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**INSTITUTE OF ENGINEERING**  
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**Energy Demand Analysis of Instant Noodles Processing Industries of Nepal**

by

Amar Baral

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The undersigned certify that they have read and recommended to the Institute of Engineering for acceptance, a thesis entitled " **Energy Demand Analysis of Instant Noodles Processing Industries of Nepal.**" submitted by Amar Baral in partial fulfilment of the requirements for the degree of Masters in Energy System Planning and Management Engineering.

---

Supervisor, Dr. Rajendra Shrestha  
Professor,  
Department of Mechanical Engineering  
Pulchowk Campus, Tribhuvan University

---

External Examiner, Dr. Ram Prasad Dhital  
Member, Regulatory and External Affairs  
Electricity Regulatory Commission, Nepal

---

Committee Chairperson, Dr, Nawaraj Bhattarai  
Head of Department  
Department of Mechanical Engineering  
Pulchowk Campus, Tribhuvan University

Date: 8<sup>th</sup> January, 2020

## ABSTRACT

There is a large potential of energy saving in the noodles industries as it is still in the traditional state. Nepal produced 103.6 thousand metric tons of Noodles in 2017 with about the total capacity 160 thousand metric tons. The average production growth rate for the past ten years is around 5.6%. In noodles industries boiler consumes about 61 % of the energy with motor drives consuming about 23% followed by process heat with 10% of the energy. Rice husk is used as the fuel in most boilers which provided about 90 % of the thermal energy with around 10% being derived from the electricity. After modeling in LEAP, about 176.77 thousand GJ of energy is being used with the prediction of about 363.84 thousand GJ of energy being demanded in 2030 under normal growth rate of 5.6%. Under low growth rate of 3%, 256.59 thousand GJ of energy will be required with 817.31 thousand GJ of energy being demanded in high growth rate of 11.5%. With the various efficiency measures being implemented, the energy demand will be 261.43 thousand GJ, 199.58 thousand GJ and 641.52 thousand GJ under normal, low and high growth efficient scenarios. This accounts for about 21.6 thousand GJ of electrical and 83.85 thousand GJ of thermal energy being saved. Under low growth 29.15 thousand GJ electrical energy and 60.32 thousand GJ thermal energy can be saved with 18.47 thousand GJ of electrical energy and 97.47 thousand GJ of thermal energy being saved from high growth scenario.

In terms of Carbon dioxide emissions, 272.48 thousand metric tonnes of carbon dioxide has been emitted from the Noodles Industries with the prediction of it reaching 560.85 thousand metric tonnes in year 2030. Using different efficient measures, the emission can be limited to 321.46 thousand metric tonnes of carbon dioxide. Thus, with proper measures being taken a significant amount of energy can be saved along with the reduction in the CO<sub>2</sub> emissions.

**Keywords:** *Energy Modeling, Energy Demand, LEAP, Noodles Industry, CO<sub>2</sub> emission*

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## LIST OF ABBREVIATIONS

AAGR	-	Average annual growth rate
ASD	-	Adjustable Speed Drives
BAU	-	Business as usual
CBS	-	Center bureau of Statistics
CFL	-	Compact Fluorescent Lamp
DSM	-	Demand Side Management
DG	-	Diesel Generator
EET	-	Energy Efficient Technology
EES	-	Energy Efficient Scenario
EIA	-	Energy Information Administration
ESPS	-	Environment Sector Program Support
FITTA	-	Foreign Investment and Technology Transfer Act
GoN	-	Government of Nepal
GDP	-	Gross Domestic Product
HID	-	High Intensity Discharge
IRP	-	Integrated Resource Planning
IRR	-	Internal Rate of Return
IVA	-	Industrial Value Addition
LDC	-	Least Developed Country
LEAP	-	Long-range Energy Alternative Planning
LED	-	Light Emitting Diode
MAD	-	Mean Absolute Deviation
MAPE	-	Mean Absolute Percentage Error
MARKAL	-	Market Allocation
MVA	-	Manufacturing Value Addition

MoF	-	Ministry of Finance
MoI	-	Ministry of Industry
NEA	-	Nepal Electricity Authority
NEEP	-	National Energy Efficiency Program
NPC	-	National Planning Commission
NRB	-	Nepal Rastra Bank
NSIC	-	Nepal Standard Industrial Classification
RMSE	-	Root Mean Square Error
WECS	-	Water and Energy Commission Secretariat
WINA	-	World Instant Noodles Association
SDG	-	Sustainable Development Goals

## CHAPTER ONE: INTRODUCTION

### 1.1 Background

Energy is a key determinant of overall productivity and economy in human society. With economic development and population growth, the energy demands will constantly be soaring. Energy use is growing fast, due to the larger role of emerging economies based primarily on fossil fuel technologies (IEA, 2013). However, it is quite difficult to produce the same amount of the energy. Hence, the production and consumption of energy is the main area of concern for the whole world currently (Suganthia & Samuel, 2012). Thus, energy management is the key to maintain the balance between the production and consumption.

The industrial sector is crucial as it is a major energy user, and a relevant share is used by food processing industries. Energy conservation is vital for the sustainable development of food industry. Energy efficiency improvement and waste heat recovery in the food industry have been a focus to increase the sustainability of food processing in the past decades. Because of the increasing energy prices and efforts for the reduction of greenhouse gas emissions, it has become significant to improve the energy efficiency, replace the existing energy-intensive operations with new energy-efficient ones, and increase the use of renewable energy in the food industry (Wang, 2014). The improvement of energy efficiency in the food industry should be considered to provide not only economic benefit but also the benefits for environmental protection, social sustainability, energy supply security, and industrial competitiveness.

Food manufacturing plants are energy-intensive plants and a significant portion of their operating cost is due to energy use. Fischer et al. (2007) reported that around 57 % of the primary energy inputs into the whole industry are lost before reaching intended processing activities. Estimates from several studies indicate that on average, savings of 20 to 30 % energy can be achieved without capital investment, using only procedural and behavioral changes (Fischer et al. 2007). Industrial energy consumption can be further cost-effectively reduced by 10 to 20 % through well-structured energy management programs that combine energy conservation technologies, operation practices, and management practices (Fischer et al. 2007). The prospective measures for the improvement of energy efficiency to be used in the food industry should be technically feasible and economically practical. The improvement of energy efficiency in food processing facilities requires the evaluation of numerous prospective measures

to increase the energy usage efficiencies of the utilities such as steam, compressed air, and electricity (Wang, 2013). Therefore, improving energy efficiency has great potential to reduce the operating cost and thereby improve the profitability of food manufacturing plants in Nepal.

To enhance business competitiveness, some food manufacturing plants are undergoing restructuring. Cost savings achieved through energy efficiency measures would play a key role in enhancing the competitiveness of the industry in the whole world (Muller et al, 2007).

## 1.2 Instant Noodles

One of the important sectors of the industrial manufacturing sector is food and beverage subsector. The food beverage and tobacco subsector contributed to 43.77% value addition to the manufacturing sector in 2011 (CBS, 2017). And with the ever-growing population, the energy requirement in this subsector is also in the upward trend. A vital component of the food and beverage industry in context of Nepal is the noodle industry. It is considered to be the third largest food and beverage industry in Nepal (MoI & GoN, 2010/11). Instant noodles are very popular in Nepal and the market for instant noodles has been growing every year. As a result, Nepal has become the third most noodle consuming country per capita (WINA, 2018). In Nepal 20 industries are established for the production of Instant noodles (MoI, 2017).

Noodles are one of the junk foods which are growing in its popularity and market size every year due to easy accessibility and easy preparation. The noodles companies are producing noodles in large variety and taste so that the consumer of the noodles never get bored by the same taste every time. This has led to the increase in demand of the noodles market globally as illustrated by the following table.

Table 1-1 Global Demand of Nepalese Noodles

Year	Demand (million servings)
2013	1020
2014	1110
2015	1190
2016	1340

Year	Demand (million servings)
2017	1480

(Source: WINA, 2018)

Noodles are a traditional food widely consumed throughout Asia. In the past, they were made within the home for consumption by the household. Today they remain a staple of Asian diets and, with improved food technology, offer variety, versatility and high nutritional quality. Noodles are readily available and can be purchased in a variety of forms including fresh, cooked or processed for longer shelf life. Due to their ease of preparation, noodles are now considered as a convenient fast food. There are many approaches used to classify noodles but the most common ways are either based on a) processing methods or b) raw materials used.

Instant noodles were first introduced commercially in Japan circa 1958 and from there the product rapidly spread to Korea and other Asian countries. Today, instant noodles are consumed in more than 80 countries and of the many types of noodles, instant noodles are the fastest growing sector due to their ease in preparation and convenience. Market research has indicated that global consumption reached more than 65 billion units (instant noodle) in 2003 and was estimated to reach 100 billion units in 2010 (WINA, 2018).

