

Energy Use in Nepalese Cement Industries: Case of Udayapur Cement Industries Limited

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Abstract— Infrastructure development and rapid urbanization all over the world make cement industries one of the fastest growing industries. Cement industries are energy intensive, and they contribute significantly to national employment and gross domestic production. In Nepal, 77 cement industries are registered so far, making cement one of the most important sectors for Nepalese economy. This work reviews the history, current technological status, energy consumption pattern, environmental impacts, and economic impacts of cement industries in Nepal and compares the energy consumption in Nepalese cement industries with the rest of the world. Udayapur Cement Industries Limited (UCIL), a government owned cement plant with a design capacity of 800 tpd is taken as a case study. UCIL's data of energy consumption, production, and maintenance practices are studied and compared with national standards and foreign countries standards. The average specific energy consumption of Nepalese cement industries is higher than that of most other countries and utilization factor is very low. Similarly, specific energy consumption of UCIL is 2 - 3 times higher than national standard, because of poor maintenance management, lack of monitoring and evaluation, and absence of energy management system. Capacity utilization factor of UCIL is 36.3 % in average. To improve the capacity utilization factor and reduce specific energy consumption, energy efficient technologies should be adopted, automation technology should be upgraded, proper maintenance should be practiced, and regular monitoring and evaluation should be performed.

Index Terms— Cement; Capacity Utilization Factor; Energy; Energy Efficiency; Specific Energy Consumption

1 INTRODUCTION

Nepal is a developing country in South Asia where the works of infrastructure development, urbanization, hydropower development, bridge, road construction are being performed rapidly. With increasing development of infrastructure, the demand of cement has also increased with an annual increment rate of 20% resulting increases in scope of cement industries day by day [1]. 73% of the global cement production is covered by the developing countries [2]. In the present context, there are 77 cement industries registered in Department of Industry, among which 48 cement industries were registered between 2004 and 2014 [3], [4].

In 2012, 32.99% of world energy consumption was covered by the industrial sub sector [5]. Among the industries, cement industries were the most energy consuming industries with 3% of world's primary energy consumption, or about 8% of the total industrial energy consumption [6]. It has been found that cement manufacturing is an energy intensive process consuming about 12 - 15% of total energy consumption of a country [7]. The cement production cost per ton depends on the production process [8]. The overall global industrial efficiency is only 30% [2]. In modern technology, the average fuel consumption is 6 GJ/t in wet kilns system, 4.5 GJ/t in Dry Kiln-Single stage preheater system and 3.6 GJ/t in Dry Kiln- Multi stage preheater system [9], [10]. In case of Nepal, the standard

energy intensity is considered as thermal energy of 750 kcal/kg clinker and electrical energy of 105 kWh/T cement according to Energy Efficiency Center (EEC), Nepal [11]. But, the specific energy consumption is found to be 148.56 kWh of electricity and 5.411 MJ of thermal energy per kg in average [1].

The histories of Nepalese cement industries started with the installation of Himal Cement industries of 160 tpd in 1975. After some time, next unit of 200 tpd was added with the financial support of China. Similarly, two big plants; Hetauda Cement Industries Limited of 750 tpd and Udayapur Cement Industries Limited of 800 tpd were established. In 2002 the Himal Cement Industries was stopped due to the environmental issues. In present context, 77 cement industries are registered in the Department of Industry, Nepal [3]. The cement industries registered in different year with installation capacity and employment are tabulated in Table 1.

Table 1: Registered Nepalese Cement Industries [3], [4]

Year	Industries Registered [no.]	Installed Capacity [Ton/Year]	Employment
Before 2004	29	-	-
2004/05	5	1,347,920	647
2005/06	5	315,100	754
2006/07	1	15,000	117
2007/08	4	641,480	881
2008/09	4	994,500	632
2009/10	7	741,300	964
2010/11	7	621,240	930

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2011/12	5	737,900	816
2012/13	3	525,000	487
2013/14	7	923,288	719
Total	77	+6862728	+6947

Generally, there are two types of cement industries registered; Lime stone based and Clinker based. It is found that about 30% of the industries are lime stone based and 70% Clinker based. It was estimated that the gross annual demand of cement in Nepal was around 2,500,000 MT in year 2010/11, in which only 70% demand was fulfilled by the Nepalese industries and other 30% was imported from India [1], [3], [4].

