Government of Nepal

Water and Energy Commission Secretariat

Singha Durbar, Kathmandu

Energy Audit Guidelines for Industrial Sectors

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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 Industrial 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 industrial sector, many of which are cost-effective. These energy efficiency options include both cross-cutting as well as sector-specific measures. However, industrial 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 industrial sectors do not have the capacity to conduct an effective energy audit. The government of Nepal policies and programs aim to assist industrial 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 industrial entities.

This energy audit guideline is intended to provide guideline for energy auditors, energy managers and all stakeholders involved in energy conservation activities in industrial sectors, 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 audits of industries without any difficulties.

SUMMARY

Energy Audit Guidelines for industrial sectors is intended to guide the process of identifying and implementing energy saving opportunities that may exist in the industries. It also aims to raise awareness of 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 industries 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.

The main purpose of the Energy Audit Guidelines for Industrial Sectors is to provide supervision in the identification and implementation of energy saving opportunities that may exist in the industrial sectors. It further aims to raise awareness about energy efficient appliances and available technologies and provide useful inputs to the owners/managers and general public. The implementation of this guideline will help achieve systematic reduction in energy use, identify and implement energy savings opportunities and achieve energy efficiency and make use of energy consuming appliances efficiently.

For preparation of energy guidelines for industrial sector, first of all baseline of energy consumption of industries were established by energy audit in the selected units. A total of 29 industries i.e. 4 cement, 4 steel rolling mills, 4 brick kilns, 4 sugar, 4 dairy, 2 beverage, 4 noodles making and 3 pulp & paper industries. The energy consumption of selected industries was obtained, and the specific energy consumption were obtained. 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 ample opportunities for improvement of energy efficiency through implementation of low and no cost measures. Some recommendations for specific industrial sectors have been provided along with other recommendations for overall all industrial sectors based on the observation during the field visit. With the adoption of the provided measures, the industries can move towards achieving energy efficiency. The guideline also includes the information sheets, formulae for calculation and outline on preparing energy audit report.

ACKNOWLEDGEMENT

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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 Industrial Sectors".

Water and Energy Commission Secretariat

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

%	:	Percent
A	:	Ampere
AC	:	Alternating Current/Air Conditioner
AEPC	:	Alternative Energy Promotion Center
APFC	:	Automatic Power Factor Control
APH	:	Air Pre Heater
APO	:	Asian Production Organization
AQC	:	Air Quenching Chamber
ASHRAE	:	American Society of Heating, Refrigerating, and Air-Conditioning Engineer
ASME	:	American Society for Mechanical Engineer
BEE	:	Bureau of Energy Efficiency
BEP	:	Break Even Point
BPT	:	Boiling Point Temperature
BTK	:	Bull's Trench Kiln
$Ca(OH)_2$	:	Calcium Hydroxide
CBS	:	Central Bureau of Statistics
CEO	:	Chief Executive Officer
CFL	:	Compact Fluorescent Lamp
CHP	:	Combined Heat & Power
CIPEC	:	Canadian Industry Program for Energy Conservation
CM	:	Centimeter
CM^2	:	Square Centimeter
CO	:	Carbon Monoxide
CO_2	:	Carbon dioxide
COC	:	Cycle of Concentration
COP	:	Coefficient of Performance
DANIDA	:	Danish International Development Agency
DC	:	Direct Current
DDC	:	Dairy Development Community
DEVC	:	Double Effect Vapour Cell
DG	:	Diesel Generator
EA	:	Energy Audit
ECO	:	Energy Conservation Opportunity
EEC	:	Energy Efficiency Center
ENCON	:	Energy Conservation

EnMS	:	Energy Management System
EPA	:	Energy Performance Assessment
EPI	:	Energy Performance Indicator
ESCO	:	Energy Service Company
ESPS	:	Environment Sector Program Support
FAD	:	Free Air Delivery
FBTK	:	Fixed Chimney Bull’s Trench
FD	:	Forced Draft
FO	:	Furnace Oil
FRP	:	Fiberglass Reinforced Plastic
FTL	:	Fluorescent Tube Lamps
GCV	:	Gross Calorific Value
GDP	:	Gross Domestic Product
GHG	:	Green House Gas
GIZ	:	German International Corporation
GJ	:	Gigajoule
GoN	:	Government of Nepal
HF	:	High Frequency
HID	:	High Intensity Discharge
HP	:	High Pressure/Horse Power
HPMV	:	High Pressure Mercury Vapour Lamp
HPSV	:	High Pressure Sodium Vapor
Hr	:	Hour
HVAC	:	Heating, Ventilation and Air Conditioner
ID	:	Induced Draft
IEE	:	Initial Environmental Examination
IEMP	:	Industrial Energy Management Project
IGEA	:	Investment Grade Energy Audit
IRR	:	Internal Rate of Return
ISO	:	International Organization for Standardization
k Cal	:	Kilo Calorie
Kg	:	Kilogram
kJ	:	Kilo Joules
KL	:	Kiloliter
KLPD	:	Kilo Liters Per Day
kV	:	Kilo Volt
KVA	:	Kilo Volt Ampere

kWh	:	Kilowatt hour
LED	:	Light Emitting Diode
LOTO	:	Log Out Tag Out
M&E	:	Maintenance and Energy
M^2	:	Square Meter
M^3	:	Cubic Meter
MD	:	Metering Data
MG	:	Machine Glazed
MJ	:	Mega Joule
ML	:	Milliliter
mmWC	:	Water Column (Millimeter Gauge)
MoEWRI	:	Ministry of Energy, Water Resources and Irrigation
MOICS	:	Ministry of Industry, Commerce and Supplies
MPC	:	Milk Producer Cooperatives
MS	:	Mild Steel
MSG	:	Monosodium Glutamate
NEA	:	Nepal Electricity Authority
NEEAP	:	National Energy Efficiency Action Plan
NEEP	:	Nepal Energy Efficiency Program
NPR/NRs	:	Nepalese Rupees
NPV	:	Net Present Value
NS	:	Nepal Standard
O_2	:	Oxygen
^oC	:	Degree Celsius
OEES	:	Office of Energy Efficiency Service
^oF	:	Degree Fahrenheit
OPC	:	Ordinary Portland Cement
PF	:	Power Factor
pH	:	Potential of Hydrogen
PHE	:	Plate Heat Exchanger
PPC	:	Pozzolana Portland Cement
PPE	:	Personal Protective Equipment
PPM	:	Parts Per Millions
PSC	:	Pozzolana Slag Cement
PV	:	Photovoltaic
PVC	:	Polyvinyl Chloride
RE	:	Renewable Energy

RO	:	Reverse Osmosis
RoI	:	Return of Interest
S. N./ S. No.	:	Serial number
SEC	:	Specific Energy Consumption
SEU	:	Specific Energy Use
SO_2	:	Sulphur Dioxide
SP	:	Suspension Preheater
SPM	:	Suspended Particulate Matter
TCD	:	Ton Crushing Per Day
TDS	:	Total Dissolved Solid
TMT	:	Thermo Mechanical Treatment
TPD	:	Tons Per Day
TR	:	Ton of Refrigeration
TSS	:	Total Suspended Solid
UNESCAP	:	United Nations Economic and Social Commission for Asia and the Pacific
UNIDO	:	United Nations Industrial Development Organization
US	:	United State
VFD	:	Variable Frequency Drive
VRM	:	Vertical Roll Mill
VSBK	:	Vertical Shaft Brick Kiln
VSK	:	Vertical Shaft Kiln
W/P	:	Writing & Printing
WECS	:	Water and Energy Commission Secretariat
WHR	:	Waste Heat Recovery

CHAPTER 1: INTRODUCTION

1.1 Background of Energy Audit Guideline

The basic purpose of the Energy Audit Guideline is to impart knowledge to industrial 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 industrial sectors. The guideline also aims to provide useful inputs about energy efficient equipment and technology relevant to industrial sectors.

In general, the key features of Energy Audit Guidelines for industrial 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;
- Provide useful inputs about available energy efficient equipment and technologies;
- Identifying and implementing energy saving opportunities;
- Demonstrating the stakeholders of the corporate commitment to comply with their best practice to protect the environment;
- Fulfilling the associated regulatory requirements and responding with confidence to green trade barriers in the global market.

The guideline provides step by step advice for industries 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. The analytical framework defines the three pillars (Path, Partners and Process) that lay the foundation to a sustainable energy efficiency action plan. Government officials concerned with the subject will be able to initiate a gap analysis for assessing their present status in the cyclic process of energy efficiency promotion.

1.2 Types of Energy Used in Industrial Sectors

Industrial sectors use both electrical and thermal energy. Electricity is supplied by 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 are diesel and furnace oil, which are 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 industries, 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 "ensuring reliable and affordable energy supply and proper utilization of energy by generation and development of renewable energy for the fulfillment of citizen's basic needs." Different acts, policies, regulations and strategy related to energy efficiency are presented below:

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 reducing consumption of energy by enhancing energy efficiency". Also, 29 "b" of the 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

Objective 7.3 of Industrial Policy 2067 states that "To establish industrial entrepreneurship as a sustainable and reliable sector by utilizing latest technology and environment friendly production process". Policies concerning the objective 7.3 are "Technical and financial assistance shall be made available to the industries that use environment-friendly and energy saving technology on their own costs" and "Special measures shall be taken to promote green industries and to make the established industries pollution free and zero to carbon emission". Policy 17.11 states that "The expenses made by any industry in the machine or instrument that help decrease consumption of energy, the capital expenses and technology and process for installation of a system for pollution control and less impact in environment may be deducted for the purpose of income tax. Such facility shall have to be utilized once or within a period of five years" and Policy 17.32 states that "No royalty shall be charged on the electricity generated by an 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 goal of this strategy is to double the average improvement rate if energy efficiency in Nepal from 0.84% per year, which existed during the period of 2000 – 2015 AD to 1.68% per year in 2030. The main objectives of the strategy are to reduce existing energy shortage, increase energy access and provide important contribution to energy security, maintain environmental balance and bring positive improvements in health by efficient use of energy.

National Energy Efficiency Strategy emphasizes the following:

- Generate awareness on energy efficiency from the consumers' level to policy makers' 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 Bioenergy Strategy, 2073

The strategy aims to increase access to and contribute to environmental protection by developing bio-energy, which has been in a traditional way, as modern, sustainable and clean energy. The following strategies are outlined for a strategy to increase efficiency and effectiveness in 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 audits 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 consumption of energy through the use of suitable tools, technologies or equipment's related to energy consumption. The state of energy efficiency can be measured by the energy required to produce goods or services. Reducing the amount of energy required to produce the right goods or services through the use of various methodology using different tools, technologies or equipment's is to increase the energy efficiency. Measuring the decreasing rate of energy intensity is the average state of optical energy efficiency; which refers to the declining energy consumption required to produce GDP.

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 industrial 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 industries 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 (walk-through) audit and a detailed (diagnostic) 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. 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.

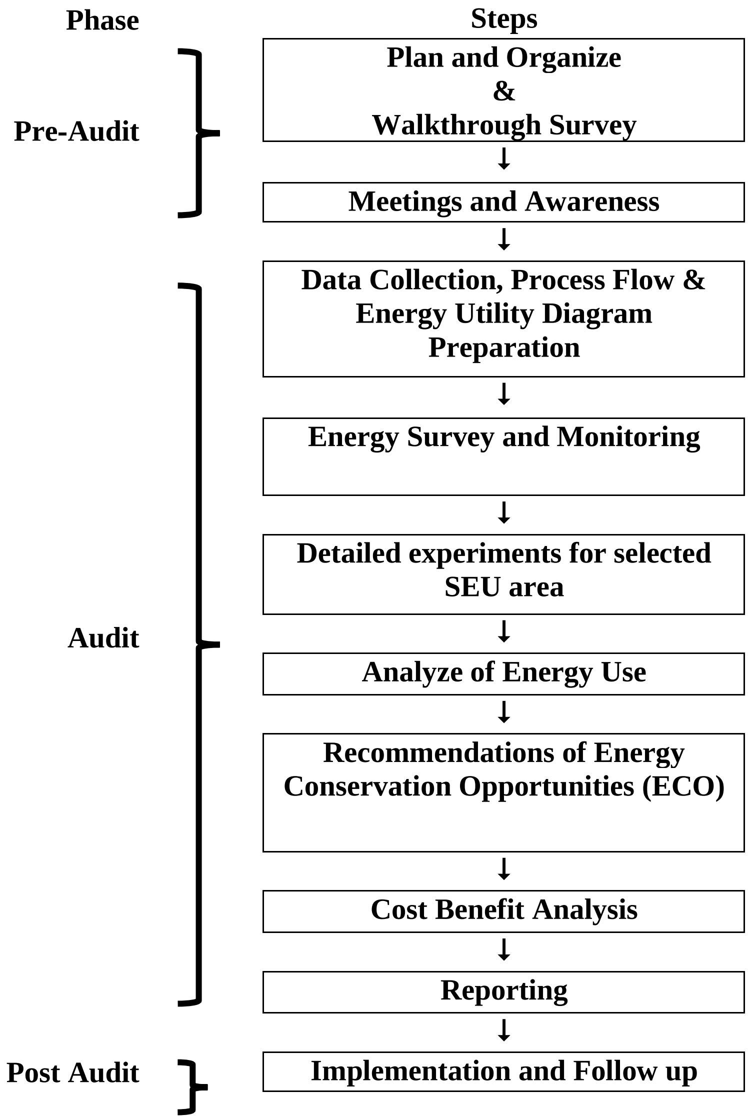
2.4.1 Preliminary Energy Audit Methodology

It is also called Walkthrough Audit:

- 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 Flow Chart

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 Consumption (SEC) 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 teams 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.

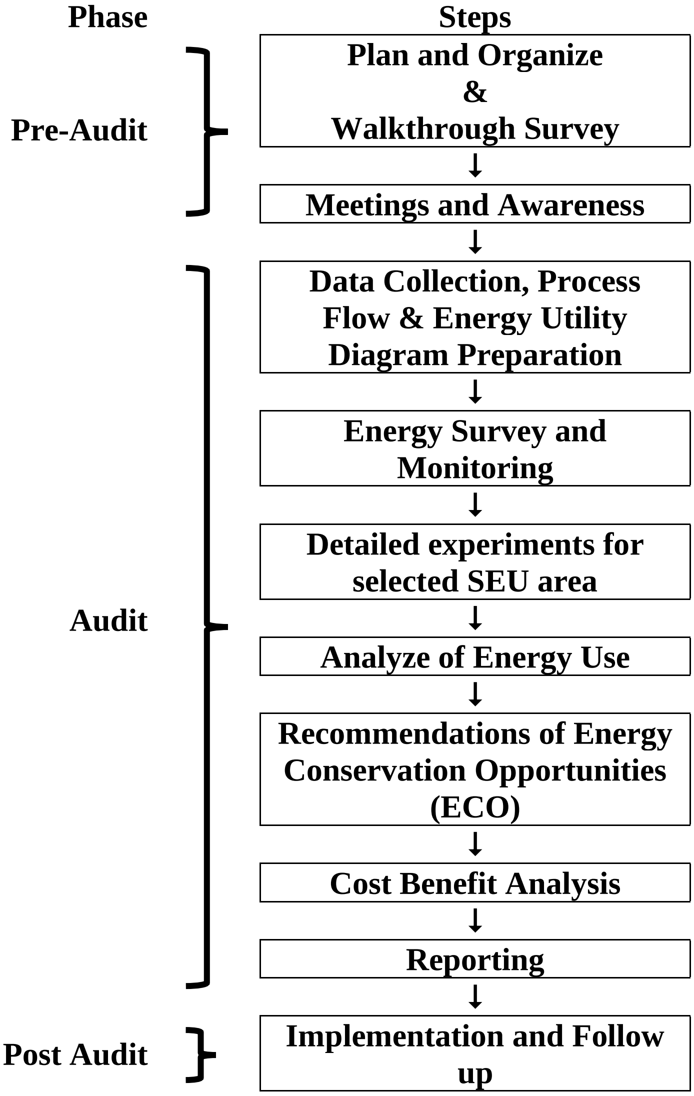
Based on all the data/information collected from the organization/site, the analysis of energy use is conducted and Energy Conservation Opportunities (ECO) are identified and developed. The cost benefit analysis of high-cost opportunities is calculated.

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.

Flow-chart of detailed energy audit:



2.5 Specific Energy Consumption (SEC) Calculation

It is the measure of amount of energy consumed to the amount of product produced. It is one of the energy performance indicators and reflects the energy efficiency of the manufacturing industries. SEC is calculated as a ratio of energy used for producing a product:

SEC=Energy used/Product or Service amount

CHAPTER: 3 ENERGY AUDIT GUIDELINES OF INDUSTRIAL SECTOR

The Guidelines consist total eight most energy intensive industrial sectors. These eight industrial sectors are brick kiln, cement, dairy, noodles making, non-alcoholic beverages, pulp and paper, steel re-rolling and sugar industries.

3.1 BRICK KILNS

3.1.1 Brick Kilns in Nepal

Brick making is one of the traditional crafts in Nepal. Brick is a primary building material in many parts of Nepal, particularly in Kathmandu valley and in the southern plain of the Terai. With the increasing demand of brick, technology shift took place in early 1950’s when traditional clamp kilns (locally known as “Thaado Bhatta”) were largely displaced by Bull’s Trench Kilns Movable Chimney, (commonly known as BTKs or "Chimney Bhatta") a technology that was brought from India in the early 1950s. At present, Fixed Chimney BTKs (FBTK) is widely used for brick making since the government banned the Moving Chimney BTKs in the Kathmandu Valley in 2002.

Brick making is an energy and labour intensive process. Most of the units in the country are handmade green brick making units as there is no mechanization of this process (except for large Hoffman Kiln units and few FBTK). The industry is seasonal and operates mostly for about 6-7 months from November to May again except for large mechanized kilns with shades for storing bricks.

Brick making is highly energy intensive process having specific energy consumption varying in adopted technology. The brick industry is faced with lower operating efficiency, higher fuel consumption and higher pollution loads which need to be tackled. The energy cost accounts for 30-40 percent of the overall production costs.

3.1.2 Energy Use in Nepalese Brick Kilns

Nepalese brick kilns use mainly coal as energy resource, which is imported from Assam in India. Apart from coal, a small fraction of sawdust/fire-wood is also used as fuel in these kilns.

Major energy consuming section of the brick industry is the kiln where coal is used as an energy source for firing of green bricks. Electricity is mainly used for lighting. Few industries with mechanized molding use electricity for clay preparation and molding of green bricks.

All brick kilns crush the coal to required size for firing. Coal is a combination of different chemicals components, which produce the heat in exothermic reaction. Some component of the coal i.e., ash do not produce any heat but after combustion remains in the kilns.

Ash can be divided into two types namely fly ash and bottom ash. Fly ash is the one of the pollutants, which is emitted as a SPM through flue gas. Along with fly ash, un-burnt carbon is also emitted through flue gas. Due to the un-burnt carbon, flue gas colour can be seen as black. Energy efficiency in brick kilns can achieve elimination of un-burnt carbon and also reduce the fly ash percentage.

3.1.3 Specific Energy Consumption (SEC) in Brick Sector

According to the present study findings, the specific energy consumption of the Industrial brick sector in Nepal is given below. Figures derived are based on the energy audit carried out in four brick kiln units of Nepal.

