 20 percent of the electric energy input reaches the point of end-use. The remaining input energy converts to wasted heat or is lost through leakage. Because of this, if compressed air is used, it should be constantly monitored and weighed against alternatives.

Despite the fact that compressors are essential for a plant operation, they are often ignored until something goes wrong with them, or the compressors fail to keep up with the rising air demand. Inadequate maintenance can lower compression efficiency and increase air leakage or pressure variability as well as lead to increased operating temperatures, poor moisture control and excessive contamination. Improved maintenance will reduce these problems and save energy. The detail of compressor performance calculations is in Annex 8. Energy saving in compressed air system could be attained by following means:

4.5.1 Cool air intake

Every 4°C rise in inlet air temperature results in a higher energy consumption by 1% to compress same volume of air in identical condition. This indicates that cooler the intake air, better the compression efficiency.

4.5.2 Dust free air intake

A compressor should have an intake air filter installed, or the air used should come from a clean, cool location, to minimize maintenance of the compressor. Air filters should have high dust separation capacity, low pressure drops and robust design to avoid frequent cleaning and replacement. As a thumb rule "for every 250 mm WC pressure drop increase across at the suction path due to choked filters, etc., the compressor power consumption increases by about 2 percent for the same output".

4.5.3 Dry air intake

Dryer the intake air, better the compression efficiency. Moisture in the intake air will deteriorate the performance of the compressor parts such as valves and piston rings and deteriorate energy performance of the compressor.

4.5.4 Reducing delivery pressure

Power consumed by a compressor is in direct relation to the operating pressure and rated capacity. Higher the operating pressure, higher the energy required to compress same volume of air. At the same time, higher mechanical load on the moving parts also leads to excessive wear, leading to further energy wastage. Reduction in the delivery pressure by 1 bar in a compressor would reduce the power consumption by 6 to 10%.

4.5.5 Avoiding Misuse of Compressed Air

Use of compressed air for body cleaning, liquid agitation, floor cleaning, drying, equipment cooling and other similar uses must be discouraged. Wherever possible, low pressure air from a blower should be substituted for compressed air, for example secondary air for combustion.

4.5.6 Avoid Air Leaks

In any facility that uses compressed air, leakage is the most common cause of the energy wastage. Leakage of compressed air to the extent of 40% and above is found to be very common. Leaks frequently occur at air receivers, relief valves, pipes and hose joints, shut off valves, quick release couplings, tools and equipment. In most cases, they are due to poor maintenance and sometimes, improper installation in underground lines.

4.5.7 Heat recovery

As much as 80–93 percent of the electrical energy used by an air compressor is converted into heat. In many cases, a properly designed heat recovery unit can recover anywhere from 50–90 per cent of this available thermal energy and put it to use heating air or water.

Typical uses for recovered heat include space heating, process heating, water heating, make up air heating and boiler make up water preheating. However, recoverable heat from a compressed air system is not normally hot enough to be used to produce steam directly.

4.6 Opportunities in Boiler and Steam System

Performance of the boiler, such as efficiency and evaporation ratio reduce with time, due to poor combustion, heat transfer fouling and poor operation and maintenance. Deterioration of fuel quality and water quality also leads to poor performance of boiler. Efficiency testing helps to find out how far the boiler efficiency drifts away from the best efficiency. Any observed abnormal deviations could therefore be investigated to pinpoint the problem area for necessary corrective action. Hence it is necessary to find out the current level of efficiency for performance evaluation, which is a prerequisite for energy conservation action in a sector.

In general, there are two standard methods of measuring efficiency, as given below:

1) **Direct Method:** Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel
2) **Indirect Method:** Where the efficiency is the difference between the losses and the energy input

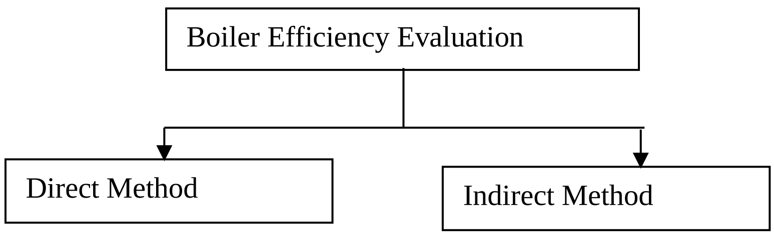

Figure 4.1: Boiler Efficiency Calculation Methods

Note:

1. The details of Direct and Indirect methods for Boiler Efficiency calculations is presented in Annex 6 (a) and (b).
2. Data collection format for Boiler Performance Assessment is in Annex 6 (d).

3. The schematic diagram of boiler and boiler house is in Annex 6 (f).
4. The detail calculation sheet for surface heat loss calculation is in Annex 7.

4.7 Benefits of FD and ID fan in boiler

a. FD (Forced Draft) Fan

- FD fan provides the required quantity of hot air to the furnace for smooth and uniform combustion of fuel and it also provides the secondary air which is the main air supply for fuel combustion.
- FD fan produces positive pressure inside the system i.e., furnace.
- FD fan pressurizes boiler so, it is started only after the ID fan is started.

b. ID (Induced Draft) Fan

- ID fan handles the flue gases i.e., hot air.
- ID fan takes the hot flue gases from furnace via dust collector or electrostatic precipitator and deliver it to chimney or stack.
- ID fan produces the negative pressure (pressure lower than the atmospheric pressure) in the system i.e., furnace to remove the flue gases from furnace.

4.8 Refrigeration and air-conditioning system

Refrigeration is the process of cooling a space, substance, or system to lower and/or maintain its temperature below the ambient one (while the removed heat is rejected at a higher temperature). Heat is removed from a low-temperature reservoir and transferred to a high-temperature reservoir. In other words, refrigeration means artificial (human-made) cooling.

Air Conditioning may be regarded as refrigeration in which control of temperature, humidity and quality of air in a building to a set of chosen or preferred conditions is achieved. To achieve this, systems need to transfer heat and moisture into and out of the air and control the level of air pollutants, either by directly removing it or by diluting it to acceptable levels.

In both cases, the work of heat transfer is traditionally driven by mechanical means, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including, but not limited to household refrigerators, commercial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to air conditioning units. The detail of HVAC performance calculations is in annex 9 and the detail of cooling tower calculations is in annex 12. Refrigeration and AC may be broadly classified into two types, as given below:

4.8.1 Vapour Compression type

In natural condition, heat flows from a hotter to a colder body. But in refrigeration system the opposite occurs i.e., heat flows from a cold to a hotter body. A substance called a refrigerant, which absorbs heat and boils or evaporates at a low pressure to form a gas is used in refrigeration system.

The functioning of a refrigeration cycle is illustrated below and can be broken down into the following stages (BEE, 2010):

1 – 2: Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 – 3: The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy put into the compression process is transferred to the refrigerant.

3 – 4: The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) de-superheats the gas before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4) so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 – 1: The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator.

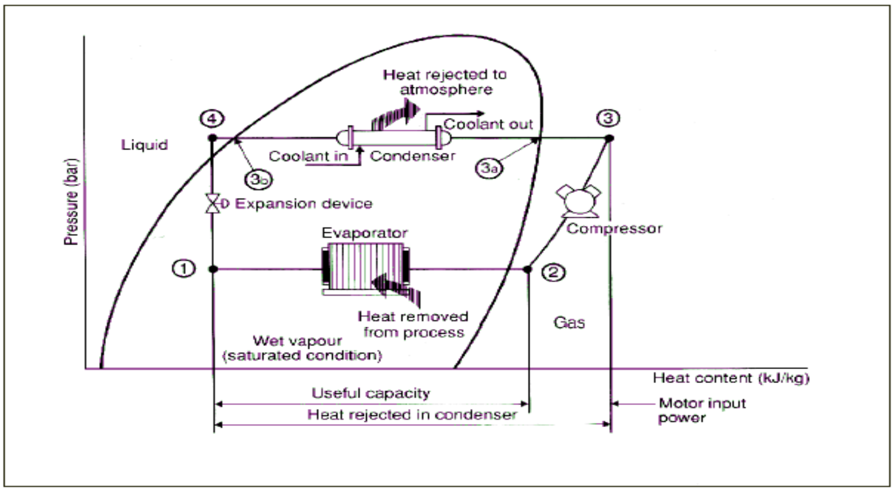

Figure 4.2: Schematic diagram of a Basic Vapour Compression Refrigeration System

Source: Energy Efficiency in Electrical Utilities, BEE.