There are three types of cement produced by the Nepalese cement industries; Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC), among which OPC is the highly produced cement type and PSC is the least produced type [1], [3], [4].

It is found that, the registered capacity of cement industries in Nepal is around 6,862,728 MT per year as shown in Table 1. A report stated that, till 2011 the capacity of clinker based plant was 2,095,250MT and limestone based plant was 1,548,250MT per year, and the utilization factors were 61.52% and 45.79%. The average installed capacity of the limestone based and clinker based cement plants were 645 and 388 tpd and their average productions were 295 and 239 tpd [1]. The important Nepalese cement industries are tabulated in Table 2.

Table2: Important Nepalese Cement Industries [3],[4]

SN	Name of Industries	Installed Capacity [Clinker Ton/Year]	Capacity [Cement Ton/Year]
1	Hetauda Cement Ind. Ltd.	247,500	259,875
2	Udayapur Cement Ind. Ltd.	264,000	277,200
3	Maruti Cement Udhyog	150,000	157,500
4	Surya Cement Udhyog	120,000	126,000
5	Kanak Cement Pvt. Ltd.	120,000	126,000
6	Buddha Cement Ind.	300,000	315,000
7	Siddhartha Cement Udhyog	150,000	157,500
8	Reliance Company Pvt. Ltd.	150,000	157,500
9	Shivam Cement Pvt. Ltd.	150,000	157,500
10	Dang Cement Ind. Pvt. Ltd.	237,600	249,480
11	Sagarmatha Cement Pvt. Ltd.	163,721	171,907
12	Shiva Shree Jagadamba Cement Mills	120,000	126,000
13	Pashupati Cement Pvt. Ltd.	132,000	138,600
14	Bishwokarma Cement Pvt. Ltd	132,000	138,600
15	Suprim Cement Pvt. Ltd.	150,000	157,500

1.1 Overview of Technologies

About 70% of Nepalese cement industries are of clinker based and motivated on commercialization. These industries are used to produce cement by grinding a mixture of clinker and gypsum imported from other countries. There isn't re-

quirement of advanced technologies in such industries and controlled semi-automatically or manually. Government of Nepal follows strict rules and regulation on environmental issues, hence standard of pollution is maintained by efficient pollution control equipment and systems except some.

The Nepalese cement industries based on limestone are few, but equipped with latest advanced technologies. Major industries are using rotating kiln to produce clinker in dry process, with pre heater or multi- pre heater and designed to achieve energy efficient results, and other industries use Vertical Shaft Kiln (VSK). Some of the biggest industries improved their control system into advanced SCADA system to get efficient manufacturing and full automation process. Most of the industries are equipped with semi- automated system and controlled by PLC system or are manually controlled. Problems in maintenance management, monitoring and evaluation lead the major failure in the industries resulting system failure and bypassing the automated system. In most of the industries in Nepal, technologies were adopted but not maintained as required and not improved. In few industries, rope way system is used to transport the raw materials from distant mine to the process plant. But, due to the various problems the systems are bypassed and run for the sake of running.

In general, only few industries have upgraded their technologies and moved toward energy efficient manufacturing processes and others are using old technologies or bypassing the technologies due to poor maintenance management policy and bad monitoring and evaluation.

1.2 Status of Energy Consumption

It is considered that, the optimum energy consumption in cement manufacturing process is 105 kWh/Ton of cement and 750 kCal/kg (3.138 MJ/kg) of clinker in limestone based industries standardized by Energy Efficiency Centre, Nepal [11]. Similarly, in clinker based industries the standard energy consumption is 35 kWh/T of cement.