Table 3.1: Specific Energy Consumption in Brick Kiln

Specific Energy Consumption		
	Electrical, kWh/MT	**Thermal, GJ/MT**
WECS, 2019/20	2.57	0.95
EEC, 2015 Nepal [1]	-	1.9-3.3
India [2]	-	0.95 – 1.82

3.1.4 General Process Flow Chart

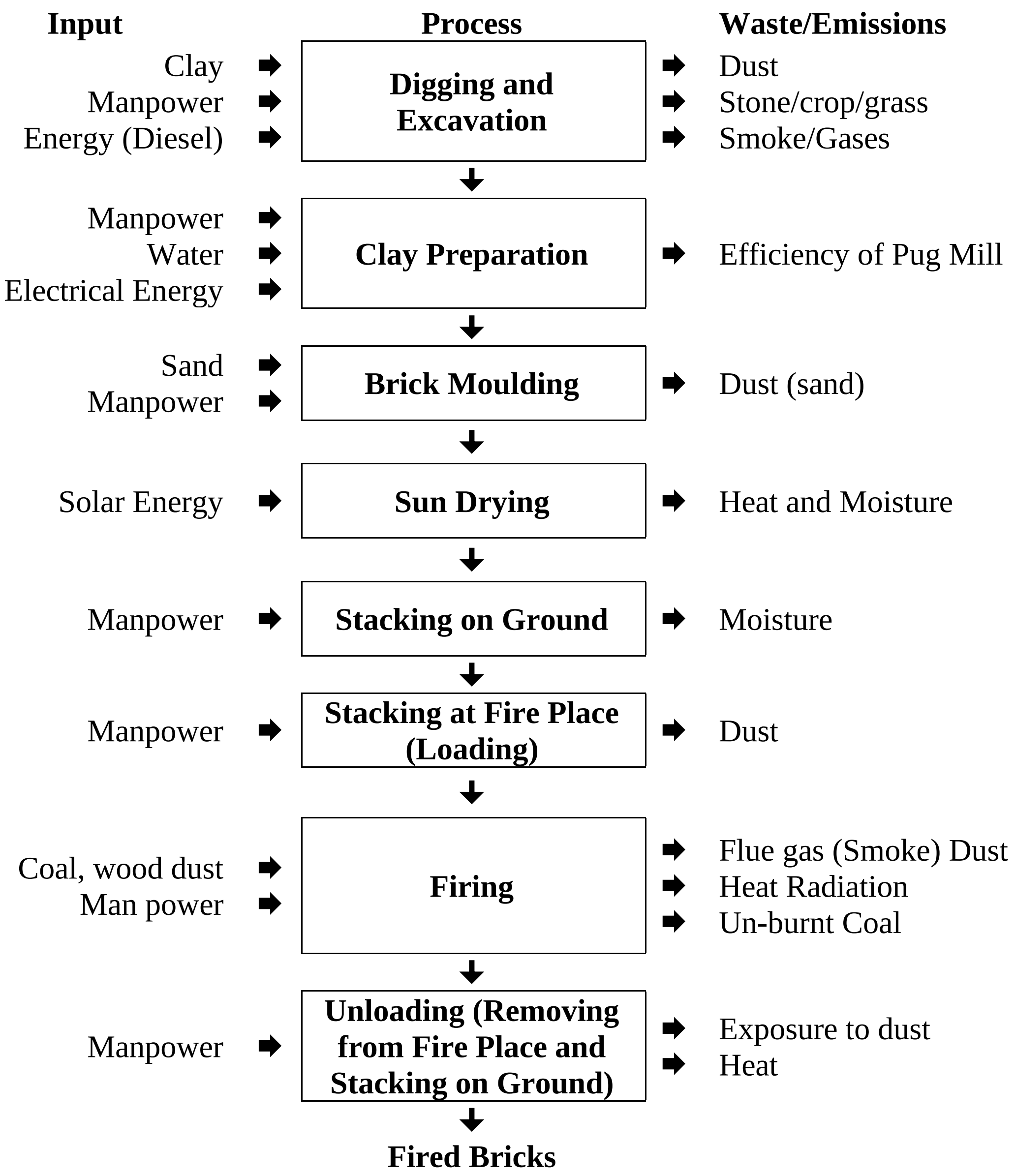


Figure 3.1: General process flow chart of brick kiln

[1] EEC/FNCCI, 2005

[2] *BEE, India*

3.1.5 Process Description

Four main processes are involved in brick making. In clay winning, the raw material i.e. clay is excavated and mixed thoroughly with water after manual removal of stones and bigger particles. The depth of clay excavation can range from 0.25m to 3m. If required, carbonaceous material such as coal dust, crop waste etc. or other additives are added to the clay at this stage. The clay preparation mainly depends on the properties of clay. The processed clay is shaped into the specific shape. This process is known as clay moulding. moulding can be done manually or mechanically using extrusion machines. Green bricks are dried naturally in open air. The natural drying uses solar energy to evaporate moisture in the green bricks. The dried (moisture content of 3 to 10% by mass on wet basis) green bricks are heated to a range of about 800 to 1100 ° C in a kiln to get the fired brick.

3.1.6 Significant energy used area and equipment in brick kiln

Brick Kiln uses mostly thermal energy in comparision to electrical energy. The following area and equipment consume significant energy:

- Kiln;
- Induction fan;
- Coal crusher;
- Pug mill;
- Brick production line;
- Diesel generator.

3.1.7 Sampling and measurement for energy audit

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

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 brick kilns:

Flue Gas Analysis: Measure oxygen, carbondioxide, carbonmonoxide, stack & ambient temperature. Calculate fuel consumption and production in one round of kiln.

Surface Heat Loss Measurement: Measure surface temperature of firing zone of kiln and kiln walls.

Air leakge test in wall of kiln: measure air movement towards the kiln by using smoke tube and anaemometer.

Green Brick Moisture and Coal Size: Analyse the green brick moisture in laboratory. Measure the coal size being fed in the kiln.

3.1.8 Potential Energy Conservation Opportunity in Brick Kiln

The following energy conservation opportunities can be found in brick kilns:

Table 3.2: Energy conservation opportunities in brick kilns

S.N.	Energy Conservation Opportunities	Types of investment
1	Stopped the leakage from top and wall of the kilns	No Cost
2	Feed ¾ inch sizes coal to kilns	
3	Feed maximum 200 gm coal at time in fuel feeding hole	
4	Use Single man fuel feeding practice with Z pattern	
5	Stacking of green bricks in chamber system	
6	Keep distance of cooling zone at least 70 ft and more	
7	Use at least 25 % of agriculture residue as a fuel	
8	Improve the Ravish thickness and keep min 9 inch thick	
9	Use VFD in induction fan	Low Cost
10	Insulation of fuel feeding cover (Tawa)	
11	Insulate the Shunt	
12	Construct wind breaking wall over kiln	
13	Use 40 % of the coal as an internal fuel	
14	Construct coal and other fuel shed with hard surface	Cost Demanding
15	Construction shed for kinl duck	
16	Change technology from BTK to energy efficient Tunnel or HKK kilns	

3.2 CEMENT MANUFACTURING

3.2.1 Cement Industries in Nepal

The cement industries are operated mostly in large scale and located mostly in urban vicinities and in the Tarai region. In the earlier period, Cement industries were established by the government. Himal Cement Company Ltd. of 360 TPD capacity was established in Chobhar in the Kathmandu Valley, Hetauda Cement Industry Ltd. of 750 TPD capacity in Lamsure, Hetauda and Udapypur Cement Industry Ltd. of 850 TPD capacity in Gaighat of Udayapur by the government. Himal Cement Company Ltd. has been closed whereas Hetauda Cement Industry and Udayapur Cement Industry are still operational.

Almost all the cement industries possess similar technology and process. But the cement goods production varies from industry to industry. Most of the industries mainly produces OPC (Ordinary Portland Cement) & PPC (Portland Pozzolana Cement). Few industries produce PSC (Portland Slag Cement). Cement grade limestone, silica reach clay and gypsum are the main raw materials for the cement production and coal is the main fuel for limestone based cement industries.

According to the Department of Industry, there are 105 cement industries registered in Nepal. Out of them, 54 industries have received Nepal Standard Mark (NS) till 2019. From the aspect of availability of raw materials, cement sector is considered as a very important sector in Nepal. It falls under the category of heavy industry. Nepal has good deposit of the main raw materials calcium carbonate or limestone and silica rich clay, as Nepal has vast limestone reserve spread over 7000 square kilometers. According to the Nepal Cement Manufacturers Association, total consumption of cement in Nepal is six million tons per annum.

Overall scenario in the context of raw material and market availability as seen in the Nepalese cement production sector is encouraging. Nepal also has to depend on import of coal, which is mainly used as fuel in the cement factory as it does not have its own reserve or production. Efficient use of energy with effective energy management is thus an essential means to ensure sustainable and cost-efficient cement production in the country.

3.2.2 Energy Use in Nepalese Cement Industries

Energy efficiency and energy conservation measures combined with proper energy management action is of high importance in cement industries as the cost of energy as part of the total production costs in the cement industry is significant. Optimizing energy demand in all areas must be combined with the search for the optimal operating point that is consistent with productivity and quality targets. Production of cement also consumes natural resources in bulk quantities.

Given the magnitude of energy consumption and greenhouse gas (GHG) emissions high importance is given to cement industry in the perspective of energy efficiency and climate policies. When building new cement plants, manufacturers install the most recently developed technologies, which are also typically the most energy efficient. Therefore, new kilns are comparatively very energy efficient. More efficient technologies generally provide a cost advantage to the producer through lower energy costs, so efficiency does increase gradually over time with the addition of new plants and upgrading of old plants. There is a very wide range of technologies available, and savings on a per unit basis range from 0.2-3.5 GJ/tonne clinker. The industry is phasing out inefficient long dry kilns and the wet production process. Market and economic forces generally trigger the closure of inefficient facilities as more advanced technologies are commissioned.

Globally, coal is the primary fuel used in cement kilns, but petroleum coke, natural gas and oil can also be combusted in the kiln. Waste fuels, such as hazardous wastes from painting operations, metal cleaning fluids, electronic industry solvents, as well as tires, are often used as fuels in cement kilns as a replacement for more traditional fossil fuels. In Nepal, coal is used almost exclusively as the fuel for the cement kilns, while electricity – both provided by the grid and through the generation of electricity on-site using DG set is used to power the plant equipment. Newer plants have also begun to have their own power plants based on coal for generating power in-house.

3.2.3 Specific Energy Consumption (SEC) in Cement Sector

According to the present study findings, the specific energy consumption of the Industrial cement sector in Nepal is given below. Figures derived are based on the energy audit carried out in four Cement units of Nepal.

Table 3.3: Specific Energy Consumption in Cement Industry

Specific Energy Consumption		
	Electrical, kWh/MT	**Thermal, GJ/MT**
WECS, 2019/20	Limestone Based: 74.68 Clinker Based: 38.4	2.75
EEC, 2015 Nepal [3]	Limestone Based : 80-550 Clinker Based: 38	3.26 – 4.48
India [4]	Limestone Based : 105 Clinker Based: 35	3.1
European Union, 2010[5]	90 to 150	3.382

[3] EEC/FNCCI, 2015
[4] BEE, India
[5] EU, 2010

3.2.4 General Process Flow Chart

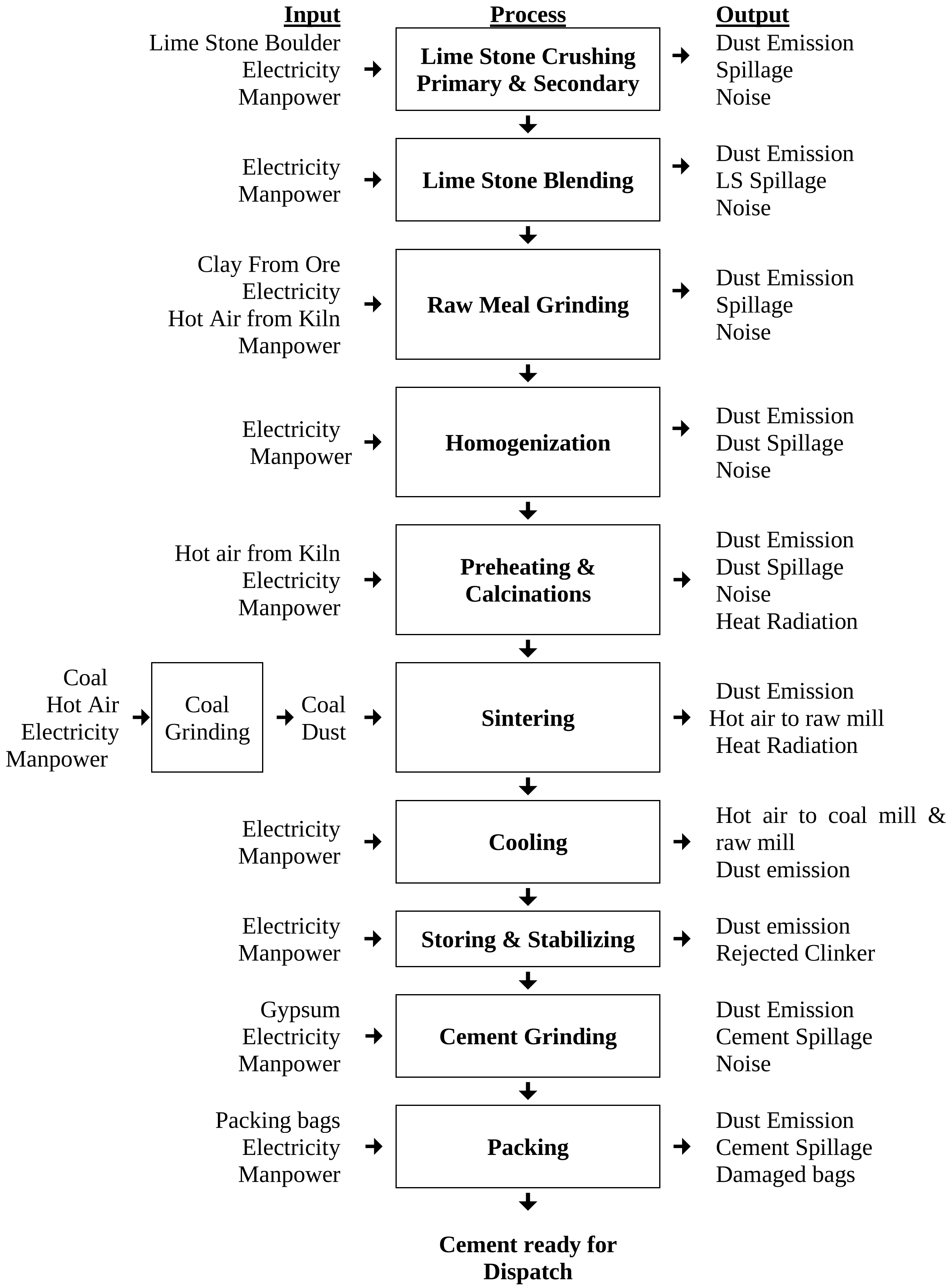


Figure 3.2: General process flow chart of Limestone based cement plant

Clinker based Cement Plant

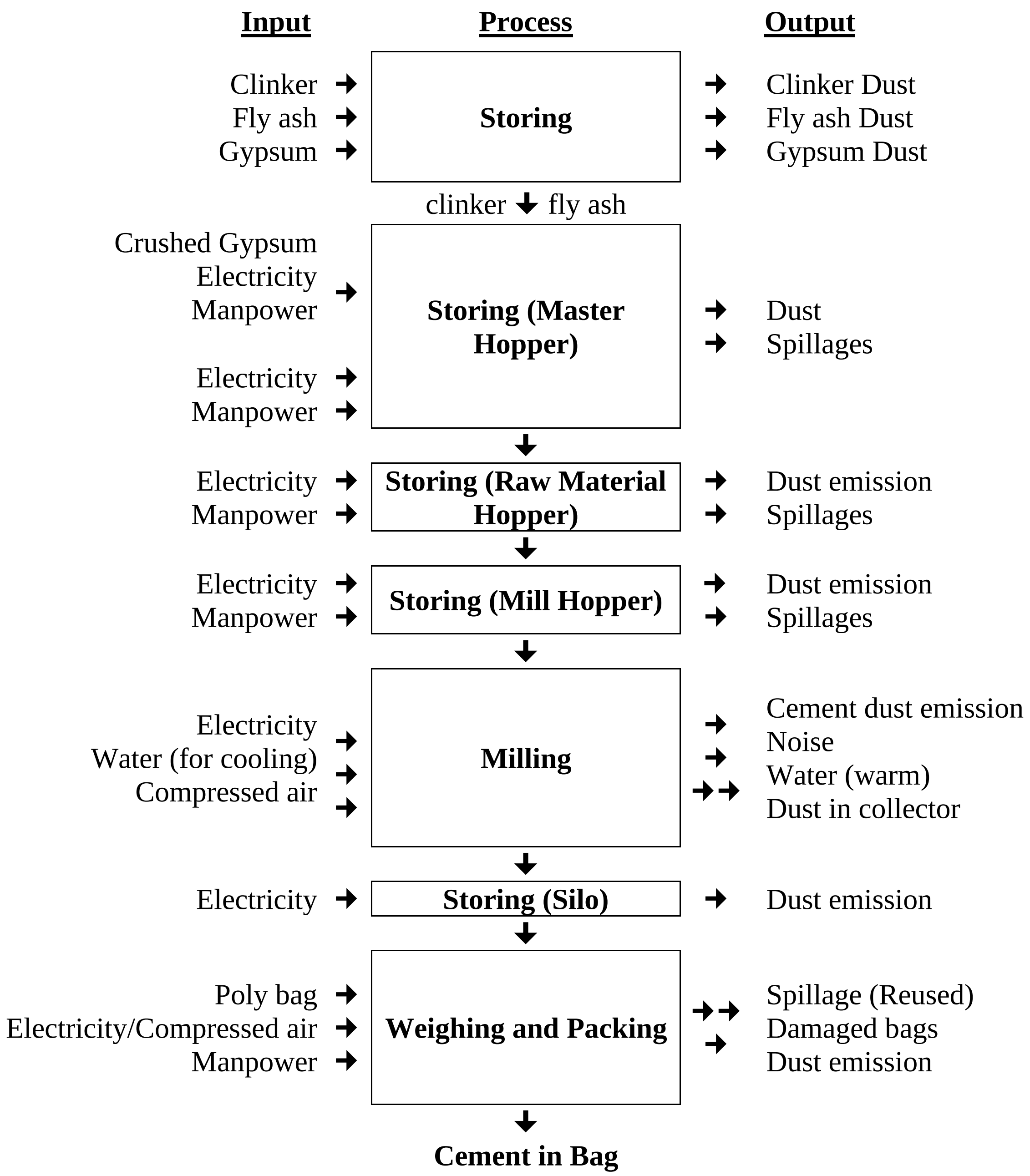


Figure 3.3: General process flow chart of clinker-based cement plant

3.2.5 Process Description

The manufacture of cement is a two-step process, notably, clinker production and cement grinding. In the first step, the raw materials are fed to the kiln system to produce clinker. Clinker consists of silicates, aluminates and ferrites of calcium obtained from the reduction of calcium, silica, alumina and iron oxides present in the raw materials. In the second step, clinker is ground (in a grinding mill) with calcium sulphates (gypsum or anhydrite) to obtain cement with desired performance such as setting time and strength development.

Raw Material Acquisition

Calcium carbonate, usually limestone is the basic raw material used in the plant. Limestone is quarried at mines and transported to the plant using rails, ropeways, trippers and dumpers depending on the available facility. The mines are equipped with the latest machinery and technology. The mined limestone is then crushed through primary jaw crusher and secondary hammer crusher. The crushed limestone is then transported to the plant site. Other raw materials such as coal, bauxite (for aluminum) iron ore and gypsum are procured from various suppliers.

Raw Milling

Raw milling involves mixing the extracted raw materials to obtain the correct chemical configuration, and grinding them to achieve the proper particle-size to ensure optimal fuel efficiency in the cement kiln and strength in the final concrete product. The raw materials are crushed, ground and mixed to obtain a homogenous blend, and then stored. Crushing operation takes place in a raw mill that could be either VRM or Ball Mill or both. The major energy input during this process is electricity.

After the material preparation and prior to entering the kiln system for clinker production, the raw materials are preheated to enable the chemical reactions to occur quickly and efficiently in the kiln and calcined (calcinations) to separate calcium oxides from calcium carbonates contained in the raw materials. During the process, significant amount of carbon dioxide (CO_2) is released. This complete operation takes place in preheater tower through cyclones at different stages.

Pyro-processing

In Pyro-processing, the raw mix is heated to produce clinkers. Clinkers are hard, gray, spherical nodules with diameters ranging from 0.32-5.50 cm (1/8 - 2") created from the chemical reactions between the raw materials. The Pyro-processing system involves three steps: drying or preheating, calcining (a heating process in which calcium oxide is formed), and burning (sintering). The Pyro-processing takes place in the burning zone of the kiln section.

The major thermal energy consumption of the plant is in this section. Coal mill consumes electricity for pulverizing coal. In the kiln system, calcium oxides are sintered at a typical temperature of 1400-1500°C to form clinker, together with oxides of silica, alumina and iron that are present in the feed materials. The clinker production ends with the cooling phase in the cooler installed in the plant. The combusted gases move from kiln through preheater tower, heating the raw material coming to the kiln through the raw meal silo.

Clinker Cooling

The clinker cooling operation recovers up to 30% of kiln system heat, preserves the ideal product qualities, and enables the cooled clinker to be maneuvered by conveyors.

Clinker Storage

Suitable transfer mechanism is used to transfer clinkers from coolers to storage areas and to the finish mill. Gravity drops and transfer points typically are vented to dust collectors.

Cement (Finish) Milling

The clinker produced in the kiln stored in the silo/stock-pile is ground along with Gypsum (about 5%) to produce Ordinary Portland Cement (OPC). The generally used grinding equipment is the ball mill in various cement plants around the world. In recently installed plants the VRM has been installed for lowering energy consumption. The other types of cement such as PPC (Portland Pozzolana Cement) and PSC (Portland Slag Cement) are also produced by grinding clinker with fly-ash and blast furnace slag respectively.

Packing and Loading

Once the production of cement is complete, the finished product is transferred using elevators and conveyors to large, storage silos. Cement is packed as per the standards/requirement. From here, cement is dispatched as per order, to different dealers and agents spread across the country.

3.2.6 Significant energy used area and equipment in cement industries

Cement industries (Limestone based) uses both electrical energy as well as thermal energy. The following area and equipment consume significant energy:

- Induction Motor;
- Kiln;
- Crushers;
- Grinding;
- Lighting;
- Cement Mill;
- Compressor;
- Diesel Generator;
- Fan & Blower;
- Pre Heater and
- Waste Heat Recovery.

3.2.7 Sampling and measurement for energy audit

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

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.

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

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

Fan & Blowers: Calculate load of Fan & Blowers.