The condenser has to be capable of rejecting the combined heat inputs of the evaporator and the compressor. There is no heat loss or gain through the expansion device.

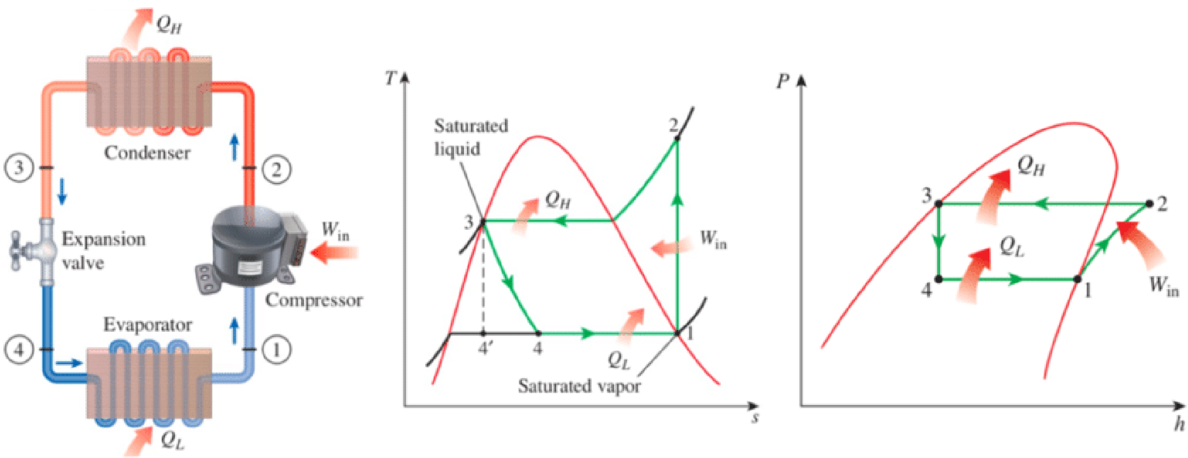

Figure 4.3: T-s and P-h diagram of refrigeration cycle

Source: Energy Efficiency in Electrical Utilities, BEE.

4.8.2 Vapour Absorption Type

In absorption type refrigeration, cooling is realized by using heat such as steam, hot water, gas, oil, etc. Cooling is produced by the principle that liquid (refrigerant), which evaporates at low temperature, absorbs heat from its surroundings when it evaporates. Pure water is used as refrigerant and lithium bromide solution is used as absorbent. Heat for the vapor absorption refrigeration system can be provided by waste heat extracted from process, diesel generator sets, etc. Absorption systems require electricity only to run the pumps. Depending on the temperature required and the power cost, it may even be economical to generate heat or steam to operate the absorption system (APO 2010). Schematic of vapor absorption refrigeration is shown in the figure below:

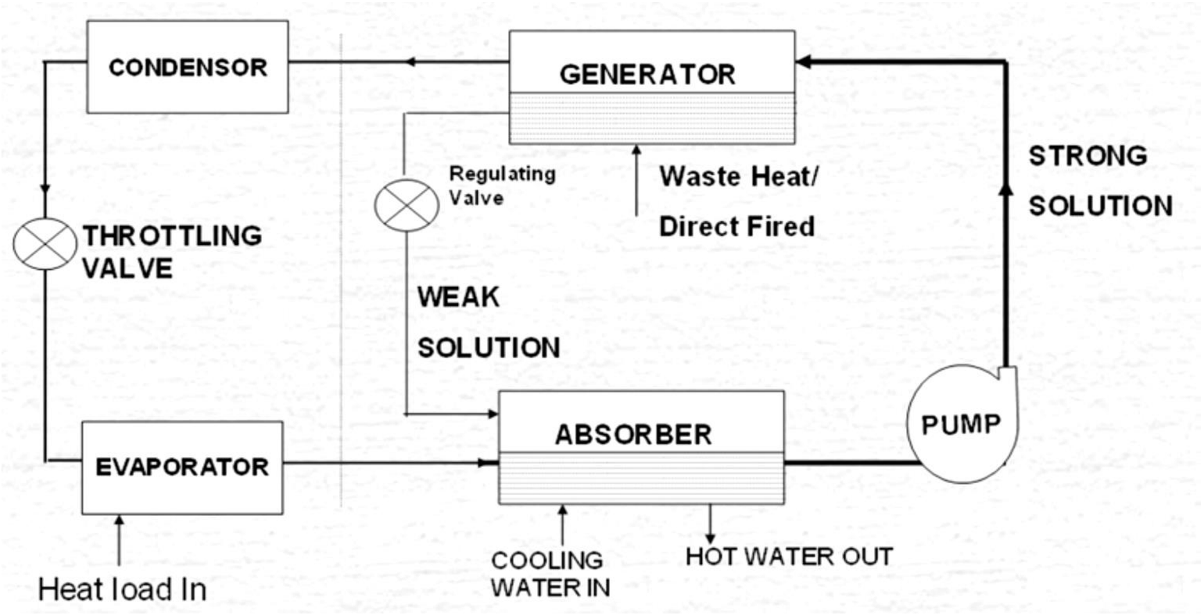

Figure 4.4: Schematic of a Basic Vapour Absorption Refrigeration System

Source: Training Manual on Energy Efficiency for Small and Medium Enterprises, APO.

Energy saving measures:

a. Proper sizing of process heat exchangers and evaporators

Proper sizing of heat transfer areas of process heat exchangers and evaporators as well as optimization of the temperature requirement is essential for minimizing load on refrigerator & AC system. A 1°C raise in evaporator temperature can help save almost 3% on power consumption.

b. Maintenance of heat exchangers

Keeping the heat exchanger surfaces clean is very important to maintain energy consumption within the design limits. If the condensers are fouled, compressor has to work harder to attain the desired capacity as the condensing temperature is increased. In the same way, fouled evaporators will also result in increased power consumption.

c. Multi-Level Refrigeration

Temperature range and level of refrigeration required is one of the important decisive factors in selection of refrigeration system. In applications where required temperature range is very wide, using multi-level refrigeration system is more economical. Many commercial entities use a bank of compressors at a central location to meet the load.

d. Chilled Water Storage

In applications where a small variation in temperature is acceptable, it is economical to provide a chilled water storage facility with good cold insulation. The storage facility can be fully filled to meet the process requirements so that chillers need not be operated continuously. This system has the added advantage of allowing the chillers to be operated at periods of low electricity demand to reduce peak demand charges - Low tariffs offered by some electric utilities for operation at night time can also be taken advantage of by using a storage facility. An added benefit is that lower ambient temperature at night lowers condenser temperature and thereby increases the efficiency.

e. Insulation

Add insulation to reduce heat flow through the cold surfaces. Use of economic insulation thickness on cold lines, heat exchangers, considering cost of heat gains is cost effective measure to realize energy savings. It is applicable especially in large chemical/fertilizer/process industry. Adoption of roof coatings/cooling systems/false ceilings as applicable, to minimize refrigeration load can also be considered.

f. Use of variable Speed drives

Constant-speed reciprocating compressors match capacity to load through loading and unloading the cylinders. This however is not the efficient way to modulate chiller capacity. In a given range, variable speed drives offer significant energy savings.

g. Reduce or optimize cooling loads

The importance of optimization of cooling loads on the running costs of refrigeration plant cannot be stressed too much. If the cooling load is higher than necessary, then more cooling is needed. This will eventually increase energy consumption and the operating costs become higher.

h. General measures

- Use of cooling towers with FRP impellers and film fills, PVC drift eliminators, etc.
- Adoption of energy efficient heat recovery devices such as air to air heat exchangers to pre-cool the fresh air by indirect heat exchange; control of relative humidity through indirect heat exchange rather than use of duct heaters after chilling.
- Adoption of variable air volume systems; adoption of sun film application for heat reflection; optimizing lighting loads in the air conditioned areas; optimizing number of air changes in the air conditioned areas are few other examples.
- Condenser water using open cooling sources such as atmospheric cooling towers, require water treatment to prevent fouling. Erosive conditions—for example, sand flowing through the tubes at high velocity—may pit tubes, decreasing tube effectiveness. Untreated water can damage tubes, piping, and other materials.
- The amount of cooling that any chiller can provide depends on how much refrigerant it moves through the compressor per unit time. It’s important to maintain the proper level of refrigerant. Leaks, as well as air and moisture, decrease efficiency and system

reliability. Low refrigerant charge, usually resulting from leaks, causes the compressor to work harder and achieve less cooling.

