TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS

A STUDY ON ENERGY EFFICIENCY, ENVIRONMENTAL EMISSIONS AND ENERGY SECURITY OF LIMESTONE BASED CEMENT INDUSTRIES IN NEPAL: CASE STUDY OF HETAUDA CEMENT INDUSTRY LIMITED(HCIL)

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a project report entitled " A STUDY ON ENERGY EFFICIENCY, ENVIRONMENTAL EMISSIONS AND ENERGY SECURITY OF LIMESTONE BASED CEMENT INDUSTRIES IN NEPAL: CASE STUDY OF HETAUDA CEMENT INDUSTRY " submitted by Sobit Sapkota, Subarna Subedi and Utsav Dahal in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

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ABSTRACT

This study is aimed at examining the energy efficiency, energy intensity, environmental emissions reduction potential and energy security scenario of Hetauda Cement Industry Limited (HCIL) in Nepal. The research is being conducted with the objective of studying an existing benchmark for the energy intensity of the cement industry in Nepal and to examine the energy security risks for the limestone-based cement industries relying on imported energy. A study of the energy efficiency of the HCIL identifies that for the past five years specific power consumption has gradually increased from 223 kWh per ton to 295 kWh per ton of cement. The capacity utilization of the plant was below 50%. The plant's continuous operation over the last 36 years has reduced the efficiency of various plant equipment, increased breakdown time, increased production costs, and increased other indirect losses. Study suggests ways to optimize energy usage and reduce costs with lighting improvement with payback period of around 2 years, a gravel bed filter installation to emission control with payback of 3 years and waste heat recovery unit of 1.2 MW electricity capacity with payback of 14 years.

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LIST OF ACRONYMS AND ABBREVIATIONS

GDP	Gross Domestic Product
kWh	kilowatt hour
kWh/T	kilowatt hour per ton
MJ/kg	Mega Joule per kilogram
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
NEEP	Nepal Energy Efficiency Program
FDI	Foreign Direct Investment
IEA	International Energy Agency
VSK	Vortex Induced Vibration
EEM	Energy Efficient Mortgages
HEL	Health Impact Assessment
CCS	Carbon Capture and Sequestration
WHL	Waste Heat Recovery
HCIL	Hetauda Cement Industry Limited
PB	Pile Building
RABH	Reverse Air Bag House
ESP	Electrostatic Precipitator
TPH	Tonnes per hour

CHAPTER ONE: INTRODUCTION

1.1 Background

As energy has been an important commodity requiring in almost every field. As accessible energy has quantitative constraints, efficient energy use has become critical. A major principle of utility-sector energy efficiency programs is that the energy they conserve reduces and balances the energy that would otherwise be delivered by the electricity grid or the natural gas infrastructure(Schumacher & Sathaye, 1999). Such saved kWh (electricity) or thermals (natural gas) are viable system resources because energy savings from customer programs can lower system demand enough to prevent the need for new supply infrastructure, such as generation plants, transmission lines, and distribution system upgrades.

The concept of energy efficiency as a resource was introduced partly during the energy conservation era in the 1970s which was started during the energy crisis to aid consumers in coping with rising energy costs(Martin et al., 1999). Today, energy efficiency is a crucial resource for utility systems and is sometimes the most affordable option when compared to supply-side improvements. Energy conservation through consumer energy efficiency initiatives may typically be accomplished for one-third to one-fourth the cost of supply-side solutions based on fossil fuels. With technological developments, energy efficiency is likely to improve throughout time. Most industries are now energy inefficient, which implies that a significant portion of the energy consumed is wasted, raising energy consumption and costs. Simply put, energy efficiency means utilizing less energy to do the same work while reducing waste. Energy efficiency has a number of advantages, including lowering home and economy-wide expenses and reducing greenhouse gas emissions. While renewable energy technology also aids in the achievement of these goals. Improving energy efficiency is the simplest and most cost-effective solution to a variety of energy-related issues(Rastra Bank,2021). In every aspect of Nepal's economy, whether it's buildings, transportation, industry, or energy generation, there are significant prospects for efficiency improvements. To achieve climate justice, energy efficiency is a necessary.

Given the tremendous growth in global energy demand, carbon emissions have also increased by folds. Carbon reduction has been a touchy subject because it is linked to a number of major challenges, including global warming and climate change. As a result, meaningful contributions from businesses and organizations of all kinds, as well as individuals, are required to reduce their carbon footprint. Reduced emissions, improved energy efficiency, the use of renewable energy, and the purchase and retirement of high-quality carbon offsets are all ways to reduce carbon emissions. As a result, reducing one's carbon footprint makes sense from both an ecological and a financial standpoint. Manufacturing industries are the biggest contributors to the generation of GHG and carbon footprints on a global scale. These industries utilize up to 54% (Wang et al., 2009)of total global delivered energy while generating 20% (Singh, 2016)of global carbon emissions. Some manufacturing businesses, such as food processing and cement manufacture, are the primary contributors to this situation. Globally, the cement industry consumes 10-15% (Martin et al., 1999)of total global energy. According to a study, the cement industry is the least efficient, particularly in developing countries. With the rise of nation-state development, demand appears to be increasing, as does inefficient energy consumption.

The cement industry is one of the most energy-intensive industries in Nepal. Considering the total production capacity of cement industries in Nepal, cement industries make up a significant portion of Nepal's energy demand. The cement industry is one of the potential industries to grow in the future, mainly because of the availability of untapped limestone and increasing developmental activities. At present around 124 cement industries have been registered in the Department of Industry and 55 of those are in operation(Department of Industry, Government of Nepal., 2019). It is estimated that the annual gross consumption of cement in Nepal at present is around 2,500,000 MT(Rastra Bank, 2021). The annual increment of demand for cement in Nepal is considered to be around 20 percent(Department of Industry Government of Nepal, 2019). Nepalese industries are mostly dependent on imported fuel from India and South Africa. Any disruption in supply chain may cause huge loss for Nepalese industries. This complicated energy scenario can be considered under Energy security which is defined based on the availability, accessibility, affordability and acceptability of energy.

There has been tremendous energy waste as a result of inefficient machinery and processes, resulting in evident GHG emission generation(Thakuri et al., 2021). At this time, no particular benchmarking for cement production per ton has been established. Within the country, there is very little research on this topic. This research is being carried out with the goal of examining Nepal's industrial energy situation and laying the groundwork for energy benchmarking in future.

1.2 Hetauda Cement Industry

Hetauda Cement Industry is located at Lamasure, Hetauda and is well-known in Nepal for its Ordinary Portland Cement. HCIL Nepal, presently generates 3000 metric tons per day.

An initiative of HMG/Nepal in Hetauda Cement Udyog Limited B.S. was incorporated under the Companies Act 2021 in 2033 Ashwin 13. It was inaugurated by then existing king his Majesty king Birendra Bir Bikram Shahdev. The factory, which was built with credit help from the Asian Development Bank, has an annual output capacity of 2.6 billion metric tons of cement. Beginning in December 1980, it began producing goods for sale. The industry has its own mines of limestone located in various places: Majuwa, Okhare, Bhainse, Jogimara. It sells its product under the brand name "Shakti". The business has delivered premium limestone from mines controlled by the government in the Sukura and IPA Panchkani districts. Gypsum, iron ore, and coal are three crucial raw materials for cement that are imported from reputable worldwide suppliers.

Mobile mining equipment and cement machines have respective economic lifetimes of 18 and 5 years. When cement production started in the fiscal year 2042–2043, nearly every machine needed to be renovated, which cost significant cash. Hetauda Cement Industry Limited has therefore decided to carry out renovation work across several fiscal years. In the upcoming fiscal year, several components of the mineral equipment and water service system will be repaired. Additionally, a study for the restoration of the ESP Greater Cooler and Cyclone will be conducted.

In the upcoming fiscal year, Hetauda Cement Industry Limited intends to distribute lime from its main procurement after beginning development work on the Okhare procurement, which has a good grade of good limestone.

Table 1: Baseline information about Hetauda Cement Industry Limited

Name of the industry	Hetauda Cement Ind. Ltd
Year of Establishment	1986
Product	Ordinary Portland Cement and Clinker

Capacity (TPD)	750
Location	Hetauda, Makwanpur
Reference Year (A.D)	2021/2022
Clinker production (Tons)	74,540.461
Cement Production (Tons)	81,193.457
Telephone number	057-520536
Email	hcilhtd@vianet.com.np
website	www.hetaudacement.org.np
a. No of shifts per day	3
b. Annual operation days	300(Average)
Total number of employees	485

1.3 Problem statement

The energy consumption in cement industries of Nepal has not been as efficient in comparison to the global scenario. Energy consumption is around 156.08 kWh/T which is more than standard consumption of 105 kWh/T. Similarly, for clinker-based production, thermal energy consumption is 5.4111 MJ/kg which is more than standard consumption of 3.138 MJ/kg(Department of Industry Government of Nepal, 2019). Coal, bituminous and petroleum coke are the primary sources of thermal energy(Singh, 2016) that are mostly imported incasing the vulnerability in energy security. Cost of energy is significant portion of the cost of operation or the turnover of the industries. A step is necessary for Nepal's cement industries to reduce their energy cost maximizing the turnover(GIZ/NEEP, 2012).

1.4 Objectives

1.4.1 Main objective

- To study energy efficiency, energy intensity, environmental emissions reduction potential and energy security scenario of Hetauda Cement Industry Limited (HCIL).

1.4.2 Specific objectives

1. To determine existing energy intensity and improvement potential of the plant as a whole.
2. To study environmental emissions including both GHG and local pollutants emissions of HCIL.
3. To examine the energy security risks for Nepal's limestone-based cement industries relying on imported energy.

1.4.3 Scope and Limitation

1) The Hetauda Cement Industry Limited was the basis for the study, which means that it may not be applicable to all industries in Nepal due to technological differences.

2) Due to the equipment's limitations, primary data collection is constrained. Due to corporate policies, all data could not be collected.

3) Study of all underlying problems was not be possible and the interventions which have more overall impact on the plant was studied.

4) Priorities was given to add new measures or technology to improve energy efficiency based on the request of the plant officials.

CHAPTER TWO: LITERATURE REVIEW

2.1 Energy Intensity Benchmarking

2.1.1 Energy Intensity

Energy intensity, in simple terms, is defined as the amount of energy used to produce a given level of output or activity. A product's energy intensity is determined by the amount of energy needed to make it, hence utilizing less energy to produce a product lowers the intensity.

Changes in energy intensity can be explained by other explanatory factors, as well as increases in process and equipment efficiency. If energy intensity is represented with the proper level of disaggregation to allow for meaningful interpretation and other explanatory and behavioral elements are identified and taken into consideration, declines in energy intensity are a proxy for efficiency improvements.

2.1.2 Energy Benchmarking

Energy benchmarking is a continuous examination of an organization's energy use in order to forecast and analyze the organization's energy performance. Energy benchmarking can be done by comparing a business's energy use pattern to previous data or to any other external entity. Energy benchmarking makes it simple to discover inefficient sections, decide on prospective upgrades, and make intelligent long-term energy management decisions. Energy benchmarking plays an important role in reducing energy costs to help maximize profits, raising awareness about efficient energy consumption be it a single building or an industry, to assisting in the identification of best practices, establishing reference points for measuring and helping reward good performance. On either side, energy benchmarking will aid in improving the energy security of enterprises and the country as a whole.

2.2 Cement production

Cement is the most common building material because it has the potential to improve the adhesiveness of concrete, resulting in a concrete mix with better sand and gravel locking properties (Tesema & Worrell, 2015). Cement is made by combining calcium, silica, aluminum, iron, and other components in a well-controlled chemical reaction.

There are four stages in the manufacture of cement:

(1) Crushing and grinding the raw materials,

(2) Blending the materials in the correct proportions,

(3) Burning the prepared mix in a kiln, and

(4) Grinding the burned product, known as "clinker," together with some 5 percent of gypsum to control the time of a set of the cement(Schumacher & Sathaye, 1999).

The wet, dry, and semi-dry manufacturing techniques are named accordingly when the raw materials are ground wet and fed to the kiln as a slurry, ground dry and fed as a dry powder, or ground dry and subsequently moistened to form nodules that are fed to the kiln. In comparison to the wet process, the dry process is more modern and energy-efficient, and the semi-wet method is somewhat more energy-efficient than the semi-dry process.

Cement manufacturing is a high-energy consuming industry. Energy consumption accounts for 50–60% of overall production costs in cement manufacturing(Shrestha et al., 2016). About 20–25 percent of the cost of cement manufacture is accounted for by thermal energy(Shrestha et al., 2016). Coal, bituminous and petroleum coke were the primary sources of thermal energy(Singh, 2016).