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

Preheater and Kiln:

- o Surface Heat Loss Measurement: Measure surface temperature of body
- o Air Preheater: Measure inlet and outlet temperature.
- o Waste Heat Recovery (Boilers): Measure surface heat loss and Condensate recovery

3.2.8 Potential Energy Conservation Opportunity in Cement Industries

The following energy conservation opportunities can be found in cement industries:

Table 3.4: Energy conservation opportunities in cement industries

S.N.	Energy Conservation Opportunities	Types of investment
1	Electrical Demand Management	No Cost
2	Power Factor Improvement by installing capacitor bank with APFC units	
3	Replace conventional lamp with LED	
4	Excess Oxygen control in down coming duct	
5	Calibrate all pressure guage and temperature indicators	
6	Regular cleaning of dust in all induction motors	
7	Control the air supply in kiln to reduce CO formation	
8	VFD for Pumps and Motors	Low Cost
9	Replace old pump and motor with energy efficient pump & motor	
10	Use of alternate fuel against coal	
11	Install energy meter to all department	
12	Arrest false air in Cooler Bag House	
13	Install on load tap changer in Transformer	
14	Implement Energy Management System	
15	Install new refractory lining in burning zone to reduce Kiln radiation and convection loss	Cost Demanding
16	Install Waste Heat Recovery Plant and Generate electricity	

3.3 DAIRY INDUSTRIES

3.3.1 Dairy Industries in Nepal

Dairy industries in Nepal have been instrumental in providing dairy products to the urban consumers and pull the urban capital to rural areas. Dairy industries have been working to bridge dairy farmers and the consumers and urban and rural trade. It is said that dairy sector contributes nearly two-third of the livestock and around 9 percent in the total GDP and regarded as the most important livestock subsector in Nepal. There are nearly 1603 Milk Producers Cooperatives (MPCs), six Milk Supply Schemes and 17 cheese factories of Dairy Development Corporation and 250 private sector dairy industries operating in Nepal (DDB, 2017).

This sector has its importance in reducing poverty through creating employment and income generating opportunities that is ensured through regular cash flow from urban to the rural areas. Formal sector contributes less than 20% of the total annual milk produced in the country. The required yearly milk production growth should be 9% but in contrast current milk production growth stands only at 3.4 percent per annum (DDB, 2017).

In dairy industries, electricity is used for the operation of machinery, refrigeration, ventilation, lighting and compressors. Thermal energy, in the form of steam producing from boiler, is used for heating and cleaning.

3.3.2 Energy Use in Nepalese Dairy Industries

Dairy industries consume both electrical and thermal energy in its production processes. Main source of electricity is the national grid whereas diesel generators are 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 pasteurization of milk and other processes. Fuel used for the boiler operation is mainly firewood and kerosene. Other sources such as rice husk and diesel are also used in some industries.

3.3.3 Specific Energy Consumption (SEC) in Dairy Sector

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

Table 3.5: Specific Energy Consumption in Dairy

Specific Energy Consumption		
Description	**Electrical, kWh/KL**	**Thermal, GJ/KL**
WECS 2019/20	103.04	1.79
EEC, 2015 Nepal[6]	40-128	0.25 – 2.85
ESPS/DANIDA, Nepal[7]	122.5	0.64
India[8]	16.44	0.1167

[6] EEC/FNCCI, 2005
[7] ESPS/DANIDA, 2001 to 2005
[8] BEE, India

3.3.4 General Process Flow Chart

Production process for different milk products vary according to products. General flowchart showing major products is given below.

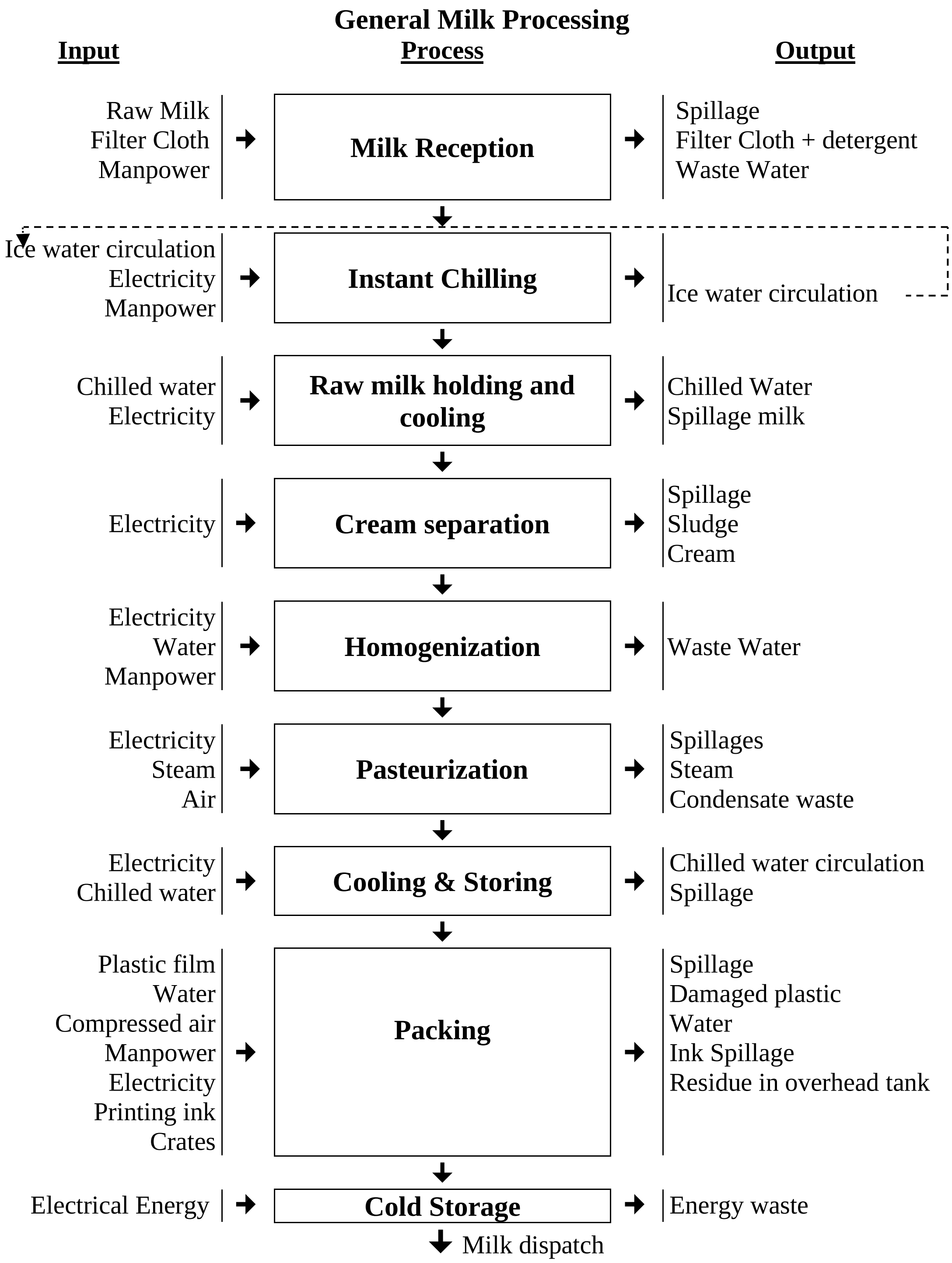


Figure 3.4: General Milk Processing Flowchart

3.3.5 Process Description

Milk Processing:

Milk is collected from different milk chilling centers around the country. Milk collected in the chilling center is transported to the dairy plant in an insulated tanker. Some dairy industries also have refrigerated van for transportation of milk. Milk is also collected in the plant gate from farmers who bring milk in the canes from nearby locations. Received milk is checked for quality after which it is chilled online, filtered and clarified. After clarification milk is stored in a chilled raw milk silo.

After being held in storage tanks at the processing site, raw milk is heated to separation temperature in the regeneration zone of the pasteurizer as per the production requirement. The milk (now hot) is standardized and homogenized by sending to a centrifugal separator where the cream fraction is removed. The skim is then usually blended back together with the cream at predefined ratios so that the end product has the desired fat content.

The pasteurization process involves killing most of the bacteria within the raw milk to increase its shelf life. This is done by rapidly heating the incoming standardized milk to the pasteurization temperature in a simple holding tube, ensuring that the pasteurization temperature is held for the correct time (e.g. 72°C for 25 seconds) to destroy the bacteria. The hot milk is then passed through the regeneration zone, giving up its heat to the incoming cold milk, and cooled to a level where the growth of any surviving bacteria is slowed to a minimum, partially sterilizing the milk and increasing shelf life. Typically, this is an in-line process with the heating and cooling conducted in a plate heat exchanger.

Finally, chilled water is used to control the milk exit temperature from the pasteurizer at approximately 4°C. As the milk is heated and cooled within a few seconds, there are intense heating and cooling demands. This process is therefore one of the largest emission sources within the industry, even though much of the heat is regenerated and re-used in the pasteurizer.

3.3.6 Significant Energy used area and equipment in Dairy Industries

The following area and equipment consume significant amount of energy:

- Boiler and steam distrubution;
- Chilling;
- Lighting;
- Pumping System;
- Packing;
- Cooling Tower;
- Compressor;
- Diesel Generator;
- Heat Exchanger and
- Ice Bank Tank.

3.3.7 Sampling and measurement for energy audit

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

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.

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

Boiler:

- **Flue Gas Analysis**: Measure oxygen, carbondioxide, carbonmonoxide, stack & ambient temperature.
- **Surface Heat Loss Measurement**: Measure surface temperature of body and steam pipelines.
- **Feed Water Analysis**: Measure pH, TDS, hardness, TSS and temperature.
- **Blow Down Water Analysis**: Measure pH & TDS.
- **Economizer & Air Preheater**: Measure inlet and outlet temperature.

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

Heat Exchanger: Measure inlet and outlet temperature.

Ice Bank Tank & Cooling Tower: Measure inlet and outlet temperature.

3.3.8 Potential Energy Conservation Opportunity in Dairy Industries

The following energy conservation opportunities can be found in dairy industries:

Table 3.6: Energy conservation opportunities in dairy industries

S.N.	Energy Conservation Opportunities	Types of investment
1	Electrical Demand Management	No Cost
	Electrical Phase Balance	
2	Regular cleaning of lighting fixtures to get maximum illumination	
3	Excess Air Control in Boiler furnace	
4	Use less moistured fuel in boiler	
5	Make habbits to turn off AC, Fan and Light while not in use	
6	Don’t waste steam by washing milk container and carratte	
7	Install capacitor bank with APFC units for Power Factor Improvement	Low Cost
8	Replace conventional lamp with LED	
9	VFD for Pumps and Motors	
10	Insulate boiler body and steam pipelines, flanges and valves	
11	Install condensate recovery system	
12	Replace old pump and motor with energy efficient pump & motor	
13	Install Economiser in boiler	

14	Feed soft water in boiler and reduce blow down	
15	Install Solar water heater	Cost Demanding
16	Insulation of Ice Bank Tank	
17	Install multifuel boiler instead of liquid fuel boiler	

3.4 NOODLES MAKING INDUSTRIES

3.4.1 Noodles Manufactures in Nepal

Nepal is an attractive market for instant noodles. Growing population of youths, increasing number of middle-class households and working population are the major reasons behind the growth of instant noodle industry in Nepal. The market is not matured in Nepal and there is a huge scope of growth remaining in this market. New instant noodle producing companies are also entering in the market.

Noodle making industries are producing plain white noodles and instant noodles in Nepal. These industries are also producing noodles for vegetarian and non-vegetarian. Domestic consumption of noodles in Nepal is very high, so all the products are consumed locally. Requirement of such raw materials varies according to the quality and type of noodles. Required main raw materials are available within the country. Nepalese noodles making industries are using wheat flour, palm oil, palmolein, salt, MSG, garlic powder, chilli powder, soya sauce, chicken, wheat gluten and soup paste as raw materials and chemicals.

As per the data of CBS 2011/12, 16 noodles making industries including production of macaroni are operating in Nepal. More than 3650 employees are directly and indirectly involved in these industries. Nepalese noodle making industries use the electricity as the major source of energy. However, rice husk, saw dust and diesel are also used as fuel for thermal energy generation.

3.4.2 Energy Use in Nepalese Noodle Making Industries

The noodle making industries are considered as energy intensive sector. Energy used for the cooking, frying and packing of product is mainly electricity for machine operation and heat energy is used for cooking and oil frying. All noodle making production units are operated with boiler for steam generation. Most of the noodle making production units use rice husk as fuel for boiler. The major electrical energy consumption area in the noodle making industry is electric motors associated with pumps, conveyer, noodle making machines and packing machine. The other areas include compressors & lighting. Thermal energy in the form of steam is mainly used for cooking and oil frying.

3.4.3 Specific Energy Consumption (SEC) in Noodle Making Sector

According to the present study findings, the specific energy consumption of the Industrial noodle making sector in Nepal is given below. Figures derived are based on the energy audit carried out in four noodle making units of Nepal.

Table 3.7: Specific Energy Consumption in Noodle Making Sector

Specific Energy Consumption		
	Electrical, kWh/MT	**Thermal, GJ/MT**
WECS 2019/20	134.6	12.31
ESPS/DANIDA, Nepal[9]	201.5	13.64

[9] ESPS/DANIDA, 2001 to 2005, Nepal

3.4.4 General Process Flow Chart

Production process for noodle making is given below.

Input	Process	Waste
Wheat Flour Electricity Manpower	**Screening/Shifting**	Flour Extraneous matter Sacs
Gluten Electricity Manpower	**Dough Mixing/Kneading**	Spillages Flour Dust Gluten
Electricity	**Feeding**	Dough pieces
Electricity	**Dough Rolling**	Dough Scraps
Electricity Manpower	**Dough Sheet Making**	Dough Scraps
Electricity Manpower	**Slitting**	Dough Scarps
Steam Electricity	**Steaming**	Water vapor Heat
Electricity	**Cooling**	Pieces of steamed Noodles
Electricity	**Cutting/Folding**	Steamed Noodles Pieces
Seasoning Liquid Electricity Manpower	**Seasoning**	Left seasoning liquid Pieces of noodle
Electricity	**Drying**	Steamed Noodle Seasoning Liquid
Manpower	**Moulding**	Noodle pieces Seasoned liquid
Electricity Manpower Hot palm Oil	**Frying**	Burnt noodle Palm oil

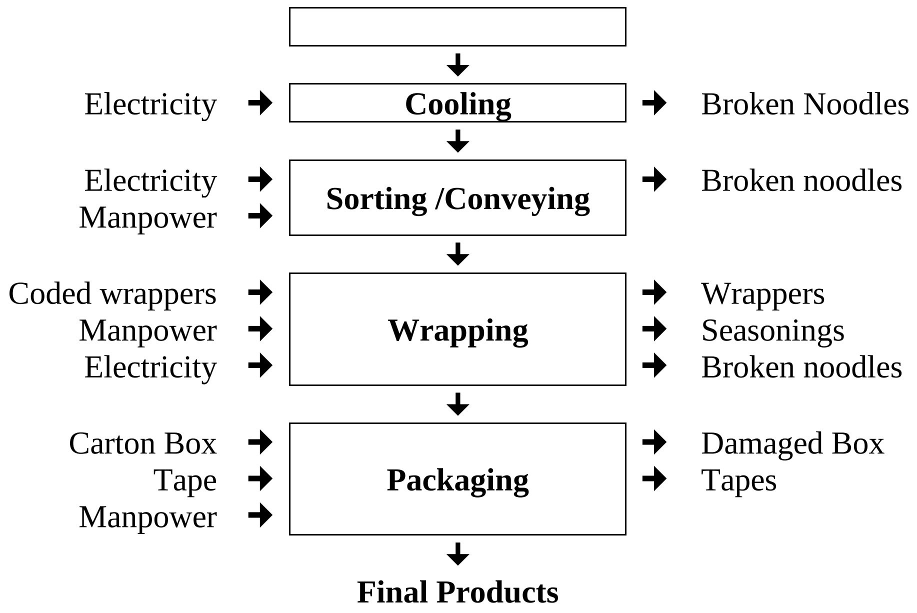


Figure 3.5: General process flow chart of Noodle Making

3.4.5 Process Description

Dough is prepared in dough making machine by mixing wheat flour and water. Additional phosphate as binder, wheat gluten and salt are mixed in the dough. This is passed through a series of rollers for homogenizing and laminating. Noodle threads are made, folded and cut into required sizes by passing the laminated dough through rotating thread rollers.

Noodles from previous process are carried by a metal conveyor belt into steaming section. Steam is supplied from the boiler section. Noodle are steamed at 100 ^{o}C during this process by a series of nozzles located under the conveyor belt. Steamed noodles in conveyor cages are fried in palm oil heated to 170 ^{o}C by steam, which are carried by conveyor to inspection table where deformed noodle cakes are removed and rest are packed in the packing wrapper.

3.4.6 Significant energy used area and equipment in noodles making industries

Noodles Making Industries uses both electrical as well as thermal energy. The following area and equipment consume significant amount of energy:

- Boiler and Steam distribution;
- Heat Exchanger;
- Fryer;
- Oil melting;
- Packaging;
- Compressor and
- Diesel Generator.

3.4.7 Sampling and measurement for energy audit

The following electrical parameters are needed to be measured for electrical energy audit in noodle making industries:

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.

The following thermal parameters are needed to be measured for thermal energy audit in noodle making industries:

Boiler:

- **Flue Gas Analysis:** Measure oxygen, carbondioxide, carbonmonoxide, stack & ambient temperature.
- **Surface Heat Loss Measurement:** Measure surface temperature of 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.

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

Heat Exchanger: Measure inlet and outlet temperature.

3.4.8 Potential energy conservation opportunity in noodle making industries

The following energy conservation opportunities can be found in noodle making industries:

Table 3.8: Energy conservation opportunities in noodle making industries

S.N.	Energy Conservation Opportunities	Types of investment
1	Electricity Demand Management	No Cost
2	Electrical Phase Balance	
3	Excess Air control in Boiler	
4	Use low moistured fuel in Boiler	
5	Regularly clean lights for maximum illumination	
6	Regular cleaning of Heat Exchanger	
7	FAD test in Compressor	
8	Regular checking of Steam trap	
6	Power Factor Improvement by installing capacitor bank with APFC units	Low Cost
7	Replace conventional lamp with LED	

8	VFD for Pump and Motor	
9	Insulate bare steam pipelines, flanges and valves	
10	Install Condensate Recovery System	
11	Replace old pump and motor with energy efficient pump & motor	
12	Insulation of bare pipes and fittings	
13	Install Economiser and Air Pre Heater in Boiler	
15	Replace old heat exchanger to energy efficient heat exchanger for oil heating of fryer	Cost Demanding
16	Install auto fuel feeding system in Boiler	

3.5 NON-ALCOHOLIC BEVERAGE INDUSTRIES

3.5.1 Non-Alcoholic Beverage Industries in Nepal

Bottlers Nepal, the oldest non-alcoholic beverage producing company in Nepal started its production in 1979 AD, marking the establishment of the first global soft drink brand bottling plant in the country. Nonalcoholic beverages industry in Nepal comprises of liquid refreshment beverages such as bottled water, carbonated soft drinks, energy drinks, fruit beverages, ready-to-drink coffee and tea, sports beverages and value-added water. Most of the non-alcoholic beverage industries are multinational companies operating in Nepal. Most of the international established brands of non-alcoholic beverages are bottled in Nepal.

As per the data of CBS 2011/12, 54 non-alcoholic beverage industries including production of mineral water are operating in Nepal. More than 3907 employees are directly and indirectly involved in these industries.

3.5.2 Energy Use in Nepalese Non-Alcoholic Beverage Industries

The non-alcoholic beverage industries are considered as energy intensive sector. Energy used for the production of beverage is mainly electricity for machine operation and heat energy for washing and HVAC system. All cola production units are operated with boiler for steam generation. Most of the cola production units use diesel and FO as fuel for boiler. The major electrical energy consumption area in the non-alcoholic beverage industry are electric motors associated with pumps, washing machines, conveyer, filling machines, refrigeration, HVAC and vacuum pumps. The other areas include compressors & lighting. Thermal energy in the form of steam is mainly used for washing of bottles and HVAC system.

3.5.3 Specific Energy Consumption (SEC) in Non-Alcoholic Beverage Sector

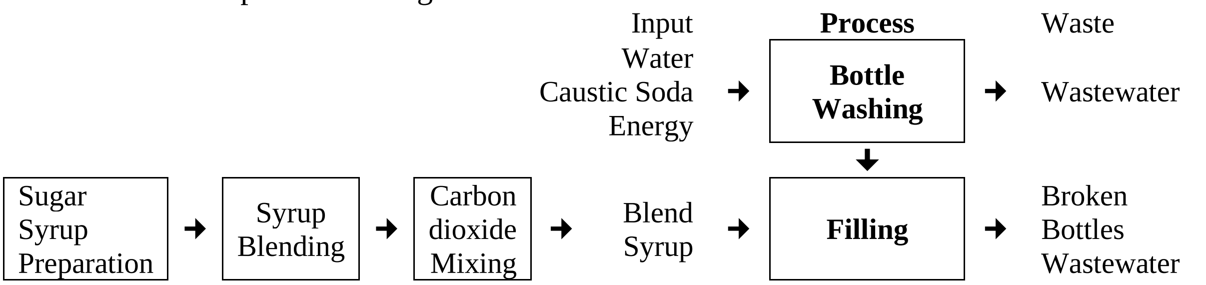
According to the present study findings, the specific energy consumption of the Industrial non-alcoholic beverage sector in Nepal is given below. Figures derived are based on the energy audit carried out in two Non-Alcoholic units of Nepal.