- Ensure regular maintenance of all A/C plant components as per manufacturer guideline.
- Ensure adequate quantity of chilled water and cooling water flows, avoid bypass flows by closing valves of idle equipment.
- Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying process load.
- Make efforts to continuously optimize condenser and evaporator parameters for minimizing specific energy consumption and maximizing capacity.

4.9 Opportunities in Fans and Blowers

A fan is a mechanical device for moving air or other gases. It uses the kinetic energy of the impellers to increase the pressure of the air/gas stream which in turn moves them against the resistance caused by ducts, dampers and other components in a system. The detail of fan performance calculations is in Annex 11.

4.9.1 Difference between fans, blowers and compressors

Fans, blowers, and compressors are differentiated by the method they use to move the air, and by the system pressure they must operate against (BEE 2010). American Society of Mechanical Engineers (ASME) distinguishes between fans, blowers, and compressors on the basis of specific ratio. The ratio of the discharge pressure over the suction pressure is called specific ratio. Accordingly, fans offer a pressure rise up to 1136 mmWg, blowers offer from 1136 to 2066 mmWg, and compressors offer pressure rises even higher than blowers. Difference is shown in the table below.

Table 4.2: Difference between Fans and Blowers

Equipment	Specific Ratio	Pressure Rise (mmWg)
Fans	Up to 1.11	1136
Blowers	1.11 to 1.20	1136-2066
Compressors	More than 1.20	More than 2066

Energy Savings measures

- Minimizing working pressure
- Optimization of air volume and reduction of air leaks
- Use of FRP Fans in Cooling Towers/Humidification Plants
- Proper fan/blower sizing
- Use of Variable Frequency Drives (VFDs) to match flow
- Use of High efficiency belts (cogged belts)
- Minimizing System resistance

4.10 Opportunities in Pumping System

Studies indicate that the average pumping efficiency in manufacturing plants can be less than 40%, with 10% of pumps operating below 10% efficiency. Oversized pumps and the use of throttled valves are identified as the two major contributors to the loss of efficiency. Energy savings between 30% and 50% in pumping systems could be realized through equipment or control system changes. The detail of pump performance calculations is in Annex 10. Some of the potential causes of inefficiency and measures for improvement are as follows.

Table 4.3: Potential causes of inefficiency and measures for improvement in Pumping System

Causes of Inefficiency	Improvement measures
Unnecessary demand on pumping system	Reduce demand on system
Oversized pumps	Select pump that operates near to BEP Change impeller Trim impeller Fit multiple-speed pump Use multiple-pump arrangements Fit lower speed pump/motor
Pump wear	Pump maintenance
Less efficient impeller	Change impeller
Inefficient pump throttling controls	As for oversized pumps Fit adjustable or variable-speed drive
Inefficient pump	Change pump
Inefficient piping configuration	Change piping inefficiencies
Oversized motor	Change motor
Inefficient motor	Change to high-efficiency motor

4.11 Opportunities in process and Heat Recovery

a. Blow down steam recovery

Boiler blow down is important for maintaining proper steam system water properties. However, blow down can result in significant thermal loss if the steam is not recovered for beneficial use. Blow down steam is typically low grade, but can be used for space heating and feed water preheating. In addition to energy savings, blow down steam recovery may reduce the potential for corrosion damage in steam system piping.

b. Pre-heating of Boiler Feed Water

Where feasible, adoption of feed water heating, using economizer from flue gases with economizer application, gives the highest fuel economy, as one can pre-heat feed water almost up to the saturation temperature of steam. The economizer is a pressure vessel. A lower order and cheaper alternative for achieving fuel economy through flue gas waste heat recovery would be a non-pressurized feed water heater, which allows feed water pre-heating up to a maximum of 100ºC only. Every rise of 6ºC in boiler feed water temperature through waste heat recovery would offer about 1% fuel savings.

c. Pre-heating of Combustion Air

Combustion air preheating is an alternative to feed water heating, and can be adopted, if no further scope for feed water pre-heating exists and where stack gases still have waste heat potential left to be tapped. Shell and tube type and rotary regenerative type air pre-heaters and regenerative burners are some of the options that can be adopted for waste heat recovery.

For every reduction in flue gas temperature by 22ºC for heat recovery, fuel savings of about 1% can be achieved. The combustion air pre-heat temperature limiting value is decided.

CHAPTER 5: PREPARING ENERGY AUDIT REPORT

Report preparation is one of the most important steps of the audit. The audit report should be prepared keeping in mind the various stakeholders who will be using the report. The final written report should include data, data analysis, recommendations, energy savings, cost savings; cost of implementation and simple payback period for recommended energy conservation measures and systems improvements.

Some key issues that should be kept in mind while writing an audit report are:

- The audit report should be written in a way that provides suitable information to the potential readers of the report which could be the CEO, plant manager, or the supervisor of engineering or maintenance department, and the plant shift supervisor.
- The audit report should be concise and precise and use direct language that is easy to understand.
- More graphs should be used rather than tables for the presentation of data, results and trends.
- The recommendation section should be specific, clear and with adequate details.
- Assumptions made in the analysis should be explained clearly. How changes in the key assumptions can influence the results should also be explained. A sensitivity analysis is a very helpful tool for this.
- The auditors should do their best to avoid mistakes and errors in the report especially in the results. Even a few errors could damage the credibility of the audit.
- The energy audit report should be consistent in structure and terminology used.
- Calculations made in the analysis work may be explained for better understanding.

Based on experiences from the present study and review of different EA reports produced by different organizations of repute, a standardized flow of an EA report with illustrative examples is in Annex-2. In order to enable industry or the facility to implement the recommended options, it is imperative to know the source of technology and equipment. Therefore, providing vendor/suppliers' list for such technology & equipment will help in procurement.

5.1. Cost Benefit Analysis

In order to enable the top management to make investment decisions, it is important to do financial analysis of identified options. The analysis should be based on:

- energy savings over a period
- financial savings against the achieved energy savings and other improvements such as services, environmental and reduced maintenance;
- necessary investments

As far as possible, opportunities should be assessed over the planned or expected operating lifetime. There are several methods to carry out cost benefit analysis such as Simple Payback Period, Net Present Value (NPV) or Cash Flow Method and Return On Investment (ROI) and Internal Rate of Return (IRR) method. Simple Payback Method is the simplest method which is used very often. It is calculated as:

Simple Payback Period = Total Investment/ Net Annual Savings

Summary of various findings with recommendations and cost benefit analysis should also be presented in the following section.

Table 5.1: Energy Efficiency Options and Payback

SN	Energy Efficiency Option	Annual Savings				Investment (NRs)	Pay Back Period (Months)
		Demand in kVA	Energy in kWh	Fuel Savings in Litres	Value of Savings (NRs)		
1							
2							
Total							

Table 5.2: Types and priority of energy saving measures

S N	Energy Efficiency Option	Types and priority of energy saving measures		
		Annual Electricity/Fuel Saving (kWh/MT)	Annual Savings in NRs.	Priority
1	**No Investment (Immediate)** Optional Improvement House Keeping			
2	**Low Investment** Controls Equipment modification Process change			
3	**High Investment** Energy efficient Devices Product modification Technology change			

Note:
No cost Measures: No any investment needed, mostly measures related to housekeeping and process control.

Low Cost Measures: Investment up to 500,000 and payback period within year.