2.2.1 Cement Production Process at HCIL

The process begins with the import of extracted limestone from the factory's limestone mining site and ends with the loading of packaged cement bag into the trucks and other vehicles. The overall process description is described below with bulleted points

There are basically two steps while producing cement in the industry of our study. Clinker production and cement grinding are the two main steps in the two-step process that creates cement. The raw materials are put into the kiln system in the first step to create a clinker. The reduction of calcium, silica, alumina, and iron oxides present in the raw materials results in silicates, aluminates, and calcium ferrites, which make up clinker. In the second phase, clinker and calcium sulfates (gypsum or anhydrite) are mixed together in a grinding mill to create cement with the necessary properties, such as a quick setting time and strength development. Only OPC, however, is formed in

HCIL with the addition of Gypsum alone. At the HCIL, Hetauda factory, cement is produced at many stages, including:

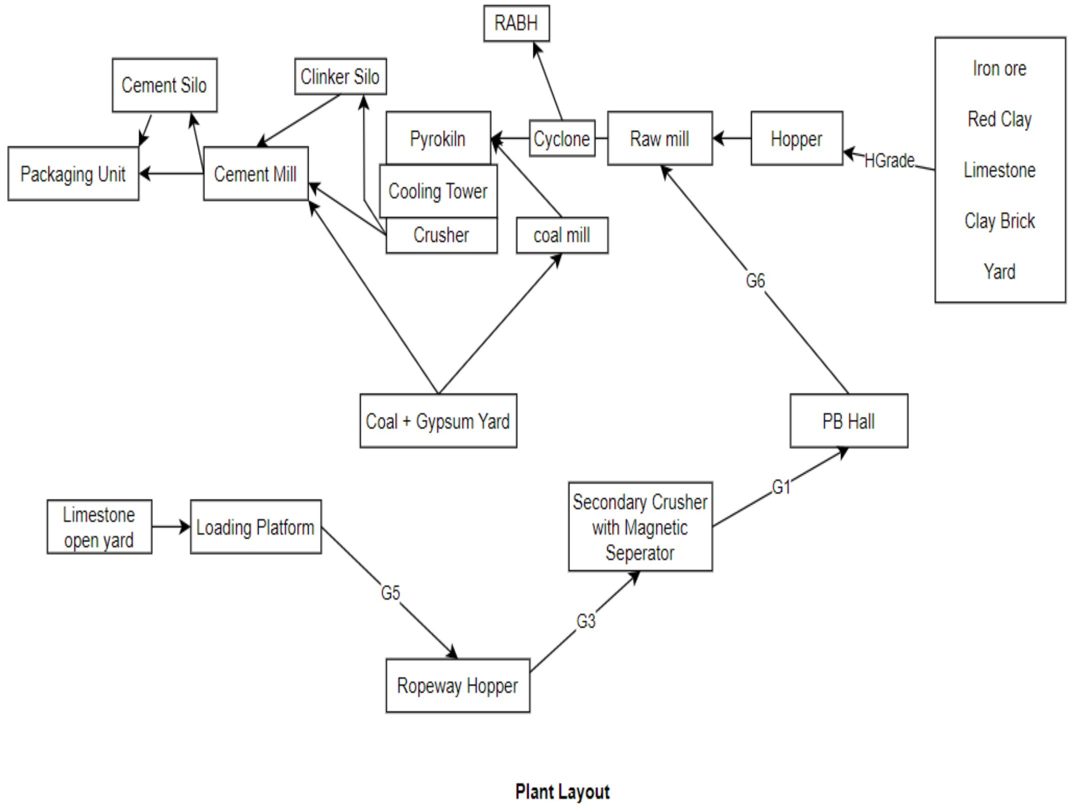

Figure 2-1: Plant Layout

Raw Material Acquisition

The primary raw material used in the facility is calcium carbonate, which is often limestone. Utilizing trippers and dumpers, limestone is hauled to the plant from quarries located at four distinct mines. Mines may be found in Bhainse, Okhare, Majuwa, and Majimtar, which are separated by, respectively, 13 km, 16 km, 14 km, and 120 km. The newest machinery and technology are available at the mines. Following mining, primary jaw crushers and secondary hammer crushers are used to crush the limestone. The crushed limestone is subsequently delivered to the factory by HCIL via a contracted vendor using trippers and dumpers. Other raw materials, such as coal, bauxite (used to make aluminum), iron ore, and gypsum, are purchased from different Indian sources.

Raw Milling

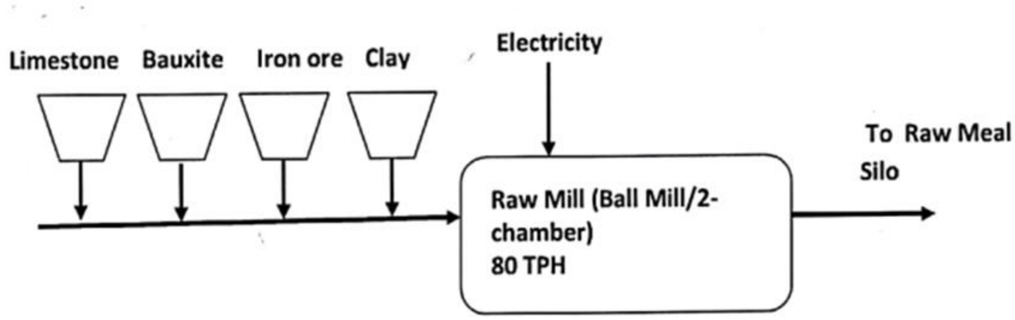

Figure 2-2: Raw milling Process

In order to ensure maximum fuel efficiency in the cement kiln and strength in the finished concrete product, raw milling entails combining the extracted raw ingredients to produce the suitable chemical configuration and grinding them to achieve the proper particle-size. To create a homogeneous blend, the basic components are crushed, ground, and combined. A raw mill, in this case a ball mill, is used for crushing. Electricity used to run the mills is a key energy input throughout this operation.

The raw materials are preheated after material preparation and before entering the kiln system for clinker production. This allows the chemical reactions to happen quickly and efficiently in the kiln. Additionally, the raw materials are calcined (calcinations) to separate the calcium oxides from calcium carbonates that are present in them. Significant amounts of carbon dioxide (CO2) are released during the process. With a twin cyclone in three stages, a single cyclone in one stage, and one cyclone in one stage, this entire procedure is carried out in the Preheater tower.

Pyro – processing

The raw mix is heated in pyro processing to create clinkers. Clinkers are spherical, gray, hard nodules that can range in diameter from 0.32 to 5.0 cm (1/8 to 2") and are the result of chemical reactions between the constituent raw elements. Three phases make up the pyro-processing system: drying or preheating, calcining (a heating process that produces calcium oxide), and burning (sintering). Due to the absence of a pre-calciner in HCIL, only the pre-heated material from the preheaters is fed straight into the kiln. In the kiln section's burning zone, pyro processing is done. The flow chart for clinkerization is shown in the figure below.

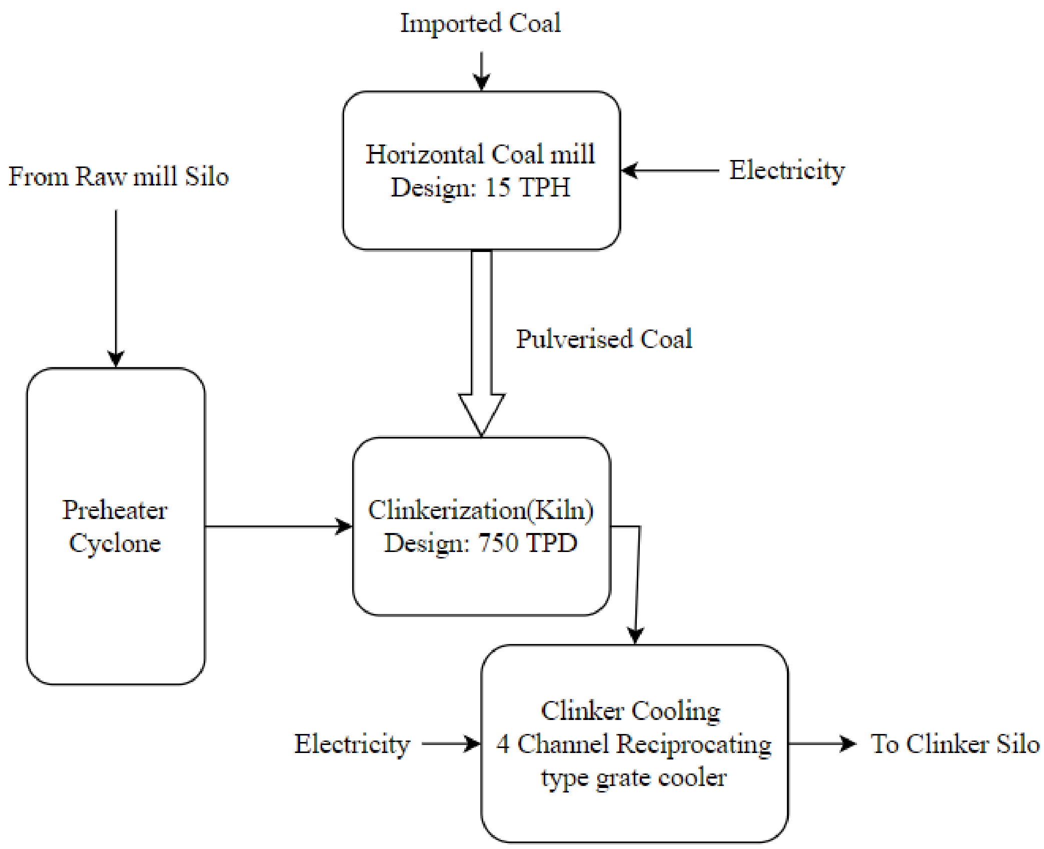

Figure 2-3: Clinker making process

This area of the facility uses the majority of the thermal energy. Electricity is used by the coal mill to pulverize the coal. In the kiln system, calcium oxides are sintered with oxides of silica, alumina, and iron that are present in the feed materials at a typical temperature of 1400–1500 °C to create clinker. The chilling stage in the plant's installed grate cooler marks the completion of the clinker production process. The raw material entering the kiln through the raw meal silo is heated by the combusted gasses as they travel from the kiln to the Preheater tower.

Clinker Cooling

The clinker cooling operation protects the ideal product characteristics, recovers up to 30% of the kiln system heat, and allows conveyors to move the cooled clinker. Here, a reciprocating cooler of the four-chamber variety is used. The high temperature clinker is cooled down below 700 degrees Celsius by the cooling fans. The clinker cooled by the clinker fan sent to the clinker silo for the storage.

Clinker Storage

Clinkers are being moved from coolers to storage spaces and to the final mill using bucket elevators. Normally, gravity drops and transfer points vent to dust collectors. Two of the three clinker silos, each with a capacity of 5000 tons, are used to store the clinker utilized in the cement mill to make cement. Reject clinker is kept in the third silo, which has a 500-ton capacity.

Cement (Finish) Milling

The clinker is ground into a fine powder with additives during the last stage of cement manufacture known as finish milling, which gives the finished product unique properties. Gypsum can be added in amounts of up to 4% to control how quickly cement sets. A ball mill is used in a closed-circuit system for the grinding process.

Hetauda Cement Industries Limited grinds cement using a ball mill that can produce 45 TPH. One of the energy-intensive steps in the manufacturing process is the grinding of the cement.

Packing and loading

After cement is produced, the completed product is moved using conveyors and bucket elevators to big storage silos. In a 50 kg plastic polywoven bag, cement is packaged. Cement is shipped from here to various dealers and agents dispersed around the nation in accordance with orders.

2.3 Past Studies

Nepalese industries are found to be using both electrical and thermal energy very inefficiently and so there are huge possibilities of improvement in the consumption of energy in the industrial sectors. The electrical saving potential is 33.60% and thermal saving potential is 41.66%. Energy efficiency margin or the energy saving potential on the product cost is highest for the Limestone based industry (above 19%) and clinker-based cement (2.43%).(GIZ/NEEP, 2012) Only a few industries have upgraded their technologies and moved towards energy efficient manufacturing processes while others are using old technologies or bypassing the technologies due to poor maintenance management policy and bad monitoring and evaluation. It is found that Nepal’s cement industries, on average, consume significantly higher electrical and thermal energy per unit of production with higher emissions. Energy cost per unit production is 100 % more than the international average.(Shrestha et al., 2016). In cement factories, energy efficiency and environment mitigation technologies are absent and the energy consumption in cement industries of Nepal has not been as efficient in comparison to the global scenario(Department of Industry Government of Nepal, 2019). FDI-based cement industries are found to be more efficient and profitable than both government owned and locally owned cement industries(Rastra Bank, 2021). Improve energy efficiency and maximize benefits by utilizing clean energy efficiently in the residential, industrial, and transportation sectors for Carbon mitigation(Government of Nepal, 2021). Categorization of energy efficiency measures at various stages of cement process, so as to meet the international best practice standards and Phase wise implementation of efficiency improvement and low carbon footprint programs is needed to be implemented in cement industries of Nepal(Singh, 2016).The use of alternative fuel, raw materials, and more efficient kilns reduce the CO2 emissions from the cement industry(Thakuri et al., 2021). Diversification of energy resources uses in different energy consumption industries must be emphasized as since 2005/06 to 2015/16, Nepal's energy security has been deteriorating, with the causes being linked to increased energy use and increased petroleum product imports(Darlamee & Ratna Bajracharya, 2021).

2.4 International Scenario

- The comparison of best technology energy consumption to average energy consumption in Indian plants reveals a higher savings potential of 24-35% in wet and semi-dry plants, more than twice the savings potential of dry process plants(Schumacher & Sathaye, 1999).
- In Turkey, when structural features of the production system parts were investigated and observed that an important amount of energy is lost from surfaces, although proper insulation has been achieved(Oral & Saygin, 2019).
- CO2 emissions linked to the cement industry come mainly due to the fuel used to produce the calcination and sintering of the raw materials which depends on the nature of the fuel and the thermal energy efficiency of the burning process

and other is due to the decarbonization process of the raw material in the kiln which is about 0.53 kg of CO2 per kg of clinker, accounting for around two thirds of the CO2 emissions in a cement plant (Pardo et al., 2011) .

- For India's cement industry, increased production of blended cement (additives: fly ash, pozzolans, limestone or/and blast furnace slag) and kiln shell heat loss reduction (improved refractories) are the two most cost-effective fuels savings measures. The two most cost-effective electricity savings measures are installation of high efficiency fan for raw mill vent fan with inverter and high efficiency motors. The largest electricity saving potential is from low temperature waste heat recovery power generation, which saves purchased electricity by generating electricity from the waste heat onsite and replacing a ball mill with vertical roller mill in finish grinding(Morrow et al., 2014).
- Use of Industry by-products such as fly ash and blast furnace slag could be used as substitutes for clinker reducing the overall emissions from the industry(Talaei et al., 2019a).
- Comparing against the global benchmarks, Nigerian plants thermal energy savings of between 19.83 and 52%, and electrical energy savings of between 35.23 and 43.10%, were possible(Njoku et al., 2017).
- 16% fuel savings and 4% electricity savings could be achieved if all clinker would be manufactured in rotary kilns instead of VSK's and Adoption of EEMs will enable the Ethiopian cement facilities to reduce the identified energy efficiency performance gap and by constructing conservation supply curves for electricity and fuel, the energy-efficiency improvement can be achieved(Tesema & Worrell, 2015).
- In Canadian Cement Industries, use of alternative feedstock and fuel and replacing the vertical shafts with suspension preheaters are the biggest contributors to GHG emissions reduction with the cost saving of carbon and more than 72% of emissions reduction is achievable at a negative cost(Talaei et al., 2019b).
- In Jing-Jin-Ji's cement industries, in order to model future cement production, different models like the GAINS model was used to estimate air pollution abatement and the changes in pollutant concentration, the IMED|CGE and HEL models to quantify the associated health effects and their effect on GDP gains at the regional and prefecture levels was made, which accounted energy saving

benefit, CO2 reduction benefits, and the health benefits to be 1.3 to 3.6 times higher than the total costs during the study period(S. Zhang et al., 2021).