Table 3.9: Specific Energy Consumption in Non-Alcoholic Beverage

Specific Energy Consumption		
Description	**Electrical, kWh/KL**	**Thermal, GJ/KL**
WECS 2019/20	85.22	2.29
ESPS/DANIDA, Nepal[10]	99.5	3.11

3.5.4 General Process Flow Chart

Production process for Non-Alcoholic Beverage varies according to product type. General flowchart for cola production is given below.



[10] ESPS/DANIDA, 2001 t0 2005, Nepal

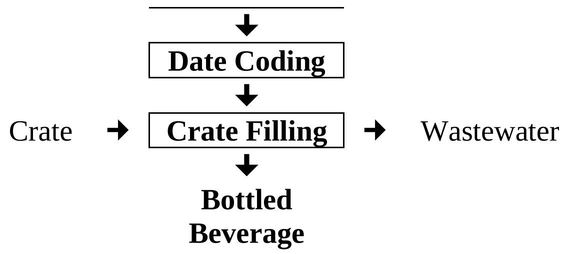


Figure 3.6: General Flowchart Cola Product Production

3.5.5 Process Description

All returned bottles in crates are collected in a warehouse then it is transferred to the plant by forklift, which is sent to the conveyer along with the crates. All the bottles are taken out from the crates and transferred to the next conveyer for another process. All the bottles are then transferred to bottle cleaner machines where steam pass at 4 kg/cm^2 pressure in chemical section with maximum temperature around 80°C. Basically, the bottle washing machine has preheating section, chemical section, hydra zone, and rinsing and discharge section. After washing, all the bottles are transferred on the conveyer to the filling hall and the filling process is carried out. Filled bottles are checked manually with light and conveyer and only quality bottles are transferred for further process and broken bottles are rejected.

Syrup are prepared from concentrate, RO water and sugar solution. Prepared syrup is cooled with glycol. Then the cooled syrup will be filled in the bottle within the filling point. Carbonification will be completed in final syrup using liquid carbon dioxide. All the filled bottles are checked manually with light and conveyer and only quality bottles are transferred for further process. All the bottles are then packaged in crates and transferred to the market and stores.

3.5.6 Significant energy used area and equipment in non-alcoholic beverages

The following area and equipment consume significant amount of energy:

- Boiler and Steam Distribution;
- Compressors;
- Lighting;
- Water Treatment Plant;
- Cooling Tower;
- Chillers and
- Diesel Generator.

3.5.7 Sampling and measurement for energy audit

The following electrical parameters are needed to be measured for electrical energy audit in nonalcoholic beverage industries:

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.

The following thermal parameters are needed to be measured for thermal energy audit in non-alcoholic beverage industries:

Boiler:

- **Flue Gas Analysis**: Measure oxygen, carbondioxide, carbonmonoxide, stack & ambient temperature.
- **Surface Heat Loss Measurement**: Measure surface temperature of 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.

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.

3.5.8 Potential Energy Conservation Opportunity in Non-Alcoholic Beverage Industry

The following energy conservation opportunities can be found in non-alcoholic beverage industries:

Table 3.10: Energy conservation opportunities in non-alcoholic beverage industry

S.N.	Energy Conservation Opportunities	Types of investment
1	Electricyty Demand Management	No Cost
2	Excess Air Control in Boiler	
3	Regular cleaning of cooling tower	
4	Regualr FAD of Compressor	
5	Calibrate all pressure guage and temperature indicator	
6	Optimise the all zone temperature in Bottle Washer	
7	Stopped conveyer while not in load	
8	Power Factor Improvement by installing capacitor bank with APFC units	Low Cost
9	Replace conventional lamp with LED	
10	Install On load tap changer in Transformer	
11	Install VFD for Pumps and Motors	
12	Insulation of bare steam pipes and fittings	
13	Install Economiser in Boiler	
14	Repair and install insulation in cold lines	
15	Improve insulation in Bottle washer	
16	Install Condensate recovery system	
17	Replace liquid fuel fired boiler to biomass or briquette fired boiler	Cost Demanding
18	Replace standard induction motors with energy efficienct motors	

3.6 PULP AND PAPER INDUSTRIES

3.6.1 Pulp and Paper Making Industries in Nepal

The pulp and paper industry has completed more than four decades of its production life in Nepal. Before that, the requirement of writing and printing paper used to be fulfilled by Indian paper industries. Nepalese handmade paper industries are also popular in Nepal but they are produced only a few ton/year and only have decorative value and belong to cottage industrial sector. As per the CBS 2011/12, there are 15 pulp and paper industries operational in Nepal.

Presently, the pulp and paper industries are producing mainly two types of products; the white (bleached writing & printing and newsprint paper) and the brown (unbleached kraft paper). Wastepaper and biomass are the main raw materials of the paper industries of Nepal. Due to international market compulsion, Nepalese industries are reducing the consumption of biomass and more focusing on wastepaper.

Papermaking is a high-energy consuming industry. Wastewater generations from pulping as black liquor and from bleaching as a white liquid are the major environmental concerns for the paper industry. These industries consume high amount of steam, which is produced from boiler mostly using husk as fuel.

3.6.2 Energy Use in Nepalese Pulp and Paper Industries

Energy used for the production of paper is mainly the electricity for machine operation and heat energy for cooking the raw materials which is derived mainly from biomass. All pulp and paper units are operated with boiler for steam generation. Most of the pulp and paper units use rice husk as fuel for boiler. The major electrical energy consumption areas are electric motors associated with pumps, agitators, paper machine and vacuum pumps. The other areas include compressors and lighting. Thermal energy in the form of steam is mainly used for cooking raw materials in digester and drying of paper that come out of the paper machine.

3.6.3 Specific Energy Consumption (SEC) in Pulp and Paper Sector

According to the present study findings, the specific energy consumption of the Industrial pulp and paper sector in Nepal is given below. Figures derived are based on the energy audit carried out in four pulp and paper units of Nepal.

Table 3.11: Specific Energy Consumption in Pulp and Paper

Specific Energy Consumption		
Description	**Electrical, kWh/MT**	**Thermal, GJ/MT**
WECS 2019/20	879.3	17.49
EEC, 2015 Nepal[11]	937	15.434
ESPS/DANIDA[12]	967	19.43
India[13]	-	2.25 to 3.0

3.6.4 General Process Flow Chart

Production process for pulp and paper vary according to product type. General flowchart for pulp and paper production is given below.

[11] EEC/FNCCI, 2005
[12] ESPS/DANIDA, 2001 to 2005, Nepal
[13] BEE, India

Input	**Process**	**Waste**
Wheat Straw Bagasse Fresh Water Caustic Sulphite Electricity Steam from boiler Manpower	Cooking (Digester)	Dust Raw material spillage Steam water spillage
Electricity	**Blowing and Store**	water spillage
Electricity Manpower	**Screening**	Foreign materials Black liquor
Decker water Fresh water Electricity Manpower	Poacher Washing and Refining	Black liquor Water spillage Rejects
Alum Rosin Soap stone Electricity Manpower	**Chemical Mixing**	Chemical spillage Water spillage
Tray water Fresh water Electricity Manpower	**Centric Cleaning**	Wastewater (Reused) Water spillage
Sodium hypo chlorite Electricity Manpower	**Bleaching**	Wastewater Water spillage
Electricity Manpower	**Turbo-beating and Thickening**	Wastewater Water spillage
Steam Electricity Manpower	**Paper Making**	Pulp spillage Condensate Broken paper
Packing materials Elect energy Manpower	**Re-winding and Packing**	Broke paper Damaged packing materials
	Paper	

Figure 3.7: General process flow chart of Pulp and Paper

3.6.5 Process Description

Raw material procurement and storage

Bagasse is the main raw material used in pulp and paper industry. Local and imported waste paper is also used as raw material besides bagasse. The processing for waste paper is however started from the hydro-pulping process.

Pulping

The bagasse is cooked in pressurized vessels called digesters. Approximately 12-16% of Sodium Sulphite is added to the loaded raw material and 10 m^3 of water at 90-95°C is added per ton of raw material. The mixture is cooked with 7-kg/cm2 steam pressures for about 5 hrs.

The digester is rotated at 0.4 rpm (approx.). Typically, delignification requires several hours at 170 to 176 °C (338 to 349 °F). Under these conditions, lignin and hemicellulose degrade to give fragments that are soluble in the strongly basic liquid.

Blowing

The cooked bagasse and wheat straw are blown to a collection tank called a blow tank that operates at atmospheric pressure. This releases a lot of steam and volatiles.

Screening

Screening of the pulp after pulping is a process whereby the pulp is separated from large shives, knots, dirt and other debris. The accepted mass is the pulp. The material separated from the pulp is called reject. The screening section consists of different types of sieves (screens) and centrifugal cleaning. The sieves are normally set up in a multistage cascade operation because considerable amounts of good fibers can go to the reject stream when trying to achieve maximum purity in the accept flow. The fiber containing shives and knots are separated from the rest of the reject and reprocessed either in a refiner or is sent back to the digester.

Washing

The brown stock from the blowing goes to the washing stages where the used cooking liquors are separated from the cellulose fibers. Normally, a pulp mill has 3-5 washing stages in series. Pulp washers use counter current flow between the stages such that the pulp moves in the opposite direction to the flow of washing waters. Several processes such as thickening / dilution, displacement and diffusion are involved.

Bleaching

Pulp must be bleached if it is used to make white paper. The objective of bleaching is to render the pulp white without degrading the cellulose. Some grades of paper don’t need bleaching at all (such as corrugated cardboard boxes) while others (newsprint) are given only light bleaching. Better grades of printing and writing papers require bleaching. Almost all bleaching is carried out with chlorine or chlorine compounds, leaving an effluent containing high levels of chemicals. In addition, bleaching is an energy intensive process and increases the energy intensity of papermaking by about 20 percent.

Stock preparation

Stock from the poacher and decker is transferred to the storage and chemical chest for sizing by adding alum and rosin. From the final storage chest stock goes through centricleaners to remove silica and other unwanted materials. Cleaned pulp stock flows to the stock regulation box for adjustment to the required consistency of the pulp by mixing recycled back water at fan pump.

Paper Making

Diluted stock is fed to the head box and discharged on the wire part of the paper machine where fibers form a uniform mat on the wire. Water is discharged through the wire and collected in the wire pit. The wet paper is de-watered mechanically using suction top vacuum and presses in 2-stage. The remaining moisture is dried in the MG drier cylinder using thermal energy. Dried paper is rolled into a spool at pop reel.

Re-winding section

Paper rolls are cut and rewinded to the required width. After quality checking, rolls are wrapped, strapped and stored for dispatch.

3.6.6 Significant energy used area and equipment in pulp and paper industries

The following area and equipment consume significant amount of energy:

- Boiler and Steam Distribution;
- Induction Motors;
- Compressor;
- Digester;
- Paper Mill and,
- Diesel Generator.

3.6.7 Sampling and measurement for energy audit

For Electrical System

The following electrical parameters are needed to be measured for electrical energy audit in pulp and paper industries:

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.

The following parameters are needed to be measured for thermal energy audit in pulp and paper industries:

Boiler:

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

- **Surface Heat Loss Measurement**: Measure surface temperature of body and steam pipelines.
- **Feed Water Analysis**: Measure pH, TDS, hardness, TSS and temperature.
- **Blow Down Water Analysis**: Measure pH & TDS.
- **Economizer & Air Preheater**: Measure inlet and outlet temperature.

3.6.8 Potential Energy Conservation Opportunity in Pulp and Paper Industries

The following energy conservation opportunities can be found in pulp and paper industries:

Table 3.12: Energy conservation opportunity in pulp and paper industries

S.N.	Energy Conservation Opportunities	Types of investment
1	Electricity Demand Management	No Cost
2	Excess Air Control in Boiler	
3	Feed less moistered fuel to boiler	
4	Regular cleaning of lighting sources	
5	Regular cleaning of all heat exchanger	
6	Install capacitor bank with APFC units for Power Factor Improvement	Low Cost
7	Replace conventional lamp with LED	
8	VFD for vaccuum Pump, agitator and Motor	
9	Replace old pump and motor with energy efficient pump & motor	
10	Insulation of bare steam pipes and fittings	
11	Install Economiser and air pre heater in Boiler	
12	Install on load tap changer in transformer	
14	Replacement of old compressors with new energy efficient compresors	Cost Demanding
15	Install Condensate Recovery System	
16	Install Super Heater	

3.7 STEEL RE-ROLLING MILLS

3.7.1 Steel Re-rolling Mills in Nepal

Steel re-rolling is one of the key segments of the steel industry. It mainly takes place in steel re-rolling mills that are considered as medium and large enterprises in Nepal. As per the CBS 2011/12, total of 20 steel re-rolling industries, which come under the category of basic iron and steel industry are under operation in Nepal. More than 4,883 employees are directly involved in these industries. Most of these industries are located in the Terai region of Nepal.

In the re-rolling industry, scrap irons, ingots and billets are mostly used as raw materials to produce rods, bars and steel sheets to be used in the domestic market. A furnace is used to heat up the billets so that they can be changed into different shapes.

Direct energy use in the rolling mills sector includes heating fuels and electrical energy. Indirect energy use is accounted by the use of energy intensive raw materials. In general, there is low awareness about energy efficiency and many companies lack the in-house engineering and technical manpower to absorb energy efficiency measures in their process and to operate high-end technologies.

3.7.2 Energy Use in Nepalese Steel Re-Rolling Industries

Steel re-rolling industries consume both electrical and thermal energy in its production processes. Main source of electricity is the national grid, whereas diesel generators are operated to conduct maintenance activities during power outage. Electrical energy is mainly consumed by motors used in rolling and machining applications, compressors (mainly air compressor), pumps, blower and cooling tower. Other electricity consuming processes are lighting and material handling. Thermal energy is required for the operation of re-heating furnace. Fuel used for the boiler operation is mainly furnace oil and coal. Diesel is also used in some industries.

3.7.3 Specific Energy Consumption (SEC) in Steel Re-Rolling Industry Sector

According to the present study findings, the specific energy consumption of the Industrial steel re-rolling sector in Nepal is given below. Figures derived are based on the energy audit carried out in four Steel re-rolling units of Nepal.

Table 3.13: Specific Energy Consumption in Steel Re-Rolling Mills

Specific Energy Consumption		
Description	**Electrical, kWh/MT**	**Thermal, GJ/MT**
WECS 2019/20	110.0	2.13
EEC, 2015, Nepal[14]	100 – 125	1.8-2.01
ESPS/DANIDA[15]	149.17	1.8-2.41
India[16]	97	2.3

[14] EEC/FNCCI, 2005, Nepal
[15] ESPS/DANIDA, 2001 to 2005, Nepal
[16] BEE, India

3.7.4 General Process Flow Chart

General flowchart of TMT bar production process is given below:

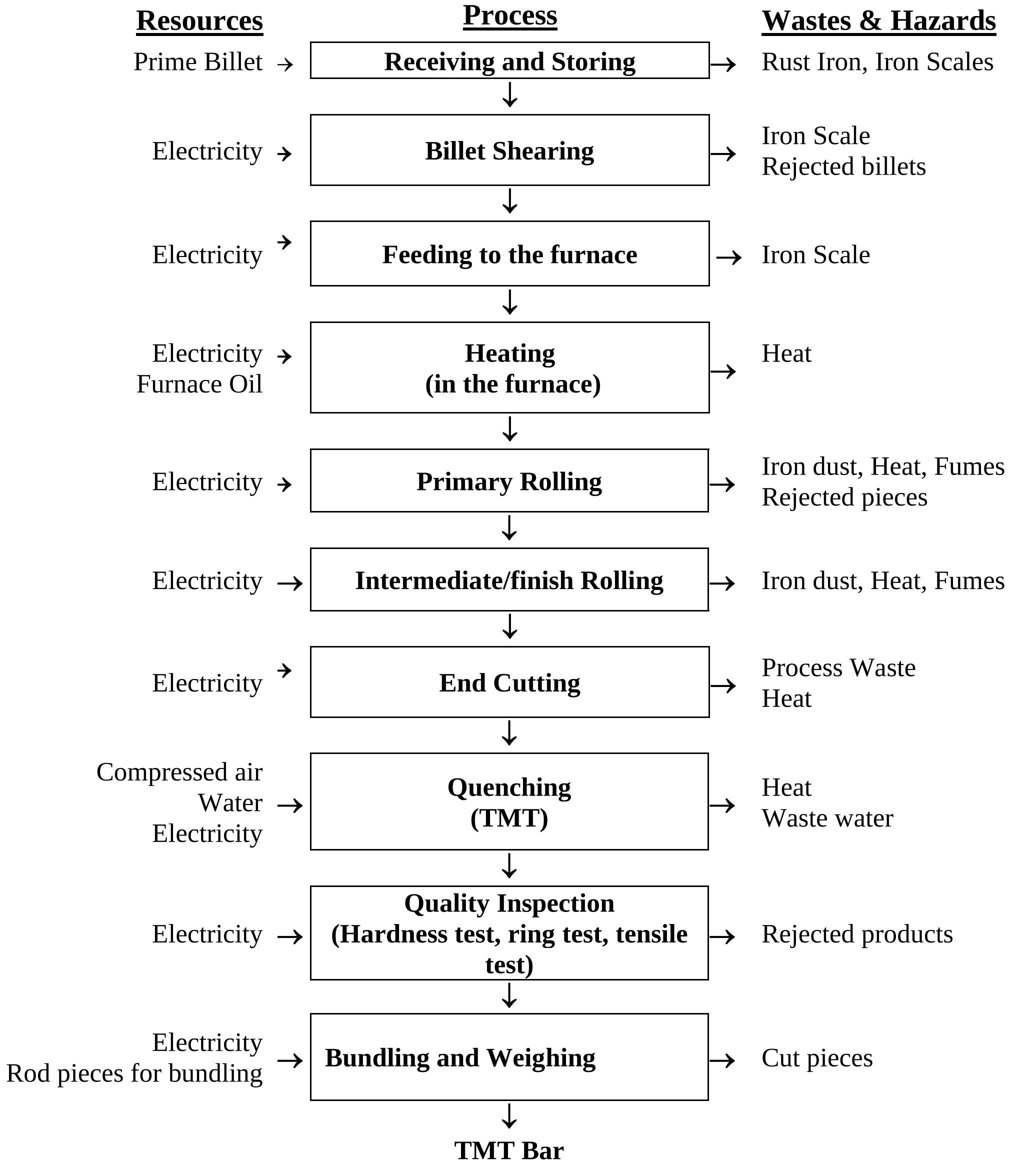


Figure 3.8: General Process flowchart of steel re-rolling mill

3.7.5 Process Description

Mild Steel billets of different area cross-section and length is mainly imported from India. These billets are the major raw material for the steel re-rolling industry for the production of TMT bars.

Billet Shearing

MS billets are transferred to the conveyer of the shearing machine by winch or overhead crane from the adjacent stockpile. The billets travel to the stopper in the conveyer such that the length of the sheared piece is as set by the operator. The billet is then cut to the required size by the shearing machine. Some industries also use in house MS ingots.

Billet Heating

Sheared billets or in house ingots are transferred to the chain conveyer of the furnace. These billets are charged inside the furnace by pusher and travel through preheating zone, heating and soaking zone of the furnace before being ejected for rolling process. Billets are heated up to 1050 - 1150° C in the furnace.

Rolling

The hot billets pass through roughing stands. There are normally four stands in the roughing unit. The first stand reduces sectional area of billets in eight stages. The second stand reduces sectional area in two stages, the third stand reduces sectional area in two stages and finally the fourth stand reduces sectional area in a single stage. After completion of roughing process, billets now in the form of deformed rod is passed through the finishing mill. There are two sections in the finishing mill, intermediate and final finishing. In between roughing and finishing mill, there is a system to cut the ends of rolled heated billets which is important to overcome the problems of miss roll formation.

TMT (Thermo-mechanical treatment)

The billet temperature again drops down to 900˚C- 950˚C during its travel through mills and thus reaching quenching process. At quenching stage, the billets are passed through high jet cold water, where the temperature is instantaneously brought down to 250˚C. The iron rods are then stockpiled according to the size in a yard and finally loaded and transported by trucks to destination. The detailed process is presented below:

TMT bar stands for Thermo Mechanically Treated bar. In this process, steel billets/ingots that are heated in a reheating furnace and rolled through a sequence of rolling stands, which progressively reduces the cross section of billets/ingots to the finished size and shape of the TMT reinforcement bar. This hot bar after exiting from the rolling process is quenched and self-tempered to give the bar more strength and ductility through three steps.

Quenching

A high pressure water spray system is used on the hot rolled bar to turn its periphery into a martensite zone (hard zone), while keeping its inner surface ferrite perlite.

Self – Tempering

In this stage, the bar leaves the quenching system with the temperature of the core being much higher than that of the surface. That makes heat to flow from the core to the surface, making the surface tempered, and a structure that is called "Tempered Martensite".

Atmospheric cooling

In this final stage, cooling takes place on the cooling bed where the final structure consists of hard outer periphery making it more stronger, more corrosion resistant and fire resistant. The soft inner surface gives the metal ductility (more bendability & elongation), and better fatigue resistance able to withstand natural calamities and other forces better. The production of quality TMT bar depends on three major factors - quality of raw materials, a properly designed and automated mill, and a well-designed quenching the tempering technology.

Cutting

Shearing machines cut the cooled rolled bars to the specified length.

Bundling and quality control

Specified numbers of bars are then bundled together by rings and are bent from the middle. They are then tied with “S” shaped hooks. Sampling is done from the finished product for quality check and approval.