But, it was estimated that, the average specific energy consumption in limestone based industries are 148.56 kWh of electricity and 5.411 MJ/kg of thermal energy. Similarly in clinker based industries, the energy consumption is 48.69 kWh/T of cement [1].

1.3 Comparison with Global Cement Industries

The specific energy consumption of the industries depends on the manufacturing processes and the technologies adopted. The average energy consumption of different countries is tabulated in Table 3 below. The specific energy consumption differs in different countries due to the different technologies' penetration and energy efficient strategies.

Table 3: Average SEC of Global Cement Industries

Country	Average Energy [kWh/Ton cement]	Consumption [M]/kg clinker	References
Nepal	148.56	5.411	[1]
Canada	110-155	3.6-4.5	[16], [17]
China	110-125	3.0-4.0	[17]-[21]
India	85-120	3.0-4.5	[17], [22]-[25]
Spain	90-110	3.0-4.0	[26], [27]
Germany	80-120	3.0-4.0	[17], [27]
Japan	80-110	3.0-3.5	[17], [18], [28]
Brazil	100-130	3.5-4.0	[17]
USA	100-155	3.5-5.0	[17],[29]-[32]

1.4 Contribution on Socioeconomic Development of Nation

It is observed that, the Principal indicators of Manufacturing Establishments carried out in the fiscal year 2011/12 by the Central Bureau of Statistics (CBS), Nepal under the Nepal Standard Industrial Classification (NSIC), with the identification number 2394, the number of manufacturers of cement, lime and plaster is 42 employing 4543 persons directly with NRs. 818 million in wages, salaries and facilities. The change in stocks at the end of year is 830,265 with gross addition of NRs. 644 million (1USD = NRs. 106.97 [12]), and gross fixed assets of NRs. 22 billion [13], [14].

It is found that, number of new industries registered in department of finance is 114 in fiscal year 2012/13 in manufacturing categories. The annual quarterly price index of cement is 129.79 and 127.04 with weight 19.31 in fiscal years 2013/14 and 2014/15 by taking base year as 2004/05, whereas the overall index are 174.45 and 187.51 with weight 100, and aggregated index are 158.97 and 170.10 with weight 100. Similarly, the Annual National Salary and Wage Rate Index of industrial labours are 275 for high skilled and 323 for unskilled manpower in fiscal year 2013/14 [4].

1.5 Environmental Impacts

It was estimated that the carbon dioxide generation per MT of limestone based cement is 277.33kg and that of clinker based cement is 8.74kg. In this assumption, the carbon dioxide emission was about 207,890 MT per year till 2011[1].

2 RESEARCH METHODOLOGY

The research covered statistics of cement industries in Nepal and reviewed worldwide trends in cement industries. The research focused on Udayapur Cement Industries Limited as a case of study. The data required and references were taken from the previous Governmental Reports of Nepal, NGO reports, INGO reports, Industrial Reports, Conference and Journal articles available.

The literature review was based on the research papers, Governmental reports, NGO documents, INGO documents and

real industrial records. For the data collection, offline survey was done with the help of governmental record and other available documents. The primary data were collected from the industry admiration. Also, a surface energy auditing was done to collect the primary data. After collecting the data, statistical analysis were done.

3 UDAYAPUR CEMENT INDUSTRIES LIMITED

Udayapur Cement industries Ltd is a fully Government owned industry located at Jaljale, Udayapur district, Nepal, established on 14th June, 1987 with capacity 800 tpd. The construction of the project was started from Sept 1989 to Oct 1992 financed by OECF- Japans assistance and equity share of Nepal Government. It was commercially started from Jan 1993 with 277,299 MT OPC Cement per year [15].

The main advantage of this industry is availability of highly calcium contained raw material (Lime Stone) with its own mine at nearby Murkuchi, which is considered to be of good quality for cement production. Another advantage of the industry is that it is well equipped with automatic machines and technologies. The industry was installed by Japanese companies HAJMA, Fuji, Mitsubishi and Kawasaki in different sectors.