### **1.2.1 Noodle Industry in Nepal**

Nepal's instant noodles production began in the early 1980s when Pokhara-based Gandaki Noodles stepped into the market with their product named Rara. This came at time when there was a growing demand for instant noodles in Kathmandu but the only ones available were the expensive Thai brands. Rara was an instant success and several other companies followed in its footsteps. Some survived and some disappeared from the market, but it is the entry of big business houses like Choudhary Group (with WaiWai) and Khetan Group (Mayos) that has changed the face of this Rs. 1250 million market (Humagain, 2000). The market of Nepalese noodles companies has not only been limited within the country's boundary but also it has been exporting its products to various countries. It still has the potential and scope to expand more. There are twenty noodles manufacturing companies such as Nepal Thai food industries, Everest noodles industries, multi food industries, Himshree (Gandaki) noodles industries etc. They product different types or brands of noodles such as Rum Pum, Wai Wai, Min Min,

2P.M. etc. They make a good contribution in national revenue today and in days to come. Noodles can be used as fried or boiled or can be eaten instantly. Now a day noodles has become popular food and it has increased in demand. The reason for its ever-increasing consumption may be attributed to its easy availability, preparation and consumption. According to the economic survey (2010/11) published by Nepal Rastra Bank, more than 23,434 tons of noodles is produced during the six-month period as against the total production capacity of 27 thousand tons (MoI & GoN, 2010/11). Hence, the demand for noodles is sky rocketing and so is its energy demand. Thus, an effective energy plan and management is required to meet the ever-increasing energy requirements.

### **1.3 Problem Statement**

Noodles industry is the third largest among food and beverage industries in Nepal (MoI & GoN, 2010/11) with the national production to be estimated at 42,840 MT for fiscal year 2010/11. Nepalese noodles are in high demand all over the world. According to World Instant Noodles Association, the consumption of Nepalese noodles is 1480 million packet every year for the year 2018. It occupies thirteenth place for the overall demand of instant noodles all over the world and is the third most noodles consuming country per capita only behind Korea and Vietnam (WINA, 2018). However, the energy management in the industrial sector of Nepal is in very poor condition and it includes the noodles industry as well. According to a study done by GIZ, there is a prospect of saving 478 GJ of electrical energy and 52,577 GJ of thermal energy (GIZ/NEEP, 2012) in noodles industries in our country and, the CO<sub>2</sub> savings potential is approximately 2353 kg. It is thus, imperative to investigate future energy demand for the noodle industry and possible ways of curtailing the emission by the use of energy efficient technologies. Hence this study focuses on possible methods to optimize the energy consumption through suitable methods like replacing the existent energy intensive equipments with the efficient ones and thus saving the overall consumption of the energy in Noodle Industry.

The industry may have substantial potential for energy efficiency improvement, as historically it has not taken a strategic approach to energy management, and firms often lack awareness of energy efficiency opportunities. Moreover, the margins in the food manufacturing industry are relatively thin compared to other manufacturing and

processing industries; thus, the sector may be typically slower to adopt technologies and processes that require significant capital outlays.

## **1.4 Research Objectives**

### **1.4.1 Main Objective**

- To assess the energy savings potential in instant noodles industries in Nepal using energy efficient technologies.

### **1.4.2 Specific Objectives**

- To assess the baseline data for various processes and equipment used in instant noodles processing.
- To develop an energy consumption profile of the instant noodles industries in Nepal by studying the major systems and equipment of each plant
- To forecast the energy demand using different growth scenario.

## **1.5 Assumptions and Limitations**

The assumptions and the limitations of the study are as follows:

- The share of each demand technology in future years will be the same and similar consumption trends will continue in future as mentioned in the base year.
- Final useful energy demand for end-use devices which are integral part of the production process like boilers, heaters and motors are assumed to grow at a same rate of production growth.
- The sample size is assumed to represent the actual energy demand of all noodle industries within Nepal.

## CHAPTER TWO: REVIEW OF LITERATURE

### 2.1 Energy Consumption in Nepal

#### 2.1.1 National energy consumption pattern

Energy is a vital input for the development of any nation. Nepal is no exception. The government has set a goal for Nepal to graduate from its current status of least developed country to a developing country by the year 2022 A.D. by achieving rapid economic growth through high, sustainable, and inclusive economic growth; promulgation of a new Constitution; and political stability. (MOF, 2015)

The rapid economic growth can be achieved only by the development of proper energy infrastructure. Development of energy infrastructure should be guided by appropriate planning and policy.

#### 2.1.2 Energy Consumption by fuel type:

Different types of fuel available in Nepal for are Agricultural residue, Dry dung, Grid Electricity, Coal, Petroleum, Renewable, Others, Fuel wood, etc. (WECS, 2014)

The energy consumption by different fuel types in Nepal for the year 2011/12 is given in the Table 2-1.

Table 2-1 Energy Consumption by Fuel types

Fuel Class	Fuel Types	Energy Consumption (in million GJ)	Percentage
Traditional	Fuelwood	267.4	71.1 %
	Agri Residue	13.2	3.5 %
	Dry Dung	19.1	5.1 %
Commercial	Grid Electricity	10.6	2.8 %
	Coal	14.8	3.9 %
	Petroleum	46.2	12.3 %
Alternatives	Renewables	4.6	1.2 %
Others	Others	0.4	0.1 %
	Total	376.3	100 %

Source: (WECS, 2014)

The pictorial view of energy consumption in Nepal by different fuel types in Nepal for the year 2011/12 is given in the Figure 2-1.

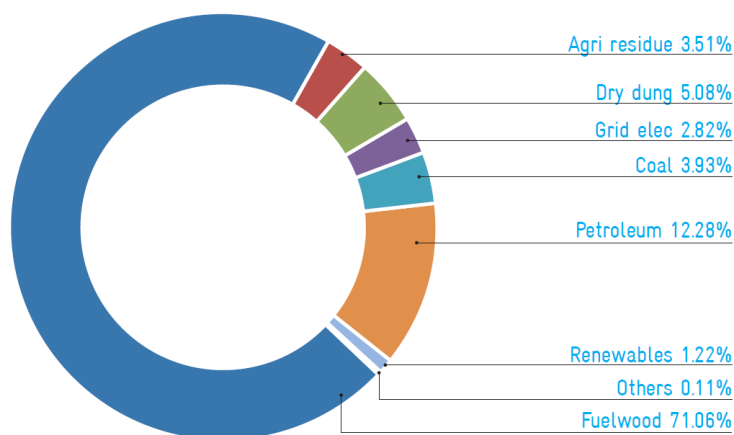


Figure 2-1 Pictorial view of energy consumption by different fuel types in Nepal for the year 2011/12

Source: (WECS, 2014)

The figures show that Nepal relies exclusively on biomass, about 80% of the total energy consumption. Among different biomass, fuel wood is the main one, accounting for 71.06 % use. Other biomass includes Agri Residue, Dry Dung, etc. and their shares are 3.51 % and 5.08 % respectively.

After biomass Petroleum holds a share 12.28 % of total energy consumption making petroleum products second main energy resources of Nepal. The main problem with these sources is that they have to be imported. They are not available in a systematic way, in affordable and economic price.

The coal accounts for only 3.93 % of total energy consumption while Renewable accounts for only 1.22 % of total energy consumption. The figure for Renewable is very small. It means renewable technologies like Solar PV, Solar Thermal, Biogas etc. are used in very small proportion. Clearly, there seems a need to switch to RETs in order to balance our energy mix, in order to increase energy security by reducing import dependency on fossil fuels, in order to reduce the environmental impacts because of the heavy use of biomass.