High Cost Measures: Investment more than 500,000 and payback period is less than 3 years

ANNEXES

Annex 1: Conversion Factors

Units	Kcal (000)	GJ	TCE	TOE
Kilo Calorie	1.0000	0.0041868	0.0001429	0.0000972
GJ	238.8459	1.0000000	0.0341208	0.0234622
TCE	7000.00	29.3076000	1.0000000	0.0687622
TOE	10290.00	42.6217000	1.4542880	1.0000000

Fuel type	Unit	Kcal (000)	GJ	TCE	TOE	Other	
Traditional Fuel							
Fuel wood	tonne	4000	16.75	0.57	0.39	1.43	m3
	m3	2800	11.72	0.4	0.27	0.7	tonne
Charcoal	tonne	7100	29.73	1.01	0.69	2.86	m3
	m3	2485	10.4	0.36	0.24	0.35	tonne
Commercial Fuel	**Unit**	**kCal (000)**	**GJ**	**TCE**	**TOE**	**Others**	
Coal	tonne	6000	25.12	0.86	0.58		
LPG	KL		30.08			0.611	Tonne
	Tonne	11760	49.24	1.68	1.14	1.637	KL
HSD	KL	9060	37.93	1.29	0.88	0.83	Tonne
	Tonne	10960	45.89	1.57	1.07	1.21	KL
LDO	KL	9350	39.15	1.34	0.91	0.85	Tonne
	Tonne	10960	45.89	1.57	1.07	1.17	KL
FO	KL	9860	41.28	1.41	0.96	0.93	Tonne
	Tonne	10560	44.21	1.51	1.03	1.07	KL
Electricity	MWh	860	3.6	0.12	0.08	5.78	GHh from oil

Source: Energy Synopsis Report WECS, 2010

Annex 2: Energy Audit Report format for Commercial Sectors

A. Title Sheet of the report to indicate:

- Report Title
- Nature of audit namely: Detailed energy audit of electrical systems and energy use.
- Name of the sector/audited entity
- Name of the auditing entity
- Duration of audit
- Sponsors, stakeholders as applicable

B. Acknowledgements:

The acknowledgements page may acknowledge contributions of key stakeholders associated in audit activity from client side as well as sponsors, signed by team leader of audit with date.

C. Study Team:

On this page, the list of study team members with designations may be presented, for future follow up references.

D. Table of Contents, List of Table, List of Figures, Abbreviations, Nomenclature used in report:

In this page, the report may list the table of content, list of figures, list of tables, abbreviations and nomenclature used in report for ease of understanding purposes.

E. List of instruments used:

In this page, the list of instruments used in energy audit is needed to be mentioned.

F. Executive summary:

In this section, the report may present the synopsis of study findings, which would at-least, include:

- Baseline details of the audited entity.
- EE Option summary listing in a table, covering all EE opportunities identified in electrical areas the option wise identified annual energy savings potential, Rupee saving potential per annum, investment needs and simple payback period.
- Prioritized options listing as short term (less than one year simple payback period); medium term (one to three year simple payback period); long term (over three year simple payback period)

Chapter 1: Introduction

1.1 Background of the study

1.2 Scope of energy audit

The scope of the energy audit includes:

- Total connected load in kW and list (break up) of major electric drives/loads in the facility, Latest (20xx-yy) year's month wise baseline data of production, capacity utilization, NEA electricity consumption, DG based generation, Cogeneration and RE based generation (if and as applicable), incurred source wise and weighted average cost of electricity and overall specific electricity consumption, with comments on variations, normative values.

The following are the opportunities to improve energy efficiency with cost savings:

- Energy efficiency improvements opportunities with cost benefits in the areas of
- Power Factor improvement
- Load Management (Maximum demand optimization)
- DG set performance improvements
- Cogeneration application potential if any
- RE application (Solar PV) potential if any.
- Boiler & Stem System audit if any
- Waste heat recovery
- HVAC
- House-keeping, etc.

1.3 About the unit

(Coverage may present location, year of establishment, facilities, capacity, current capacity, shifts/day and days/year normal operation, electrical and thermal energy consumption and cost per annum).

Chapter 2: Plant Energy Systems

2.1 Electrical Energy Use features

Coverage to present plant/facility features relating to electrical energy and load management practices, grid, diesel generation, cogeneration cost, power factor, time of use tariffs, maximum demand trends, specific electrical energy consumption, major equipment (such as drives, refrigeration, pumping, compressors,) consuming power, breakup and factors affecting consumption.

2.2 Thermal Energy Use features

Coverage to present facility features relating to thermal energy use, specific thermal energy consumption, layout, operational features and specifications of boiler.

Chapter 3: Strategic Energy Management Program

(May cover rationale of a strategic energy management program at the unit, voluntary policy statement desirable as a measure of management commitment to energy efficiency, desirable features of a MIS system and any desirable upgrades in plant automation as relevant)

Chapter 4: Energy Efficiency Opportunities

EA report to cover energy efficiency opportunities in electrical systems in this chapter in a clear manner, presenting for each opportunity the following aspects:

1. Title of measure (EE opportunity)
2. Present situation
3. Recommendation
4. Cost benefits:

- Approximate investment require to implement options

-Cost benefits present simple payback period of measure in months or years.

Plan of Action:

The following plan of action should be prepared and submitted in Energy Audit Report:

<table>
<tr><th rowspan="2">SN</th><th rowspan="2">EE Measures</th><th rowspan="2">Responsible Person</th><th colspan="2">Implementation Date</th><th rowspan="2">Time Bond</th><th rowspan="2">Remarks</th></tr>
<tr><th>Start</th><th>End</th></tr>
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</table>

Chapter 5: Exhibits: Vendor information as relevant

The menu of EE measures are very exhaustive and sector and application specific and broadly may include measures such as:

- Maximum demand optimization, load shifting for Time of Use tariff advantages.
- Power factor improvement, Automatic Power Factor Controls (APFC).
- Variable speed drive applications for energy efficient capacity control.
- EE in process utilities like pumps, fans, compressors, refrigeration and lighting.
- Renovation, modernization and process modifications/upgrades.
- Boiler & Steam System.
- Efficiency improvements in DG sets, electric furnaces, heaters, ovens and melting baths etc.
- Cogeneration adoption.
- Automation adoption such as temperature controls, occupancy sensors, building energy management system etc.
- Loading improvements for better capacity utilization.
- Housekeeping improvements to abate wastages and leakages in compressed air, pumps, fans, refrigeration.
- Heat Exchanger performance improvements such as condenser de-scaling.
- RE applications, wherever possible.

Chapter 6: Exhibits

Each energy audit report should include exhibits to support the report findings, as deemed necessary, for clarity, better understanding, and may include information such as:

- Line diagrams,
- Technical specifications
- Design data

- Detailed calculations such as heat balance
- Details of motor load survey, lighting survey, steam trap survey, insulation survey etc.
- Vendor information on product literature
- Generic tips, housekeeping measures, maintenance guidelines etc.

Exhibits also address any incentive schemes available from the Government, Ministries, NEA, or financial institutions or international institutions if any, that are prevalent and applicable, to enhance the viability of the EE proposals.

Annex 3: Equipment needed for Energy Audit

The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. The parameters generally monitored during energy audit may include the following:

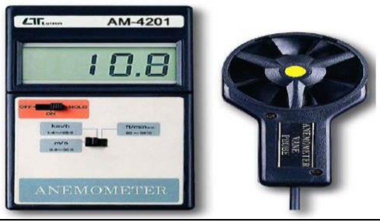
Basic Electrical Parameters in AC system: Voltage (V), Current (I), Power (kW), Apparent Power (demand) (kVA), Reactive Power, Energy Consumption (kWh), Frequency (Hz), Harmonics etc.

Basic Electrical Parameters in DC system: Voltage (V), Current (I), Power (kW), Energy Consumption (kWh) etc.

Parameters of importance other than electrical are: temperature & heat flow, radiation, air and gas flow, liquid flow, revolution per minute (RPM), air velocity, noise and vibration, dust concentration, total dissolved solid (TDS), pH, moisture content, relative humidity, flue gas analysis – carbon dioxide, oxygen, carbon monoxide, oxides of sulphur, oxides of nitrogen, combustion efficiency etc.

The following energy monitoring/measuring equipment is needed to conduct energy audit in commercial sectors:

SN	Equipment's	Equipment's Image	To Measure
1.	Electrical Power Analyzer (Three Phase)		Used to measure electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts, etc. In addition, some of these instruments also measure harmonics. It is used for recording the data.
2.	Electrical Power Clam Meter		Used to measure electrical parameters such as kVA, kW, PF and Ampere.
3.	Combustion Analyzer/ Gas analyzer/Fyrite kit		This device is used to analyze the composition of flue gas from boilers and hot water generators. It measures gases such as O_2, CO, CO_2 in the flue gas and calculates the combustion efficiency.
4.	Contact thermometer		Used to measure flue gas, hot air, hot water temperatures by insertion of probe into the stream.