3.7.6 Significant energy used area and equipment in steel re-rolling mills

The following area and equipment consume significant amount of energy:

- Furnace;
- Induction;
- Pumping System;
- Cooling Tower;
- Coal Crusher;
- Lighting;
- Compressor and,
- Diesel Generator.

3.7.7 Sampling and measurement for energy audit

The following electrical parameters are needed to be measured for electrical energy audit in steel re-roling industries:

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.

The following thermal parameters are needed to be measured for thermal energy audit in steel re-roling industries:

Furnace:

- **Flue Gas Analysis**: Measure oxygen, carbondioxide, carbonmonoxide, stack & ambient temperature.
- **Surface Heat Loss Measurement**: Measure surface temperature of body and steam pipelines.
- **Recuperator**: Measure inlet and outlet temperature.

Heat Exchanger: Measure inlet and outlet temperature.

Cooling Tower: Measure inlet and outlet temperature.

3.7.8 Potential Energy Conservation Opportunity in Steel Re-Rolling Mills

The following energy conservation opportunities can be found in steel re-rolling mills:

Table 3.14: Energy conservation opportunities in steel re-rolling mills

S.N.	Energy Conservation Opportunities	Types of investment
1	Electricity Demand Management	No Cost
2	Optimum supply of air in Furnace	
3	Optimum opening of furnace door to reduce heat loss	
4	Use less moistured fuel in Furnace	
5	Reduce retention time of billette in furnace for prevention of scaling	
6	Use rolled billets in place of continuous cast billets to save electrical energy	
7	Power Factor Improvement by installing capacitor bank with APFC units	Low Cost
8	Install Temperature measuring device in all zone of Furnace, stack and inlet air	
9	Replace conventional lamp with LED	
10	Install VFD for Pumps and Motors	
11	Replace old pump and motor with energy efficient pump & motor	
12	Repair Insulation of Furnace	
13	Install Recupuretor	Cost Demanding
14	Ceramic paint coating inside the furnace	

3.8 SUGAR MILLS

3.8.1 Sugar Mills in Nepal

Sugar industries are the agriculture based seasonal industries. As per the CBS 2011/12, there are 54 sugar industries under operation in Nepal. Among them, only 13 are considered large scale sugar industries. These mills have 800 to 5000 TCD capacities to crushed sugarcane per day (DoI, 2019). Due to the availability of the main raw material i.e. sugarcane, most of the sugar industries are located in the Terai region. Large-scale sugar industries have the semi-automatic type of production system. It produces different grades of sugar and molasses as a byproduct. Sugarcane is the main raw material of this industry and it also consumes many chemicals for processing and purification of sugar.

Larger capacities of boilers are operated in large-scale sugar industries. Sugar mills use their own byproduct "Baggasse" as a fuel for boiler. All the large-scale sugar industries have cogeneration system, so they generate electricity for their own use.

3.8.2 Energy Use in Nepalese Sugar Industries

Sugar industries consume both electrical and thermal energy in their production processes. The combined heat and power (CHP) system also known as co-generation serves as the major source of energy for the plant during the crushing season. However, electricity supply from the Nepal Electricity Authority (NEA) is the main source of energy to the plant during non-crushing season. Major electrical energy consuming areas are motors installed in the cane cutters, cane kicker, fibriser, milling tandem, pumps, vacuum system, carriers, centrifuges, ID and FD fans of boiler and compressed air generation. Thermal energy is mainly for generation of electrical power in the co-generation plant and for process heating.

3.8.3 Specific Energy Consumption (SEC) in Sugar Sector

According to the present study findings, the specific energy consumption of the Industrial sugar sector in Nepal is given below. Figures derived are based on the energy audit carried out in four sugar industry units of Nepal.

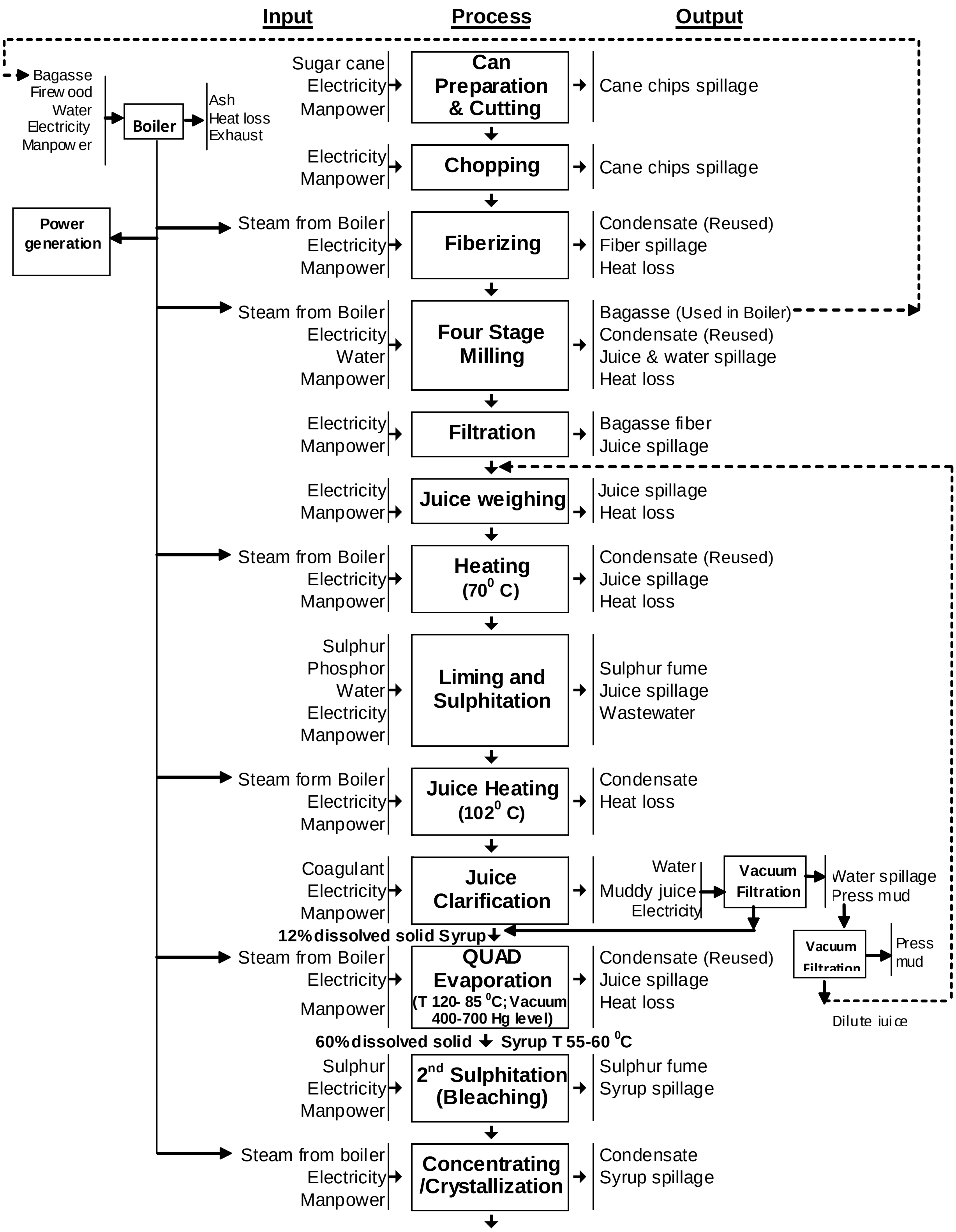
Table 3.15: Specific Energy Consumption in Sugar Sector

Specific Energy Consumption		
Description	**Electrical,** kWh/MT (Cane Crushed)	**Thermal, GJ/MT** (Cane Crushed)
WECS 2019/20	33.5	4.03
ESPS/DANIDA [17]	45 – 50	4.11
India[18]	22	3.48

[17] ESPS/DANIDA, 2001 to 2005, Nepal
[18] BEE, India

3.8.4 General Process Flow Chart

General process flowchart for sugar production is given below:



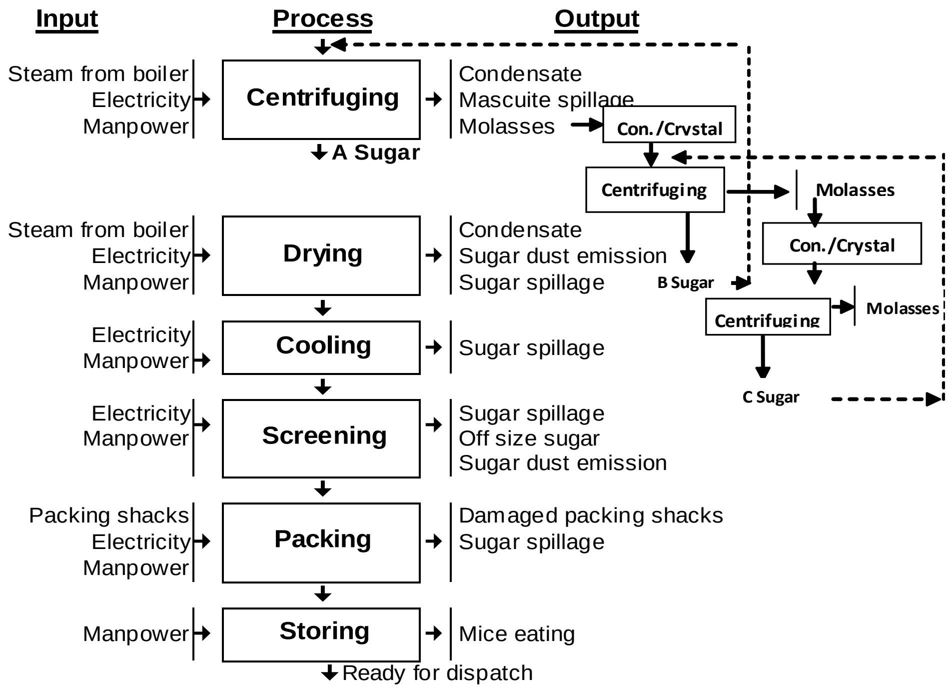


Figure 3.9: Sugar Production Process Flowchart

3.8.5 Process Description

The process in the sugar plant starts with the cane preparation process and subsequently followed by processes as described below:

Cane Preparation

The cane from transportation means is unloaded with the help of three unloaders into the cane carrier. The cane carrier transports cane to the cane mill. Cane kicker installed over the carrier helps to push back the cane to regulate the flow. The cane leveler further helps to level the cane to the bed height with the help of rotating knives. Cane cutter, which is a rotating drum with knives on its hub, cuts the incoming cane to small pieces. The pusher regulates the correct flow into the fibriser. The fibriser, which consists of rotating drum with arm filled with swing hammers, helps to fibrise the cane. The preparation index of the prepared cane is maintained at 80 to 85 %.

Rack Carrier, transports the prepared cane from the fibrizer to the belt conveyor. Over the belt conveyor, magnetic separator helps in capturing iron pieces, if any. The belt conveyor feeds the fibrised, cleaned cane to the first mill.

Milling:

There are five sets of mills, each having three rollers. These are the top roller, feed roller and discharge roller. The rollers squeeze the cane fibers and the juice move to the troughs. The juice rich bagasse from one mill move to the next mill.

The bagasse obtained after de-juicing the cane in the mills is transported in the rake conveyors towards the boilers. The opening slots provided in the trough of the rake transporter facilitates feeding the bagasse to the individual boilers. The balance bagasse is transported to the bagasse storage yard. The return bagasse carrier transports the bagasse from the bagasse storage yard to the main carrier whenever necessary.

Juice Clarification:

The mixed juice obtained from the mill is pumped into the sugar boiling (process house) for processing through the flow meter for the measurement of juice quantity. First of all, the mixed juice is heated up to 70 to 72°C in two stages (up to 50 to 60°C in the first stage using 4th evaporator vapour and thereafter to the desired temperature of 70 to 72°C using either vapour from vapour cell or from the back pressure turbine exhaust header). Then the heated mix juice goes to the juice sulphiter where milk of lime $Ca(OH)_2$ and SO_2 gas (prepared by dummy sulfur in air to produce SO_2) are added. The $Ca(OH)_2$ is added followed by SO_2 to maintain pH at 7-7.2. In this process, the mixed juice is neutralized and the muddy substance begin to flocculate for easy settlement in clarifier.

The sulphited juice obtained from the sulfiter is called sulphited juice which is further heated up to 101 to 105°C in 2 stages. In the first stage, heating is done in the juice heater using evaporator's second body vapour and the temperature is raised up to 85 to 88°C. In the second stage juice heater, the exhaust from back pressure turbine header is used to raise temperature further to desired level (101-102°C). The heated sulphited juice is pumped to the clarifier for settlement, which takes around 2.5 hours (and the process remains continuous).

The top supernatant clear juice is directly drawn (through overflow spout) from the clarifier and sent to the evaporator through clear juice heater which are (plate type heat exchangers) PHE, where it is heated up to 108 to 110°C by using semi kestres vapour or exhaust steam from BPT headers. The bottom muddy juice (clarifier sludge) is sent by gravity to a rotary vacuum filter for filtration, where it is separated as filter cake and filtrate. The filter cake (mud) is sent to the bio-compost manufacturing plant through a belt conveyor. Condensate from steam of juice heater is pumped to the vapour condensate (hot water overhead) tank by individual pumps.

Evaporation

The heated clear juice having a concentration of 12-13% brix is fed to multiple effect evaporator for concentration. The factory has a double effect vapor cell (DEVC) plus quintuple effect evaporators. The concentrated juice coming out of the evaporator is known as syrup with concentration of 55-60% brix. The vapour is bled through a bleeding arrangement as follows:

I. 1st effect of DEVC (SK): for C pan boiling, clear juice is heater

II. 2nd effect of DEVC (VC): for A and B pan boiling, raw juice 2nd heating compartment.

III. 3rd effect of quintuple evaporator: Sulphited juice first heating.

IV. 4th effect of quintuple evaporator: Raw juice 1st heating

The exhaust steam condensate from the 1st effect of DEVC (SK) and 1st effect of quintuple evaporator is sent to the boiler as feed water at temperature of about 110 to 112°C. Vapor condensate from the remaining 4 effects of the quadruple evaporator is individually pumped and collected in the vapor condensate (O/H hot water) tank and is used for, i) mill imbibitions ii) filter cake washing, iii) lime preparation iv) sugar washers in centrifuges etc. The balance quantity of vapor condensate is cooled in a cooling tower (package type) up to 35°C and used as fresh cold water (bearing cooling water, laboratory etc.)

The vacuum required for the quintuple effect evaporator is created by the single entry multi jet condenser. Vacuum of around 25 mm HG is created at the last effect of the quintuple effect evaporator. The vacuum in the preceding 3 effects will gradually decrease (one single pump suffices to supply water to the condenser for vacuum creation). Syrup is firstly sent to the syrup sulfiter where it is sulpited up to the pH of 5.5-5.2 by blowing SO_2 gas. Here the bleaching action occurs and viscosity is reduced.

Juice Crystallization:

Seven numbers of vacuum pans are used for the crystallization of sugar. The distribution is as follows:

i) 3 nos. for A massecute boiling

ii) 2 nos. for B masecute boiling

iii) 2 nos. for C massecute boiling.

Here, vacuum in each pan is created by individual condensers. The pressurized water is supplied through a common header fed by four pumps at a time. There are seven condenser pumps in total, of which one pump is for quintuple evaporator, four are for pans and two are standby.

"A" massecute is prepared using sulfited syrup, sugar melt obtained from melting of B and C sugar and dry seed (mother crystals) from sieve of sugar grades. It is dropped to the 'A' crystallizer when desired size of crystal is attained. The crystallizer helps further crystallization as well as acts as a massecute storage vessel.

A massecute is cured using flat bottom plough centrifugal machines where sugar crystals and mother liquor (molasses) are separated. Sugar is then conveyed and dried in grass- hoppers. Sugar is then sent to a vibrating screen feeder where it is graded. The Crystals below the desired size is separated and used as mother crystals (seed) for A-pan boiling. The graded sugar is sent to the sugar packing section through a belt conveyor where it is bagged in 50 kg bags.

The molasses obtained from the A-massecute in curing is known as A-molasses, which is used for B-massecute boiling. The B-massecute is similarly centrifuged and the B sugar and B molasses is obtained. The B molasses is again crystallized in C-pan to obtain C-massecute.

The C-massecute is centrifuged to obtain c-sugar and final molasses. The C-sugar is double cured (again centrifuged) and the double cured C-sugar along with B-sugar is melted in a sugar melter and sent to A-pan for A-massecute preparation. The final molasses is sent to the molasses storage tank as a raw material for distillery plant with a concentration of around 80-90% brix.

3.8.6 Significant Energy used area and equipment in Sugar Industries

The following area and equipment consume significant amount of energy:

- Boiler and Steam Distribution;
- Co-generation;
- Induction Motors;
- Milling;
- Lighting;
- Pumping System;
- Cooling Tower;
- Compressor;
- Diesel Generator;
- Heat Exchanger and,
- Water Treatment Plant.

3.8.7 Sampling and measurement for energy audit

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

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.

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

Boiler:

- **Flue Gas Analysis**: Measure oxygen, carbondioxide, carbonmonoxide, stack & ambient temperature.
- **Surface Heat Loss Measurement**: Measure surface temperature of body and steam pipelines.
- **Feed Water Analysis**: Measure pH, TDS, hardness, TSS and temperature.
- **Blow Down Water Analysis**: Measure pH & TDS.
- **Economizer & Air Preheater**: Measure inlet and outlet temperature.

Heat Exchanger: Measure inlet and outlet temperature.

Cooling Tower: Measure inlet and outlet temperature.

3.8.8 Potential Energy Conservation Opportunity in Sugar Industries

The following energy conservation opportunities can be found in sugar industries:

Table 3.16: Energy conservation opportunities in sugar industries

S.N.	Energy Conservation Opportunities	Types of investment
1	Electricity Demand Management	No Cost
2	Excess Air Control in Boiler	
3	Savings achievable by Proper Boiler tuning.	
4	Reduction in moisture content of bagasse used in boiler from 50 % to 30 %.	
5	Contro steam leakages from valve and flanges	
6	Regualr FAD in Compressor	

7	Install capacitor bank with APFC units for Power Factor Improvement	Low Cost
8	Replace conventional lamp with LED	
9	Install VFD for Pumps and Motors	
10	Replace old pump and motor with energy efficient pump & motor	
11	Insulation of bare steam pipes and fittings	
12	Install Economiser and Air Pre Heater in Boiler	
13	Regular Cleaning of heat exchanger	
14	Install Condensate Recovery System	Cost Demanding
15	Install Efficient turbine to generate electricity	
16	Install Super Heater	

3.8.9 Benefits of Cogeneration in Sugar Industries

Cogeneration is defined as the generation of electricity and heat from the same energy source. The term is often applied to systems that use waste material from an industrial process to generate steam, which is used to generate electricity and process heat for the industrial process itself. Sugar mills, where bagasse leftover from cane crushing is used to generate steam, which conventionally powers a steam turbine generator and produces heat for the sugar production process. The electricity produced is often more than what is required in the mill, and is usually fed into the grid. This surplus electricity is an important asset as it can be sold to the utility.

Bagasse is the fibrous residue of cane stalk obtained after crushing and the extraction of juice in sugar mills. Each ton of sugarcane can yield 250 kg of bagasse. The composition of bagasse varies with variety and maturity of sugarcane as well as with harvesting methods used and efficiency of the sugar mill in processing the sugarcane. Every ton of sugar has an energy potential equivalent to that of 1.2 barrels of petroleum. Sugar mills have been designed to meet their energy requirements by burning bagasse: this was seen as an economic means of producing electricity whilst cheaply disposing of bagasse.

Electricity costs and tariff hikes are making it profitable for sugar mills to generate surplus electricity from biomass such as bagasse and supply to the grid. In most sugar mills, the bagasse produced exceeds what is required for both sugar production and mill electricity demand, and could be used to produce carbon neutral electricity for sale to the grid. The process of bagasse cogeneration is sketched out in the figure below.

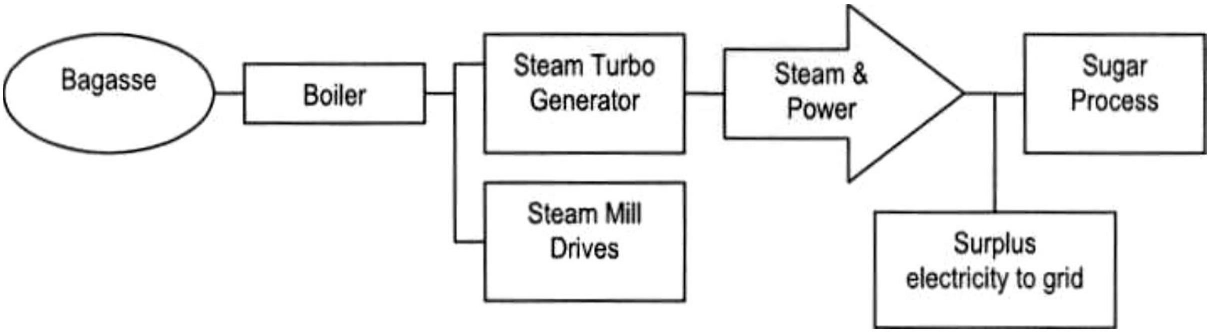


Figure 3.10: Overview of Bagasse Cogeneration

Almost all sugar mills are self-sufficient in terms of energy supply and many of them have been selling their surplus electricity to the grid. In many mills, the bagasse production is more than required for the daily energy requirements of the mill, and excess can be stored for electricity production in the off season. This is only possible with a steam cycle where steam production can be separated from the process steam usage cycle. The inclusion of sugar trash in the fuel used for boiler makes a tremendous difference to the amount of electricity that can be generated.