### 2.1.3 Energy Consumption by Economic Sectors:

The different economic sectors in Nepal are Residential, Industrial, Transport, Commercial, Agriculture and others (WECS, 2014)

The energy consumption by different economic sectors in Nepal for the year 2011/12 is given in the Table 2-2:

Table 2-2 Energy Consumption by Economic Sectors

Sectors	Energy Consumption In million GJ	Percentage
Residential	302.4	80.36 %
Industrial	29.7	7.89 %
Transport	26.8	7.12 %
Commercial	12.9	3.43 %
Agriculture	4.4	1.17 %
Others	0.1	0.03 %
Total Consumption	376.3	100 %

Source: (WECS, 2014)

The pictorial view of energy consumption by different economic sectors in Nepal for the year 2011/12 is given in the Figure 2-32.:

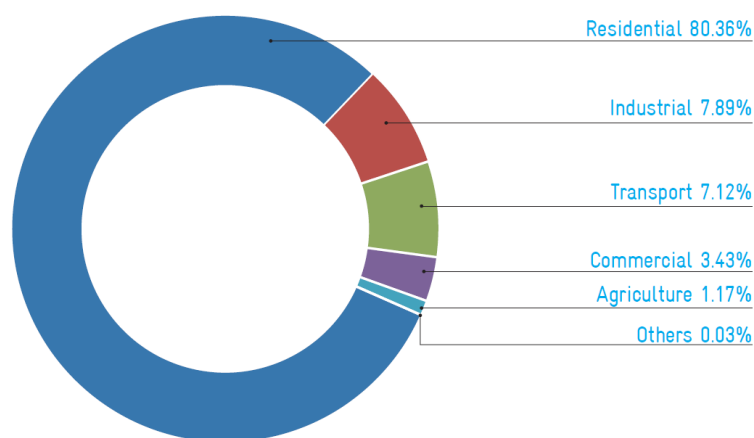


Figure 2-2 Pictorial view of energy consumption by different economic sectors of Nepal for the year 2011/12 (WECS, 2014)

Figure 2-3 shows that majority of energy consumption in Nepal is dominated by Residential Sector. The figure is 80.36%. The energy consumption by the industrial sector is only 7.89% and that by transport, commercial and agriculture sector are 7.12%, 3.43%, and 1.17% respectively. The figures for industrial sector, transport sector, commercial sector and agriculture sector are very small. It is therefore, we are in the status of under developed country.

#### **2.1.4 Energy consumption in the industrial sector**

Total Energy consumption in the industrial sector is about 13.4 million GJ (2008/09) which is about 3.3% of the total energy demand. The energy consumption has been increasing marginally during the last few years. The industrial energy consumption has increased only by about 0.4% annually since last eight years. The main end uses in the industrial sector are process heating, motive power, boiling in the boilers and lighting. WECS (1998) has assessed the industrial sector energy consumption pattern both in traditional and modern sector. Industrial energy consumption was 9.1 million GJ for the year 1996/97. Industrial sector is broadly categorized into two types; modern and traditional. Modern industries are also grouped into large industry and medium industry.

Figure 2.4 shows the energy consumption of manufacturing industries in Nepal for the year 2008/09 and 2011/12. The energy consumption for the manufacturing sector is marked with high contribution of commercial source of about 75% as compared to 12% in the overall national demand. Coal alone contributed 46% of the total manufacturing sector energy demand. Although use of coal has increased from 7.7 million GJ in the year 2008/09 to 13.7 GJ in the year 2011/12, the share of coal in the energy mix has decreased from 58% in year 2008/09 to 46% in 2011/12. Manufacturing industries consumed 4.1 million GJ of electricity in the year 2011/12 as compared to 3.1 in the year 2008/09. The share of electricity in the energy mix of the manufacturing industries has decreased from 23% in the year 2008/09 to 14% in the year 2011/12, mainly due to the unavailability of electricity. The use of High-Speed Diesel has witness most significant growth from 0.2 million GJ in the year 2008/09 to 4.5 million GJ in the year 2011/12 thus, increasing the share of diesel on the energy mix from 2% in 2008/09 to 15% in 2011/12. Diesel has been intensively used by industries due to the unavailability of electricity.

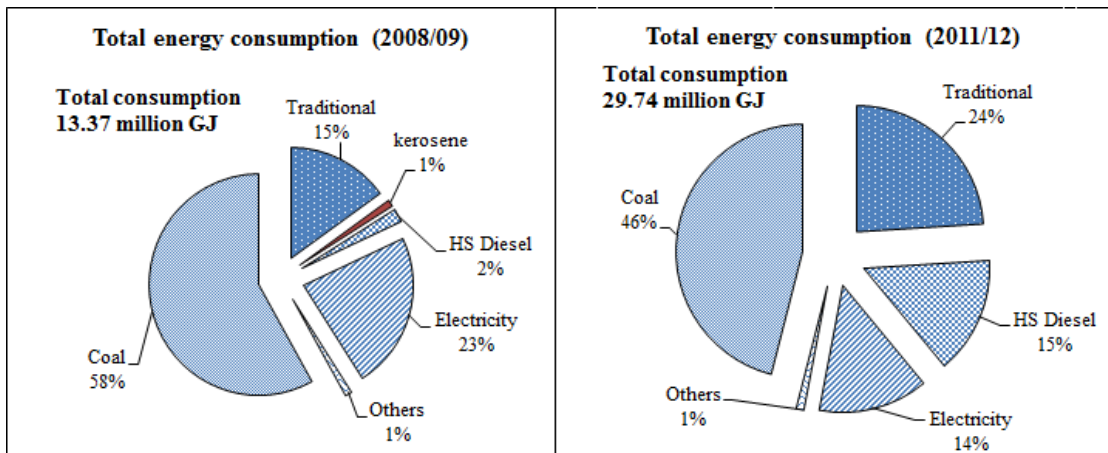


Figure 2-3: Manufacturing sector energy consumption by fuel types

(Source: WECS, 2010; WECS, 2014)

The share of energy consumption in large modern industry is about 78%, followed by medium industry (17%) and traditional industry (5%). Industrial energy consumption by physiographic region shows wide variation. 63% of the total energy is consumed in Terai region, whereas 29% in Hills and only 8% is consumed in Mountain region. Regarding end use, Boiler dominated other type of end use with 37%. Other end uses of the sectors are power motive (31%), process heating (30%) and lighting (2%).

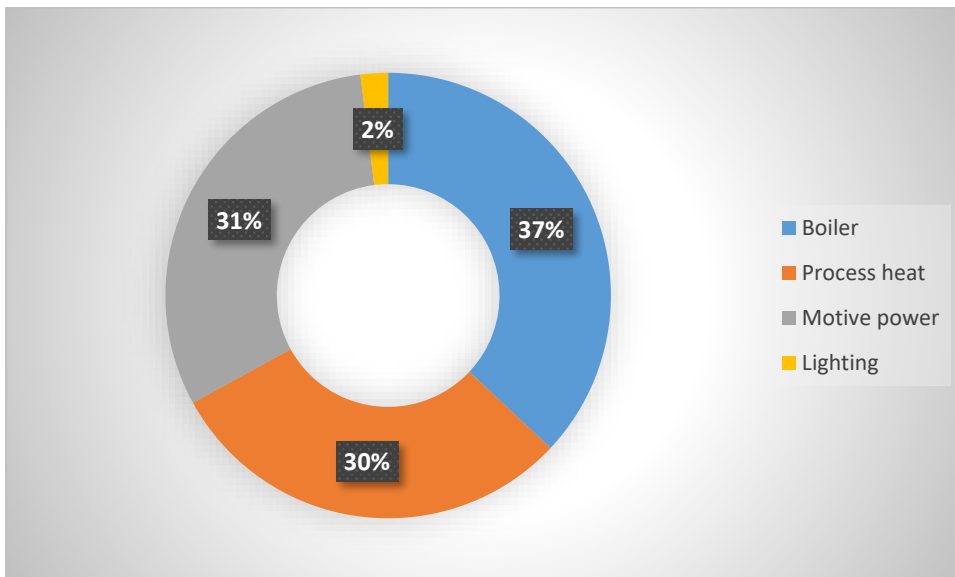


Figure 2-4: Share of energy end use in Industrial sector

Source: (GoN/WECS, 2017)

## 2.2 Instant Noodle production process

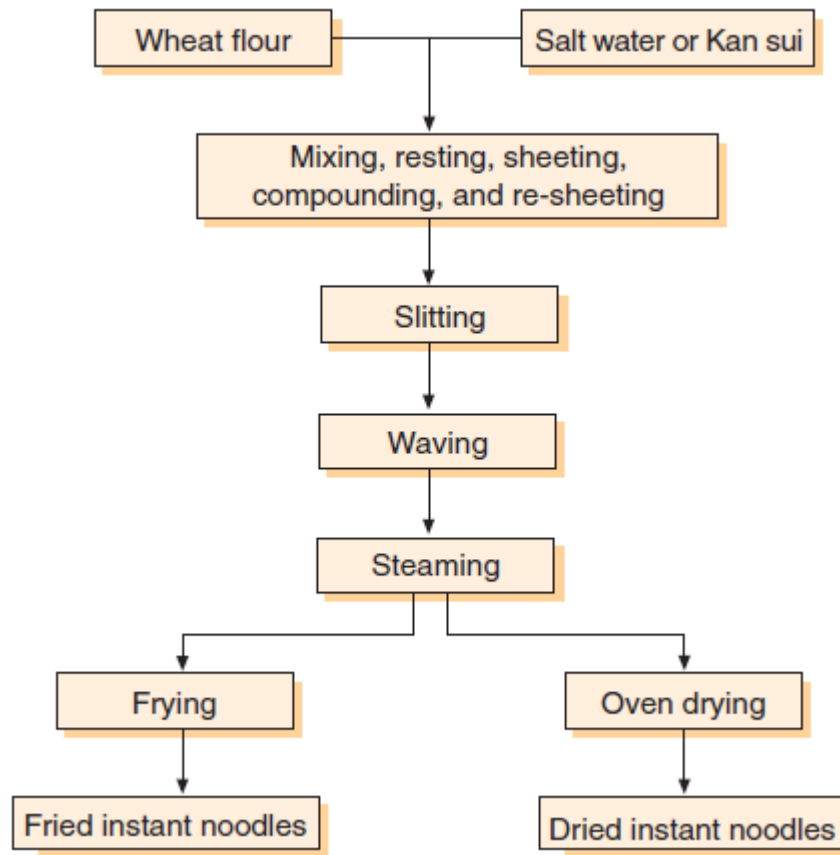


Figure 2-5: Simplified flow chart diagram of Instant noodles making procedure

Source: (Choy, 2011)