The industry uses about 330,000 MT Lime stone, 4,000 MT Iron ore, 57,000-82,500 MT Clay, 10,500 MT Gypsum and up to 21,00 MT Silica Sand per year as raw materials, and 50,000 MT Coal, 12,000 kL Furnace Oil per year and 1500 m³/day of water, and 8,000 kW electricity as input fuels. The lime stone, clay and silica is extracted from its own quarry and other raw materials like coal, iron ore and oil are imported from India and Bhutan. The industry sells their product under the brand name of "Gaida Cement", one of the best in Nepal, and known for its quality and strength [15].

3.1 Cement Manufacturing Process

The cement manufacturing process in UCIL was designed to be controlled automatically using advanced PLC system. As per design, the raw materials from different origins are stored in the store yard of the industry. The raw materials are placed at the mixing hopper from where the required percentage composition is mixed by using automated weighing feeders. The mixture is passed to raw mill through conveyor belt and grinded to a fineness of 90 microns, which is then stored in blending silo. The materials are passed through a rotary kiln, which burns the feed and makes clinker at 1400° C to 1450° C and has a capacity to produce 800 tpd clinker. Generally coal is used as source of thermal energy and furnace oil is used in firing. After this stage, the clinker produced is cooled by using cooler at 100° C and stored in clinker silo. Now, the clinker is mixed with around 5% of gypsum and grinded in cement mill to produce cement, which is stored in cement silo, and cement is now ready for sale. In the industry, two automatic packers are available to pack the cement direct into vehicle.

3.2 Energy Uses

The main energy sources used in the UCIL are NEA electricity, Coal and the Diesel fuel. Figure 1 shows the comparison of cost breakup of energy in UCIL with standard cost break in international cement industries. From this data, it was shown that, high amount of energy was used for per ton of cement. The detail of energy consumption was presented in upcoming section.

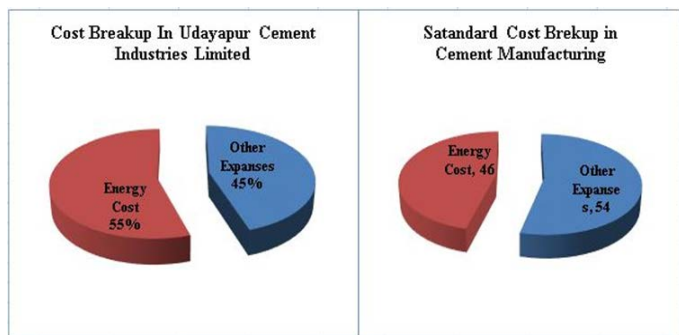


Fig1: Cost Breakup Comparison

3.2.1 Electrical Energy

The UCIL receives electric power from Nepal Electricity Authority (NEA) through the 11 kV overhead feeder line. The 11 kV power is then stepped down to 6.6 kV through 1 units of each 8 MVA transformers. There is dedicated feeder line, but due to the frequent problem in NEA grid, industries faces problem of power outage frequently. The power cut is a major problem facing the industry. A DG is placed to continue the auxiliary system during the power interruption. UCIL is planning to procure a big DG set of 2 MW to continue the production during the power problem of NEA grid. The figure 2 below shows the electricity consumption per unit production of cement. The consumption is compared with the standard value given by the Energy Efficiency Center (EEC), Nepal. Similarly, the table 4 presents the installed power rating and actual consumed power at various sector in the industries. These data shows that, only 64.56 percentage of power is consuming, i.e. a huge portion of equipment is non-working or in failure condition.