- Blended cement production could be key to a cost-effective strategy for energy efficiency improvement and carbon dioxide emission reductions in the U.S. cement industry(Martin et al., 1999).
- In Asian market, along with the measures like alternative fuels, reduction of clinker to cement ratio, co-processing and blending; Innovative and emerging technologies like WHR, renewable power generation, CCS technology presents a higher emission reduction capability(Ahmed et al., 2021).
- For decarbonization of Swiss Cement factories, scenario study using The Integrated MARKAL-EFOM System (TIMES) model, BAU - Business as usual model , CAP - CO2 Cap scenario group model , EE - Energy efficiency scenario group , TAX - CO2 tax scenario group model was done and stated measures like reducing clinker content in cement , replacing of old inefficient kiln with rotary cyclone kiln , involvement of AI in cement production technology would direct the Swiss cement factories towards net zero emission by 2050(Obrist et al., 2021).
- Laos demonstrates that a developing, agrarian, and overwhelmingly rural economy can still achieve acceptable levels of energy security if it commits to using widely available domestic resources (such as hydroelectricity) and collaborates with international organizations like the World Bank to expand energy access(Sovacool, 2013).

2.5 Research Gap

Awareness level in the industries on energy efficiency is still low as per the study done by GIZ/NEEP in 2012. This detailed Baseline Study of Selected Sector Industries by GIZ was focused on overall energy consumption for the process but not for an individual equipment/machinery. Several studies have been done regarding the carbon emission of cement industries but not on the energy intensity and efficiency. There have been studies conducted for Nepal's energy security, but none for a specific industry. The study of Cement industries done by department of industry in 2019 and study by Nepal Rastra bank on 2021 identifies a need for detailed study of energy efficiency and intensity of cement industries in Nepal. Furthermore, the benchmark set by the Energy Efficiency Centre is based on the IEA's global norm, and no national benchmark has been established for Nepalese industries. Since the energy intensity of industries differs by country, national benchmarking is essential. Our research on Hetauda Cement Industry Limited would help to set a benchmark for the energy intensity of the cement industry in Nepal.

CHAPTER THREE: METHODOLOGY

The following procedures were followed to carry out in the project:

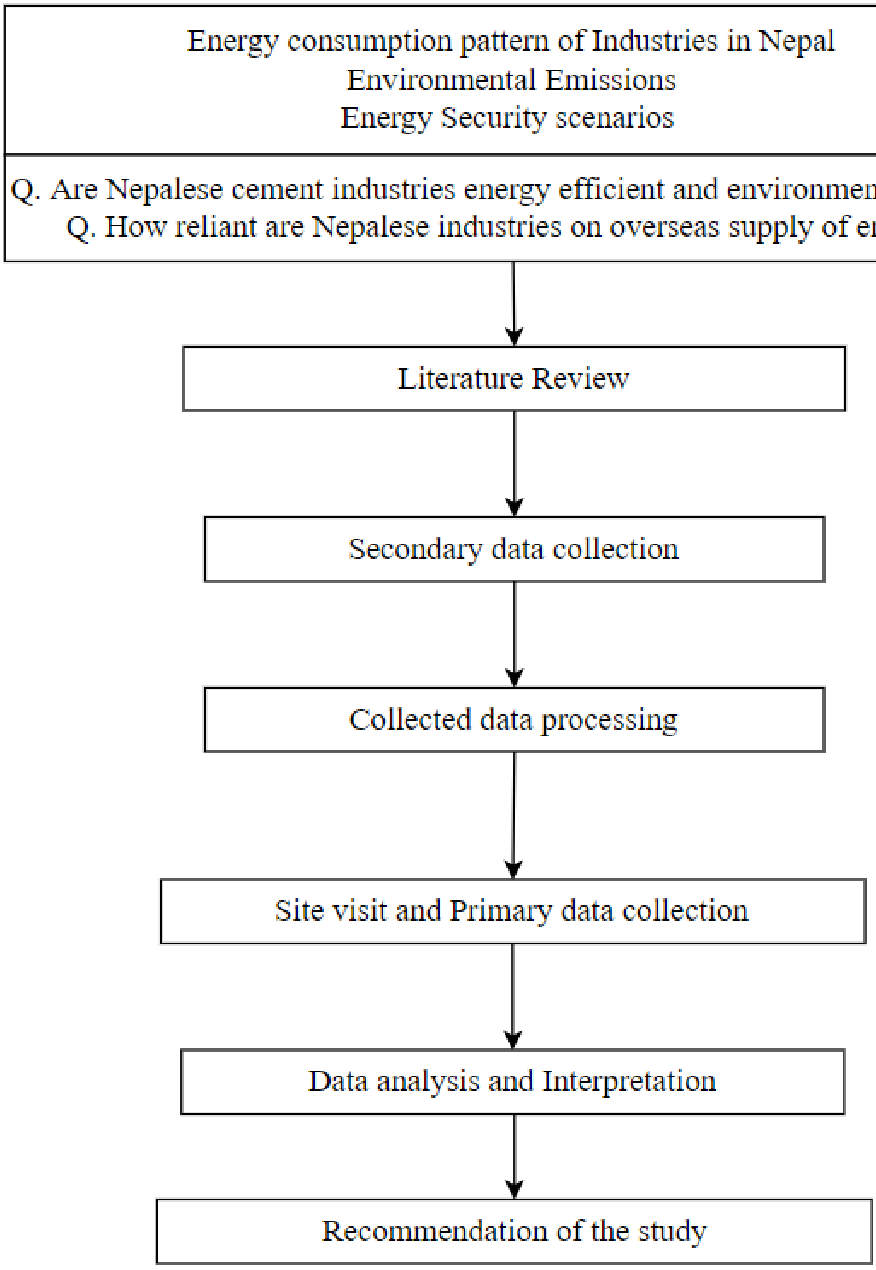

Figure 3-1: Methodology for our study

1. Literature Review

An extensive literature review was carried out on the issues related to energy efficiency-based policies, especially focusing in the context of energy intensive industries. Conducted a thorough evaluation of the pertinent literature to identify any knowledge gaps, set research objectives, and develop a complete grasp of the study problem. Through the literature review the cement industry was identified as a major industry having the potential to grow in Nepal.

2. Secondary data collection and analysis

Gathered and analyzed data from existing sources, such as government reports, industry publications including financial reports and other relevant reports, and academic papers, to gain insight into the research problem and identify potential solutions. The secondary data played an important role to identify the technological issues faced by the industry. Through the secondary data analysis, the problems in equipment and process were identified for the primary data collection.

3. Primary Data collection and analysis

Conducted innovative research using techniques like surveys, focus groups, interviews, and experiments to get fresh data that can fulfill study goals. Different energy audit equipment was used to identify the energy leakage. The instruments used are:

- Thermal Gun
- Probe type thermometer
- Luxmeter
- Anemometer

The collected data from secondary and primary sources was analyzed to make inferences and come up with suggestions that could solve the research problem.

4. Recommendation of the study

During the recommendation development, those recommendations were identified that could be implemented by the industry. Provided specific suggestions based on the research's analysis and findings, stressing the advantages and drawbacks of each alternative.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Electrical and thermal energy of the industry

Table 2: Energy aspect of the industry

Energy aspect	
a. From NEA grid(kWh)	22,025,824.6
Total cost of grid electricity (NRs)	7.877
From generators	(Rarely used)
Type of fuel used	Diesel
Fuel consumed (liter)	-
Total DG capacity	2.5MW

The Diesel generator at HCIL is primarily used for cement kiln only during the power cutoff from Nepal Electricity Authority. The shutting of kiln can result in significant thermal energy consumption so generator is primary focused for it. The high-speed diesel is used as a fuel for diesel generator and its consumption data was unavailable as diesel is consumed for other processes as well. During this year, kiln has been shut down for most of the time so diesel consumption is assumed negligible as well.

Thermal Energy from Coal

Table 3: Thermal Energy

Type of fuel used	Coal
Quantity of fuel consumed (Ton)	17681.563
Total cost of fuel consumed (NRs)	296,873,442.8
Total electrical energy (kWh per ton of cement)	295.49
Total thermal energy (kCal/kg clinker)	1190

Coal is a basic raw material for manufacturing a cement. It is used as a compositional particle in cement and as a source of heat in other industries. HCIL imports the coal from outside Nepal. Coal is burned in a kiln with grinded limestone to form clinker and that clinker is further grinded with gypsum to make cement. The quantity of thermal energy plays an significant role in the quality of cement.

4.2 Secondary Data Analysis

We obtained the secondary data through the annual financial report of the factory. The energy audit report by GIZ that we were provided was quite outdated as the audit was conducted in 2013. We analyzed the obtained data and reports, and here are some of the outcomes. The primary goal of this analysis was to comprehend the yearly average pattern of energy consumption and production. The data analysis has the shown the issue the plant is facing since last few years. Decrease in the production of clinker over the year with the increase in energy intensity has been a major issue which is further defined by the graphs presented below.

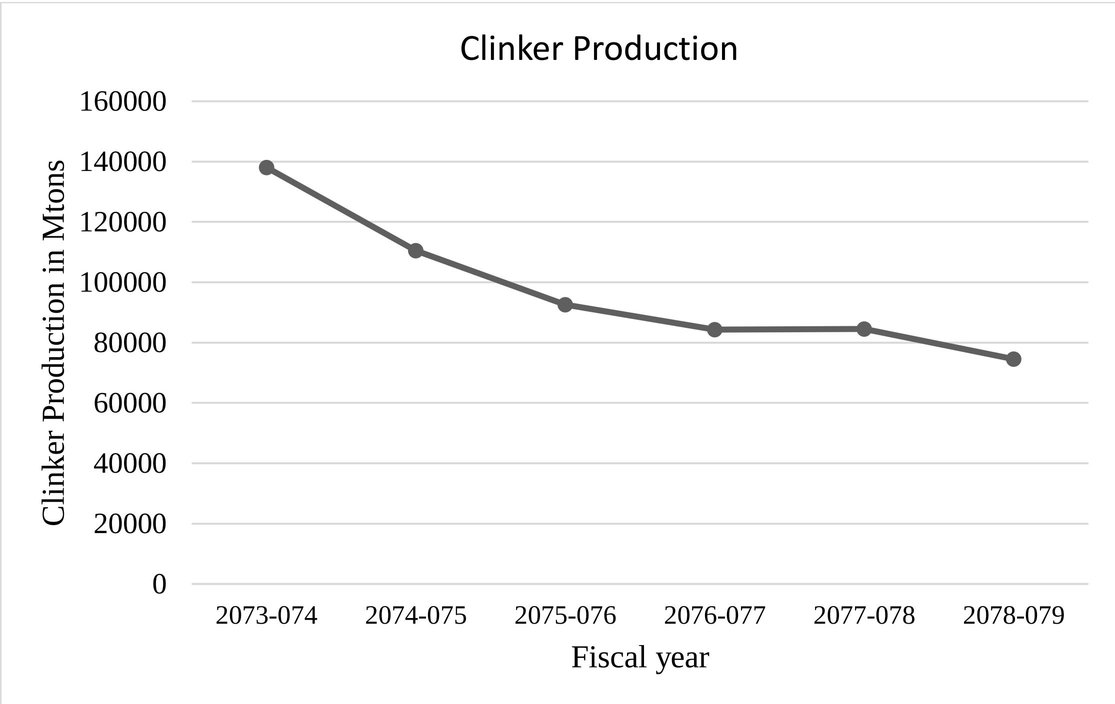

Figure 4-1: Clinker Production

The graph above shows that clinker production has decreased on an annual basis. The sharp decline has been observed since 2075. The various reports suggested that this was due to a continuous rise in the price of coal and difficulty importing it as well. But in our conversations with managers, they blame the outdated equipment.

At the optimal production of cement; electricity consumption should be 150kWh per ton of cement. But for the past five years specific power consumption has gradually increased from 223 kWh per ton to 295 kWh per ton of cement. At the same time clinker production has continuously decreased from 138100 MT to 74540 MT. Inefficient operation of the plant equipment has increased the electricity consumption by 200% and clinker production decreased by 50% as presented on table below.

Table 4: Energy Intensity

S.N.	Fiscal year	Designed		Actual		Deviation from design	
		Coal (%)	Electricity (kWh/ton)	Coal (%)	Electricity (kWh/ton)	Coal (%)	Electricity (kWh/ton)
1	2073-074	16.5	150	20.45	223.303	3.95	73.303
2	2074-075	16.5	150	21.58	237.448	5.08	87.448
3	2075-076	16.5	150	23.62	249.327	7.12	99.327
4	2076-077	16.5	150	23.54	253.63	7.04	103.63
5	2077-078	16.5	150	23.4	268.89	6.9	118.89
6	2078-079	16.5	150	23.7	295.49	7.2	145.49

Additional investigation into cement manufacturing reveals that electrical and thermal energy losses are rapidly raising the plant's energy consumption.

The plant's continuous operation over the last 36 years has reduced the efficiency of various plant equipment, increased breakdown time, increased production costs, and increased other indirect losses. Various vital production equipment and systems has already been permanently damaged and are not in operation. The plant is running at low capacity with old machinery which operates at lower efficiency. HCIL is behind by 40 years in terms of technological innovation. A significant proportion of the plant machinery is obsolete.

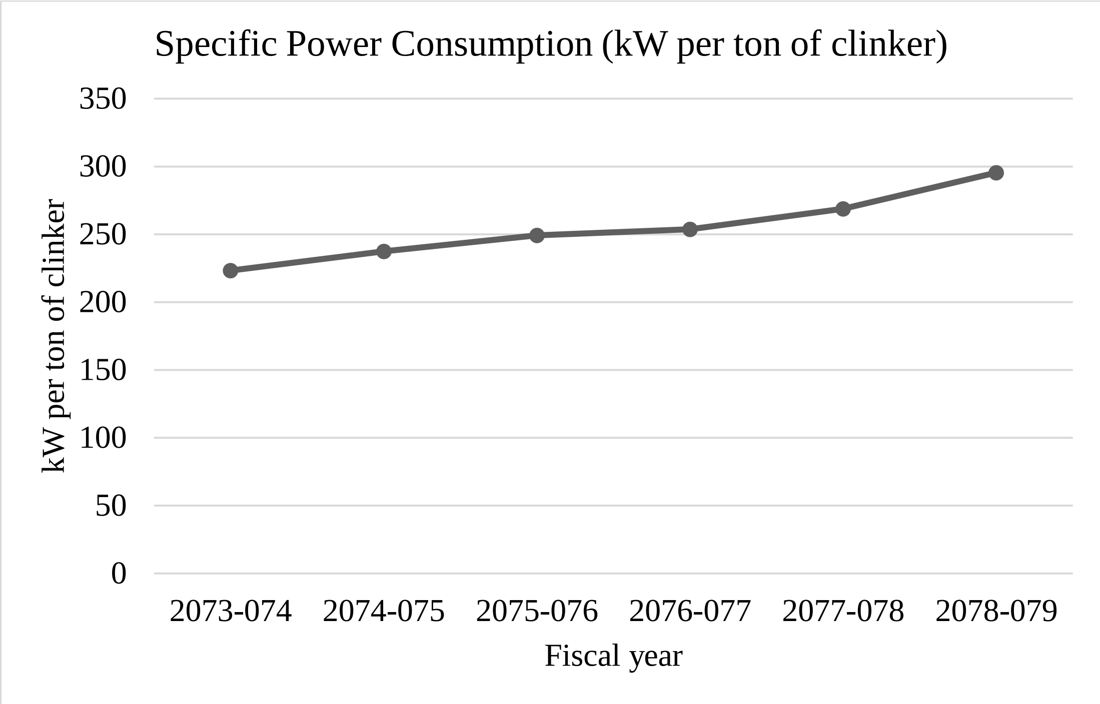

Figure 4-2: Specific Power Consumption

Since the average energy consumption for a ton of clinker production has been increasing over the years. It's the amount of electrical energy used for clinker formation, starting with raw limestone grinding. The issue in the secondary crusher, PB hall, and raw mill might have led to this scenario.