Note: The performance calculation for steam turbine and gas turbine is in Annex 15.

CHAPTER 4: ENERGY CONSERVATION OPPORTUNITIES IN INDUSTRIAL SECTORS

4.1 Electrical load and demand management

In Nepal, electricity billing adopted for industrial 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, apparent power, and power factor (PF).

Typical billing pattern by NEA for an industrial sector having 11 kV electricity supply is given below. Tariff scheme for industries/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 industrial sectors from Baishak to Mangsir 2074/75

S.N	Period	NPR./kWh
1.	Peak time (5 PM to 11 PM), T1	10.50
2.	Normal time (5 AM to 5 PM), T2	08.52
3.	Off peak time (11 PM to 5 AM), T3	05.40
Demand charges		NPR.250/kVA

Table 4.2: Electricity tariff (NEA) applicable to industrial sectors from Poush to Chaitra 2074/75

S.N	Period	NPR./kWh
1.	Peak time (5 PM to 11 PM), T1	10.50
2.	Normal time (5 AM to 5 PM), T2	08.52
3.	Off peak time (11 PM to 5 AM), T3	08.52
Demand charges		NPR.250/kVA

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 to 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.

4.3.2 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.

4.3.3 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.

4.3.4 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.

4.3.5 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 $\sqrt{3}$ 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.

4.3.6 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 calculations is in Annex 9. 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 industrial 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, industrial 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 an industry.

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

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

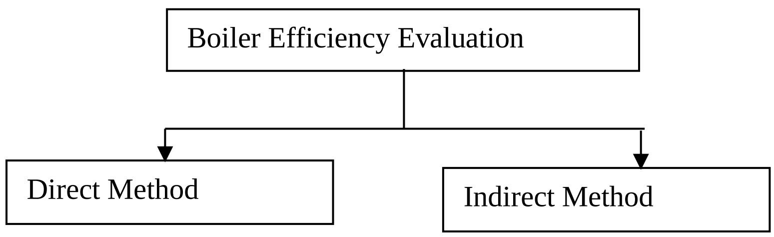


Figure 4.1: Boiler Efficiency Method

Note: The details of Direct and Indirect methods for Boiler Efficiency calculations is in Annex 6 (a) and (b).

- Data collection format for Boiler Performance Assessment is in Annex 6 (d).
- The schematic diagram of boiler and boiler house is in Annex 6 (f).

- The detail calculation sheet for surface heat loss calculation is in Annex 8.

4.7 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. Heat is removed from a low-temperature reservoir and transferred to a high-temperature reservoir. In other words, refrigeration means artificial 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, industrial 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 for HVAC calculation is in Annex 9 and the detail for Cooling Tower calculation is in Annex 12. Refrigeration and AC may be broadly classified into two types, as given below:

4.7.1 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.

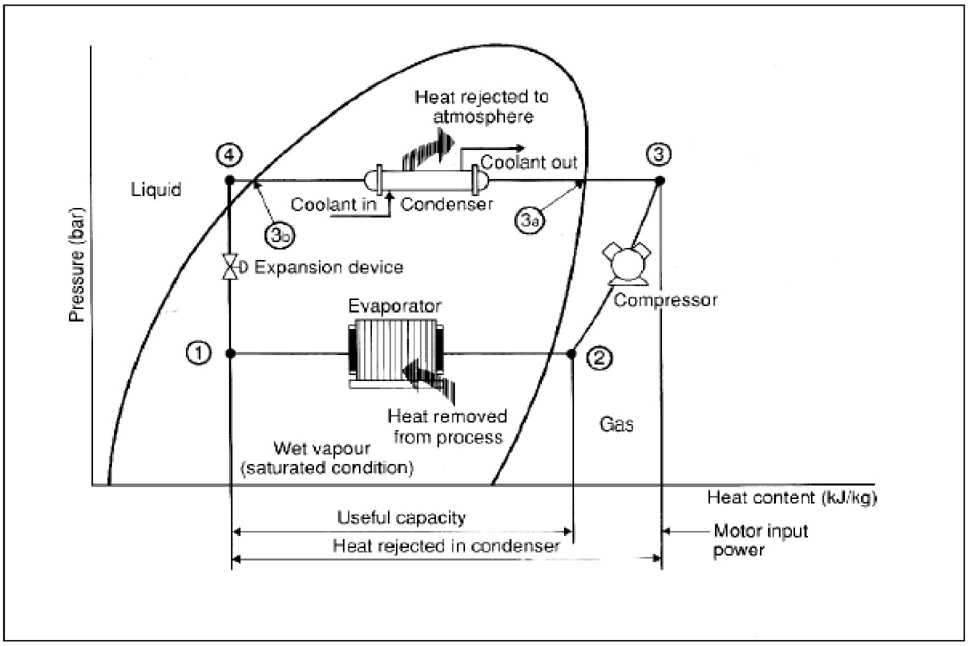


Figure 4.2: Schematic of a Basic Vapour Compression Refrigeration System

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.

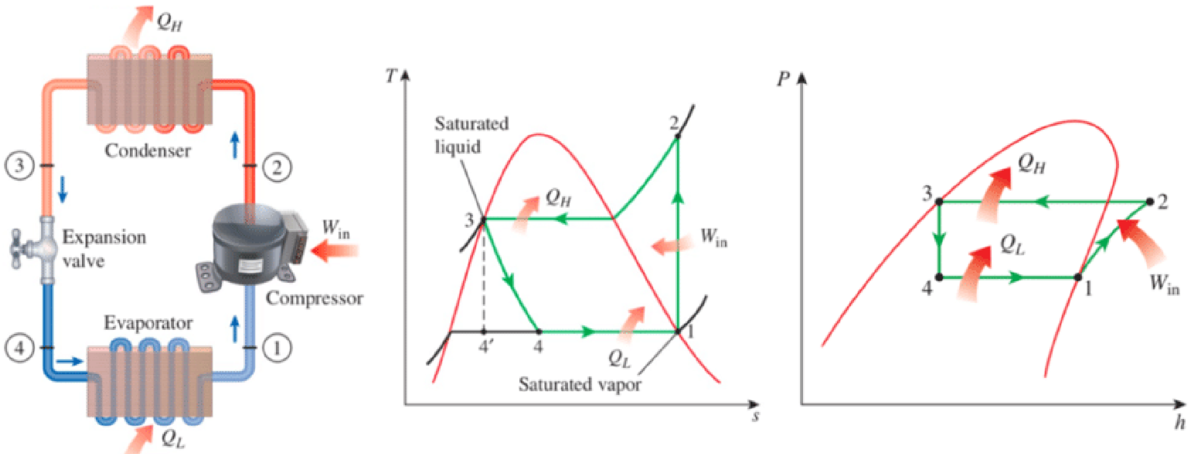


Figure 4.3: T-S and P-V diagram of Refrigeration cycle

4.7.2 Vapor 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:

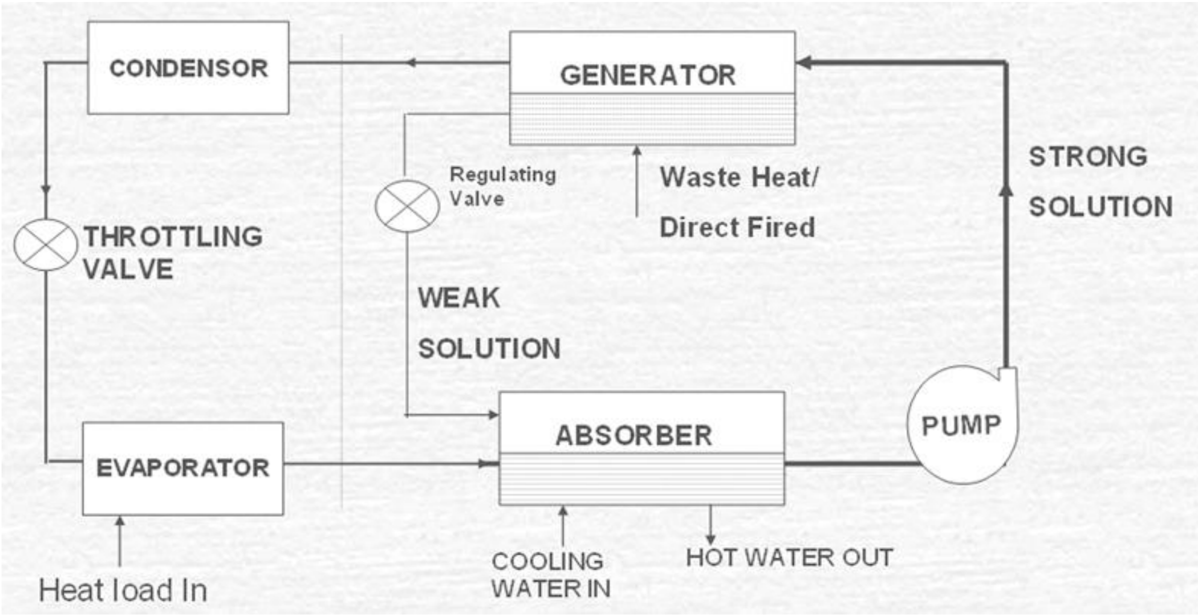


Figure 4.4: Schematic of a Basic Vapour Absorption Refrigeration System

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^{o} 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 industries 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 (second, minutes or hours). 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 AC plant components as per manufacturer guidelines;
- 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.

4.8 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 for calculation of fan is in Annex 12.

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. 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 4.3: 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.

4.9 Opportunities in Pumping System

Studies indicate that the average pumping efficiency in manufacturing plants can be less than 40%. Oversized pumps and the use of throttle valves are identified as the two major contributors to the loss of efficiency. Energy saving of between 30% and 50% in pumping systems could be realized through equipment or control system changes. The detail for calculation of pump is in Annex 11. Some of the potential causes of inefficiency and measures for improvement are as follows.

Table 4.4: 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

4.10 Opportunities in process and Heat Recovery (Boiler)

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 100 ºC only. Every rise of 6 ºC 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 22 ºC for heat recovery, fuel savings of about 1% can be achieved.

4.11 Benefits of FD & ID Fan in Boiler

a. FD (Forced Draft) Fan

- FD fan provides the required quantity of 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 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 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.

4.12 Firing optimization and better operating practices (Brick Kiln)

a. Storing of Coal

Proper storage of coal minimizes the chances of self-ignition in the coal stock itself. Improper storage leads to deterioration of its quality. Therefore,

- Never allow dust and keri to mix with coal;
- Stack coal on a raised platform with proper flooring and drainage;
- Height of the coal stack should not be more than 1.5m;
- Coal should be stored in a shed with proper ventilation.

Figure 4.5: Existing Practices

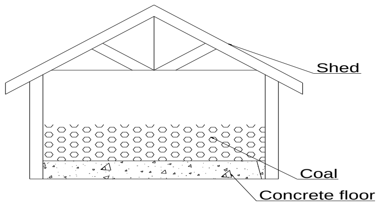


Figure 4.6: Recommended Practice

b. Coal Size

- Recommended coal size: Powdered to 3/4inch. This would help in uniform brick quality as powdered coal ignites immediately on feeding thereby releasing heat to the top layer of brick setting, whereas large sized coal particles release heat at the bottom of the brick setting.
- If large sized coal lumps are fed, bricks at the bottom of the kiln get over- burnt.
- Small sized coal improves air-fuel mixing thus accelerating the rate of combustion. Appropriate size of coal can be obtained by screening/crushing of large sized coal, with the use of coal crusher.
- Use coal crushers for crushing of coal.

Figure 4.7: Large Size Coal

Figure 4.8: Recommended Smaller Size Coal

c. Spoon Size

Use of large spoon of capacity 1.5 –2.0 kg leads to the wastage of fuel and over-burning of bricks. Therefore,

- Feed coal at uniform intervals with a spoon of 450-650 grams capacity.
- Large size spoon could be used only for raising the temperature in particular lines.

Figure 4.9: Convectional large size spoon

Figure 4.10: Recommended small size spoon

d. Fuel Feeding Pattern

Since there is a continuous flow of air in the kiln, ideally fuel feeding should also be done continuously. This can be achieved by single man firing with Z pattern.

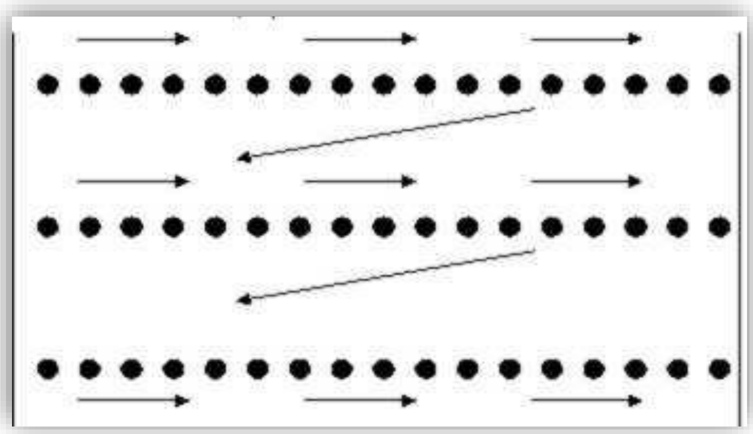


Figure 4.11: Fuel feeding pattern

e. Function of Chimney

In a Bull Trench Kin, a draught is necessary for fire to travel horizontally and for proper combustion. The draught may be provided by a chimney or a mechanical device (Fan). Draught available in a BTK can be classified under two heads:

i. Static draught
ii. Operating draught

The static draught depends on the height of the chimney and the temperature gradient and operating draught is the net draught available for operating the kiln. Apart from the height of the chimney and temperature gradient, the operating draught also depends upon the diameter of the chimney.

Figure 4.12: Conventional Fixed Chimney

Figure 4.13: Improved Fixed Chimney

f. Role of Air

The role of air in a BTK can be described as follows:

- To support combustion process;
- To act as a medium of heat transfer from cooling zone to firing zone and from firing zone to pre-heating zone;
- To help in carrying away the steam generated during the drying of green bricks.

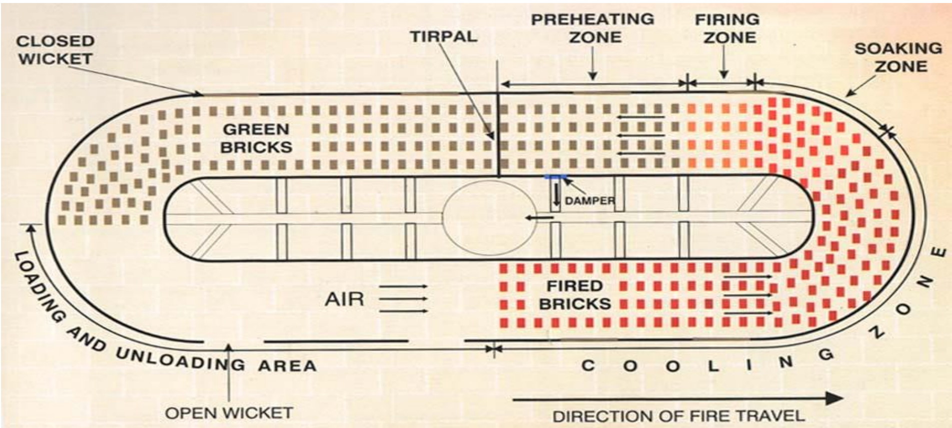


Figure 4.14: Air flow diagram in brick kiln

Sufficient air supply should be maintained in a kiln by adopting following practices:

- Stacking the bricks properly (loose setting);
- Keeping the cooling zone 150-160 feet long;
- Inspecting and cleaning of flues and chimney (in case of fixed chimney);
- Avoiding leakages from various components of kilns;
- In case of fixed chimney, the flue gas temperature in chimney should not fall very low, while inducing in the next chamber, which can be achieved by:
  - Controlling draught using plate dampers (Chavi) in the side flues;
  - Removing the temporary partition; opening the next and closing one flue in use simultaneously.

Figure 4.15: Straight Line Brick Setting

Figure 4.16: Zigzag Brick Setting (Chamber system)

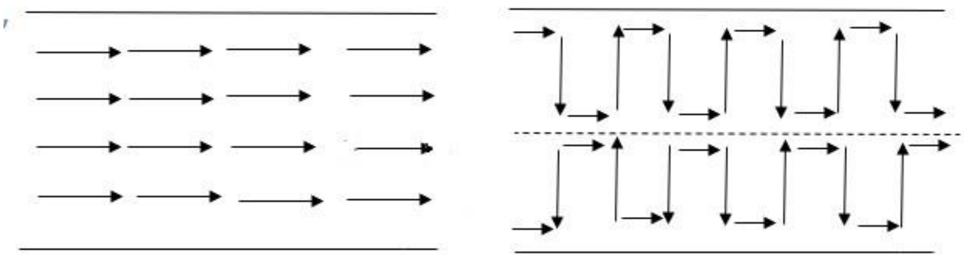


Figure 4.17: Straight Air flow & Zig Zag Air flow

g. Combustion Practices

The Optimal length of firing/combustion zone depends on the rate of travel of fire in the kiln. The longer the firing zone, the better the combustion of fuel.

The use of Damper/Tirpal

Tirpal/Dampers are used in a BTK to divide the kiln into different chambers. Various dampers used in practice are:

- Jute Tirpal;
- Plastic sheet.

Figure 4.18: Jute Tripal

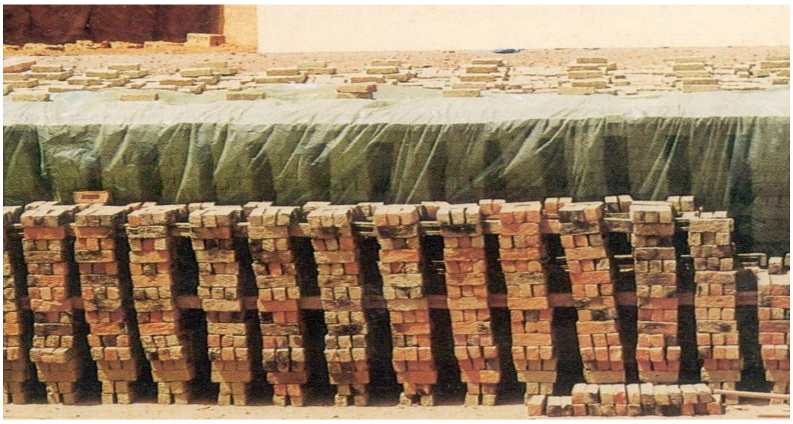


Figure 4.19: Plastic sheet

Dampers provided as temporary partition at the time of brick setting are removed whenever a new chamber is to be induced in the circuit. The following recommendations are made for the proper use of dampers

- The damper/tirpal should be placed after brick setting (*Bhara*i) at the end of the day. A minimum distance of 80-90 feet is recommended between the damper and the firing zone (preheating zone).
- The dampers should be ensured airtight; otherwise, leakage will reduce draught leading to lower combustion and fuel consumption.
- When green brick with higher moisture content are loaded, it is recommended that dampers be used at smaller distance. Otherwise, the moisture will accumulate near the damper that can cause the brick setting to crumble (***Dhasan***).

4.13 Reduction of Fuel Consumption

Fuel is the largest component in the input cost for the manufacturing of bricks. It accounts for 40–50% of the production cost in fixed chimney kilns and 50-60% in movable kilns. Typical coal consumption in fixed chimney BTK varies from 8 to 15 tons per lakh of fired bricks.

a. Heat balance from different processes

Only a small amount of fuel supplied (generally in the range of 25-40%) is useful in the kiln. Here, useful utilization refers to:

- The energy required for removal of moisture in green bricks as set in the kilns;
- Energy required for completing irreversible chemical reactions in the clay.

Rest of the 60-80% of the fuel supplied to the kiln is dissipated in various forms. The main components of heat losses are:

1. Sensible heat in unloaded fired bricks (5 to 10%);
2. Sensible heat in dry flue gases (5 to 10%);
3. Heat loss from the surface of the kiln, particularly from the top ash covering (15-25%);
4. Heat loss to ground and kiln structure (10-25%);
5. Unburnt fuel in the form of unburnt or partially burnt coal, carbon monoxide and unburnt hydrocarbon gases (5-10%).

b. Fuel saving by improving operation

Some common measures of better operating practices in kilns can lead 10-20% fuel savings. Some of the commonly practiced measures of this kind are:

- The fuel required for drying green bricks in the kiln can be reduced by ensuring that only dry green bricks with moisture contents of 5% or less are loaded on the kiln.

- Sensible heat loss in dry flue gases can be reduced by controlling the air quantity and temperature of flue gases. In general, the excess air level should not exceed 300–400%, while the temperature of flue gas should be kept between 100-120°C. Almost all the kilns suffer from the problems of air leakage. Particularly care should be taken to plug air leakage through wall constructed to block flue ducts, tripal and wicket gates.
- The unburnt fuel/gases can be minimized by improving fuel feeding practices in following ways:
  a) Manual feeding of fuel in small quantity at an interval of 15-20 minutes or restoring to mechanical coal stoker feeding;
  b) Using coal crusher to reduce the coal partial size to less than 20 mm;
  c) Starting coal feeding in a fresh row only after ensuring that the temperature at the bottom of the row is in the excess of 700°C.

c. Fuel saving by minimizing the heat loss through structure

Improvements of kiln design and construction are particularly useful for reducing the kiln structure losses, which can be as high as 25% in some of the kilns. Following are the major areas from which maximum heat loss occurs.

a) Heat loss through surface of the kilns;
b) Heat loss to ground;
c) Heat loss from wicket gate (Dwari);
d) Heat loss through feed hole covers (Tawa).