SN	Equipment's	Equipment's Image	To Measure
			For surface temperature, a leaf type probe is used with the same instrument.
5.	Infrared Thermometer		Infrared thermometer when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.
6.	Anemometer		Used to measure air velocity to calculate air flow from a given area. Total flow is measured by multiplying air velocity and area cross-section.
7.	Ultrasonic flow meter		Used to measure the flow of liquid. It uses ultrasonic transducers that measure the average velocity along the path of an emitted beam of ultrasound based on which calculates volumetric flow.
8.	Digital Camera		To capture images.
9.	Thermal Image Camera		Measures the temperature at the surface of the objects. This device can detect overloaded section of the thermal system. It also locates the fault, leakages, damages part of thermal system.
10.	Lux Meter		Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, coverts to electrical impulses which are calibrated as lux.

SN	Equipment's	Equipment's Image	To Measure
11.	Humidity Meter		To measure the humidity, WET bulb and DRY bulb thermometer is used.
12.	Leak Detector		Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases, which are normally not possible to detect with human abilities.

Annex 4: Safety Consideration during energy audit

An energy audit requires working close to machineries and various utilities. Hence, safety considerations should be very important part for any energy audit team. The audit team should be thoroughly briefed on safety procedures, Personal Protective Equipment (PPE) and should never put themselves in a dangerous situation while conducting the audit. Auditors should be extremely careful making any measurement on electrical systems or high temperature devices such as boilers, heaters, etc. Electrical or asbestos gloves should be worn whenever necessary.

The auditors should also be very careful when examining any operating piece of equipment, especially those with open drive shafts, belts or gears, or any form of rotating machinery. The equipment operator or supervisor should be pre notified that the auditor is going to look at the equipment to prevent any risk associated with safety of the auditor. The auditor should never approach a piece of equipment and inspect it without the operator or supervisor being notified in advance. The audit team should avoid wearing loose clothes as they can be caught by nearby running machines, if any. A safety checklist should be prepared and carried with the audit team with followings:

For protection from Electricity and Heat

- Avoid working on live circuits if possible.
- Securely lock off circuits and switches before working on a piece of equipment.
- Implement Log Out Tag Out (LOTO).
- Always try to keep one hand in your pocket while taking measurements on live circuits to help prevent cardiac arrest.
- Vinyl nitrile gloves, electrical safety shoes should be worn while working in an electrical system.
- Leather gloves, mechanical safety shoes should be worn while working in an electrical system.
- Check temperature of any equipment using infra-red gun before approaching close to the equipment.

For protection of Respiratory System

- When necessary, wear a full face respirator mask with adequate filtration particle size.
- Use activated carbon cartridges in the mask when working around low concentrations of noxious gases. Change the cartridges on a regular basis.
- Use a self-contained breathing apparatus while working in a toxic environment.

For protection of Hearing System

- Use ear plugs or ear muffs while working around high noise areas.

Annex 5: Baseline Data Collection Format

Parameters	**Information**
Name of Commercial Sector	
Year of Establishment (A.D.):	
Scale: (Large/Medium/Small)	
Reference baseline year A.D.:	
Total Area (M^2)	
Location:	
Contact Person:	
Designation:	
Telephone Number:	
E-mail:	
Website:	
No of Employees:	
Presence of Energy Manager:	
Compliance with any National/International Standard (NS/ISO):	
Energy Aspects:	
A) Electrical Energy	
A1) From NEA Grid in kWh:	
Total Cost of Grid Electricity in NPR:	
Electricity Consumption kWh/M^2	
A2) From Generators:	
Types of Fuel used:	
Fuel Consumed in Liters:	
Total DG Capacity in KVA:	
Diesel Energy Generated in kWh:	
DG Electricity Consumption kWh/M^2	
% of Electrical Energy Generated from DG Set:	
Total Cost of DG Electricity in NPR:	
Total Electrical Energy Consumed (Grid+Captive) in kWh/year:	

Parameters	**Information**
Cost of Total Electrical Energy Consumed (Grid+Captive) in NPR:	
B) Thermal Energy	
B1) Types of Fuel used:	
Quantity of fuel consumed in Liter:	
Total cost of Fuel in NPR:	
B2) Types of Fuel used:	
Quantity of fuel consumed in Liter:	
Total cost of Fuel in NPR:	
Total Thermal Energy Consumption in MJ:	
Total Cost of Thermal Energy Consumed in NPR:	
Key Parameters:	
Annual Turnover in Million NPR:	
Capacity Utilization in %:	
Weighted Average Unit Cost of Electrical Energy in NPR:	
Specific Thermal Energy Consumption in MJ/ Area:	
Specific Electrical Energy Consumption in kWh/ Area:	
Total Annual Cost of Electrical + Thermal Energy in NPR:	

Note: For Five Star Hotel and Hospital Sectors specific energy consumption is presented as:

1. For Hotels: kWh/Room (Electrical) and MJ/Room (Thermal)
2. For Hospitals: kWh/Bed (Electrical) and MJ/ Bed (Thermal if available)

Annex 6: Boiler Efficiency calculation by direct and indirect methods

a. Direct Method

In this method of efficiency calculation, the ratio of total heat gained by the feed water in changing its state from water to steam of desired parameter is compared with the total heat contained in the fuel used. It is also known as 'input-output method' due to the fact that it only needs the useful output (steam) and the heat input (i.e., fuel) for evaluating the efficiency.

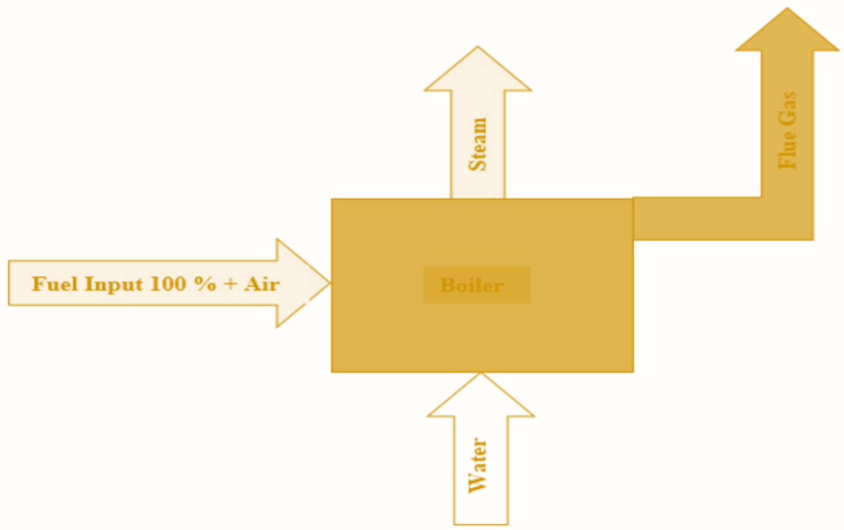


Figure I: Boiler Efficiency Calculations by Direct Method

This efficiency is calculated by given formula:

$$\text{Boiler Efficiency} = \frac{\text{Heat Output}}{\text{Heat Input}} \text{ x } 100$$

$$\text{Boiler Efficiency} = \frac{\text{Heat addition to Steam}}{\text{Gross Heat in Fuel}} \text{ x } 100$$

Boiler Efficiency =

$$\frac{\text{Steam Flow Rate x (Steam enthalpy)} - \text{Feed Water Flow Rate (Feed water enthalpy)}}{\text{Fuel Firing rate x Gross calorific value}} \text{ x } 100$$

$$\text{Boiler Efficiency} = \frac{Qs * hs - Qf * hf)}{q \text{ x } GCV} \text{ x } 100$$

Where,

Qs	=	Quantity of steam generated in kg/hr.
Qh	=	Quantity of feed water in kg/hr
q	=	Quantity of fuel used in kg/hr.
hs	=	Enthalpy of saturated steam in kcal/kg of steam.
hf	=	Enthalpy of feed water in kcal/kg of water.
GCV	=	Gross calorific value of the fuel in kcal/kg of fuel

Note: The working pressure should be in kg/cm^2 and superheat temperature and feed water temperature in ^{o}C.