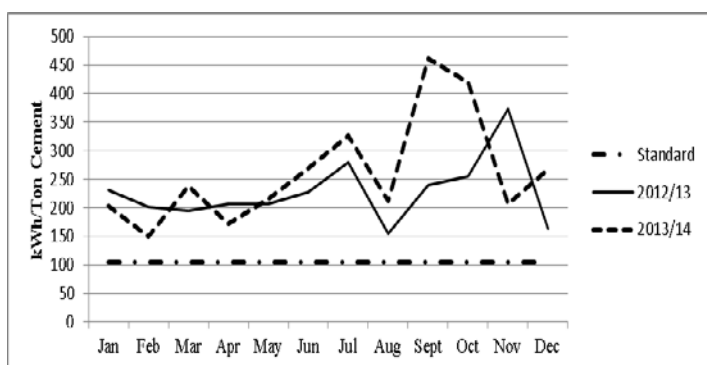


Fig 2: Electricity Consumption (2012/13 and 2013/14)

Table4: Power Consumption at various sector

S.N	Department	Installed Power (kW)	Actual Consumed Power (kW)
	Raw Material		
1	Handling	689.8	463.9
2	Raw Mill	1934.1	1434.06
3	Pyro (B/Silo, Preheater, Kiln & Coller)	2341.7	1145.4
4	Coal Handling	61.1	40.68
5	Coal Mill	332.1	237.37
6	Cement Mill	2176.9	1777.06
7	Packing Plant	179.9	137.13
8	Utility (Water)	615.4	143.58
	Total	8331	5379.18

3.2.2 Thermal Energy

Next important energy type used in cement industries is thermal energy. In UCIL coal is used as source of thermal energy. The month-wise production and specific coal consumption trends provide an indicator for plant thermal energy performance, benchmarking and target setting. The specific thermal heat consumption of the last 2 years (2012/13 and 2013/14) is given in the figure 3 and 4. From the graphs, it is observed that specific thermal heat consumption is 2-3 times greater than the standard value given by the Energy Efficiency Center, Nepal.

The reasons of high consumption of energy are explained in discussion and conclusion. In UCIL, the electricity consumption is to be taken by the cement manufacturing unit only, but in UCIL, the specific electrical energy is calculated using the total electricity bill consumed by office, staff quarter, street lighting and other expenses divided by the total cement produced. This type of data leads to wrong interpretation and calculation. Due to the absence of proper equipment and monitoring system, the same data was used in this study.

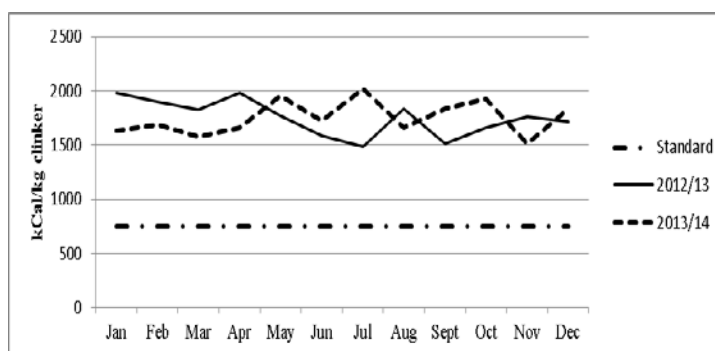


Fig 3: Specific Heat Consumption (2012/13 and 2013/14)

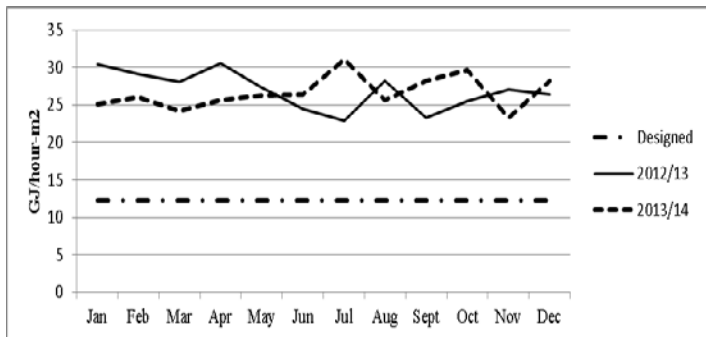


Fig 4: Thermal Load in Kiln (2012/13 and 2013/14)