In these cases, we can minimize the heat loss by taking following consideration.

1. Wicket wall: Minimum thickness as 22 inches with 3-4 inches Kerri filling between the walls and mud plastering on both sides;
2. Side flue cut off wall: 13.5 inches thick with staggered joints and mud plastering;
3. Kerri thickness at the top of the brick setting should be 7 inch or more;
4. Feedhole cover (Tawa) should be insulated from which remarkable amount of heat is radiated;
5. Heat loss from the ground can be minimized by putting the insulating material at the bottom of the kiln during construction.

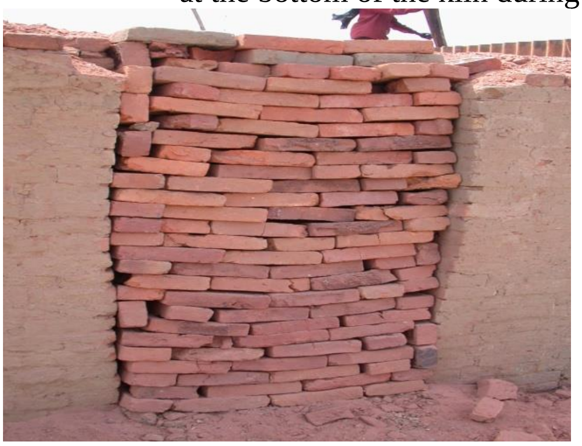


Figure 4.20: Conventional type wicket wall

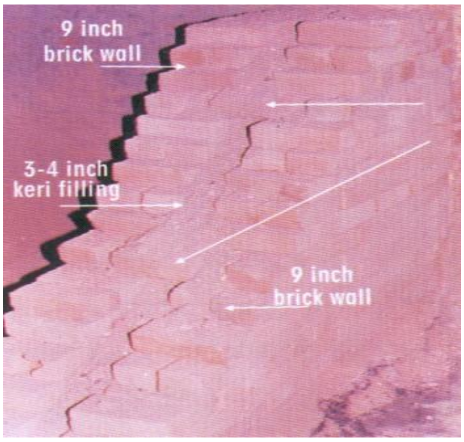


Figure 4.21: Recommended type wicket wall

Figure 4.22: Heat loss from Tawa

4.14 Energy Management and Process Control in Grinding (Cement)

Control systems for grinding operations are developed using the same approaches as for kilns. The systems control the flow in the mill and classifiers, attaining a stable and high quality product. Several systems are marketed by a number of manufacturers. Expert systems have been commercially available since the early 1990s.

Typical energy savings are 3 to 3.5 kWh/t (reduction in power consumption by 2%-3%) and simple payback periods are typically between 6 months to 2 years. Other benefits include reduced process and quality variability as well as improved throughput/production increase.

4.15 Improved Grinding Media for Ball Mills

Improved wear resistant materials can be installed for grinding media, especially in ball mills. Grinding media are usually selected according to the wear characteristics of the material. Increases in the ball charge distribution and surface hardness of grinding media and wear resistant mill linings have shown a potential for reducing wear as well as energy consumption. Improved balls and liners made of high chromium steel is one such material but other materials are also possible. Other improvements include the use of improved liner designs, such as grooved classifying liners. Improved grinding media have the potential to reduce grinding energy use by 5-10% in some mills, which is equivalent to estimated saving of 3-5 kWh/t cement.

4.16 Replacing a Ball Mill with Vertical Roller Mill

Roller mills employ a mix of compression and shearing, using 2-4 grinding rollers carried on hinged arms riding on a horizontal grinding table. The raw material is ground on a surface by rollers that are pressed down using spring or hydraulic pressure, with hot gas used for drying during the grinding process. Typical energy use is between 18.3 and 20.3 kWh/t clinker compared to 30-42 kWh/t clinker for a ball mill, depending on the fineness of the cement. A vertical roller mill can accept raw materials with up to 20% moisture content and there is less variability in product consistency.

4.17 High Pressure Roller Press and Pre-Grinding to Ball Mill

A high pressure roller press, in which two rollers pressurize the material up to 3,500 bars, can replace ball mills for finish grinding, improving the grinding efficiency dramatically. A roller press with a V-separator uses 15.6 kWh/t clinker for finish grinding. This technology can achieve an increase in throughput of about 20% and energy savings of about 7 to 15%.

4.18 Low Temperature Waste Heat Recovery for Power Generation

A large amount of energy consumption for the production of cement occurs in the calcination process. This involves passing raw materials through a preheater stack containing cyclone heaters to a long rotating kiln to create clinker and then cooling clinker in the clinker cooler. In clinker production process, a significant amount of heat is typically vented to the atmosphere without utilization. This situation wastes natural resources and causes serious heat pollution in the workplace. If the waste heat is captured and used for power generation, it can significantly improve energy efficiency and reduce the amount of power imported from the electric grid.

A Waste Heat Recovery (WHR) system can effectively utilize the low temperature waste heat of the exit gases from Suspension Preheater (SP) and Air Quenching Chamber (AQC) in cement production. The WHR captive power plant consists of WHR boilers (SP boiler and AQC boiler), steam turbine generators, controlling system, water-circulation system and dust-removal system etc. The steam from SP boiler and AQC boiler is fed to the steam turbine generator to produce power.

4.19 Blended Cement

The production of blended cement involves the inter-grinding of clinker with one or more additives (fly ash, pozzolans, blast furnace slag, volcanic ash) in various proportions. Blended cements demonstrate a higher long-term strength, as well as improved resistance to acids and sulfates, while using waste materials for high value applications. Short-term strength (measured after less than 7 days) of blended cement may be lower, although cement containing less than 30% additives will generally have setting times comparable to concrete based on Portland cement.

Blended cement has been used for many decades around the world. Blended cement was introduced in the U.S. to reduce production cost for cement (especially energy costs) to expand capacity without extensive capital cost to reduce emissions from the kiln. The use and production of blended cement is still limited in the U.S. However, Portland ordinary cement and Portland slag cement are used widely in other parts of the world. In addition, due to technical advancement and market development allowing the production of different kinds and grades of cement, some industrial byproducts such as blast furnace slag, fly ash, coal gangue, limestone, zeolite, pozzolana as well as natural minerals are widely used in cement production.

Prices for different additives vary greatly. Prices change with location, output, market need, produce type and ways of handling. Fuel savings of at least 10% is estimated with a similar increase in production. The use of blended cement is a particularly attractive efficiency option since the inter-grinding of clinker with other additives not only allows for a reduction in the energy used (and carbon emissions) in clinker production, but also corresponds to a reduction in carbon dioxide emissions in calcination as well. For blended cement with, on average, a clinker/cement ratio of 65%, the reduction in clinker production corresponds to a specific fuel savings of 1.42 GJ/t cement (48.5 kgce/T cement).

There is an increase in fuel use of 0.09 GJ/t cement (3.1 kgce/t cement) for drying of the blast furnace slags but a corresponding energy savings of 0.2 GJ/t cement (7 kgce/t cement) for reducing the need to use energy to bypass kiln exit gases to remove alkali-rich dust. Energy savings are estimated to be 9 to 23 MJ/t cement (0.3 to 7.1 kgce/t cement) per percent bypass. The cost of applying additives in cement production may vary. Capital costs are limited to extra storage capacity for the additives. However, blast furnace slag may need to be dried before using in cement production. This can be done in the grinding mill, using exhaust from the kiln, or supplemental firing, either from a gas turbine used to generate power or a supplemental air heater.

4.20 Kiln Shell Heat Loss Reduction (Improved Refractories)

There can be considerable heat losses through the shell of a cement kiln, especially in the burning zone. The use of better insulating refractories (for example Lytherm) can reduce heat losses. Refractory choice is the function of insulating qualities of the brick and the ability to develop and maintain a coating. The coating helps to reduce heat losses and to protect the burning zone refractory bricks. Refractories protect the steel kiln shell against heat, chemical and mechanical stress. The choice of refractory material depends on the combination of raw materials, fuels and operating conditions.

Extended lifetime of the higher quality refractories will lead to longer operating periods and reduced lost production time between relining of the kiln and hence, offset their higher costs. The use of improved kiln-refractories may also lead to improved reliability of the kiln and reduced downtime, reducing production costs considerably, and reducing energy needs during start-ups. Estimates suggest that the development of high-temperature insulating linings for the kiln refractories can reduce fuel use by 0.12 to 0.4 GJ/t (4.1 to 13 kgce/t) of clinker. Nevertheless, structural considerations may limit the use of new insulation materials.

4.21 Use of Alternative Fuels

Alternative or waste fuels can be substituted for traditional commercial fuels in a cement kiln. In North America, many of the alternative fuels are focused on the use of tires or tire-derived fuel. Tires accounted for almost 5% of total fuel inputs in the U.S. cement industry in 1999 and all wastes total about 17% of all fuel inputs. New waste streams include carpet and plastic wastes, filter cake, paint residue and (dewatered) sewage sludge. Cement kilns also burn hazardous wastes.

A cement kiln is an efficient way to recover energy from waste. The CO_2 emission reduction depends on the carbon content of the waste-derived fuel, as well as the alternative use of the waste and efficiency of use (for example incineration with or without heat recovery). The high temperatures and long residence time in the kiln destroy virtually all organic compounds, while efficient dust filters may reduce some other potential emissions to safe levels. Biomass has also been used as an alternative fuel in the cement industry around the world. Biomass is considered carbon neutral; thus, 100% reduction in CO_2 emissions is achievable compared to the other commercial fossil fuels used in the cement industry.

4.22 Energy Management and Process Control Systems in Clinker Making

Heat from the kiln may be lost through non-optimal process conditions or process management. Automated computer control systems help to optimize the combustion process and conditions. Improved process control will also improve product quality and grinding ability, for example reactivity and hardness of the produced clinker, which may lead to more efficient clinker grinding. A uniform feed allows for steadier kiln operation, saving on fuel requirements. In cement plants across the world, different systems are used, marketed by different manufacturers. Most modern systems use so-called “fuzzy logic” or expert control, or rule-based control strategies.

An alternative to expert systems or fuzzy logic is model-predictive control using dynamic models of the processes in the kiln. Additional process control systems include the use of online analyzers that permit operators to instantaneously determine the chemical composition of raw materials being processed, thereby allowing for immediate changes in the blend of raw materials. Several companies provide optimized information technology for energy management and process control, such as ABB. Most technologies for this measure are made by international companies such as Siemens and ABB. Energy savings from process control systems vary between 2.5% and 10%.

4.23 Optimize Heat Recovery/Update Clinker Cooler.

The clinker cooler has to drop the clinker temperature from 1200°C down to 100°C. The most common cooler designs are of the planetary (or satellite), traveling and reciprocating grate type. All coolers heat the secondary air for the kiln combustion process and sometimes also tertiary air for the pre-calciner. Reciprocating grate coolers are the modern variant and are suitable for large-scale kilns. Grate coolers use electric fans and excess air.

Grate coolers may recover between 1.3 and 1.6 GJ/t (44 to 55 kgce/t) of clinker sensible heat. Heat recovery can be improved through reduction of excess air volume, control of clinker bed depth and new grates such as ring grates. Improving heat recovery efficiency in the cooler results in fuel savings, but may also influence product quality and emission levels. Control of cooling air distribution over the grate may result in lower clinker temperatures and high air temperatures. Additional heat recovery results in reduced energy use in the kiln and pre-calciner, due to higher combustion air temperatures.

4.24 Opportunities in Furnace

i. Proper storage and Handling

Fuels degraded or contaminated due to poor storage and handling are difficult to burn, requiring more excess air with lower thermal efficiency. Fuel storage and handling is an important and often neglected area but needs attention in order to prevent wastage or contamination. In case of coal and bio-mass, fuel storage over a long period of time deteriorates the quality of fuel and increase potential for fire hazard. Oxidation loss during storage is common in coal and losses such as wind and carpet loss is common in all solid fuel including coal.

ii. Optimization of Excess Air Level

The quantity of air required for complete burning of fuel based on the chemical equation, is known as the stoichiometric or theoretical air requirement. Ideally, this quantity of air is sufficient to completely burn the fuel. But in practice, it is observed that combustion is not complete unless some excess air is supplied to the system. The quantity of this additional air affects the mass flow rate of the flue gases. By maintaining the optimum quantity of excess air, heat loss through the stack can be minimized. The higher the excess air, the greater the flue gas volume and hence, loss through the stack becomes higher. Besides, flame temperature and rate of heat transfer across the heating surface is reduced.

The quantity of excess air in flue gases can be determined by measuring the percentage of either O_2 or CO_2 in the flue gases. With the measured value of O_2, the percentage excess air can be calculated by the following formula:

$$\boxed{\textbf{\% Excess Air} = (O_2\%/21 - O_2\%)*100}$$

Where, actual O_2 % indicates measured O_2 % in the flue gas.

After the quantity of excess air has been established, suitable measures to vary combustion air could be adopted.

Table 4.5: Excess Air levels for different types of fuels

EXCESS AIR LEVELS FOR DIFFERENT FUELS		
Fuel	**Type of Furnace or Burners**	**Excess Air (% by wt)**
Pulverized coal	Completely water-cooled furnace for slag-tap or dry-ash removal	15-20
	Partially water-cooled furnace for dry-ash removal	15-40
Coal	Spreader stoker	30-60
	Water-cooler vibrating-grate stokers	30-60
	Chain-grate and traveling-grate stokers	15-50
	Underfeed stoker	20-50
Fuel oil	Oil burners, register type	15-20
	Multi-fuel burners and flat-flame	20-30
Natural gas	High pressure burner	5-7
Wood	Dutch over (10-23% through grates) and Hoff type	20-25
Bagasse	All furnaces	25-35
Black liquor	Recovery furnaces for draft and soda-pulping processes	30-40

Source: Energy Efficiency in Thermal Utilities, BEE

iii. Controls to ensure proper combustion

Complete or maximum combustion of fuel is a must to obtain the best efficiency in the furnace or any combustion system. In any combustion system, chemical combination of oxygen with the combustible part mainly carbon of the fuel releases heat. The requirements of a combustion process are:

- Fuel;
- Oxygen (air);
- The three `T's viz., Time, Temperature and Turbulence.

A specific quantity of air is necessary to supply the required amount of oxygen for combustion. Higher excess air will reduce flame temperature, furnace temperature, and heating rate. To obtain complete combustion of fuel with the minimum amount of air, it is necessary to control air infiltration, maintain the pressure of combustion air and monitor fuel quality and excess air. If the excess air is less than the required value, un-burnt components in flue gases will increase and will be carried away in the flue gases through the stack. Therefore, the optimization of combustion air with proper control and instrumentation is essential for combustion efficiency improvements in the furnace.

Various methods are available to control the excess air:

- Use of portable oxygen analysers and draft gauges can help the operator to manually adjust the flow of air for optimum operation.
- Use of continuous oxygen analyser with a local readout mounted draft gauge to know the level of excess air.
- Continuous oxygen analyser can also be used to control flow using pneumatic or servomotor controlled damper. This enables an operator to remotely control a number of firing systems simultaneously.

iv. Proper Heat Distribution

For best output from the furnace, heat distribution should be uniform. The flame should not touch the stock, since this will increase scale losses. Flames from various burners should not intersect each other, which can be ensured by staggering the burners on either side. The loading of the charge on the furnace should be arranged so that

- It receives the maximum amount of radiation from the hot surfaces of the heating chambers and the flames produced;
- The hot gases are efficiently circulated around the heat receiving surfaces.

Stock should not be placed in the following position:

- In the direct path of the burners or where impingement by flame is likely to occur;
- In an area which is likely to cause a blockage or restriction of the flue system of the furnace;
- Close to any door openings where cold spots are likely to develop.

v. Optimum Furnace Temperature

Temperature maintained within the furnace has to be as per the process requirement and should not be too high or too low. Maintaining low temperature will deteriorate the quality of product or may generate more rejects. Operating at too high temperature than the optimum cause heat loss, excessive oxidation, de-carbonization as well as over stressing of refractories.

vi. Optimum Furnace Loading

Furnaces are designed to offer maximum thermal efficiency at a particular load. If the loading on the furnace is low, the load consumes a smaller fraction of the heat available and offer low efficiency. In an over-loaded furnace, the stock may not be uniformly heated, leading to poor quality and again lower efficiency.

Optimal loading is generally obtained by trial, recording weight of the material in each charge, time taken to reach the required temperature and amount of fuel used. Load disposition on furnace hearth should be such that maximum heat is radiated to the load from hot surfaces of heating chambers and the flames produced. Hot gases should be efficiently circulated around heat receiving surfaces.

vii. Furnace utilization

Furnace utilization is one of the important aspects that affect furnace efficiency. It is also often ignored or underestimated. Utilization factor may be reduced due to the reasons such as frequent breakdown, poor production planning and capacity mismatch.

viii. Control of Furnace Draught

Ingress of uncontrolled free air must be prevented in any furnace. It is better to maintain a slight excess pressure inside the furnace to avoid air infiltration. If negative pressures exist in the furnace, air infiltration is liable to occur through the cracks and openings, thereby affecting air/fuel ratio control. Neglecting furnace pressure could mean problems of cold metal and non-uniform metal temperatures, which could affect subsequent operations such as forging and rolling and could result in increased fuel consumption.

ix. Oxygen Enrichment

Air contains 21% oxygen and 78% inert nitrogen by volume. During combustion, oxygen combines with carbon and hydrogen of the fuel to liberate heat. The inert gases of the air absorb heat from the combustion and carry it out of the furnace resulting in loss of heat, also reducing flame temperature and thus reducing the rate of heat transfer to the stock. If the inert content of air could be reduced, more efficient combustion would be attained. This can be done by addition of oxygen to combustion air. Consequently, when the amount of fuel is not increased, sensible heat loss in the flue gas is decreased due to the smaller heat capacity of the lower volume.

x. Minimizing Heat Loss from Furnace Walls

In intermittent or continuous furnaces, heat losses generally account for around 30–40 percent of the fuel input to the furnace. The appropriate choice of refractory and insulation materials is very important for achieving fairly high fuel savings in industrial furnaces.

Several materials with different combinations of heat insulation and thermal inertia should be considered to minimize heat losses through furnace walls. For intermittent furnaces, the use of insulating refractories of appropriate quality and thickness can cut down heat storage capacity of walls and the time required to bring the furnace to operating temperature by as much as 60–70 percent.

xi. Ceramic coatings to improve emissivity

Heat transfer in a furnace depends mainly on radiation, which in turn depends on emissivity. At higher temperatures, emissivity of the normal refractories decreases whereas the emissivity of ceramic coating increases. High emissivity refractory coating, if applied on the internal surface of the furnace, increases emissivity thus contributing to increased heat transfer. Energy savings of the order of 8-20% have been reported depending on the type of furnace and operating conditions.

xii. Prevention of Heat Loss through Openings

During operation heat loss from the furnace door and openings is inevitable due to radiation. It is also caused due to leakage of flue gas through the door/openings. It is necessary to make sure that the openings are kept to the optimum level to avoid heat loss. The heat loss is about 1% of the total heat generated in the furnace, if the pressure in the furnace is controlled properly (BEE 2010). Heat loss from an opening is calculated using the following formula:

$$\mathbf{Q = 4.88 * T^{4} * a * A * H/100}$$

Where,
T: absolute temperature (K)
a: factor for total radiation
A: area of opening
H: time (Hr)

xiii. Waste Heat Recovery in the furnace

Heat generated in an industrial process by way of fuel combustion or chemical reaction and not brought to use in a meaningful way is termed as waste heat. Sources of waste heat could be hot combustion gases discharged to the atmosphere, heated products exiting industrial processes, and heat transfer from hot equipment surfaces.

Heat loss due to the flue gas exiting from the furnace is significant as furnaces normally operate in high temperature range. The stack temperature is very high and waste heat recovery is a major energy efficiency opportunity in furnaces. The recovered waste heat is conventionally used for either preheating of combustion air or to preheat the material. Before going for waste heat recovery, it is essential to ensure that heat losses have been minimized at the source. In furnaces, a substantial part of the waste heat in the flue gas can be recovered by installing a Recuperator to preheat combustion air required for the burners.

xiv. Use of Fuel Efficient Burners

Fuel efficiency of burners used in any combustion system plays major role in the overall combustion efficiency of the system. Fuel efficient burners operate at low excess air levels and offer a turndown ratio of up to 7:1. Energy savings in the range of 10-15 % have been obtained in several facilities. Recuperative and regenerative burners offer better combustion efficiency and work on the principle of heat recovery.

4.25 Furnace Efficiency

The efficiency of a furnace is the ratio of useful output to heat input. The furnace efficiency can be determined by both direct and indirect methods.

a. Direct Method: Efficiency of the furnace is computed by measuring the amount of fuel consumed per unit weight of material produced from the furnace.
b. Indirect Method: Efficiency of the furnace is calculated by subtracting all the sensible losses from the input of the furnace.