For calculating evaporation ratio, following formula is used;

$$\text{Evaporation Ratio} = \frac{\text{Quantity of steam generation}}{\text{Quantity of fuel consumption}}$$

Advantages of direct method:

- Boiler efficiency can be evaluated quickly and does not involve a lengthy calculation
- Requires only a few parameters
- Requires a few instruments for monitoring

b) Indirect Method

This method is also known as heat loss method as the efficiency is calculated by subtracting the heat loss fractions from 100. It does not include blow down loss in the efficiency determination process. A detailed procedure for calculating boiler efficiency by indirect method is given below. However, it may be noted that current energy managers prefer simpler calculation procedures.

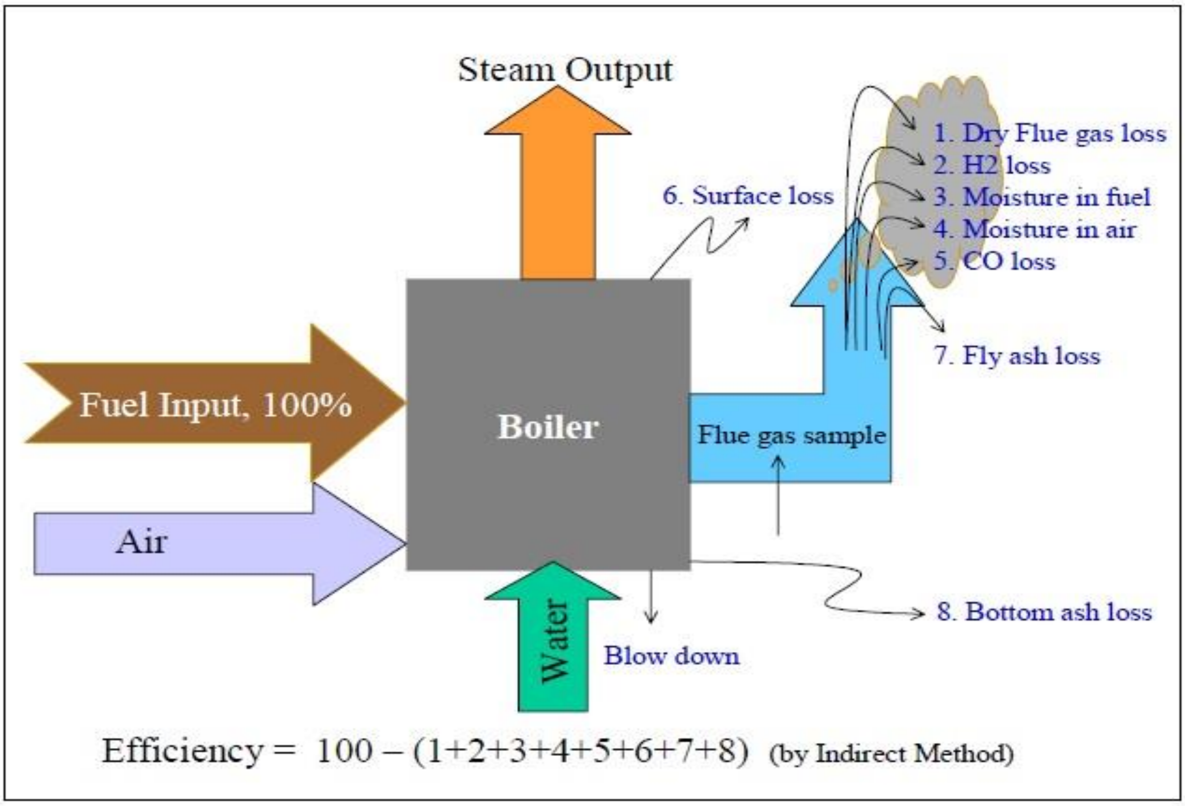


Figure II: Boiler Efficiency by Calculation Indirect Method

Following losses are applicable to liquid, gas and solid fuel fired boiler:

L1- Loss due to dry flue gas (sensible heat)

L2- Loss due to hydrogen in fuel (H_2)

L3- Loss due to moisture in fuel (H_2O)

L4- Loss due to moisture in air (H_2O)

L5- Loss due to carbon monoxide (CO)

L6- Loss due to surface radiation, convection and other unaccounted *

*Losses which are insignificant and are difficult to measure.

The following losses are applicable to solid fuel fired boiler in addition to above;

L7- Loss due to unburnt in fly ash (carbon)

L8- Loss due to unburnt in bottom ash (carbon)

Boiler Efficiency by Indirect Method = 100 – (L1+L2+L3+L4+L5+L6+L7+L8)

Calculation Procedure and Formula for calculating Boiler Efficiency by Indirect Method:

In order to calculate the boiler efficiency by indirect method, all the losses that occur in the boiler must be measured. These losses are conveniently related to the amount of fuel burnt.

A) Theoretical Air required for Combustion =

$$\frac{[(11.6 * C) + \{34.8 * (H2 - O2/8)\} + (4.35 * S)]}{100}$$

Where,

C = Percentage of Carbon present in the fuel.
H_2 = Percentage of Hydrogen present in the fuel.
O_2 = Percentage of Oxygen present in the fuel.
S = Percentage of Sulphur present in the fuel.

B) % Excess Air (EA) Supplied =

$$\frac{O2}{21 - O2} * 100$$

C) Actual mass of air (AAS) supplied/ kg of fuel =

$$1 + \frac{EA}{100} * \mathit{Theoretical\ Air}$$

1) Heat loss due to dry flue gas (L1) =

$$\frac{m * Cp * (Tf - Ta)}{GCV \text{ of fuel}} * 100$$

Where,

m	=	Mass of dry flue gas in kg/kg of fuel (CO_2+SO_2+ Nitrogen in fuel + Nitrogen in actual mass of air supplied + O_2 in flue gas) or m = AAS + 1 kg of fuel
Cp	=	Specific heat of flue gas in kCal/kg
Tf	=	Flue gas temperature in ^oC
Ta	=	Ambient air temperature in ^oC

2) Heat loss due to hydrogen in fuel (L2) =

$$\frac{9 * H_2\{584 + Cp\ (Tf - Ta)\}}{GCV \text{ of fuel}} * 100$$

Where,

H_2	=	Kg of hydrogen present in fuel on 1 kg basis
Cp	=	Specific heat of superheated steam in kCal/kg ^oC
Tf	=	Flue gas temperature in ^oC
Ta	=	Ambient air temperature in ^oC
584	=	Latent heat corresponding to partial pressure of water vapour

3) Heat loss due to moisture present in fuel (L3) =

$$\frac{M * \{584 + Cp(Tf - Ta)\}}{\text{GCV of fuel}} * 100$$

Where,

M	=	Kg of moisture in fuel in 1 kg basis
Cp	=	Specific heat of superheated steam in kCal/kg °C
Tf	=	Flue gas temperature in °C
Ta	=	Ambient air temperature in °C
584	=	Latent heat corresponding to partial pressure of water vapour

4) Heat loss due to moisture present in air (L4) =

$$\frac{\{AAS * \text{Humidity factor} * Cp\ (Tf - Ta)\}}{\text{GCV of fuel}} * 100$$

Where,

AAS	=	Actual mass of air supplied per kg of fuel
Humidity Factor	=	Kg of water/ kg of dry air
Cf	=	Specific heat of superheated steam in kCal/kg °C
Tf	=	Flue gas temperature in °C
Ta	=	Ambient air temperature in °C (dry bulb)

5) Heat loss due to incomplete combustion (L5) =

$$\frac{\%CO * C}{\%CO + CO_2} * \frac{5744}{\text{GCV of fuel}} * 100$$

Where,

CO	=	Volume of CO in flue gas leaving economizer (%)
CO_2	=	Actual volume of CO_2 in flue gas (%)
C	=	Carbon content kg/kg of fuel
5744	=	Heat loss due to partial combustion of carbon

6) Heat loss due to radiation and convection (L6) =

$0.548 * [(Ts / 55.55)^4 - (Ta / 55.55)^4] + 1.957 * (Ts – Ta)^{1.25} *$ sq. rt. of $[(196.85\ Vm + 68.9) / 68.9]$

Where,

Vm	=	Wind velocity in m/s
Ts	=	Surface temperature (K)
Ta	=	Ambient temperature (K)

7) Heat loss due to unburnt in fly ash % (L7) =

$$\frac{\text{Total ash collected}}{\text{kg of fuel burnt}} * \frac{\text{GCV of fly ash}}{\text{GCV of fuel}} * 100$$