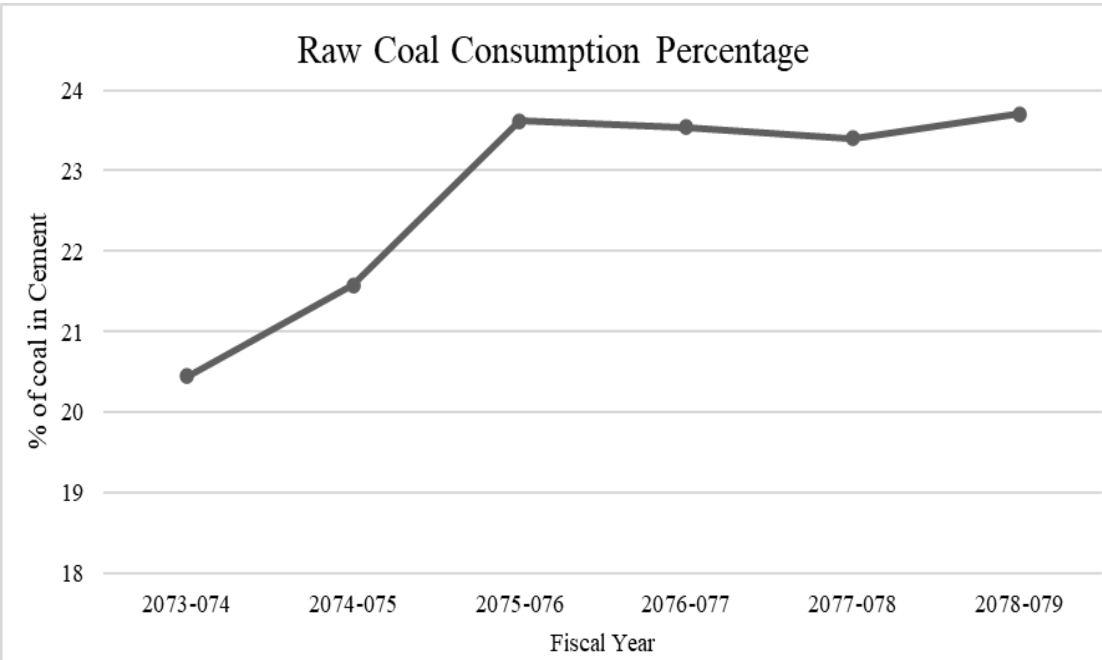

Figure 4-3: Raw Coal Consumption Percentage

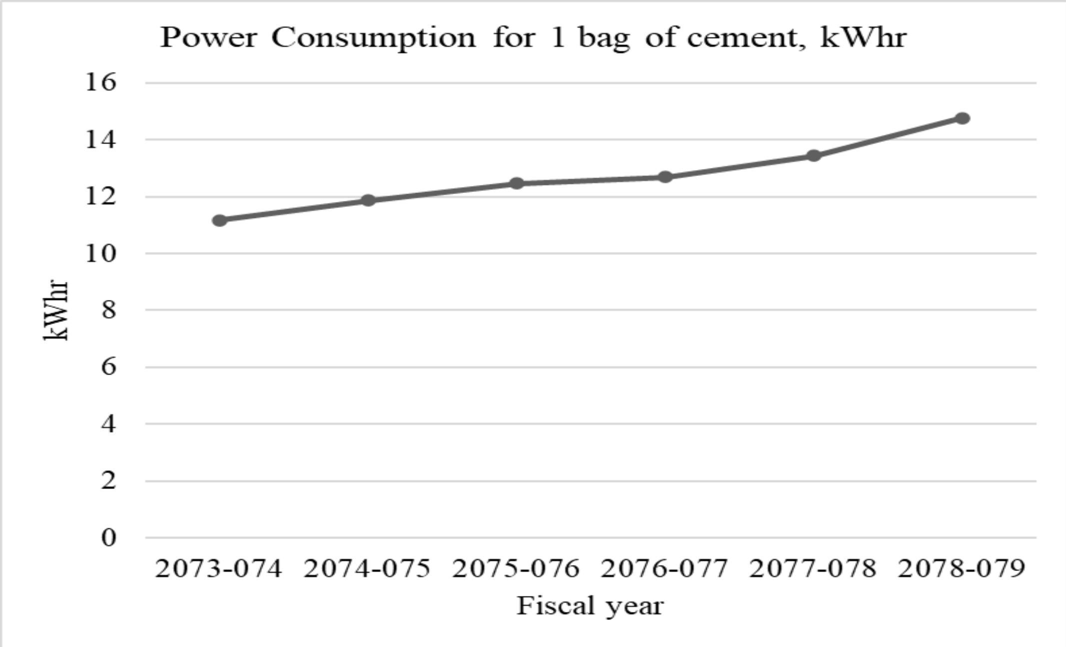

Figure 4-4: Power Consumption for a bag of Cement

Coal is not only used for heating purposes. It is one of the main ingredients contained in cement. The raw coal consumption percentage for manufacturing cement is about 20%. But the annual consumption data shows that HCIL is using more coal than standard. This is due to the degradation of the pyro kiln. Coal is imported through a company based in India. Due to the import difficulties, the plant sometimes has to shut down operations due to lack of coal.

Analysis of the obtained data in the graph below shows that the factory's power consumption for manufacturing a bag of cement has been increasing over the past years. Increased energy consumption is leading to an increase in manufacturing costs and a decrease in profit margins for the organization. As a result, the final selling price of a bag of cement produced at HCIL is almost 30–40% more than that produced at the FDI factory set up in recent years. The plant is selling the product at a lower price than its manufacturing cost. Analysis of financial statements has shown that HCIL has been at loss for a few years.

4.3 Identified Problems at the Plant

After an initial visit to the cement factory and after observing the present condition of the machinery there, some problems were identified within the plant. Following is a detailed analysis on the identified problem with the plant:

4.3.1 Quality of Raw material

Due to the mining at a particular location over the year, the quality of limestone has been decreasing. This might not be a bigger issue as the factory is planning to change the location within it's mining site. Since the Coal, Gypsum and Iron oxide is imported from India, its acquisition is a bigger issue. Decrease in the specific heat value of coal is leading to the higher consumption for clinker production.

4.3.2 Limestone Secondary Crusher

Only 55% of the rated capacity is currently being produced by the secondary limestone crusher, which has an output capacity of about 167 TPH.

Major problems for its low-capacity operation are:

1. The grate bar and rotor disc are worn out and not operating properly
2. The size of the limestone being fed from the quarry is far larger than the secondary crusher's intended capacity.
3. Because the crushing hammer and grate bar are worn out, their gap is larger than the design value.

Figure 4-5: figure: Oversized crushed limestone from secondary crusher

Possible mitigations

1. Replacement of worn-out crusher hammer.
2. Adjustment of gap between hammer and grate bar as per design.
3. Equipment inspection checklist should be prepared and the inspection should be documented.

4. Preventive maintenance Schedule should be prepared
5. The magnetic separator should be replaced as it is not in working condition.

4.3.3 Raw mill

The raw mill is used in the cement manufacturing process to grind raw materials such as limestone, clay, shale, sand, and iron ore into a fine powder, which is then used as the feedstock for the production of cement.

Raw mill is central discharge ball mill of diameter 3.6m (effective diameter 3.4m) with a drive motor of 2300kW installed with a Dynamic Air separator. There are two chambers of length 4.11m and 4.99m. The partition wall between the drying chamber and first chamber has been removed. The rated production capacity of raw mill is of 70 TPH. The mill is not working up to its marked capacity. With general consulting with the operator, it was found that the designed value and the present working values like temperature, pressure, and material flow, are not same and have a large deflection, causing a decrease in productivity. There is also a problem with the inner liner; we got a chance to get inside it more recently since it was under maintenance. The shell liner was found to be worn out, the liner thickness was also low, and the grinding temperature was always way higher than it used to be, so the mill, at some point, needs to be closed to let it cool. This operating and non-operating cycle for high numbers has also caused inefficiency in milling. The cement mill is almost very similar in dimension and orientation with the raw mill. Similar issues of raw mill were observed at the cement mill. The overheating of cement mill and leakage of dust is also an issue.

Figure 4-6: Raw Mill

Condition of Raw mill Liner

Heavy rotating machinery and abrasive grinding media are used in the grinding operation, which can seriously damage the raw mill shell. The raw mill liner aids in defending the shell against this harm, hence extending mill life and lowering maintenance expenses. The shell liners (Step liner, Spiral Liner, wave type liner and Wedge type mill liner) used in first compartments are worn out.

The identified problems encountered in raw mills and their causes are listed below:

1. Low Grindability

The main causes of low grindability in raw mill are:

- The shell liner has been worn out and the thickness is low.
- Inadequate ball charge to raw meal ratio.
- Shape and width of diaphragm slit is distorted and clogged
- The supply of raw materials in the raw mill is also lower than the rated input.

2. Low Circulation Load

3. Blending system of Raw Mill Silo not in operation

Various equipment and infrastructures of blending system of Raw Mill silo are not operational. So, homogenization of raw material is not being done. This results in inconsistencies in the raw material for kiln.

4. Grinding Media not in sufficient amount

The rated filling of grinding media is around 28% for both the chambers but only 18-21% of the filling media is obtained which accounts to low grindability of the plant.

Figure 4-7: Worn out liner

Figure 4-8: Damaged inside line

Possible mitigations

1. Replacement of the worn-out liners.
2. Regular cleaning of diaphragm screen liner slit.
3. Regular inspection and preventive maintenance.
4. Sorting of the grinding balls in accordance to their size.
5. Cleaning of the raw mill silo.

4.3.4 Kiln

Rotary kiln installed in the HCIL is of 56-meter length with inside diameter 3.8meters.

Table 5: Kiln Capacity

Kiln capacity (with 4 stage suspension preheater)	
Rated TPD clinker output	750 TPD
Rated Outlet Clinker temperature from kiln	1350-1450° C

The pyro-processing at the factory hasn't changed significantly in the past 35 years of operation. Due to recurring breakdowns, a high level of air intrusion into the kiln system, entire unit damage, outdated technology, and poor design. The plant is not producing its rated output of 750 TPD.

Factors affecting for lower clinker production and higher energy consumption

1. Frequent breakdowns:

The frequent breakdown of the kiln increases the length of time it may take to fix the kiln and resume operations, which has slightly reduced the production as well as affects the production capacity of the kiln. As per our survey, the kiln breakdown has resulted in temperature fluctuation and irregular firing which has affected the quality of the final product.

2. Brick Failure:

Due to frequent breakdown the kiln goes through a unwanted repeated heating and cooling. Kiln bricks, also known as refractory bricks, are used to line the interior of the kiln and protect it from the high temperatures and harsh conditions of the manufacturing process. The bricks in klin undergo many stages of tempering which has reduced the material properties of the brick.

The brick failure causes various anomalies including production downtime, temperature irregularities, increased energy consumption, overheating on the outside surface of the kiln,

3. Cyclone clogging:

Frequent clogging of preheater cyclone is major reason for untimely breakdown. The cyclone is a crucial part of the cement manufacturing process' preheater system. The heated exhaust gases produced by the kiln during the manufacturing process are separated from the raw meal, which is a mixture of raw minerals such limestone, clay, and iron ore inside the preheater system. The raw meal is preheated and partially calcined in the cement manufacturing process before entering the kiln. Because it assists in removing the tiny particles from the exhaust gases and redistributing them to the preheater, the cyclone is an essential component of this system.

4. High thermal and electrical energy consumption

Figure 4-9: Horizontal kiln at HCIL.

Figure 4-10: Inside the kiln

Possible mitigations

1. Roller, shaft and bucket inspection, maintenance and replacement if necessary.
2. Maintenance of kiln inlet seals.
3. Replacing the worn-out Brick lining of cyclone and kiln.
4. Complete Equipment inspection and repair of damaged components.

4.3.5 Reverse Air Bag House (RABH)

RABH (Reverse Air Bag House) was installed by Batliboi Environmental Engineering Ltd. India. RABH replaced the nonfunctioning ESP (Electrostatic Precipitator) for the collection of dust from Kiln and Raw Mill. RABH has 18 TPH maximum design capacity and 12 TPH. Presently the de-dusting system is capable of collecting dust from the exhausts of Kiln and Raw Mill but cannot properly transport the collected dust to silo.

Figure 4-11: Ductway to RABH

4.3.6 PB hall piling issue

Stacker and Reclaimer are the two machines which are installed at PB hall to pile up the crushed limestone that is imported from different mines. Bulk goods like coal, iron ore, and fertilizer are intended to be stacked or recovered via a material handling system. Reclaiming involves relocating these things from storage to another location, whereas stacking is the act of arranging them into stacks. A stacker-reclaimer has the versatility to carry out both jobs, while dedicated stackers and reclaimers are used for their specialized responsibilities.

Reclaimer

Structural and mechanical condition of the reclaimer is as explained below:

1. The equipment's main structural components are all in good shape.
2. Because the chain drive gearbox failed, the reclaimer has not been in use for a long time.