### 2.2.1 Mixing Ingredients

Mixing formula ingredients (flour, water, CMC guar gum, salt, Calcium carbonate, Potassium bicarbonate, Sodium tripolyphosphate) are carried out in a horizontal mixer for 20-25 minutes. Mixing results in the formation of a crumbly dough with small and uniform particle sizes. Since the water addition level is relatively low (vs. bread dough), gluten development in noodle dough during mixing is minimized. This improves the dough sheet ability, sheeted dough smoothness and uniformity.

### 2.2.2 Dough Resting

After mixing, the dough pieces are rested for minutes before compounding. Dough resting helps water to penetrate into dough particles evenly, resulting in a smoother and less streaky dough after sheeting. The dough is rested in a receiving container while being stirred slowly.

### **2.2.3 Sheeting**

Crumbly dough pieces are divided into two portions, each passing through a pair of sheeting rolls to form a noodle dough sheet. The two sheets are then combined (compounded) and passed through a second set of sheeting rolls to form a single sheet. Further dough sheeting is done on a series of rolls with decreasing roll gaps.

### **2.2.4 Cutting and weaving**

Noodle slitting is done by a cutting machine, which is equipped with a pair of calibration rolls, a slitter, and a waver. The sheet is cut into noodle strands of desired width with a slitter and noodle strands are waved before steaming and cutting.

### **2.2.5 Steaming and Cutting**

The wavy noodle-strands are conveyed to a steamer for 2.11 min with 90°C temperature approximately to cook the noodles. The purpose of steaming is to gelatinize the starch and fix the noodle waves. After steaming noodles are allowed to cool down for few seconds. The raw noodles are cut to a final slice and it folds the slice into 2 folds. The raw noodle is fold according to the predefined size. It is controlled by quality department.

### **2.2.6 Souping**

Souping causes development of colour in outer and inner surface of noodles. Ingredients consists of green chilli, black pepper powder, soya sauce, fried onion, tomato sauce, salt, MSG, citric acid, water, chicken flavour etc. depending on the variety of noodles. These ingredients are firstly pressure cooked and then mixed along with chicken extract. About 10g of soup is absorbed by single cut cake. Immediately blowing is carried out so that soup can penetrate and unwanted soup can be removed out from surface.

### **2.2.7 Frying**

Frying of noodles is carried out by dipping them in hot palm oil (160-170°C) for about 2min 15sec. The noodles are made crispy during this process. Process vaporizes water quickly from the surface and the dehydration of the exterior surface drives water to migrate from the interior to the exterior of the noodle strands. Eventually, some of the water in the noodles is replaced by oil. Many tiny holes are created during the frying

process due to the mass transfer, and serve as channels for water to get in upon rehydration in hot water.

### **2.2.8 Cooling process**

The hot noodles are cooled for 1.4 minutes with the help of six electro cooler fans, cooling to ambient temperature ensures product shelf life. This process makes instant noodle to touch with hand so further, it is possible to remove out irregular shaped and underweight cake.

### **2.2.9 Topping with seasoning**

The seasoning packet is placed on the noodle which contain chili powder (pure dry chilly), taste enhancer and palmolein (with onion flavor).

### **2.2.10 Packaging and Cartooning**

Along with seasoning it is packed in a metallic plastic with the help of roller packaging machine with long and end sealer.

Length of the wrapper: 159 mm

Temperature of middle seal: 148°C

Temperature of upper seal: 158°C

## **2.3 Existing literatures**

Wang (2014) studied about the energy efficiency improvement and waste heat recovery in the food industry with a focus to increase the sustainability of food processing. Replacement of conventional energy-intensive food processes with novel technologies such as novel thermodynamic cycles and non-thermal and novel heating processes provides another potential to reduce energy consumption, reduce production costs, and improve the sustainability of food production. Some novel food processing technologies have been developed to replace traditional energy intensive unit operations for pasteurization and sterilization, evaporation and dehydration, and chilling and freezing in the food industry.

Wang et al. (2016) investigated the energy consumption and output of dryers for dried Chinese noodles, using a new 130-m long tunnel dryer with two lines of noodles (ND), an old 60-m long tunnel dryer with five lines of noodles (OD) and a modified new 130-m long tunnel dryer with automation techniques. The energy saving effect was

determined from the enthalpy difference between the inlet and outlet humid air of the ND and MND. The MND was found to be better than ND in terms of energy efficiency and throughput and the difference can be attributed to a more efficient oil heater, properly designed air exhaust system, and well-insulated buildings and pipelines which accounts to 60% energy savings in the drying process.

GIZ/NEEP (2012) analyzed the energy intensity and estimated the potential electrical and thermal energy savings as well as CO<sub>2</sub> emission per unit products of eight different sectors one of them being food sector with noodles as a subsector. Considering four establishments, it was found that the Instant Noodle industries consume both electrical and thermal energy in its production process. Electrical energy is used for drives, compressors, pumps and lighting and thermal energy is required for the operation of boiler to get steam for the cooking of noodles and other hot processes. Fuel used for the boiler was rice husk. It was calculated that the electrical saving potential is 6.15% and thermal saving potential is 11.38%, for Noodle industries.

In IOE thesis, Pradeep Singh studied the effect of implementation of best available technologies in cement industries of Nepal. He calculated the impact of penetration of best available technology in energy consumption depending on three main factors, viz. penetration of proposed energy efficiency technology, the baseline energy (projected on various growth rates) and environment forecast and the effectiveness of the policy compared to the existing policy. It was found that the potentiality of efficiency improvement in finish grinding is 48% and around 40% of efficiency improvement can be done in motors and fans. Similarly, low temperature for waste heat recovery power generation can be employed in rotary kiln industries, which account the saving of 9% of electricity. Likewise, the fuel energy intensity of saving can be attained in integrated cement industries. The majority of the fuel energy is found to be lost from the kiln surface and the use of better insulating refractories can be used to reduce heat losses up to 37%. Further, the use of alternative fuel can save energy up to 30%.

Similarly, Gyanwali (2012), Timilsina (2015) and Bhandari (2017), studied the energy efficiency in industrial sector, hotel sector and food sector using Leap creating different scenarios with efficient end use equipment. They all concluded that using energy efficient technologies contributes to the significant energy savings and reduces the carbon intensity and GHG emissions in their respective fields of research.

Bhattarai (2015) studied the industrial sectors energy demand projections and analysis of Nepal for sustainable national energy planning process of the country. The purpose of this study was to project the sectorial energy demand up to 2030 under different anticipated growth scenarios of national economy. To project future energy demand, the end-use industrial sector energy demand model based on Long –range Energy Alternative Planning (LEAP) framework was formulated with four GDP growth scenarios namely business as usual (BA), low growth (LG), medium growth (MG) and high growth (HG) respectively. It has been found that the total sectorial energy demand and electricity demand can be reduced from 1.78 and 2.42 times of the base year demand in BA scenario to 1.53 and 2.24 times of the base year demand in 2030 respectively.

### CHAPTER THREE: RESEARCH METHODOLOGY

Research methodology is a way to systematically solve the research problem (Kothari, 2004). It illustrates the systematic steps undertaken in confronting a problem. For the insightful formulation and conclusion of the research, both qualitative and quantitative strategies were followed. To understand the general background of the research, institutional setup of the manufacturing industries and the current energy consumption pattern of the industries; qualitative approach was followed. Intensive literature review of various editions of Census of Manufacturing Establishments, Economic survey and various reports on manufacturing industries was followed by consultation with the professionals involved in the manufacturing industries to understand the overview of the manufacturing sector. Quantitative approach was pursued for the collection and analysis of data regarding the end use device and their energy consumption. Figure 3-1 illustrates the general framework of this research.