8) Heat loss due to unburnt in bottom ash % (L8) =

$$\frac{\text{Total ash collected}}{\text{kg of fuel burnt}} * \frac{\text{GCV of bottom ash}}{\text{GCV of fuel}} * 100$$

9) Boiler Efficiency = 100 – Total Losses
= 100 - (L1+L2+L3+L4+L5+L6+L7+L8)

c) **For Humidity Factor:** The mass of vapour that air contains can be obtained from psychometric charts and typical values are included below:

Dry Bulb Temp ° C	**Wet Bulb Temp ° C**	**Relative Humidity %**	**Kilogram water per Kilogram dry air (Humidity Factor)**
20	20	100	0.016
20	14	50	0.008
30	22	50	0.014
40	30	50	0.024

d) **Data collection format for Boiler Performance Assessment**

S.N.	**Sheet 1- Technical specification of boiler**	
1	Boiler ID code and Make	
2	Year of Manufacture	
3	Boiler capacity rating	
4	Type of Boiler	
5	Type of fuel used in boiler	
6	Maximum fuel flow rate	
7	Fuel GCV	
8	Steam Generation Pressure	
9	Superheat Temperature	
10	Heat transfer area in sq.mt.	
11	Waste Heat Recovery System	
12	Type of draft	
13	Chimney Height (M)	
14	Fuel Consumption per hour	
15	Water Consumption per hour	

Sheet 2 – Fuel Analysis Details			
Fuel Fired GCV of fuel Specific gravity of fuel (Liquid) Bulk density of fuel (Solid)			
S.N.	**Proximate Analysis**	**Date of Test**	**Unit**
1	Fixed carbon		%
2	Volatile matter		%
3	Ash		%
4	Moisture		%
S.N.	**Ultimate Analysis**	**Date of Test**	**Unit**
1	Carbon		%
2	Hydrogen		%
3	Sulphur		%
4	Nitrogen		%
5	Ash		%
6	Moisture		%

7	Oxygen		%
S.N.	**Water Analysis**	**Date of Test**	**Unit**
1	Feed water TDS		PPM
2	Blow down TDS		PPM
3	pH of Feed Water		
4	pH of blow down		
S.N.	**Flue Gas Analysis**	**Date of Test**	**Unit**
1	CO_2		%
2	O_2		%
3	CO		%
4	Flue Gas Temperature		^oC

Typical instruments used for Boiler Performance Assessment

Instrument	Type	Measurements
Flue gas analyzer	Portable of Fixed	% CO_2, O_2, CO, Temperature (Flue and Air)
Temperature indicator	Thermocouple, Liquid in glass	Fuel temperature, flue gas, combustion air temperature, boiler surface temperature, steam temperature
Draft Gauge	Manometer, differential pressure	Amount of draft used or available
TDS meter	Conductivity	Boiler water, TDS, feed water TDS, make-up water TDS
Flow meter	As applicable	Steam flow, Water flow, Fuel flow, air flow

Sheet 3: Format sheet for boiler efficiency testing

Date: ………………………………… Boiler Name: …………………………

SN	Time	Ambient Air		Fuel		Feed Water		Steam			Flue Gas Analysis				Surface Temp. of Boiler, ^OC
		Dry bulb Temp. ^OC	Wet bulb Temp. ^OC	Flow rate kg/hr	Tem ^oC	Flow rate m^3/hr	Tem ^oC	Flow rate m^3/hr	Pressure kg/cm^2	Tem ^oC	O_2 %	CO_2 %	CO %	Tem ^oC	

………………… ……………….. ……………….
Boiler Operator Boiler In-Charge Boiler Auditor

e) Factors affecting Boiler Efficiency

- Controls to ensure proper combustion of fuel and optimum boiler efficiency
- Optimization of excess air level
- Pre-heating of boiler feed water
- Pre-heating of combustion air
- Reduction of scaling and soot losses
- Minimized radiation and convection losses
- Adoption of automatic blow down controls
- Optimization of steam pressure
- Variable speed control for fans, blowers, and pumps
- Steam line insulation
- Appropriate trap selection and trap testing
- Condensate recovery
- Avoiding/Arresting steam leakage

f) Schematic diagram of boiler system.

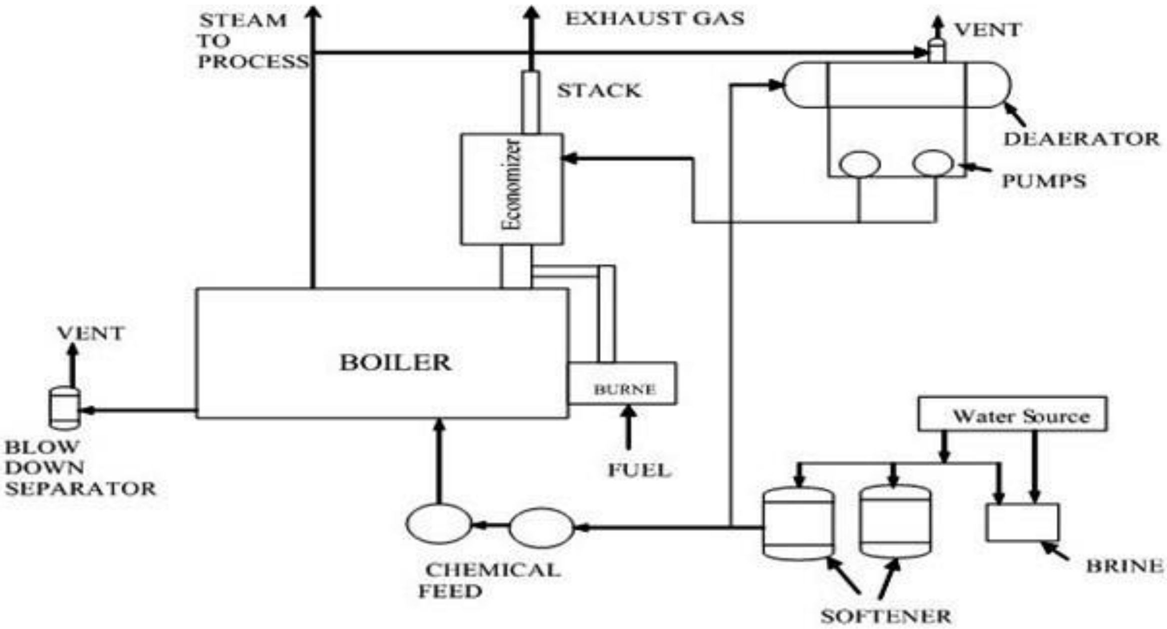


Figure III: Schematic diagram of boiler system

g) Theoretical Combustion Data for Common Boilers fuels

THEORETICAL COMBUSTION DATA – COMMON BOILER FUELS					
Fuel	**kg of air req./kg of fuel**	**kg of flue gas/kg of fuel**	**m^3 of flue/kg of fuel**	**Theoretical CO_2% in dry flue gas**	**CO_2% in flue gas achieved in practice**
Solid Fuels					
Bagasse	3.2	3.43	2.61	20.65	10-12
Coal (bituminous)	10.8	11.7	9.40	18.70	10-13
Lignite	8.4	9.10	6.97	19.40	9-13
Paddy Husk	4.6	5.63	4.58	19.8	14-15
Wood	5.8	6.4	4.79	20.3	11.13
Liquid Fuels					
Furnace oil	13.90	14.30	11.50	15.0	9-14
LSHS	14.04	14.63	10.79	15.5	9-14

Annex 7: Surface Heat Loss Calculation

Particulars	Formula/Value	Units
Boiler Efficiency =		%
Area (A)=		m^2
Operating hours per day=		hrs/day
Operating days per year =		days/year
Annual Operating Hours =		hrs
GCV of Fuel =		Kcal/kg
Cost of Fuel per kg =		NPR/kg
Surface Heat Loss (Qs)=	[10+(Ts-Ta)/20]*(Ts-Ta)	Kcal/hr m^2
Total Heat Loss (Q)=	Qs*A	Kcal
Energy Saving per year=	(Q_{before} - Q_{after}) * Annual operating hrs	Kcal
Equivalent fuel saving per year =	Energy saving per year/(GCV of fuel*furnace efficiency)	kg/year
Annual savings in NPR =	fuel savings per year*cost per kg	NPR/year