3. Drive failure and a lack of a power source have rendered the Reclaimer All Cables in reclaimer damaged and disconnected.
4. Two motors with clutch arrangements were provided for the travel drive unit to provide for reclaiming and shunting operations at two different speeds.
5. The material buildup in the chain guide support structure caused the scrapper chain guide support to twist.
6. Due to cable falling during slewing, circular guide rollers were not used to lay cables.
7. The gear's contact point is clogged with debris, and sufficient lubrication is not being applied.

Figure 4-12: Stacker and Reclaimer assembly

Stacker

1. The central column structure's stacker is operational.
2. The hydraulic cylinder and boom attachment's foundation and beams are deflected.
3. Slewing gearbox pinion has a frequent failure.

Possible Mitigations

1. Regular cleaning of the reclaimer track to remove the limestone blocking the track.

2. Replacing of the reclaimer chain drive gearbox.
3. Proper operational training should be given to the operator.

Figure 4-13: Inside PB hall

4.3.7 Coal Mill

Coal mill is vertical roller mill of 12 TPH capacity but at present it is running at around 6-7 TPH (50 % of full capacity).

Low Grindability of the coal mill and its cause

- The shape and size of Table liners and roller liners inside the coal mill is worn out.
- The moisture content of the coal is high.
- Air flow ducts are worn out and significant amount of false air is present.

Possible Mitigations

1. Preventive maintenance and documentation of inspections.
2. Cleaning of diaphragm liner of the mill.
3. The coal should be properly dried before being ground in the mill by using pre drying techniques such as air drying.

4.3.8 Cement mill

Cement mill is ball mill of diameter 3.6m and length 11.5m with a drive motor of 2300kW installed with a Dynamic Air separator. The rated production capacity of cement mill is of 45 TPH. The average cement production is 25 to 28 TPH which is low from the design or rated capacity of the cement mill. The capacity utilization is just around 55% of the rated capacity. This results with high production cost and more over the time of production is also low.

Problems in cement mills and their causes

1. The shell liners (Step liners, Spiral Liners, wave type liners and Wedge type mill liners) used in first compartment are worn out. The shell liner has been worn out and the thickness is low.
2. The clinker temperature feed to the cement mill as well as the grinding temperature is higher than rated temperatures. To reduce the temperature; clinker is sprayed with water stream resulting the increase of moisture content of the clinker. This is not recommended as standard practice because increase in moisture content of clinker increases the energy required for the grinding.
3. Dynamic Air separator shaft frequent failure.

Possible mitigations

1. Inspection and Cleaning of clogged bags should be done immediately and replacement if necessary.
2. Diaphragm screen liner slit should be gauged for cleaning.
3. Cleaning of the lining of material in air flow duct should be done if lining is developed.
4. Proper operation training.
5. Preventive maintenance and proper documentation.
6. Proper positioning of shell liners and screen liner as per the design drawings.

4.3.9 Packaging Unit

A new rotary packing system was installed recently, but the system is semi-automatic, meaning it still requires manpower to hold the packing bags while they are filled. This results in dusty areas, and the workers were deemed to be using low quality protective equipment.

Along with this, there is a sufficient amount of loss of the final product through dust. The fins and vents for air circulation in the packaging buildings are all blocked, and the walls are clogged with cement, which is lost as dust.

4.3.10 Lighting

Since the industry was established 25 years ago, the lighting bulbs used at that time are still in use. The prevailing bulbs are of lower energy efficiency. The lights were found to be used day and night with no proper closing and opening routine.

Lux reading for light intensive sites in HCIL

The lux meter readings were taken at the workshop site and the packaging unit since these are the areas where most of the manual operations take place and where a high level of precision is required with minimal margin for error.

The obtained outcome with their comparison with recommendation are given in the table below.

Table 6: Light intensity at different location of HCIL

Particulars	units	HCIL	Recommended
Workshop	lux	63-77	330-450
welding spot (Mechanical/Electrical room)	lux	45-63	200-500
Packaging Room	lux	56-71	100-300

The day light lux was just around 12-16 lux in these places.

The main reasons for the low lux in HCIL are:

1. The lighting bulbs which were setup 25 years ago at that time are still in use which have less efficiency.
2. The windows are totally covered with dust which greatly affect the penetration of the sunlight.
3. Many lights are burnt out and are not replaced.

Possible mitigations

- The windows must be clean at proper time interval.
- The lack of required light intensity can be resolved by the installation of new lights as per the energy audit recommendation by GIZ**.**

Figure 4-14: Windows and lights at the workshop

4.4 Problems of HCIL plant

The sustainability of the facility is being questioned as HCIL's productivity declines on an annual basis. During our visit at HCIL, we found a few issues, which are detailed below:

- Outdated equipment and old technology
- Low efficiency and low production
- High coal and electricity consumption
- high maintenance and production cost
- Imminent catastrophic failure of major equipment, and lack of contingency plant
- Highly competitive market

- Environmental pollution

The plant is beyond the threshold of profitable clinker production at present. The trend of the last five years shows that the condition will continue to get worse until any significant technological intervention and plant retrofitting are introduced.

High coal and electricity consumption, lower production of cement and frequent breakdowns of the plant has significantly increased the cost of production per bag of cement. But the prevalent market price per bag of cement is gradually decreasing. To remain competitive in the cement market HCIL has also decreased the price per bag of cement. A replacement in machinery with high efficiency equipment will decrease the maintenance cost, decrease breakdown time and increase productivity while reducing the cost of production making the plant profitable.

Increase in hauling the equipment operation and mobilization of human resources are intangible losses occurring in the plant that cannot be quantified.

4.5 Overall Possible Interventions

With the preliminary site visit and our first glance at the industry, it was found that there were many underlying problems which were hindering the performance of the whole. From small things to large-scale problems as described earlier were the major problems there. But with the aim of making a profoundly visible change in the industry in terms of energy consumption, a possible intervention study was made. The interventions were mainly focused on very easiest and very feasible methods of solution which in the long term would provide significant good changes in terms of consumption and intensity of the industry itself.

Keeping our aim in mind, interactions with the industry official were made. In our interactions with the plant's manager, both mechanical and electrical, they suggested that we study the secondary crusher's crushing jaw's geometry, the raw mill's inner lining's effectiveness, the leakage of cement dust at the packaging unit, and the lighting issue.

Our targeted interventions are mainly focused on industry efficiency improvement, the health of the workers working around and the environment and surrounding (environmental emission).

The secondary crusher's crushing jaw geometry fixation is a simple yet effective method for improving the crushing efficiency, reducing energy for crushing, which would help the raw materials be crushed into specific required size, which in turn helps in smooth formation of cement.

The raw mill inner liner and cement mill have problems with the inner liner because of which extra energy needs to be provided. If this problem would be encountered then the effective energy for production could be saved.

The packaging unit is semi-autonomous meaning manual workers are needed to catch the cement bag while filling. Because of this there is excess leakage of cement to the surrounding, making direct loss in terms of the material, energy consumed etc, along with causing health hazards for workers and the locals. With the solution of this problem, effective results in terms of energy, material loss, financial loss and health hazard due to air pollution could be solved.

Lightning is one of the major problems that needs to be addressed. Because of the old high energy-consuming light bulbs which are turned on almost all the time, in the long run, it has caused massive financial and energy loss in the industry. This problem can be addressed easily and it can provide a large impact in terms of energy consumption as a whole by the industry.

4.6 New intervention in industry

4.6.1 Gravel bed filter

The installed clinker dust collector from the grate cooler of the plant is Gravel Bed Filter. The technology used for the de-dusting of clinker is outdated technology. Most of the components of the Gravel Bed Filter are outdated and not in operating condition. Due to the inefficient operation of the Gravel Bed Filter, most of the clinker produced is emitted into the atmosphere. This has a direct effect on production and a detrimental effect on the environment. The daily loss of 12 metric tons of clinker due to the existing inefficient functioning of the gravel bed filter amounts to NRs. 5,04,00,000 loss of revenue opportunity annually on 300 days of operation. Similarly, the direct release of clinker into the atmosphere causes negative impacts on the environment and air quality.

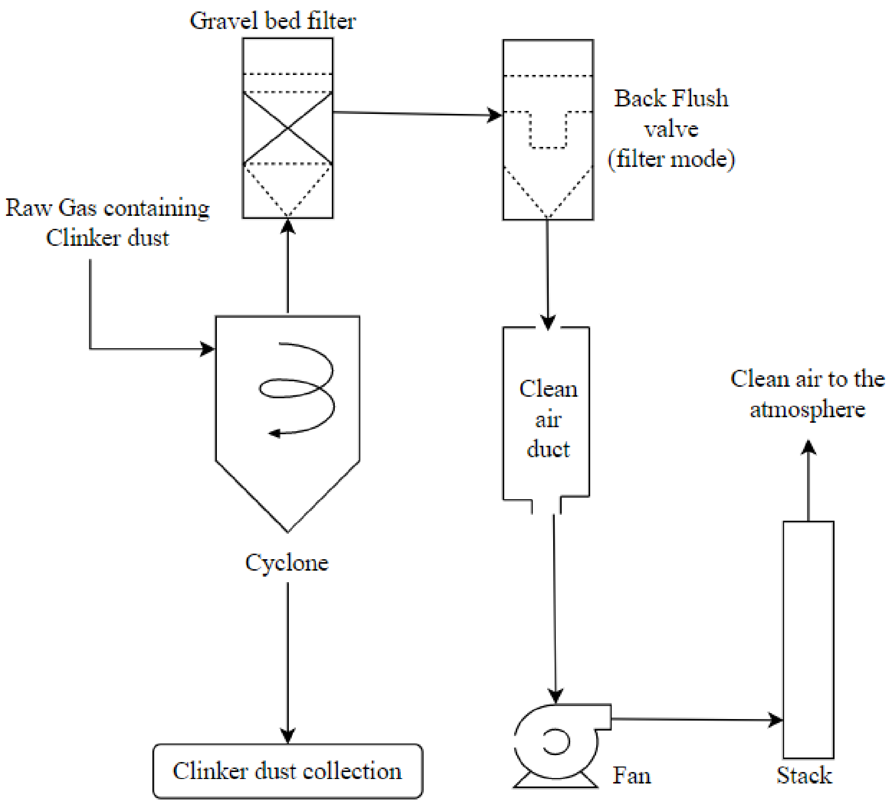

Figure 4-15: Gravel bed filter system layout

Existing conditions of the equipment:

1. Filter Chamber/Gravel Bed: Bed of sand is not functional
2. Stirring Rake Motor and Stirring Rake system: Clogged and jammed
3. Backwash Control Valve: Clogged and jammed
4. Backflush fan: Operating structure and fan motor missing

Through our observation, we identified complete replacement of the existing gravel bed system and installation of a new dedusting system is necessary. Production is directly loosed by the emission of semifinal products into the air and reducing the production of the plant. Approximately, 12 tons of clinker is loosed in a day with improper functioning of the Gravel Bed filter.

Replacement analysis of equipment

For the remedy and improve the production of the plant, the existing Gravel Bed Filter should be replaced with new technology of dust collection of clinker available.

Initial Investment (I)=Rs. 10,00,00,000 (Estimated)

Annual Operation and Maintenance cost (C)= 2,00,00,000

Annual Clinker saved by the installation of project= 300 * 12 = 3,600 Metric ton

Annual cost of production saved by the installation of projection = Rs. 3,600x14000=Rs. 5,04,00,000 (Assuming Cost of Clinker =Rs. 14,000)

Net annual amount saved = Rs. 5,04,00,000-2,00,00,000=Rs. 3,04,00,000.

The simple payback period will be: 3.289 years

The existing Gravel Bed Filter system for the clinker dust collection is outdated technology and is not functioning properly. For the replacement of the existing system with available new technology, a financial analysis of the project with an initial investment of NRs. 10,00,00,000 shows that it has a payback period of 3.289 years. This shows that enhancement in the production of the plant should be done. It is beneficial as well from the environmental perspective as the TSP of the local area can be reduced according to the ambient air quality standard of Nepal.

A detailed project report (DPR) should be prepared through consultants having recognition in the field of dust collection system installation.

4.6.2 Waste Heat Recovery Unit

Introduction:

Waste Heat Recovery Technologies:

Cement production is one of the most energy-intensive industries, requiring large amounts of heat for the calcination process that transforms raw materials into clinker. As a result, cement plants generate significant amounts of waste heat, which can be harnessed and used to improve energy efficiency and reduce carbon emissions through waste heat recovery (WHR) technologies.

WHR technologies involve capturing and utilizing waste heat from various sources within the cement production process, including preheater and cooler exhaust gases, clinker cooler air, and kiln combustion gases. The recovered heat can be used to generate electricity, heat for other industrial processes, or for district heating and cooling.

The implementation of WHR technologies can lead to significant cost savings and environmental benefits, including reduced energy consumption, lower greenhouse gas emissions, and improved energy security. Many cement producers have already adopted various WHR technologies, and as the push towards more sustainable and environmentally-friendly practices continues, the demand for these technologies is likely to increase.

WHR relies on conventional recovery equipment such as HEs, recuperators, and regenerators. However, these WHR technologies have not been widely adopted by industry, owing to the following reasons/factors:

(i) high costs and long payback periods (PBPs), especially for custom-made designs that increase design and manufacturing costs.
(ii) material constraints—especially for HT streams.
(iii) high chemical activity for streams to be cooled below the condensation temperatures.
(iv) corrosion.
(v) low efficiencies and

(vi) possible unavailability of convenient end-use of the waste heat.

It must also be noted that generating electrical power from WHR, in particular from LT streams, is still not mature, despite the existence of a number of ORC-based power-generation systems, as their efficiency has not reached high levels in order to motivate their wide adoption by industry.

WHR technologies are usually classified based on the output provided, namely heat recovery (HR) or heat-to-power (H2P) conversion. To date, several WHR technologies have been deployed in industry.

(i) Technologies recovering heat from a primary flow and making it available as heat of lower or similar quality in a secondary flow. Typical examples are HEs, recuperators, and regenerators, as mentioned above.

(ii) Technologies recovering heat from a primary flow and upgrading it to a higher-temperature useful heat using another heat source as input.

(iii) Technologies recovering heat from a primary flow and converting it to electricity. Typical examples are the conventional Steam Rankine Cycle and the ORC. There are also other potential systems at different stages of research, development, and application, such as the organic flush cycle (OFC), the Kalina cycle, the TFC, and the sCO_2 Brayton cycle(Christodoulides et al., 2022).