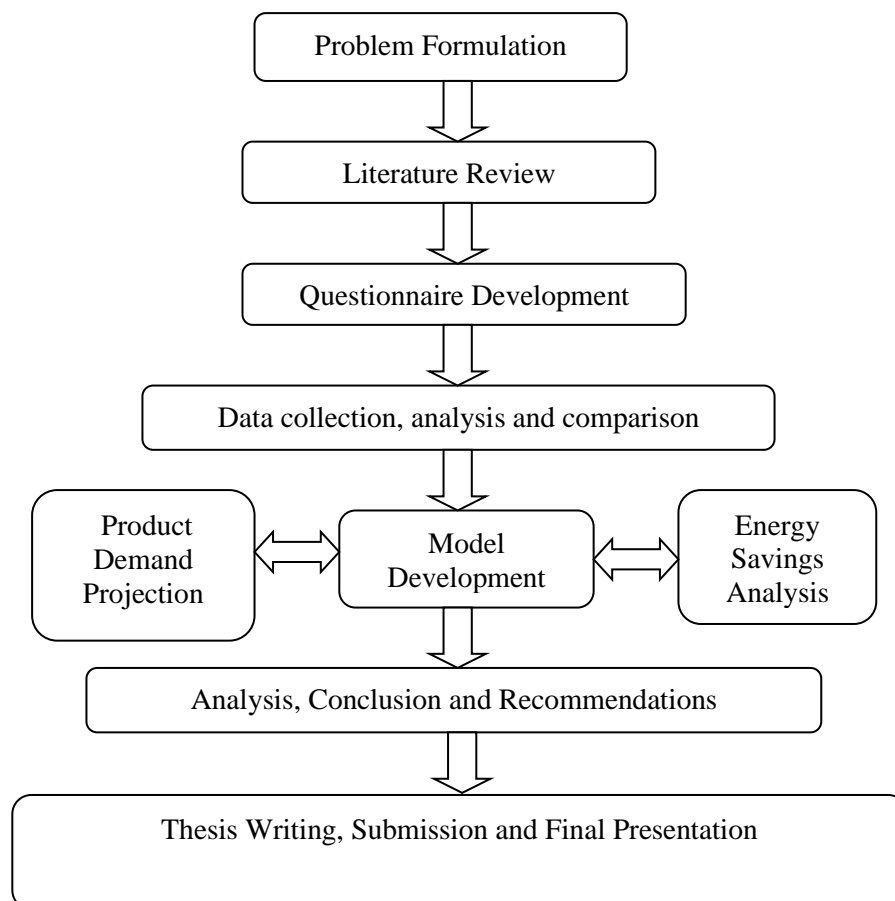


Figure 3-1: Flowchart of research methodology

### **3.1 Problem formulation**

Problem Formulation is an activity which defines the cognitive gap between what is and what is desirable and delineates the resources for closing it. The lack of concrete study on the energy consumption of the noodle industry was identified as the problem, this research aimed to address.

### **3.2 Literature review**

Intensive study of existing literature on energy consumption in the manufacturing sector and food processing was carried out to access the overview of the manufacturing sector, food processing processes, end use equipment and their energy consumption and energy saving prospects. Various editions of Energy Survey Report by Water and Energy Commission Secretariat (WECS), various editions of Census of Manufacturing Establishments by Centre Bureau of Statistics (CBS), various editions of Economic Survey by Ministry of Finance (MoF), reports by Nepal Rastra Bank (NRB) and other government agencies were collected and vividly reviewed. Journals from national and international publishers relating to the study were also collected and extensively reviewed. The literature review regarding the energy-use energy model Long Range Energy Alternatives Planning (LEAP) and energy efficient technology was primarily based on online materials. Finally, various academic books were referred during the course of study whenever felt necessary.

### **3.3 Questionnaire Development**

Questionnaire was developed to access the energy demand for the end-use devices. The total energy consumption was divided into five end-use categories; namely, Lighting, Motor drives, Process Heat, Boilers and Other equipment. WECS (2010) has used similar classification to identify the energy consumption in the manufacturing sector. The questionnaire was developed to collect the information regarding the different types of end-use devices, their rated power, number, and average hours of operation and fuel used.

### **3.4 Sample size Calculation**

There are various formulas for calculating the required sample size based upon whether the data collected is to be of a categorical or quantitative nature (e.g. is to estimate a proportion or a mean). These formulas require knowledge of the variance or proportion in the

population and a determination as to the maximum desirable error, as well as the acceptable Type I error risk (e.g., confidence level).

It is possible to use one of them to construct a table that suggests the optimal sample size for given a population size, a specific margin of error, and a desired confidence interval. This can help researchers avoid the formulas altogether. The table below presents the results of one set of these calculations. It may be used to determine the appropriate sample size for almost any study.

Many researchers (and research texts) suggest that the first column within the table should suffice (Confidence Level = 95%, Margin of Error = 5%). To use these values, simply determine the size of the population down the left most column (use the next highest value if your exact population size is not listed). The value in the next column is the sample size that is required to generate a Margin of Error of 5% for any population proportion.

However, a 10% interval may be considered unreasonably large. Should more precision be required (i.e., a smaller, more useful Margin of Error) or greater confidence desired (0.01), the other columns of the table should be employed.

$$\text{Sample size (n)} = \frac{\chi^2 * N * (1-P)}{ME^2(N-1) + (\chi^2 * P * (1-P))}$$

Where

n = required sample size

$\chi^2$  = Chi square for the specified confidence level at 1 degree of freedom

N = Population size

ME = Desired Marginal error (expressed as a proportion)

Table 3-1 Sample size calculation

Confidence interval= 80%	
Degree of accuracy= 0.1	
Population size	Sample size
21	14

Since the population size is very small. The sampling size comes out to be 74% of population. Due to time constraints, all 21 sample industries cannot be surveyed. However, the similar sampling has been done in the baseline study (GIZ, 2012). Hence, 12 industries have been surveyed. Considering the instant noodles sector in Nepal, CG foods shares about 45% of the market share. However, CG foods has not been considered in this research due to the unavailability of the data from CG foods.

### **3.5 Data collection**

The primary data of end-use energy devices and their energy consumption was collected through questionnaire survey and field visit to the noodle industries. The collected data was then compiled in excel spreadsheet.

The secondary data of noodle production was compiled from various editions of economic survey and world instant noodles publications. The secondary data on calorific value of diesel, electricity and petrol was compiled using energy conversion calculator provided online by Energy Information Administration (EIA). Dayal (2014) used the conversion data from the same source for all the fuel types. The efficiency of current end-use devices was taken from results of comprehensive survey of manufacturing industries by Gyanwali (2012) while the technological selection and potential savings from implementation of energy efficient technology is based on the recommendation by the Ernest Orlando Lawrence Berkeley National Laboratory (2012) to the snack processing for energy efficiency improvement.

### **3.6 Data compilation, analysis and comparison**

The collected data was compiled on Microsoft Excel to facilitate analysis. The annual energy demand for end-use device category was calculated as,

$$E.D_i = N_i * P_i * T_i * U_i * D$$

Where,  $N_i$  = Number of end-use device

$P_i$  = Rated power of end-use device

$T_i$  = Average hours of operation

$U_i$  = Capacity utilization factor

$D$  = Average number of working days in a year

(Suganthia & Samuel, 2012)

The data on number of end-use devices, their rated power and average hours of operation were retrieved from the information gathered during survey. Average number of working days in a year was assumed to be 300 days, and the capacity utilization factor of 0.6 was taken for the year 2017 based on the suggestion by Er. Lincoln Koirala, production manager at Quality Noodles. The total energy demand for the Noodle industry was summed up and the specific energy consumption i.e. GJ/MT of Noodle industry was calculated. Noodle industry uses four types of fuels. Rice husk and furnace oil was used to power boiler. Electricity was mainly used for driving motors and heating. Diesel was mainly used for heating and powering diesel generators.

### **3.7 Model development**

Bottom-up end-use LEAP Model is developed to investigate the possibility of demand side management with 2017 as base year and 2019 as first year of projection. Energy demand and GHGs emission were estimated up to the year 2030 for case study. Both Gyanwali (2012) and Bhattarai and Bajracharya (2015) have taken industrial value addition to project the future energy demand for the manufacturing sector was considered, hence it was followed in this research as well. The LEAP model was developed to assess the energy saving potentials. The model was based on the end-use energy devices and their fuel consumption. The energy demand was basically segregated into five end-use and fuel types were specified to each end-use category.