3.3 Current Problems occurred in UCIL

Within the Udayapur Cement Industries Limited, various problems were identified, due to which caused significant impact in process, control and manufacturing system. During the study, it was observed that the limestone stacker is not functioning simultaneously for transport as well as for piling the raw materials. Whole raw material handling system operates on local mode, in contrast to the default control system in the control room (CR2). Each and every equipment needs to be started and stopped manually in sequence which causes delay in operation as well as consumes higher amount of energy. Weighing Feeders used in different parts of the industry like in raw mill mixing hopper, kiln feeder, coal mill, and cement mill for the measurement of mass flow rate and quality control have failed. Hydraulic Oil leakage in Raw Mill system created low pressure than recommended. Designated blower placed at Raw Mill Silo for material homogenization were out of order and was replaced by utility compressor.

High free lime fluctuations in kiln feed composition occurred, resulting frequent feed flushing, inconsistency of kiln feed quality, and low production factor. Frequent damage of kiln refractory lining (3 months life against 12 months standard) were recorded. Different causes that stopped the kiln in 2013/14 is given in figure 5. In 2013/14, 7.91% of total annual stoppage occurred due to those causes. Two out of three Electrostatic Precipitators were in a state of failure resulting in heavy emission of particulate matter as well as fine particles that results in the loss of energy and material. The remaining working EP was operating in manual mode, as opposed to the default automatic mode.

In coal mill, inertization system was not in operation and high amount of reject was observed. Feed size to the coal mill was designed to be 80mm but present feed was found to be around 20mm in size. In Gravel Bed Filter, the output temperature and rejected materials were found to be higher than standard value, and heavy particulate emission was recorded. Due to shorter height of stack, smoke was spreading to surrounding, which could have potential health hazards.

Cement mill diaphragm is damaged, hence, lower grinding media was found and separated at the O-sepa location. Stationary Packers was found to be inaccurate with +/- 6% of accuracy.

Similarly, frequent load shedding effected the industries significantly. Most of the conveyor belts were operating unnecessarily. The designed automatic system was bypassed needing the system to be operated manually. The capacitor bank was in a state of failure resulting in higher demand charge and lower power factor. Regular predictive and corrective maintenance were done to majority of mechanical equipment (e.g. Chain Conveyor, Air Slides, and Belt Conveyor).

Analyzing the collected data, one of the problem in UCIL was found to be improper maintenance schedule. The main part of the cement industries is rotating kiln, and in UCIL, kiln stoppage was a main reason for system failure in which around 33.59 % of time is taken by the brick lining breakdown and 27.39 % by mechanical maintenance shown in Figure 5 below. It was found that, one of the main reason to decrease the utilization factor is frequent failure of rotating kiln.

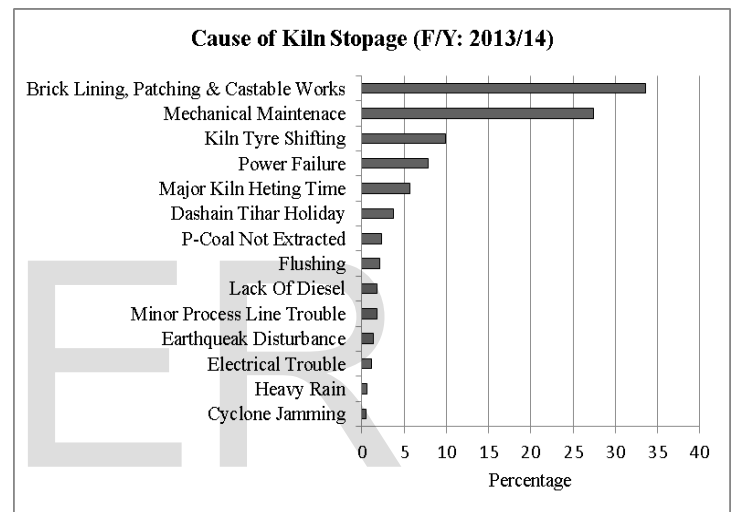


Fig 5: Cause of Kiln Stoppage (2013/14)