Cogeneration:

A cogeneration or combined heat and power (CHP) system generates steam, which delivers thermal energy to heat exchangers as well as mechanical energy via expansion to turbine units or process heat and power generation. The mechanical energy is subsequently transferred by the turbine units to generators, which produce electricity. The primary technological advantage of cogeneration systems is their capacity to increase fuel efficiency in the production of electrical and thermal energy. It takes less fuel to produce a given amount of electrical and thermal energy in a single cogeneration unit than it does to produce the same amounts of both types of energy using separate traditional methods.

The operation of a cogeneration plant by generating steam using waste heat recapture is a more cost-effective option than direct steam generation, which is possible in steel mills and cement factories. Because of the increased need for building and construction materials, there is more opportunity for power generation in cement factories(Onovwiona & Ugursal, 2006).

Kalina Cycle:

Aleksander Kalina invented the Kalina cycle in the late 1970s and early 1980s. The fundamental distinction between the Kalina cycle and the ORC or steam Rankine cycle is that the Kalina cycle employs an ammonia-water mixture as its working fluid. The temperature profile during boiling and condensation differs in a binary fluid cycle. During evaporation in the steam Rankine cycle and the ORC, the temperature remains constant. Temperature will rise during evaporation during the Kalina cycle due to the boiling temperature differential between water and ammonia. Because of non-isothermal boiling, the employment of a combination in the Kalina cycle results in good thermal matching with the waste heat source and cooling medium in the condenser. The results of a second law study revealed that utilizing a binary fluid lowered the irreversibility of the Kalina cycle in the boiler. As a result, the cycle's overall efficiency was greatly enhanced. Furthermore, as indicated in multiple studies, it is widely assumed that the Kalina cycle outperforms both the steam Rankine cycle and the ORC. The Kalina cycle is primarily used to generate electricity from geothermal and waste heat.

Since this cycle has more power generation capacity which is around 25% rather than 18-20% efficiency in other cycle, this method is used for our feasibility study(X. Zhang et al., 2012).

First law of thermodynamics

According to the first law of thermodynamics, energy can only be changed from one form to another and cannot be generated or destroyed. Mass crossing the control boundary, external work, or heat transfer across the barrier are all examples of energy transfer for any system (Ali Khalifa, 2019). The first law of thermodynamics' equation is expressed as

$$\Delta U = Q - W$$

where,

ΔU = change in internal energy

Q = heat added

W = work done by the system

The above equation can be changed as

$$Q = W + \Delta U$$

If external work done is neglected the equation becomes

$$Q = \Delta U$$

$$Q = m * s * \Delta T$$

where,

m = mass

s = specific heat capacity

ΔT = temperature difference available.

For, gas flow, the total available heat for a mixture of gas is given as

$$Q_{available} = \text{mass flowrate} * \text{mean specific heat capacity} * \text{temperature difference}$$

Waste Heat Recovery Unit feasibility study of HCIL

During our visit at HCIL, we discovered that heat was lost to the environment during the dedusting process in the RABH filter. Waste gases from the kiln exit gases and the kiln pre-heater system contain useful energy that can be transformed into power. Only in long-dry kilns is the exhaust gas temperature high enough to recover heat through power generation cost-effectively.

Cogeneration systems can be direct gas turbines that use waste heat (top cycle) or a waste heat boiler system that runs a steam turbine system (bottom cycle). Because the heat in the kiln exhaust is used for raw material drying, heat recovery has limited utility in operations with in-line raw mills.

Gases and dust from the raw mill and preheater enter the RABH intake. The temperature in the preheater is around 600 °C, and when it reaches the RABH, the average temperature at the RABH's entrance is roughly 400 °C. The primary function of the RABH filter is to improve dust dedusting before releasing waste gases into the air.

There is currently a filter in the RABH for the dedusting mechanism that operates at a temperature of 250 degrees Celsius. Sudden cooling is used to lower the inlet temperature to the filter working temperature by mixing waste gas with ambient air. The energy is lost to the environment for no reason here.

For our proposal, we suggest a more dependable mechanism for de-dusting at higher temperatures, and then utilize the waste gas energy in a waste heat recovery system to reduce the industry's particular energy consumption.

Feasibility study of the waste heat recovery unit for pre heater section only is given as:

- Temperature of the waste gases : 400 °C
- Incoming mass flow rate at the existing RABH : 18 TPH: 18000 kg/hr.
- Ambient air temperature : 30 °C
- Total energy available for utilization:

$Q_{available}$ = mass flowrate * mean specific heat capacity * temperature difference

= 18000 kg/hr * 1.05 kJ /kg * (400 – 30)

= 69,93,000 kJ/hr

- Total clinker production per hour : 50,000 kg/hr.
- Waste thermal energy per unit clinker production : 139.86 kJ/kg of clinker per hour

(*Thermal energy available for electrical heat generation*)

- Recovery efficiency : 0.25
- Total Power generated :35 kJ/kg clinker

= (35*1000)/3600

= 9.72 kWh/ton of clinker

- Plant Clinker capacity :50 tons/hr
- Total gross potential power generated: :486 kWh
- Auxiliary power consumption by WHR system @ 15% : 73kWh
- Net Potential Power Generation = : 413 kWh

(Ali Khalifa, 2019)

Hence the power generation capacity from the pre heater, typically from the waste heat at RABH is found to be 0.413 MWh.

In addition to the preheater, there are losses in the clinker cooling section. Statistically, the air at the exhaust fan at the cooler end is nearly 600-800 °C, but when it comes out, it is pressured by the blower fan, causing the air temperature to drop to 350°C. Currently, this 350°C hot air comes into touch with the atmosphere before reaching the filter and cools to 100°C before being filtered and discharged into the atmosphere. Analyzing revealed a zone of energy loss, which could be recovered and used to generate power utilizing the waste heat recovery approach. With the installation of the waste heat recovery plant, the overall specific energy intensity in the industry's consumption will be reduced.

Feasibility study of the waste heat recovery for clinker cooling section is given as:

- Temperature of the waste gases: 350 °C
- Mass flow rate out of cooling fan: 0.83 kg/kg of Clinker
- Inlet temperature for filter: 100°C
- Total thermal energy available for utilization:

  $Q_{available}$ = mass flowrate * mean specific heat capacity * temperature difference

  = 0.83 kg/kg * 0.2425* 4.2 KJ /Kg * (350-100)

  = 212 kJ/kg of Clinker per hour

- Recovery efficiency = 0.25
- Total Power generated: 53 kJ/kg clinker

  = (53*1000)/3600

  = 14.72 kWh/ton of clinker

- Plant Clinker capacity: 50 tons/hr
- Total gross potential power generated: 756 kWh
- Auxiliary power consumption by WHR system @ 15% = 111 kWh
- Net Potential Power Generation = 0.625 MWh

(Ali Khalifa, 2019)

The thermal energy analysis of the clinker cooling gases was found out that it contained 212 kJ/kg clinker of thermal energy per hour, which translated to 50.47 kcal/kg clinker per hour. Hence the power generation capacity from the waste heat from clinker cooling is found to be 0.625 MWh.

Total power generation capacity form both the RABH waste heat (pre heater) and clinker cooling waste heat is calculated to be (413 + 625 = 1038) kWh.

For the installment of the Waste Heat Recovery unit, there are some of the commercially available units around the world. Since in cement industry, the heat loss accounted is after it being reused, the most viable option for WHR unit is to use either gas turbine or steam turbine. Since the flue gases consists of many harmful gases, using it to heat water to run a steam turbine seems the most logical option. This is eventually help in reducing net energy intensity of the cement industry to some extent.

The steam turbine on most cases have only 20 percent recovery rate, but at present many WHR unit utilize Kalina cycle which increases the recovery rate to around 30 percent, thus helping to increase the overall electricity production.

Following are some of the commercially available steam turbines suitable for this project. Selection on the basis of the local availability and cost consideration can be done before the implication of WHR unit.

Table 7: Commercially available steam turbine models of the required size and input

NO.	Model	Capacity (MW)	Speed (r/min)	Inlet			Exhaust pressure (MPa)	Weight (t)	Overall dimensions L × W × H (mm)
				Pressure (MPa)	Dryness ()	Temp ()			
1	S1.0-0.3	1	3000	0.3		200	0.008	14.6	3220 × 2150 × 1750
2	S1.3-0.36	1.3	3000	0.36		180	0.013	18.2	4550 × 2300 × 2600
3	S1.5-0.14	1.5	3000	0.14	0.995		0.0072	18.7	3200 × 2300 × 2532
4	S1.5-0.16	1.5	3000	0.16	0.995		0.0088	18.7	3200 × 2300 × 2532
5	S1.5-1.7	1.5	3000	1.7		240	0.098	9.8	4120 × 2650 × 2530
6	S2-0.6	2	3000	0.6		275	0.0061	12	4257 × 2145 × 2375
7	S2.6-1.08	2.6	3000	1.08	0.995		0.009	17.7	3500 × 2850 × 2500
8	S3-0.5	3	3000	0.5	0.995		0.009	16	3250 × 2850 × 2500
9	S3-0.5	3	3000	0.5		230	0.009	16	3250 × 2850 × 2500
10	S3-0.5	3	3000	0.5		270	0.008	15.7	3500 × 2250 × 1750
11	S3.69-1.27	3.69	3000	1.27		300	0.007	17.7	3500 × 2850 × 2500
12	S3.9-1.08	3.9	3000	1.08	0.995		0.009	17.7	3500 × 2850 × 2500
13	S4-0.5	4	3000	0.5		230	0.01	16.3	3300 × 2840 × 2500
14	S5-1.0	5	3000	1		260	0.01	17.9	3510 × 2830 × 2485
15	S6-0.5	6	3000	0.5		230	0.01	38.1	5000 × 3900 × 2610
16	S6-0.5	6	3000	0.5	0.995		0.01	38.1	5000 × 3900 × 2610
17	S6-1.0	6	3000	1		230	0.009	42.1	5160 × 3900 × 2600
18	S6-1.0	6	3000	1	0.995		0.01	42.1	5160 × 3900 × 2600
19	S8-1.0	8	3000	1		260	0.01	42.9	5160 × 3900 × 2600
20	S8-1.0	8	3000	1	0.995		0.01	42.9	5160 × 3900 × 2600
21	S9-1.35	9	3000	1.35		310	0.005	43.2	5190 × 3900 × 2600
22	S10-0.981	10	3000	0.981		300	0.008	43.9	5200 × 3900 × 2600
23	S10-1.0	10	3000	1		260	0.01	43.8	5160 × 3900 × 2600
24	S10-1.0	10	3000	1	0.995		0.01	43.9	5160 × 3900 × 2600
25	S12-0.785	12	3000	0.785		415	0.0073	45	5205 × 3770 × 2450
26	S12-1.0	12	3000	1	0.995		0.01	42.9	5160 × 3900 × 2600
27	S12-1.25	12	3000	1.25		315	0.01	39.1	4910 × 3900 × 2600

Economic Feasibility of the WHR plant

The simple Payback analysis is used to quantify the time required to return the project's initial cost in years. The payback period is the amount of time it is projected to take for the earnings from fuel savings, decreased energy costs, and greater clinker output to fully cover the initial investment. The fuel savings are the result of lower consumption of heavy furnace oil (HFO) and coal (thermal fuels) during plant restart after a power outage. The plant setup includes preheating the kiln system to achieve the required operating temperatures for the clinkering process.

Operation and maintenance costs for a 1.2-Megawatt waste heat recovery plant range between $0.005 and $0.020/kWh, reflecting the wide range of maintenance requirements that may be encountered. The energy intensity per ton of clinker can be reduced by 24.44 kWh through the installation of waste heat recovery unit at HCIL.

The net power generation from the waste heat recovery power plant is calculated by factoring in the auxiliary power need of (10-15%) of the gross power generation. The generation cost per MW is around 2.5 million USD(Irungu et al., 2017).

Waste Heat Recovery (WHR) payback calculations

- Exchange rate, USD to NPR: NRs 133
- Operating days per year: 280 days
- Total running hours in a year: 5000 hrs.
- Average power supplied unit cost: 7.877 NRs per unit

Table 8: Waste heat recovery unit payback calculation

Item Description	Units	Value
Cost of WHRS per MW	million USD	2.5
Gross WHR Potential	MW	1.242
Net power generation (85% of gross)	MW	1.038
Project cost estimates	million NRs	412
Expected Net generation annually	kWh	51,90,000

Expected generation per month	kWh	4,32,500
Operating costs	USD per kWh	0.2
Total Operating costs per year	USD	86,500
	NRs	1,15,04,500
Revenues		
Costs of units substituted from national grid	NRs	4,08,81,630
Net revenue offsetting O&M costs	NRs	2,93,77,130
Simple Payback in years	Years	14.02

In this economic analysis, only the benefit through reducing in electricity consumption is accounted. There are other many benefits such as no losses due to frequent power cuts, more production is yet to be measured. Along with this, the socio-emotional sentimental improvement can also be a good take from this installation.

Hence after the economic analysis, we found that the simple payback period of the plant if installed today is around ten years. The economic feasibility study done above does not account for the future value. This analysis shows that waste heat recovery plant can be implemented at HCIL. The detailed feasibility study needs to be done for the implementation.

4.6.3 Energy Security Status Improvement

Hetauda Cement Industry Limited (HCIL) is dependent on the import of industrial coal from India. HCIL regularly checks the coal's Calorific Value (CV) and only rejects coal batches that don't satisfy the necessary CV. Due to several financial issues and the frequent interruptions in the coal supply during this year, the industry was frequently compelled to cease operations. Through the secondary data analysis, it’s very clear that thermal energy consumption has also increase over the years.