#### **3.7.1 Lighting**

The lighting end-use energy demand has been divided into two categories namely, electricity and DG sets to reflect the fuel types used. Four sub-categories with energy intensity named incandescent, CFL, fluorescent and LED were created for both categories and fuel type was specified. During the survey, it was found that the share of the fluorescent bulbs was the highest followed by the incandescent lamps. The share of CFL and LED lights were the least and to save the energy the incandescent lamps and fluorescent lamp have to be switched with the more efficient lighting devices.

#### **3.7.2 Machine Drives**

The machine drives energy end-use energy demand was divided into two categories namely electricity and DG sets and it was further sub categorized into three categories named motors, pumps and compressor. The motors are used to operate the mixer, shaper, sheet cutter, sheet roller and all types of conveyors and the pumps are used to

pump water while making the dough and while cleaning of the units. The motors are primary used to move materials from one part of the equipment to other part or simply to provide rotational or translational motion to the processed materials. Primarily, pumps are used to pump the water and other fluids required for various processes. Compressors are used to produce the pressurized air that are used for drying processes.

### **3.7.3 Process Heat**

Under this category, direct heating and indirect heating were created. In direct heating, materials were heated for a shorter time in an elevated temperature. The materials were directly exposed to the source of heat whereas in indirect heating, the method of convection was used. The products were heated using hot air or steam which were heated before. In indirect heating, the products are exposed for longer period of time and it is mainly used to reduce the moisture content from the noodles strands that are being processed. The energy demand for direct heating has been modelled for single fuel type but for indirect heating two fuel types were used.

### **3.7.4 Boilers**

Similarly, under boilers four different types of boilers were created based on the use of fuel in different industries. The rice husk boiler is mainly used in those regions where there is accessibility of rice husk and generally the industries from terai region are using this as fuel for the boilers whereas wood fired boiler is being used in the hilly regions. Likewise, the recent establishments are using furnace oil too. With the plan of government to promote the use of electricity, electric boilers too are considered under this category however presently no industries are using the electric boilers. The boilers were categorized under this single category because the steam generated by the boiler is also used in the drying process along with the heat exchangers. Since, boiler is integral part of the production process; its energy consumption was assumed to be proportional to the industrial output.

## **3.8 Scenario Analysis**

To investigate the implication of various policy interventions on energy mix, various scenarios were constructed. The scenarios constructed to study the energy use in noodle industry of Nepal can be listed as:

- BAU scenario

- Low Growth Scenario
- High Growth Scenario
- BAU efficient scenario
- Low Growth efficient scenario
- High Growth efficient scenario

### **3.8.1 Normal Growth**

Normal growth scenario represents the energy demand for the noodle industries under the normal growth rate scenarios without any intervention. Considering all the factors to be remaining as the present context, the normal growth rate for noodles industries was calculated and found to be 5.7%. Using this scenario, the energy demand profile for the various processes was determined along with the energy mix.

### **3.8.2 Low Growth**

Since the change in the production determines the energy demand too, so, a low growth scenario was used to study the impact in the energy mix when the conditions became unfavorable. Analyzing the historical data, the average of two low growth rates were considered in this scenario which was found to be 2.36. So, an optimistic value of 3 was chosen to facilitate the energy mix under low growth scenario.

### **3.8.3 High Growth**

Similar to that of the low growth scenario high growth scenario was also used to find out how the change in production results the change in demand. The high growth rate was considered to be 12.5.

## **3.9 Efficient scenarios**

Now the introduction of various energy efficient devices was done to see the impact created when these efficient devices were used. The use of diesel generators will phase out eventually considering the uninterrupted supply of the electricity. With the power supply being regular the electric devices which used the electricity generated by the diesel generators will all be dependent on the electricity from the grid rather than that produced by the generators. From the year 2019, all share electricity from diesel generators is considered to be zero as the government has declared that the end of power outage from all sectors.

### **3.9.1 Efficient lighting**

For the lighting, currently the industries are using incandescent and fluorescent lamps with a minimal use of the CFL. However, as the Government is planning to reduce these less efficient lamps with the more efficient one as mentioned in the Sustainable Development Goals, the share of the CFL and LED were considered to grow with time (National Planning Commission, 2015). Different methods to reduce the energy demand in lighting are

- Turn off lights in unoccupied areas
- Establish lighting level standards
- Use lighting controls
- Use day-lighting
- Replace incandescent lamps with compact fluorescent lamps (CFL) and LED lights
- Reduce high-intensity discharge (HID) voltage

For estimating the energy saving potentials in lighting, only the effect of replacement by LED lighting is considered as it is regarded as best available technology. In accordance to the sustainable development goals adopted by the government of Nepal, the share for CFL is targeted to be around 80 percent in 2022, around 50 percent in 2025 and zero percent by 2030. Similarly, the share of LED is expected to grow to 20 percent in 2022 reaching 50 percent and by 2030, all CFL and other lighting systems to be replaced by LED i.e. reaching 100 percent in year 2030. (National Planning Commission, 2015). Lighting demand is measured by a quantity of lumen of visible light needed at a certain point of time. The quantity of electricity (in watts) needed to supply the demand for lighting (in lumen) is expressed as the efficacy of the light source (in lumen/watt). The maximum theoretical efficiency is 700 Lumen/Watt. Thus, for estimating the energy saving potential in lighting, average efficacy of different bulb type was considered. The energy intensity was expected to reduce by 21% when all the bulbs are replaced by LED bulb (Bhandari & Bajracharya, 2016).

### **3.9.2 Efficient Machine Drives**

Motors are used in noodles production mainly during dough making which is concerned with mixing of ingredients and water. During field visit, it was observed that motors were not optimally run according to the fluctuating production i.e. Gyanwali (2012)

considered the effects of motor maintenance in reducing energy demand for motive end-use for overall manufacturing industries. Since motors are major component of electrical load in noodles production, it was observed that motors were regularly inspected and maintained, and thus, for estimating the energy saving potentials in motive end-use, only the effect of adjustable speed drives (ASDs) was considered. Adjustable-speed drives better match speed to load requirements for motor operations, and therefore ensure that motor energy use is optimized to a given application. These systems are offered by many suppliers worldwide. Energy savings may vary from 7% to as high as 60%, depending on the use pattern of the motor (Worrell, Bode, & de Beer, 1997). Thus, energy demand was expected to decrease by 7% for efficient operation of motor and pumps (Bhandari & Bajracharya, 2016). Different technologies to reduce the energy demand in motive are:

- Develop a motor management plan
- Select motors strategically
- Maintain your motors
- Ensure that motors are properly sized
- Motor Automation
- Consider adjustable speed drives (ASDs)
- Correct power factor
- Minimize voltage unbalances

### **3.9.3 Efficient Process Heating**

Heating is required in noodle industry to dry the noodle cake to heat (inside oven) at temperature around 220°C. During field visit, it was observed that heat in exhaust gas was unutilized. Heat recovery can result significant reduction in energy demand with little capital investment. To investigate the energy saving potentials in process heat, thus only the effect of heat recovery was considered. Heat recovery systems reduce the energy required to heat or cool facility intake air by recovering the thermal energy of the exhaust air. Common heat recovery systems include heat recovery wheels, heat pipes, and run-around loops. The efficiency of heat pipes is in the 45% to 65% range (U.S. EPA, 2003), while the efficiency of run-around loops can be slightly higher, in the 55% to 65% range (U.S. EPA, 2001). Thus, for efficient heating, the energy demand

and emission were expected to reduce by 9% (Bhandari & Bajracharya, 2016). Different methods of reducing the energy demand in process heat are,

- Install energy monitoring and control systems
- Adjust non-production hours set-back temperatures
- Repair leaking ducts
- Consider variable-air-volume systems
- Install adjustable-speed drives (ASDs)
- Consider heat recovery systems
- Modify your fans
- Use ventilation fans
- Install efficient exhaust fans
- Add building insulation
- Improve building reflection

#### **3.9.4 Efficient Boiler**

During field visit, it was observed that the pipes for supplying steam were not well-insulated. Thus, for estimating energy saving potentials in boiler, only effect of improved insulation was considered. It is possible to use new materials, such as ceramic fibres, that both insulate better and have a lower heat capacity (thus allowing for more rapid heating). Savings of 6% to 26% can be achieved if improved insulation is combined with improved heater circuit controls (EOLBNL, 2012). Thus, the energy demand and emission were expected to decrease by 6% for efficient boiler as compared to business as usual (Bhandari & Bajracharya, 2016). Different methods to reduce energy demand in boiler based on the recommendations of EOLBNL are,

- Control boiler processes
- Reduce flue gas quantities using visual inspection
- Reduce excess air
- Properly size boiler systems
- Improve boiler insulation
- Implement a boiler maintenance program
- Recover flue gas heat
- Return condensate to the boiler

- Recover blow-down steam
- Replace old boilers

Energy efficient scenario was created to investigate the energy saving potential when all the aforementioned measures are taken to reduce the energy demand. The total energy demand for energy efficient scenario was based on the reduction in each end-use by the use of energy efficient technology.