3.4 Efficiency, Utilization Factor and Rated Capacity

Here the terms are given by [33];

$$\text{Efficiency} = \frac{\text{Standard hours of work produced}}{\text{Hours actually work}} * 100$$

$$\text{Utilization Factor} = \frac{\text{Hours actually work}}{\text{Available hours}} * 100, \text{ and}$$

$$\text{Rated Capacity} = \text{available time} * \text{utilization factor} * \text{efficiency}$$

By using the data, the efficiency and utilization factor for 24 years of production in UCIL was calculated. The calculated value was given in graphical form as shown in figure 6. From this, it was occurred that, the utilization factor of UCIL is very low in compare to the other countries cement plant.

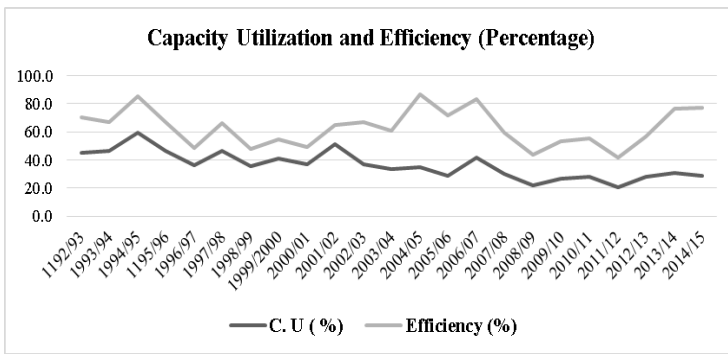


Fig 6: Capacity Utilization Factor and efficiency (1992/93 to 2014/15)

The yearly cement production by UCIL over the past 23 years is shown in the Figure 7 below. From the figures, it's shown that the production rate is in decreasing order resulting reducing capacity utilization factor as shown in Figure 8.

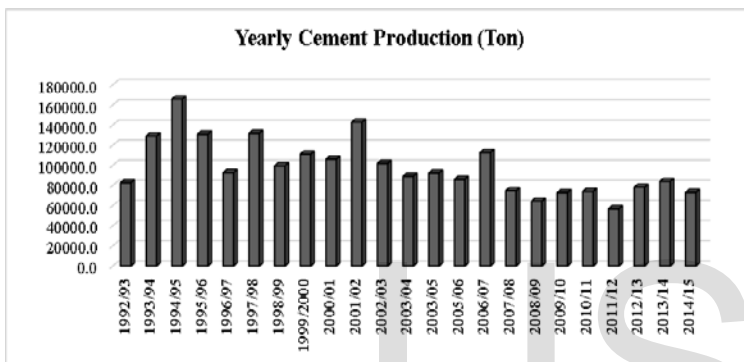


Fig 7: Yearly Cement Production (1992/93 to 2014/15)

4 RESULT

The error term was considered to be normally distribute. Taking the data of important parameters, following table 5 was listed.

Table 5: Discriptive testing Result

Parameters	Period	Min	Max	Mean	Std. Deviation
Capacity Utilization (%)	23(Yr)	20.7	59.7	36.3	9.791
Efficiency (%)	23(Yr)	41.31	86.77	63	13.18
Production (Ton)	23(Yr)	54530	157594	92240.7	23828.1
Electricity (kWh/Ton)	24(Mt h)	111	461	243.04	81.76
Thermal Energy (kCal/kg)	24(Mt h)	1486	1991	1728.91	152

From the descriptive analysis of the collected data of 23 years, the capacity utilization of the industry was found to be

36.3 % in average with 9.791 % standard deviation. Similarly, the efficiency was found to be 63% in average with 13.18 % of standard deviation. The electricity consumption per ton of cement was 243.04 kWh in average and thermal energy per kg clinker was 1728.91 kCal.