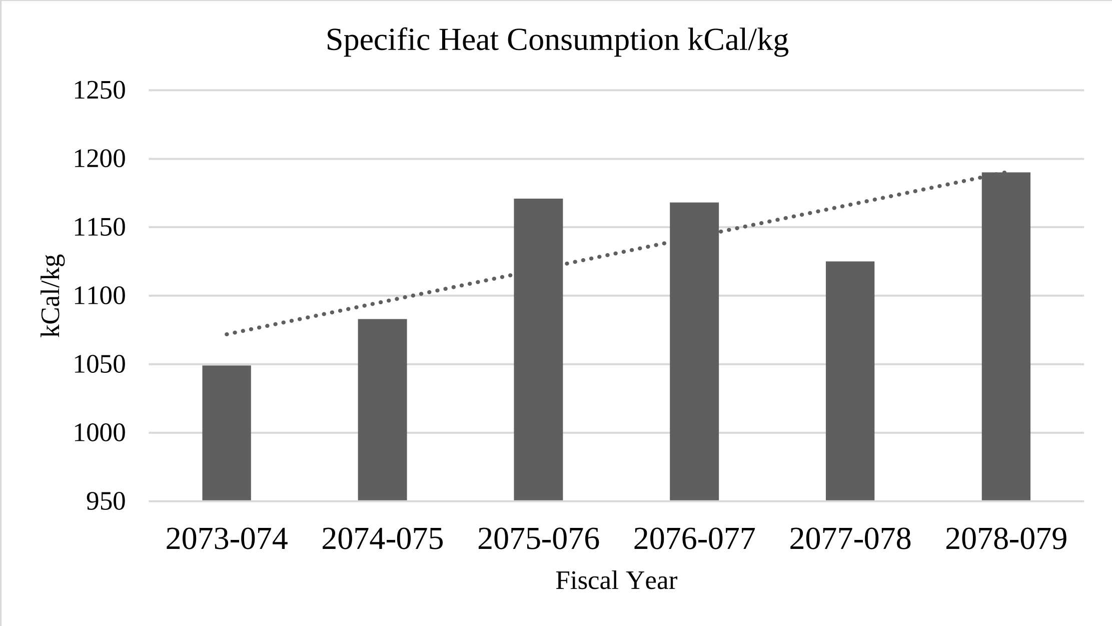

Figure 4-16: Specific Heat Consumption

It's clear from the above graph that the specific heat consumption is increasing which means the price to manufacture a bag of cement is also increasing. The condition of the kiln is one of the reasons for this but also the reduction in the production is a major cause for this rise. The problems existing in the Reverse air bag house (RABH) and preheater cyclone are also responsible for it. Coal is the only source of thermal energy at Hetauda cement industry limited. In our informal discussion with the factory workers, they mentioned the open yard storage is increasing the moisture content in the coal reducing the CV of coal. The poor functioning of the coal mill can also be held responsible for increasing thermal energy consumption as pulverization of coal at HCIL is inefficient. The price of the coal is increasing at a rapid rate which is shown in the figure below. HCIL uses the high quality of coal from India lacking the diversity in term of supplier.

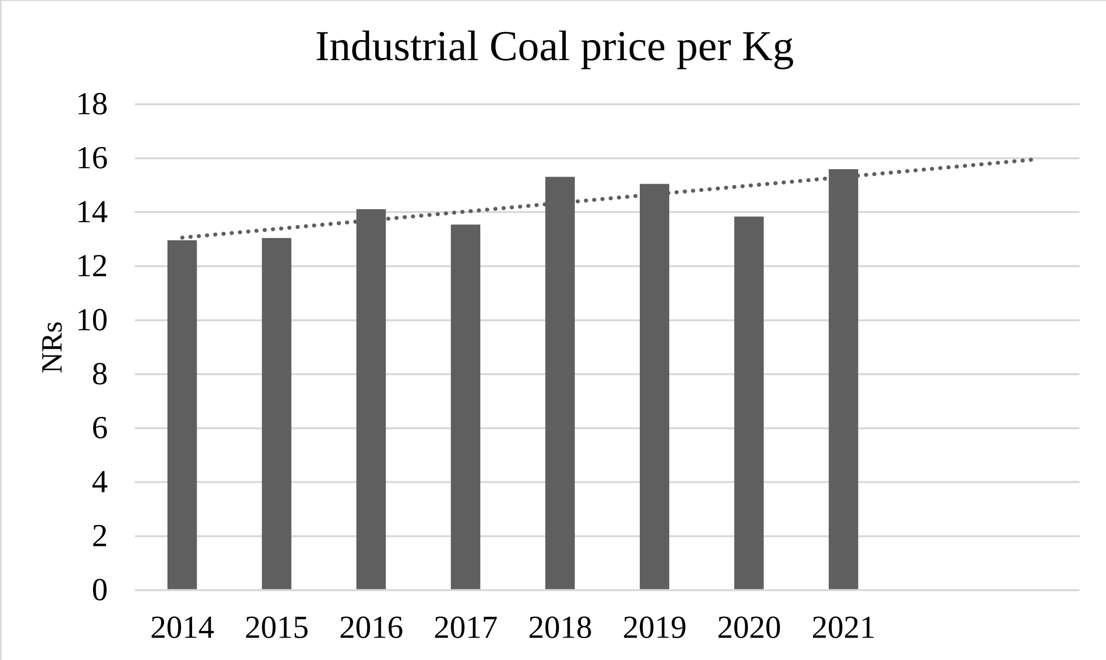

Figure 4-17: Industrial coal price per kg

Regarding the technical cause of increased coal consumption per ton of cement at HCIL, we identified the increase in kiln fire rate. Kiln needs to be operated twenty-four hours a day with proper firing to optimize it operation. Stopping the kiln fire for few hours means additional thermal energy will be used for heating the kiln to rated temperature to start its operation again.

HCIL doesn’t have an official record of number of firings done in a year. The tentative data suggests that in fiscal year 2078-79, the kiln has been fired around 80 times.

Table 9: Coal Consumption during firing

Coal used for heating the kiln in Tons (Approximately)	20
No. of firings	80
Total coal consumed (Tons)	1,600
Price per ton of coal (NRs)	15,600
Total cost of firing (NRs)	24,960,000

This economic analysis suggest that plant can better halt its clinker production if there is not enough coal in reserve. Stopping and later starting the kiln with supply of coal is responsible for huge economic loss. We recommend not to start a kiln fire until there is enough coal for an extended period of time.

4.6.4 Lighting improvement

The poor condition at workshop and other places can result in accident causing the health impact to the workers. On the other hand, the capacity utilization is also affected by poor lighting.

Table 10: Investment for lighting improvement at Workshop

No. of lights to be installed (LED)	200
Rating (Watt)	10
Cost per unit bulb (NRs.)	300
Total Investment needed (NRs)	60,000

Most of the existing lights at workshop are not operating so the payback analysis couldn’t be done for workshops.

The lighting replacement analysis was done for technical building and main office and it suggest the payback of around two years replacing 20-Watt CFL bulbs by 10-Watt LED lights.

Table 11: Replacing 20-watt lights with 10-watt

Total number of CFL lights to be changed	No.	150
Avg. power consumption of CFL	Watt	20
Avg. operating hours	Hours	12
Total working days	Days	300
Annual energy saving	kWh	5400
Per unit cost	NRs	7.877
Annual cost saving	NRs	42,535.8
Investment	NRs	90,000
Payback period	years	2.1158

The high intensity high has been placed at different outdoor setups. Replacing 40-Watt Fluorescent bulbs by 18-Watt LED Tube for such settings at HCIL will have a payback period of slightly more than a year.

Table 12: Replacing 40-watt lights with 20-watt

Total number of lights to be changed	No.	500
Avg. power consumption of light	Watt	40
Avg. operating hours	Hours	12
Total working days	Days	365
Annual energy saving	kWh	43,800
Per unit cost	NRs	7.877
Annual cost saving	NRs	3,45,012.5
Investment	NRs	4,50,000
Payback period	Years	1.3043

From the above analysis, overall light replacement cost will be around 6 lakhs rupees with the payback period of one and a half years. HCIL needs to focus on lighting as it plays a significant role in improving the productivity of the employees.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

In the beginning the preliminary visit to HCIL was conducted with the sole purpose to be familiar with the plant. The plant was at breakdown maintenance during the visit which forbid us to observe the production process. The general idea of the plant layout, the machines and the overall process was identified. The machinery had many flaws as they were outdated and old. From the discussions with the industry officials, the required information about the plant and the major processes included during the production was obtained.

The results were obtained as per the objective set on the project which concludes as follows:

1. The energy intensity calculated shows that electrical energy has increased from the rated 150 kWh/ton to 295.49 kWh/ton and coal consumption has increased from rated 16.5% to 23.7%. Investigation into cement manufacturing also reveals that electrical and thermal energy losses are rapidly raising the plant's energy consumption. The lower capacity utilization was found responsible for this increase in energy intensity reducing the energy efficiency.

2. The environmental emission due to lack of clinker filtration can be control using the Gravel bed filter with an investment of NRs. 10,00,00,000. Clinker wastage can also be prevented which accounts for NRs. 5,04,00,000 and will have a payback period of around 3 years. The local pollutant and global GHG emission will also be controlled.

3. To improve the energy security of the plant waste heat recovery unit and firing rate control is significant. Waste heat recovery unit with the capacity of 1.2 MW is proposed with the payback period of 14 years can reduce the energy intensity by 24.44 kWh/ton of clinker. Increasing number of kiln firing is responsible for increased thermal energy intensity which can be controlled by using energy from waste heat recovery. Any disruption in NEA grid, will not hamper the kiln functioning if energy from waste heat is utilized.

The industry seems to be more inclined towards efficient operation of the plant but due to lack of proper resources and investments is not able to comprehend the total production potential with the preexisting facilities. As the energy saving measures to be implemented the management is responsible for 80% of the work and while the technical team is only 20%, so for the plant to operate at its maximum potential proper coordination between the technical and management team is necessary. In order to compliment this, following recommendation based on our study are provided:

Table 13: Recommendations

Equipment and Process	Recommended actions
Limestone Secondary Crusher	**Short term:** Crusher Hammer replacement, General Maintenance of Apron Feeder and conveyor belt
	Medium term: Crusher Rotor Disc and Grate bar replacement, Circular Stacker General Maintenance
	Long term: Installation of Magnetic Separator, repair Stacker and reclaimer
Raw mill section	**Short term:** Clearing works, Equipment inspection and Maintenance Schedule, Operator Training
	Medium term: Sorting of Grinding Media
	Long term: Operation of Blending System in Raw mill Silo
Kiln and RABH	**Short term:** Sealing works in the Preheater, Kiln inlet maintenance, Grate Cooler Maintenance
	Medium term: Inlet modification works, Brick lining
	Long term: Inlet Gas Analyzer and Preheater fan gas analyzer installation, Gravel Bed filter Operation works
Coal Mill Section	**Short term:** Equipment inspection and Maintenance Schedule
	Medium term: Impeller fan repair works
	Long term: Hydraulic cabinet modification and up gradation work
Cement mill	**Short term:** Diaphragm Screen liner slit gauging, Air Flow Duct Cleaning
	Medium term: Sorting of Grinding Media
	Long term: Grinding media replacement works, Cement mill Liner and Screen liner replacement works
Packaging section	**Short term:** Sealing of unnecessary pipe opening

Further recommendation to the industry will be:

- Each Section has its own technicality of operation and maintenance. Special procedure should be followed while taking action for each section maintenance and upgradation works. That technicality has not been included in this study. So, further details of individual equipment wise study should be carried out.
- Timely management of spare parts and inventory level should be done as per the yearly schedule.
- Hetauda Cement Industry Limited needs to focus on retrofitting and upgradation as the technology has been obsolete.

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CHAPTER SIX: APPENDIX A: GLIMSES OF OUR VISIT

Figure 6-1: Cement mill building

Figure 6-2: Limestone Open yard

Figure 6-3: Gypsum yard

Figure 6-4: Coal yard

Figure 6-5: Ropeway starting point and hopper

Figure 6-6: Secondary crusher

Figure 6-7: Conveyer belt carrying limestone to SC


Figure 6-8: Inside of PB hall


Figure 6-9: Stored crushed limestone

Figure 6-10: Iron ore yard

Figure 6-11: Hopper section

Figure 6-16: Horizontal kiln

Figure 6-12: Clinker wasted

Figure 6-13: Raw mill

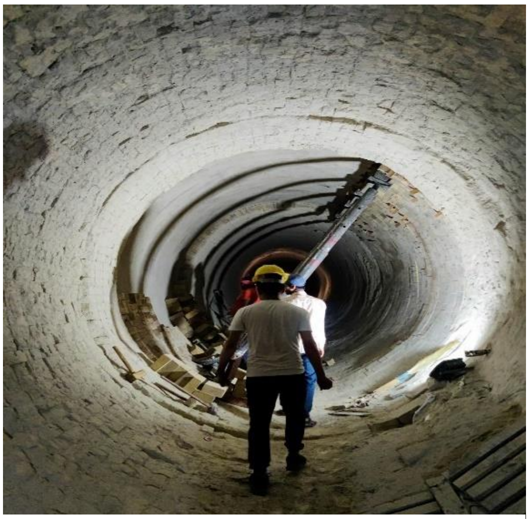


Figure 6-14:Inside of kiln


Figure 6-21: RABH


Figure 6-18: Cyclone


Figure 6-20: Cement mill

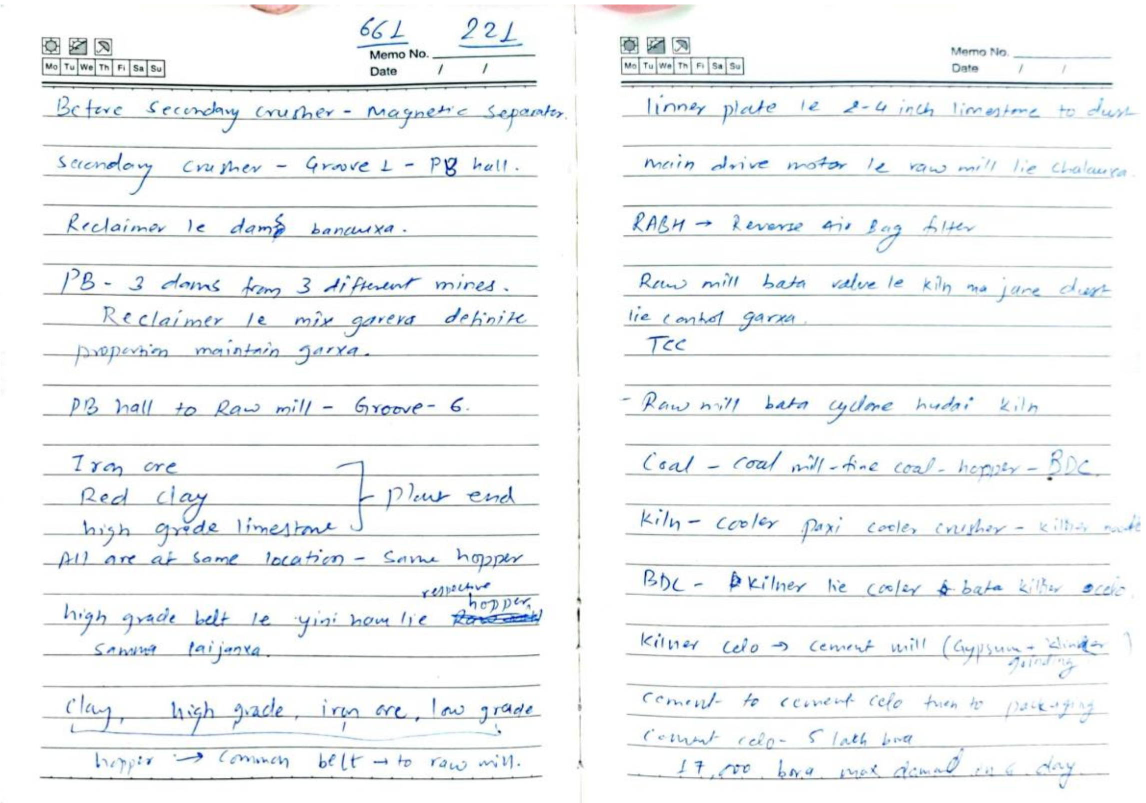

Figure 6-19: Clinker silo


Figure 6-22: Packaging Hall


Figure 6-17: Semi-autonomous packaging system and counter

Figure 6-23: With Mechanical Engineer during primary data collection

Figure 6-24: Meeting with top level management including GM and DGMs



Mo Tu We Th Fi Sa Su
Memo No. 66L 22L
Date / /

Before secondary crusher - Magnetic separator.

secondary crusher - Groove 1 - PB hall.