### **3.10 Modelling conditions**

The base year for the model is considered to be 2017 and span of 13 years is used, thus modeling until 2030.

### **3.11 Analysis, conclusion and recommendation**

After the development of the scenarios, the data was compiled in the MS excel and all the unit of end use energy processes were converted to GJ. And the final result and discussion was done. From the compiled data, the sectorial energy consumption pattern was prepared and the thermal energy calculation and the electrical energy calculation was done. Finally, the difference between the energy consumption of both the thermal energy and electrical energy gives the energy saving potential.

## CHAPTER FOUR: RESULTS AND DISCUSSION

### 4.1 Data Analysis

The end-use data collected from the survey was compiled on Microsoft Excel to facilitate further computation. The end-use energy database was then developed to investigate energy consumption pattern for the industry.

Table 4-1 Energy Demand for various processes based on fuel type

Branches	Biomass	Wood	LPG	Residual Fuel Oil	Diesel	Electricity	Total (GJ)
Lighting	-	-	-	-	0.95	2.23	3.18
Motor Drives	-	-	-	-	12.12	28.29	40.41
Process heat	-	-	2.74	-	4.65	10.86	18.25
Boiler	86.86	3.26	-	16.29	-	2.17	108.58
Others	-	-	-	-	1.90	4.44	6.35
Total (GJ)	86.86	3.26	2.74	16.29	19.64	47.99	176.77

From the data collected, the demand processes for various processes were tabulated for the base year 2017 as shown in table 4-1. Among the end processes, the demand for the lighting was found to be 3.181 GJ. Similarly, the demand for the machine drives and process heat were found to be 40.41 GJ and 18.25 GJ respectively. Likewise, the maximum demand was for boilers with about 108.58 GJ and for other equipment it was 6.35 GJ. So, the share of the electricity and thermal demand are 47.99 GJ and 128.39 GJ which meant the electric load consumes 27.15 % of the energy and remaining 72.85 % energy is consumed by the thermal load.

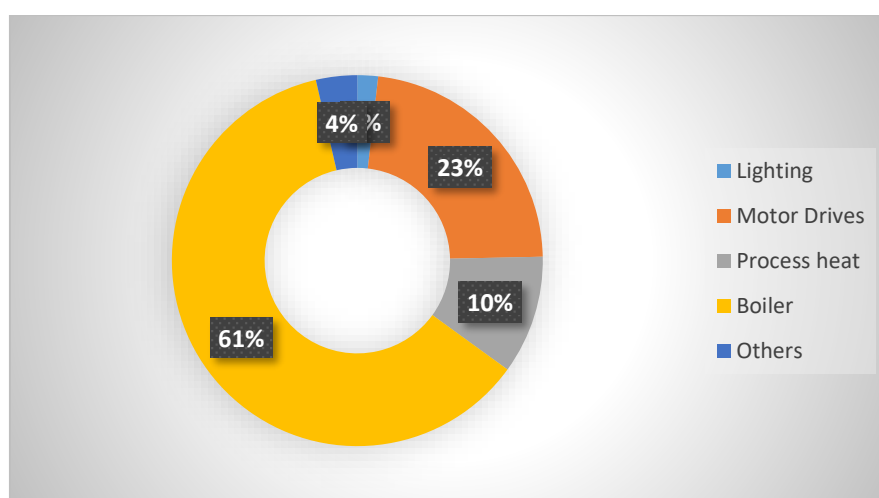


Figure 4-1: Share of end use process in Noodles industry

As evident from the figure 4-1, the maximum energy is used by the boilers which is around 61% followed by machine drives with 23%. About 10% of energy was used for the process heat and the share of energy for the lighting and other equipment was found to be 2% and 4% respectively. Hence, it can be said that, boiler is a major energy consuming end-use equipment in the Noodles industry which consumes 85.91 % of thermal energy, whereas rest of the thermal energy is utilized by the process heat where the Noodles are fried using palm oil.

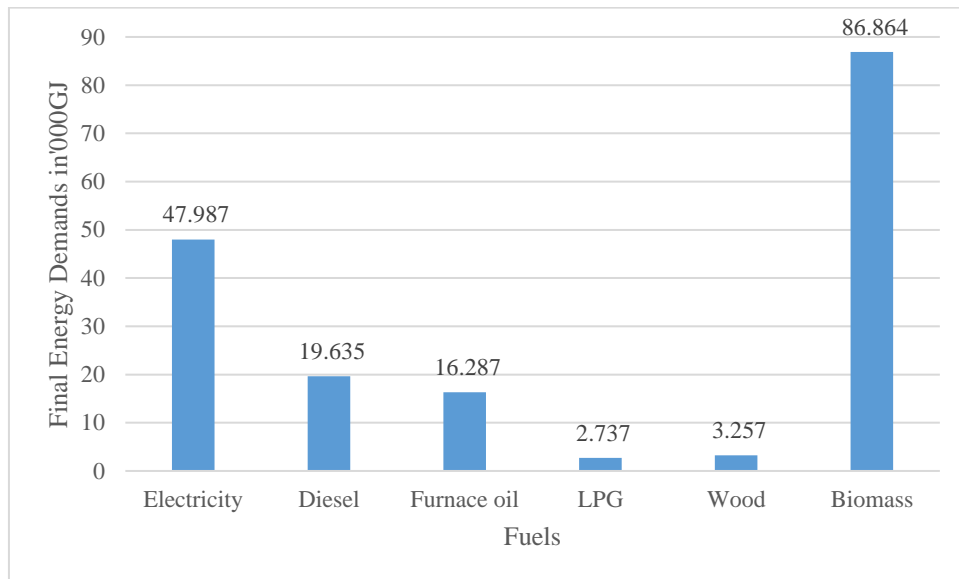


Figure 4-2: Final Energy Demand for different fuel types

Considering the final energy demand for the different fuel types, maximum energy was gained from the biomass that is rice husk which provided for about 85 thousand GJ followed by electricity 48 thousand GJ of energy. The proportion of other fuel were less than 20 thousand GJ. Diesel which was primarily used in the diesel generators during the power outage accounted for 20 thousand GJ with furnace oil also aiding some significant amount of energy whereas the energy from LPG and wood were very few, as very few industries used wood as the source of fuel in the boilers and LPG gas was used in minimal proportion.

#### 4.2 Growth rate

The future noodle production in Nepal can be projected as a function of gross value addition in the food and beverage industry sector because the relevant data related to only instant noodles industries was not found and food and beverage industry being the most relevant was chosen. Growing youth segment and increasing working population,

rising incomes and rising purchasing power, higher brand consciousness, changing consumer preference, growing urbanization and increase in number of middle-class populations are the biggest drivers in the growth of Instant Noodles industry of Nepal (Adhikari, 2016). Also, lack of time, fast paced life and changing food preferences are also helping Instant Noodles sector to grow in Nepal. The noodles demand scenario can be classified as the following

- High growth scenario
- Medium growth scenario
- Low growth scenario

Similarly, the energy efficiency scenario can be penetrated as mentioned in different literatures

### 4.3 Demand Forecast

The historical noodles production data have been collected from the report published by World Instant Noodles Association, 2018 and economic survey 2012. The end-use demand of noodles is estimated using the following equation, as mentioned in different literature (Shakya & Shrestha, 2011; Shrestha & Rajbhandari, 2010; TERI, 2006).

$$ESD_{noodles,t} = (VA_t / VA_o)^\beta \times ESD_{noodles,o}$$

where,  $ESD_{noodles,t}$  = end use service demand in year t for food sector

$VA_t$  = value added in the food sector in year t

$\beta$  = sectoral value-added elasticity of demand for noodles industry.

The future growth of GDP is forecasted using the regression model from the data available from various sources. Hence, growth rate is calculated at low growth rate is considered to be at 3% per year. Similarly, the growth rate for normal and high growth rate are considered to be 5.7% and 12.5% respectively. The forecasted GDP growth rate is used to generate the future growth rate of value addition of food and beverage sector. The sectoral value-added elasticity for noodles sector is calculated using above equation. The historical data for national level food demand and value addition used is 20 years from 2001 to 2017. The elasticity of demand for food industry was determined to be 1.36. Present production capacity of noodles being 103.6 thousand metric tonnes is expected to reach approximately 213 thousand metric tonnes in 2030, with a demand

of 152 thousand metric tonnes in case of low growth rate scenario. Similarly, the demand would rise from 10.3 thousand metric tonnes in 2017 to 479 thousand metric tonnes in 2030 in case of high growth rate scenario. The historical and future noodles demand is shown in Fig.4-3.