5 DISCUSSION

This research reviewed the history, status, technology, market, energy demand, production, contribution and environmental impacts of cement industries in Nepal. Demand of cement has been rapidly increasing in Nepal in effect of growing urbanization and infrastructure development. Abundance of the principal raw material – limestone, in Chure hills of Nepal in large quantities, along with clay and silica sand has made cement production a continually growing industry of Nepal, although import of iron ore, gypsum, bunker oil and large amounts of coal is still needed. Importing clinkers, mainly from India, and adding gypsum to produce cement should also be significantly profitable, considering 70 % of cement industries in Nepal are clinker based.

Cement industry is one of the most energy intensive industries in Nepal. Considering the total production capacity of cement industries in Nepal, cement industries should make a significant portion of Nepal's energy demand. However, contribution of cement industries in Nepal's gross domestic production and employment seems worth mentioning, cement industries play important roles in the national economy. Hindrances in doing manufacturing business in Nepal like poor energy security and reliance on imports for fuel, raw materials, and spares have made it difficult for running cement industries in Nepal, especially small and private clinker based industries.

The research also scales energy consumption in Nepal's cement industries with the rest of the world. It is found that Nepal's cement industries, on average, consume significantly higher electrical and thermal energy per unit of production. Similarly, emissions are relatively higher. Evident problems like chronic power cuts have forced the energy intensive cement industries in Nepal to rely on increased diesel imports that further worsens Nepal's energy security and trade deficit. Government imposed restrictions on cement industries are not strict.

From the study, it is found that, the number of cement industries is increasing at a high rate. The capacity utilization factor is very low of the industries in average due to various factors such as low technology penetration, improper maintenance management, unavailability of fuel etc. The utilization factor of clinker based industries is higher than the limestone based industries.

UCIL – a government owned industry has its inbuilt merits and demerits. The industry has a better chance at running sustainably, and can use government resources like land and limestone mines, but seems to have suffered the tragedy of the commons to some extent with evident poor maintenance prac-

tices. The utilization factor is only 36.3% in average. Both thermal and electrical specific energy consumption is higher than the national average, and so is the thermal load in rotary kiln. Energy cost per unit production is 100 % more than the international average. In 23 years since operation, technology remains same, with many automated systems by-passed after failure which has further increased energy consumption. The production is decreasing day by day.

This study is unable to cover the real data for all of the cement industries in Nepal. This overview of industries is based on the literature review and online survey for the industries except for UCIL. It will be good, if the data of all the cement industries are based on survey and real data like UCIL.

5 CONCLUSION

The number of cement industries in Nepal is rapidly increasing, as 48 cement industries were registered between 2004 and 2014, out of a total of 77 cement industries registered. Specific electrical energy consumption of cement industries in Nepal is 148.56 kWh/T of cement and specific thermal energy consumption is 5.411 MJ/kg of clinker, which is higher than the average values of the rest of the world. Capacity utilization factors are meagre 0.6152 and 0.4579 for clinker and limestone based industries respectively. Industries that produce cement, lime, and plaster provided 4543 jobs, and the change in stock at the end of year was 830,265 in 2011/12. Cement industries in Nepal rely on India and other countries like Bhutan for importing coal. Penetration of energy efficient and more productive technologies is low.

Cement production of UCIL is decreasing day by day, down to around 300 tpd from designed value of 800 tpd. Capacity utilization factor is about 36.3 % and specific energy consumption is 2 - 3 times more than national standard. Thermal load in kiln is not monitored. Maintenance management system is poor, energy management system is non-existent, and technology has not been upgraded since installation.

This research has reviewed the contribution of cement industries in national economy and highlighted the major problems in cement industries in Nepal. Cement industries in Nepal can contribute more to the economy and ongoing infrastructure development works by utilizing available raw materials, and reducing overall cement and clinker import in Nepal. Production of cement in industries of Nepal can be improved by increasing energy efficiency, practicing better maintenance management and monitoring, and upgrading existing technologies.

UCIL should practice better maintenance management, make a new energy management system, monitor data and practice evidence based decision making, adopt energy efficient technologies and better automation systems.

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