Reclaimer le dams banauxa.

PB - 3 dams from 3 different mines.
Reclaimer le mix garera definite
proportion maintain garxa.

PB hall to Raw mill - Groove - 6.

Iron ore
Red clay } - plant end
high grade limestone
All are at same location - same hopper

high grade belt le yini haru lie respective hopper samma laijanxa.

Clay, high grade, iron ore, low grade
hopper → common belt → to raw mill.

Mo Tu We Th Fi Sa Su
Memo No.
Date / /

linner plate le 2-4 inch limestone to dust

main drive motor le raw mill lie chalauxa.

RABH → Reverse air Bag filter

Raw mill bata valve le kiln ma jane dust
lie control garxa.
TCC

- Raw mill bata cyclone hudai kiln

Coal - coal mill - fine coal - hopper - BDC.

Kiln - cooler paxi cooler crusher - kilner nodle

BDC - kilner lie cooler & bata kilner celo.

Kilner celo → cement mill (Gypsum + clinker grinding)

cement to cement celo then to packaging
cement celo - 5 lakh bora
17,000 bora max demand in a day

Figure 6-25: Primary data collection

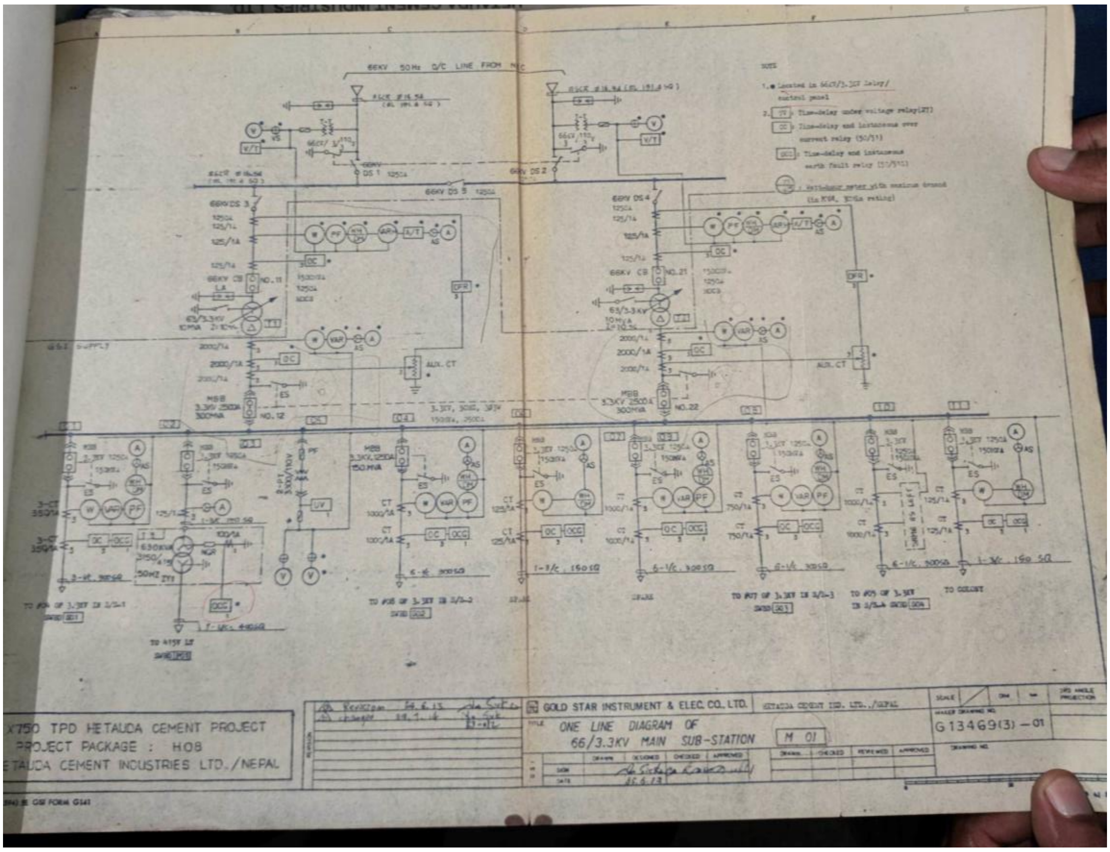
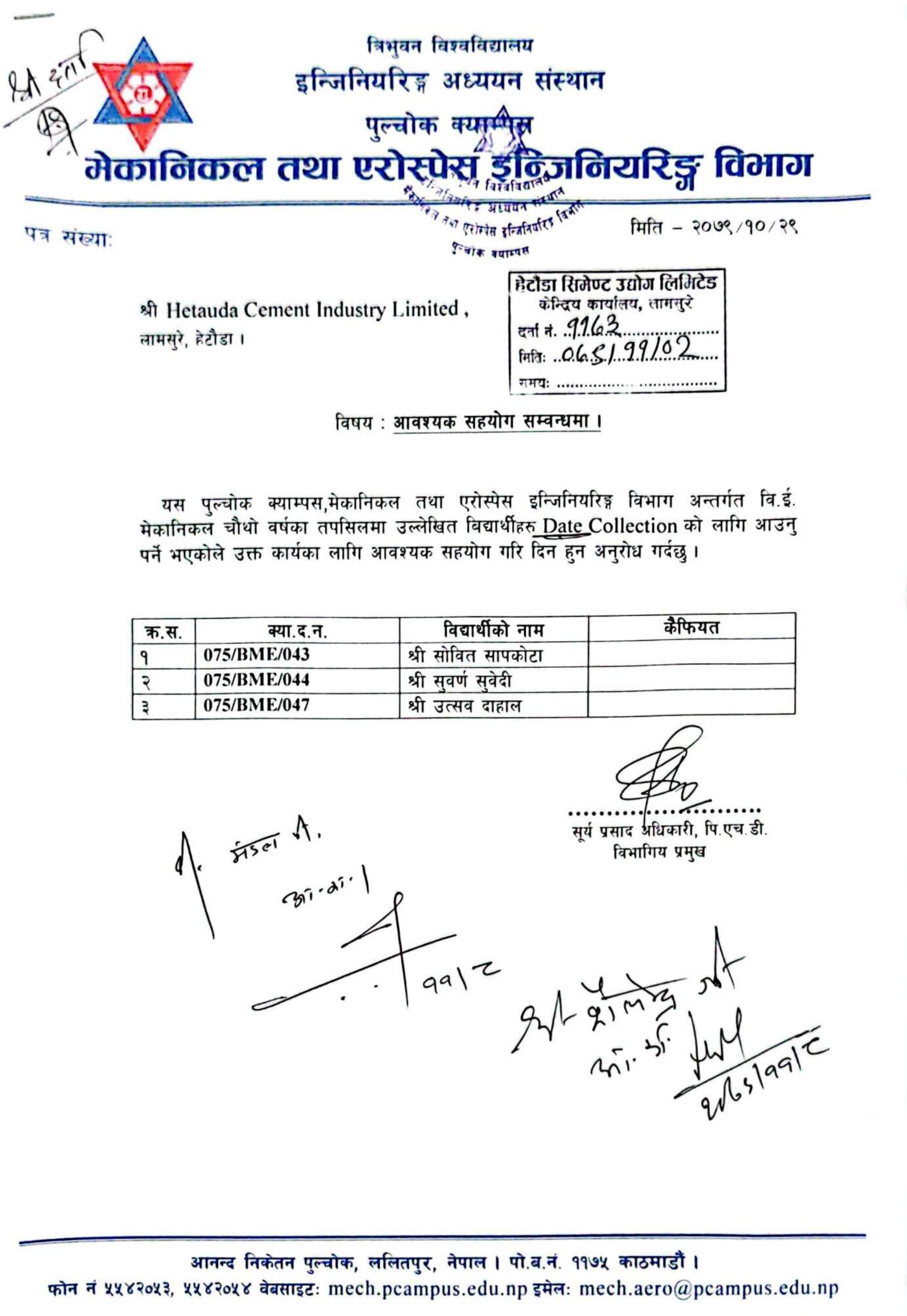


Figure 6-26: Electrical layout



त्रिभुवन विश्वविद्यालय
इन्जिनियरिङ्ग अध्ययन संस्थान
पुल्चोक क्याम्पस
मेकानिकल तथा एरोस्पेस इन्जिनियरिङ्ग विभाग

पत्र संख्या:

मिति – २०७९/१०/२९

हेटौडा सिमेण्ट उद्योग लिमिटेड
केन्द्रिय कार्यालय, लामसुरे
दर्ता नं. ११६३
मिति: ०७९/११/०२
समय:

श्री Hetauda Cement Industry Limited ,
लामसुरे, हेटौडा ।

विषय : आवश्यक सहयोग सम्वन्धमा ।

यस पुल्चोक क्याम्पस,मेकानिकल तथा एरोस्पेस इन्जिनियरिङ्ग विभाग अन्तर्गत वि.ई. मेकानिकल चौथो वर्षका तपसिलमा उल्लेखित विद्यार्थीहरु Date Collection को लागि आउनु पर्ने भएकोले उक्त कार्यका लागि आवश्यक सहयोग गरि दिन हुन अनुरोध गर्दछु ।

क.स.	क्या.द.न.	विद्यार्थीको नाम	कैफियत
१	075/BME/043	श्री सोवित सापकोटा	
२	075/BME/044	श्री सुवर्ण सुवेदी	
३	075/BME/047	श्री उत्सव दाहाल	

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सूर्य प्रसाद अधिकारी, पि.एच.डी.
विभागिय प्रमुख

आनन्द निकेतन पुल्चोक, ललितपुर, नेपाल । पो.ब.नं. ११७५ काठमाडौं ।
फोन नं ५५४२०५३, ५५४२०५४ वेबसाइट: mech.pcampus.edu.np इमेल: mech.aero@pcampus.edu.np

Figure 6-27: Letter for our visit

CHAPTER SEVEN: APPENDIX B: DESIGN SPECIFICATIONS OF MACHINARIE

Table 14: Plant Location Details

Plant Location Details			
1.	Altitude. m	345	
2.	Ambient Temperature, Deg C	Max 40	Min 6
3.	Electrical Frequency, Hz	50	

Table 15: Raw mill specifications

S.N.	**Description**	**Value**	**Units**
1.	limestone, Sand, Iron Ore, Clay recommended feed rate		
2.	Limestone	94.8	%
3.	sand	1.2	%
	clay	2.2	%
	Iron Ore	1.8	%
4.	Maximum ball charge of mill grinding chamber volume	28	%
5.	Raw Mill Discharge Circulation load	· 4 times of the rated mill circuit production rate for fineness 10%	

6.	Mill noise level at 1 m distance	75-85	db
	Air Flow		
	Hot Gas Flow to Mill	46,600	Nm^3/Hr
	Hot Gas Temperature	320 to 340	^0C
7.	Raw mill Main BDC Volume (Mill Exhaust Volume)	90,000 to 1,10,000	m^3/hr
8.	Raw mill Main BDC Volume (Mill Exhaust Volume) Temperature	90 to 100	℃
	Draft Conditions		
9.	Mill inlet	-20 to -40	mm WG
10.	Mill outlet	-200 to -220	mm WG
11.	Before Exhaust fan	-450 to -480	mm WG
12.	Normal temperature of finished raw meal	100 and maximum 110	℃
13.	Mill exhaust air temperature	90 to 100	℃
14.	Grit Separator angle	20 degrees<angle<45 degree	degree

Table 16: Kiln Specification

Plant Details		
Kiln Size	D x L, in meter	I.D 3.8mx56m
Kiln Capacity (Design)	TPD	750
Refractory Thickness	mm	200
Cooler Type	Conventional	Reciprocating grate cooler
Cooler effective area	in m^2	32
Kiln Feed System	BE/Air Lift/others	Air lift
Parameters		**Design value**
Kiln Feed (tph)		50
Kiln Feed to Clinker factor		1.6
Kiln fuel type – Fuel mix if applicable		Coal
Kiln Coal Consumption (tph)		5.25
PH fan Operating Details		
PH Fan		
Operating	**Unit**	**String 1**

Operating speed/ Design speed RPM		990
Flow	m^3/s	45
Inlet static	mmwg	600 mm wcl
pressure		
Fan outlet static pressure	mmwg	
Power	KW @ meter	550

Table 17: Cement Mill Specification

S.N.	Description	Value	Units
1.	Clinker and Gypsum recommended feed rate		
2.	Clinker	94 to 96	%
3.	Gypsum	6 to 4	%
4.	Maximum ball charge of mill grinding chamber volume	29.5	%

5.	Cement mill Discharge Circulation load	· 3.9 times of the rated mill circuit production rate for fineness 3400 Blaine · 4.3 times of the rated mill circuit production rate for fineness 3200 Blaine	
6.	Mill noise level at 1 m distance	75-85	db
	Air Flow		
7.	Cement mill Main BDC Volume (Mill Exhaust Volume)	39,000 to 43,000	m^3/hr
8.	Cement mill Main BDC Volume (Mill Exhaust Volume) Temperature	90 to 100	℃
	Draft Conditions		
9.	Mill inlet	-20	mm WG
10.	Mill outlet	-180 to -200	mm WG
11.	Before Exhaust fan	-480 to -530	mm WG

12.	Normal temperature of finished cement	110 and maximum 125	℃
13.	Mill exhaust air temperature	Should not drop below 80 and should not exceed 110	℃
14.	Grit Separator angle	20 degrees<angle<45 degree	degree