Annex 8: Calculation for Compressor

Compressor Specification Data Format

Make	Unit	Value/Remarks
Type		
No. of stages		
Discharge capacity	Nm^3/min	
Discharge pressure	kg/cm^2	
Speed	RPM	
Receiver capacity	m^3	
Motor rating		
Power	kW	
Full-load current	A	
Voltage	V	
Power factor	PF	
Speed	RPM	
Frequency	Hz	
Specific power consumption	$kW/m^3/min$	

Leakage Test in Compressed Air System

Item	Unit	Value/Remarks
Compressed air users	No.	Area/section
Load time (t_1)	min	
Unload time (t_2)	min	
Capacity of compressor	m^3/min	
Leakage = $[t_1/(t_1+t_2)] \times 100$	%	
Leakage = % Leakage * Capacity of compressor	m^3/min	

Capacity Testing of Compressor

Compressor Reference	Unit	Remarks/Value
Receiver volume plus volume of pipeline between receiver and the air compressor (V)	m^3	
Suction air temperature (t_1)	°C	
Discharge air temperature (t_2)	°C	
Initial receiver pressure (P_1)	kg/cm^2	
Final receiver pressure (P_2)	kg/cm^2	
Time taken to fill receiver from P_1 to P_2(T)	min	
Atmospheric pressure (P_o)	kg/cm^2	
Air compressor capacity (free air delivery) Q = $\{(P_2-P_1)/P_o*(V/T)\}*(273+t_1)/(273+t_2)$	Nm^3/min	

Annex 9: HVAC Calculation

Refrigeration and AC system rated specifications

Description	Unit	Value
Make		
Type		
Capacity of cooling	TR	
Chiller		
• No. of tubes		
• Tube diameter	m	
• Total heat transfer area	m^2	
• Chilled water flow	m^3/hr	
• Chilled water temp difference	^oC	
Condenser		
• No. of tubes		
• Diameter of tubes	m	
• Total heat transfer area	m^2	
• Condenser water flow	m^3/hr	
• Condenser water temp difference	^oC	
Chilled water pump		
• Numbers		
• Capacity	m^3/hr	
• Head developed	mWC	
• Rated power	kW	
• Rated efficiency	%	
Condenser water pump		
• Numbers		
• Capacity	m^3/hr	
• Head developed	mWC	
• Rated power	kW	
• Rated efficiency	%	

Refrigeration and AC system Operating parameters

S.N.	Parameter	Unit	Values
1.	Chilled water flow (using a flow meter or assessed by level difference)	m^3/hr	
2.	Chilled water pump motor input power	kW	
3.	Chilled water pump suction pressure	kg/cm^2	
4.	Chilled water pump discharge pressure	kg/cm^2	
5.	Chiller water inlet temperature to chiller	^oC	
6.	Chiller water outlet temperature from chiller	^oC	
7.	Condenser water inlet temperature	^oC	
8.	Condenser pump suction pressure	kg/cm^2	
9.	Condenser pump discharge pressure	kg/cm^2	
10.	Condenser water outlet temperature	^oC	
11.	Chiller (evaporator) outlet refrigerant	^oC	

S.N.	Parameter	Unit	Values
	temperature		
12.	Refrigerant pressure	kg/cm^2 (or psig)	
13.	Condenser inlet refrigerant temperature	oC	
14.	Refrigerant pressure	kg/cm^2 (or psig)	
15.	Actual cooling capacity [(1)*(6-5)/3024]	TR	
16.	COP [11/(10-11)]	-	
17.	Compressor motor input power	kW	
18.	Specific energy consumption	kW/TR	
19.	Input power to CT fan	kW	
20.	Input power to chilled water pumps in operation	kW	
21.	Input power to condenser water pumps in operation	kW	
22.	Overall system specific power consumption [(2+17+19+20)/15]	kW/TR	

Annex 10: Pump Calculation

S.N.	Item reference	Units	Value/Remarks
1	***Design Condition***		
2	Pump Reference		
3	Pump Rated Power	kW	
4	Rated Flow rate	m^3/hr	
5	Rated Head	m	
6	Rated Efficiency	%	
	Actual Condition		
7	Actual Power (electrical)	kW	
8	Actual Flow Rate (Q)	m^3/hr	
9	Actual Head (h_{dis}-h_{suc})	m	
10	Fluid density, ρ	Kg/m^3	
11	Acceleration due to gravity (g)	m/sec^2	
12	Hydraulic power = $Q*(h_{dis}-h_{suc})* \rho * g/1000$	kW	
13	Shaft Power (P_s) = Hydraulic power/pump efficiency, η	kW	
14	Electrical Input Power = Shaft Power/ motor efficiency, η	kW	

Annex 11: Fan Calculation

Rated Fan specifications

Parameter	Unit	Values
Make		
Type (axial/centrifugal) (Backward curve/forward curve)		
Discharge flow	m^3/hr	
Total head developed	mWC	
Name of fluid medium handled		
Temperature of fluid medium handled	^oC	
Density of fluid handled	Kg/NM^3	
Dust concentration	mg/Nm^3	
Flow control type		
Flow control range	%	
Fan input power	kW	
Fan speed	RPM	
Fan efficiency	%	
Specific power consumption	kW/(m^3/hr)	
Fan motor		
Rated power	kW	
Full-load current	amps	
Voltage	volts	
Power factor	pf	
Speed	RPM	
Frequency	Hz	
Efficiency	%	

Fan Operating parameters and performance

SN	Parameter	Unit	Values
1	Fluid (medium) flow (Q) (measured using pitot tube at fan discharge)	m^3/sec	
2	For suction pressure (measured at fan inlet using U-tube manometer)	mmWC	
3	For discharge pressure (measured at fan discharge using U-tube manometer)	mmWC	
4	Total head developed (TDH) [3–4/1000]	mWC	
5	Temperature of fluid medium (measured at fan inlet using a thermometer)	^oC	
6	Density of fluid medium handled (r) (taken from standard data and corrected to operating temperature/pressure conditions)	kg/m^3	
7	Motor input power (P) measured at motor terminals or switchgear using panel or portable energy meter/power analyzer	kW	
8	Frequency	Hz	
9	Combined efficiency (fan + motor) {(Q x r) (9.81) (TDH/r) x 100}/ P x 1000	%	
10	Fan efficiency = (Combined efficiency x 100) / Motor efficiency	%	
11	% Motor loading w.r.t rated power	%	

SN	Parameter	Unit	Values
12	% Motor loading w.r.t rated capacity	%	
13	% Motor loading w.r.t rated head	%	
14	Specific power consumption	kW/(m^3/hr)	

Annex 12: Cooling Tower Performance

The important parameters, from the point of determining the performance of cooling towers, are:

i. "Range" is the difference between the cooling tower water inlet and outlet temperature.
ii. "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the `Approach' is a better indicator of cooling tower performance. Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach).
iii. Cooling capacity is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.
iv. Evaporation loss is the water quantity evaporated for cooling duty and, theoretically, for every 10,00,000 kCal heat rejected, evaporation quantity works out to 1.8 m^3. An empirical relation used often is:

4 Evaporation Loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x (T_1-T_2)

5 T_1-T_2 = Temperature difference between inlet and outlet water.

Source: Perry's Chemical Engineers Handbook

v. Cycles of concentration (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in make-up water.
vi. Blow down losses depend upon cycles of concentration and the evaporation losses and is given by relation:

6 Blow Down = Evaporation Loss / (C.O.C. – 1)

vii. Liquid/Gas (L/G) ratio, of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through measures like water box loading changes, blade angle adjustments.

Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air:

$$\mathbf{L (T1-T2) = G (h2-h1); L/G = (h2-h1)/ (T1-T2)}$$

Where:

L/G = liquid to gas mass flow ratio (kg/kg).

T_1 = hot water temperature (°C).

T_2 = cold water temperature (°C).

h_2 = enthalpy of air-water vapour mixture at exhaust wet-bulb temperature.

h_1 = enthalpy of air-water vapour mixture at inlet wet-bulb temperature.

Annex 13: Model Minutes for Energy Audit conduction

Meeting Minutes for Energy Audit

Date:

Opening:

(When the meeting was called to order, where it was being held and who called it to order).

Present:

1.

2.

3.

…

Absent:

1.

2.

…

Agenda:

Agenda 1.

Agenda 2.

…

Decisions:

1:

2:

…

Conclusion:

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