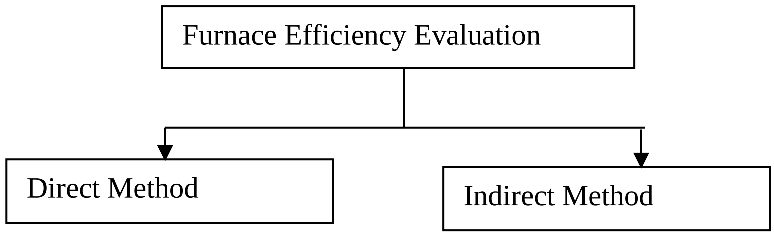


Figure 4.23: Furnace Efficiency Methods

Note: The details for calculating furnace efficiency by direct and indirect methods is in Annex 7.

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 an industry or a 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

S N	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							
3							
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: Not 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 Industrial 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, Tables, Figures and abbreviations, 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 need 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:

- Reporting on 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.

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 plant/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:

- Title of measure (EE opportunity);
- Present situation;
- Recommendation;
- Cost benefits;
- Approximate investment requires 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:

SN	EE Measures	Responsible Person	Implementation Date		Time Bond	Remarks
			Start	End		

Chapter 5: Exhibits: Vendor information as relevant

The menu of EE measures is 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.

Chapter6: Exhibits

Each Investment Grade Energy Audit (IGEA) report may 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 may also address any incentive schemes available from the Government, Ministries, NEA, or financial institutions or international institutions, 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:

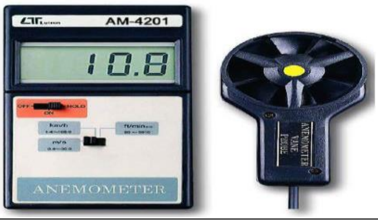
Basic Electrical Parameters in AC system – Voltage (V), Current (I), Power Factor (PF), Active Power (kW), Apparent Power (demand) (kVA), Reactive Power, Energy Consumption (kWh), Frequency (Hz), Harmonics, etc.

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, combustion efficiency, etc.

The following energy monitoring/measuring equipment is needed to conduct energy audit in industrial 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, 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. 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 devices 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.

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 IR 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 Industrial Sector	
Year of Establishment (A.D.):	
Scale: (Large/Medium/Small)	
Reference baseline year A.D.:	
Production Capacity MT or KL	
Annual Production MT or KL	
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/MT or kWh/KL	
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/MT or kWh/KL	
% of Electrical Energy Generated from DG Set:	
Total Cost of DG Electricity in NPR:	
Total Electrical Energy Consumed (Grid+Captive) in kWh/year:	
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/MT or MJ/KL:	
Specific Electrical Energy Consumption in kWh/MT or kWh/KL:	
Total Annual Cost of Electrical + Thermal Energy in NPR:	

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.

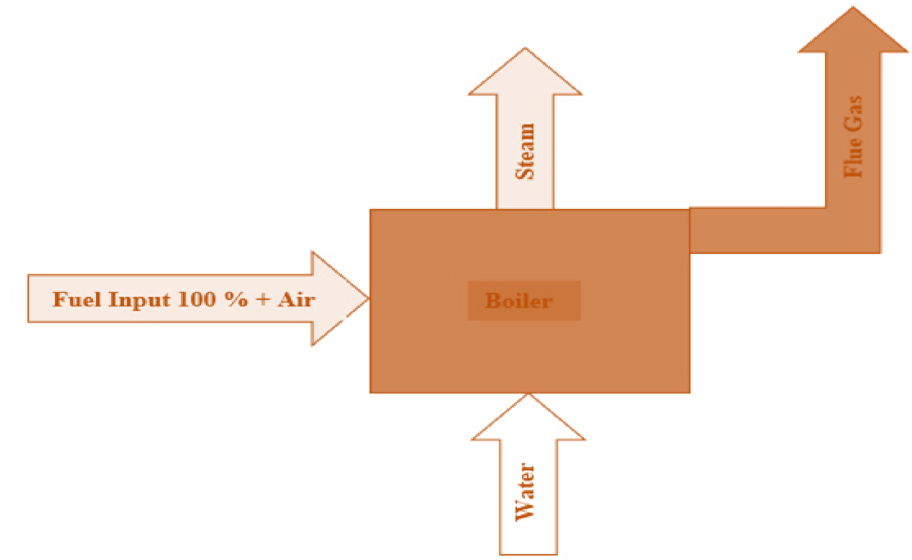


Figure 1: Boiler Efficiency by Direct Method

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 =

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

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

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 now the energy managers in industries prefer simpler calculation procedures.

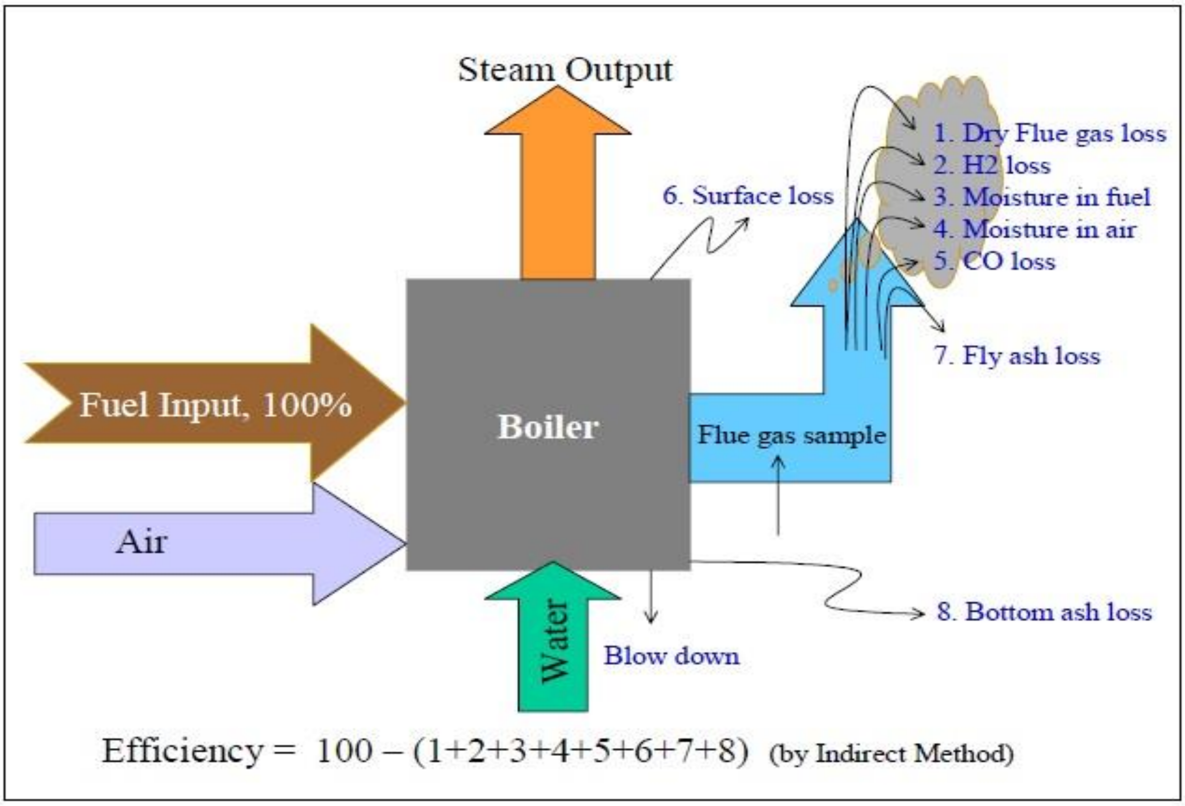


Figure 2: Boiler Efficiency by Indirect Method

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 =**

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

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 =**

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

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

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

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

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

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) =

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

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 ^oC
Tf	=	Flue gas temperature in ^oC
Ta	=	Ambient air temperature in ^oC
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 ^oC
Tf	=	Flue gas temperature in ^oC
Ta	=	Ambient air temperature in ^oC (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 ^{o}C	**Wet Bulb Temp ^{o}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		^{o}C

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, ^{O}C
		Dry bulb Temp. ^{O}C	Wet bulb Temp. ^{O}C	Flow rate kg/hr	Tem ^{o}C	Flow rate m^3/hr	Tem ^{o}C	Flow rate m^3/hr	Pressure kg/cm^2	Tem ^{o}C	O_2 %	CO_2 %	CO %	Tem ^{o}C	

………………… ……………….. ……………….

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.

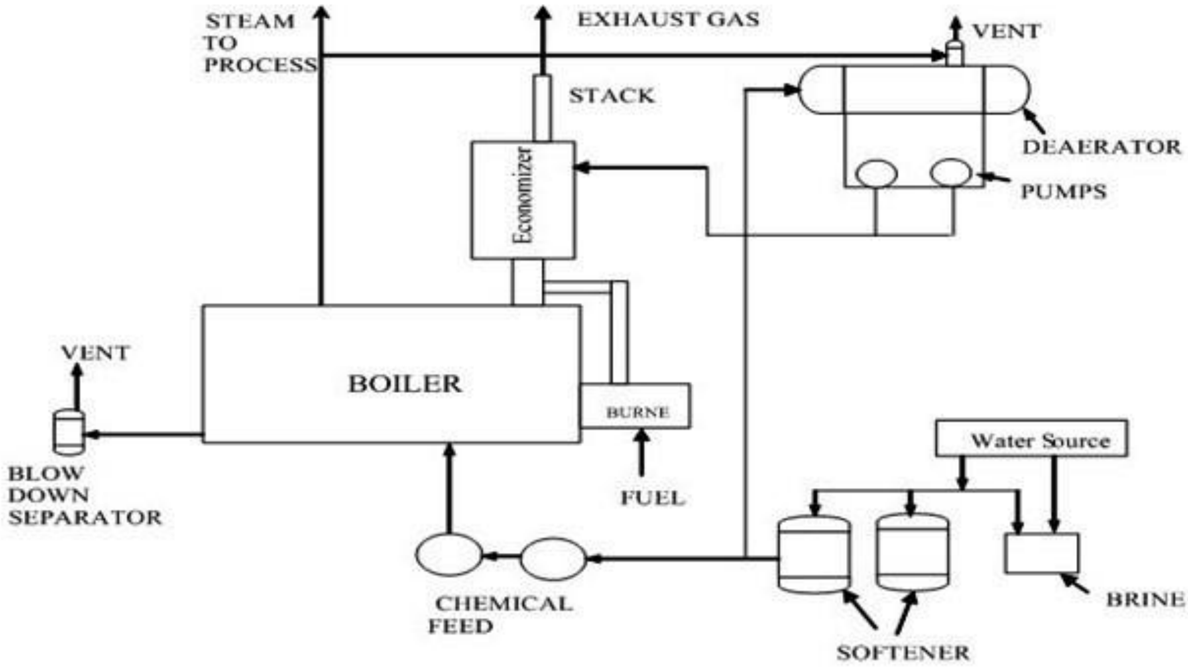


Fig 3: Schematic Diagram of Boiler System

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: Furnace Efficiency Direct & Indirect Method

Direct Method:

$$\text{Thermal Efficiency of the Furnace} = \frac{\text{Heat in the Stock (Q)}}{\text{Heat in the fuel consumed}}$$

$$= \frac{M * Cp * (T2 - T1)}{(m * \text{GCV of fuel})}$$

Where,
Q – Quantity of heat in kCal
M – Weight of the material in Ton/hr
Cp – Mean specific heat, kCal/kg °C
T_2 – Final Temperature desired, °C
T_1 – Initial Temperature of the charge before it enters the furnace, °C
m – Mass of fuel in Kg or L

Indirect Method:

In order to find out furnace efficiency using indirect method, various parameters required are hourly furnace oil consumption, material output, excess air quantity, temperature of flue gas, temperature of furnace at various zones, skin temperature and hot combustion air temperature. Instruments such as infrared thermometer, fuel efficiency monitor, surface thermocouple and other measuring devices are required to measure the parameters mentioned below.

Parameters	**Unit**	**Value**
Weight of the input stock, M	Ton/hr	
Initial temperature of material, T1	°C	
Final temperature of material, T2	°C	
Specific heat of material, Cp	kCal/kg °C	
Fuel consumption, m	Kg/hr	
GCV of fuel used	kCal/kg	

1. Sensible Heat Loss calculation in Flue Gas:

Excess air in flue gas = $(O_2 \times 100) / (21 - O_2)$

Where, O_2 is the actual % of oxygen measured in the flue gas

Sensible heat loss = m x Cp x ΔT

Where,

m = mass of flue gas (theoretical plus excess air)

Cp = Specific heat

ΔT = Temperature difference between flue gas and combustion air

2. Loss Due to Evaporation of Moisture Present in Fuel

% Loss = $M \{584 + 0.45 (T_{fg} - T_{amb})\} * 100 / \text{GCV of Fuel}$

Where,

M - % Moisture of in 1 kg of fuel oil (0.15 kg/kg of fuel oil)

T_{fg} - Flue Gas Temperature

T_{amb} - Ambient temperature

GCV - Gross Calorific Value of Fuel

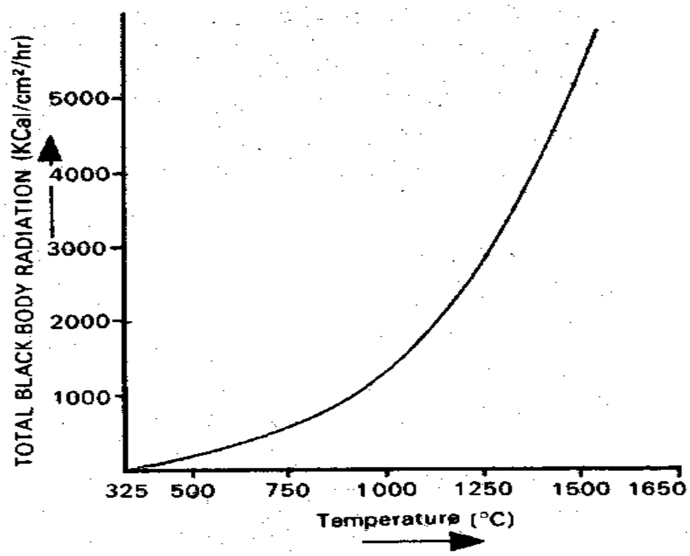
3. Loss Due to Evaporation of Water Formed due to Hydrogen in Fuel

% Loss = 9 x H2 {584 + 0.45 (T_{fg}-Tamb)}*100/ GCV of Fuel

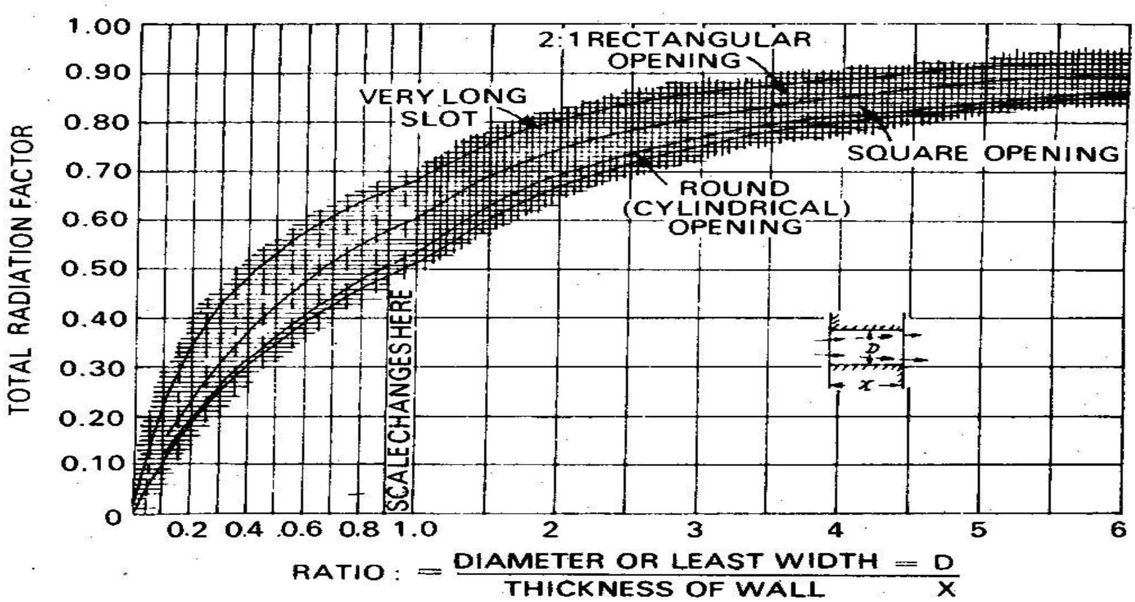
Where, H_2 – % of H_2 in 1 kg of fuel oil (0.1123 kg/kg of fuel oil)

4. Heat Loss due to Openings:

If a furnace body has an opening on it, the heat in the furnace escapes to the outside as radiant heat. Heat loss due to openings can be calculated by computing black body radiation at furnace temperature, and multiplying these values with emissivity (usually 0.8 for furnace brick work) and the factor of radiation through openings. The black body radiation losses can be directly computed from the curves as given in the figure below. Factor for radiation through openings can be determined with the help of graph shown below.



Graph for Determining Black Body Radiation at a Particular Temperature



RADIATION THROUGH OPENINGS OF

Factors for determining the equivalent of heat release from openings to the quantity of heat release from the perfect black body.

5. Heat Loss through Skin:

Surface heat loss forms a large portion of the heat loss that occurs in the furnace system. It is essential to have an efficient insulation on all hot surfaces including surfaces of combustion air supply pipes, fuel lines and heat recovery equipment. The recommended thickness of insulation will mainly depend on the desired surface temperature after insulation. The energy and cost savings will depend on the total area, the temperature of the hot surface and the surroundings, heat temperature coefficient and the number of hours of operation of furnace. Simplified formula for heat loss calculation is given below:

$$\boxed{S = [10 + (Ts - Ta)/20]*(Ts - Ta)}$$

Where,

S = Surface heat loss in kCal/hr/m^2

Ts = Hot surface temperature in ^oC

Ta = Ambient temperature in ^oC

Total heat loss/hr = S*A

Where ‘A’ is the surface area in m^2

6. Unaccounted Loss

These losses comprise of heat storage loss, loss of furnace gases around charging door and opening, heat loss by incomplete combustion, loss of heat by conduction through hearth, loss due to formation of scales.

Furnace Efficiency by indirect method is given by 100 minus the sum of all losses from 1 to 6 calculated above.

Furnace Efficiency = 100 – (L1+L2+L3+L4+L5+L6)

h) Data collection format for Furnace Performance Assessment

S.N.	**Sheet 1- Technical specification of furnace**	
1	Furnace ID code and Make	
2	Year of Manufacture	
3	Boiler capacity rating	
4	Type of Furnace	
5	Type of fuel used in furnace	
6	Maximum fuel flow rate	
7	Fuel GCV	
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	

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.	**Flue Gas Analysis**	**Date of Test**	**Unit**
1	CO_2		%
2	O_2		%
3	CO		%
4	Flue Gas Temperature		^{o}C

Annex: 8 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: 9 Compressor Calculation

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 10: 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 Temperature	ºC	
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 11: 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 12: 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	%	
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 13: Methodology for calculating heat losses (Brick Kiln)

I. Calculation of dry flue gas heat losses:

Temperature of flue gas : ^oC
Flow rate of flue gas : kg/s
Specific heat of flue gas : kJ/kg K
Total dry flue gas heat loss per day : MJ/day

II. Calculation of heat loss due to incomplete combustion:

Average CO concentration : ppm
Heat loss % due to incomplete combustion
((CO% x C% fuel) x 5744) / ((CO% + CO_2%) x (GCV)
Calculated heat loss % : %
Total heat loss in MJ/day : MJ/day

III. Calculation of surface temperature heat losses

Ash surface heat loss

Average temperature of the ash surface = ^oC
Ambient temperature = ^oC
Convective heat loss = kW
Radiative heat loss = kW
Total heat loss = kW
Total Surface area = m^2
Total heat loss in a day (MJ/day) = MJ/day
Heat absorbed by ash from solar radiation (MJ/day) = MJ/day
Net heat loss from the surface (MJ/day) = MJ/day

Tawa surface heat losses

Surface temperature before insulation = ^oC
Diameter of Tawa = cm,
No. Tawas = N
Total Surface area = m^2
Convective heat loss = kW
Radiative heat losses = kW
Total heat loss = MJ/day

Annex 14: 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:

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

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:

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:

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 15: Performance Calculation of Turbine

i. Steam Turbine Performance, % =

$$\frac{\text{Actual Enthalpy drop across the turbine, kCal/kg}}{\text{Isentropic Enthalpy drop across the turbine, kCal/kg}} * 100$$

ii. Gas Turbine Performance:

a) Air Compressor Efficiency, % =

$$\frac{\text{Theoritical temperature rise across the compressor, (deg. C)}}{\text{Actual temperature rise, (deg. C)}} * 100$$

b) b) Overall Gas Turbine Efficiency = (Compressor + Gas Turbine), % =

$$\frac{\text{Power Output, kW} * 860}{\text{Fuel Input for Gas Turbine,} \frac{\text{kg}}{\text{hr}} * GCV\ of\ fuel, \frac{kg}{hr}} * 100$$

Annex 16: 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.

Agendas:

Agenda 1.

Agenda 2.

..

Decisions:

1:

2:

Conclusion:

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