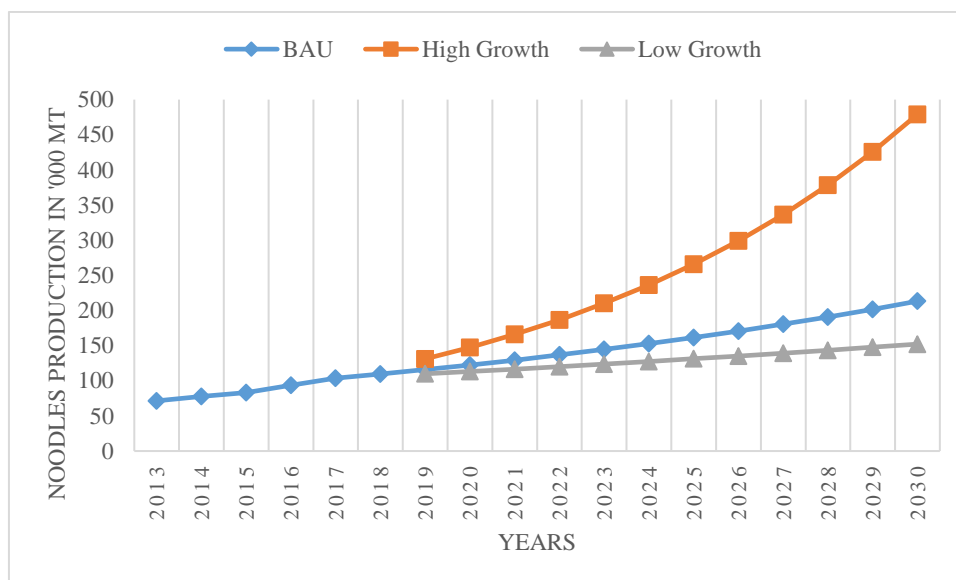


Figure 4-3: Historical and Future noodles demand projection

#### 4.3.1 General Assumption and Base Year

The following were the assumptions for the reference case scenario

- The base year is considered to be 2017.
- The major energy intensive fuels like electricity from grid and diesel gen-sets were considered for electrical energy.
- Rice husk, furnace oil, fuelwood, LPG and electricity are considered for thermal energy.
- The calculated value of final energy demand in the base year 2017 is 176.77 thousand GJ.

#### 4.3.2 Comparison with Benchmarked data

A similar research for the bench marking for food manufacturing plants was conducted by LJ Energy Pte Limited. The percentage share of various energy end use devices along with the research findings is tabulated in table 4-2.

Table 4-2 Comparison with Benchmarked data

End-use processes	Benchmarked findings	Research findings	Deviation
Lightings	1.7 %	2 %	0.3%
Motor Drives	15.5%	23%	7.5%
Process heat	8.5%	10%	1.5%
Boilers	59%	61%	2%
Others	15.3%	4%	11.3%

With the exception of other equipment, the energy demand for all other processes is almost with the range of 10% deviation. Hence, the data collected is considered to be valid and subjected to further analysis.

#### 4.4 Energy Demand Projection

Based on the data collected from survey, the energy demand for the base year 2017 in LG, BAU and HG is 47.99 thousand GJ. With the calculated growth rate for LG, NG and HG, the final energy demand would increase to 70.47, 98.77 and 221.88 thousand GJ in the year 2030. This energy demand projection for different growth scenarios is shown in Fig 4-4.

Table 4-3 shows the energy demand from different fuel types. The fuel used for different end-use processes are different. Electricity is directly used for lighting, machine drives, other equipment whereas it is used for process heat also, but majority of energy for process heat is derived from the thermal energy sources i.e. rice husk, furnace oil, fuel wood and LPG. So, the demand for electricity is expected to be 98.77 GJ in the year 2030. Likewise, the demand for the diesel will be 40.42 GJ with that of the rice husk approaching 178.79 GJ. The energy demand from the other fuels like residual oil is 33.42GJ with the least from firewood which is about 6.71GJ accounting for the total of 363.84 GJ in the year 2030.

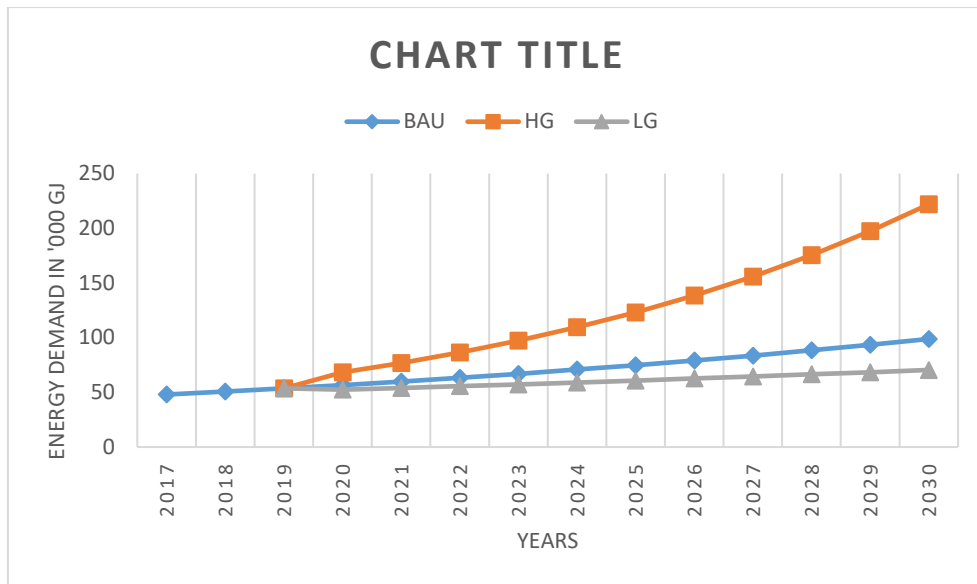


Figure 4-4: Final Energy Demand for different growth scenarios (2017-2030)

Table 4-3: Energy Final Demand according to fuel types

Fuels	2018	2020	2022	2024	2026	2028	2030
Electricity	50.728	56.686	63.344	70.785	79.099	88.390	98.773
Diesel	20.757	23.195	25.919	28.964	32.366	36.167	40.416
Residual Fuel Oil	17.217	19.239	21.499	24.024	26.846	30.000	33.523
LPG	2.893	3.233	3.613	4.037	4.511	5.041	5.633
Wood	3.443	3.848	4.300	4.805	5.369	6.000	6.705
Biomass	91.824	102.609	114.662	128.130	143.180	159.998	178.792
Total	186.861	208.810	233.337	260.745	291.372	325.597	363.841

#### 4.5 Results of efficiency scenarios

The efficiency scenario is constructed as an efficiency improvement in technology employed in noodles industries. The scenario can be studied as an efficiency improvement in the three growth scenarios. In other words, efficiency scenario studies the effect of technological improvement in three growth scenarios viz. BAU, LG and HG scenario.

Table 4-4 Final Energy Demand for different Scenarios

Scenarios	Others	Boiler	Process heat	Motor Drives	Lighting	Total
BAU	13.07	223.49	37.55	83.18	6.55	363.84
BAU efficient	10.05	153.08	29.11	64.16	5.04	261.45
LG	9.32	159.45	26.79	59.35	4.67	259.59
LG efficient	7.30	121.05	20.77	45.99	4.46	199.58
HG	29.35	502.03	84.36	186.86	14.71	817.31
HG efficient	23.46	390.19	66.81	146.95	14.11	641.52

As seen from the table 4.4, various processes consume various energies under different growth conditions. Lighting consumes 6.55 thousand GJ with motor drives consuming 83.18 thousand GJ followed by process heat with 37.55 thousand GJ. Boilers is the most energy consuming end use device with 223.49 thousand GJ. Under different efficient scenarios, the results obtained are tabulated in table 4.4.

Table 4-5 Comparison of final energy demand for BAU and BAU efficient scenarios

Scenarios	2017	2030
BAU	176.77	363.84
BAU efficient	176.77	261.45
Total	353.54	625.29

The efficient BAU, efficient LG and efficient HG scenario projects the total final energy demand to be at 142, 160.7, and 176.12 thousand GJ, respectively. Compared to the BAU scenario, in EFF BAU scenario, 11% of total cumulative energy consumption can be reduced.

Table 4-6 Comparison of final energy demand for LG and LG efficient scenarios

Scenarios	2017	2030
LG	176.77	259.59
LG efficient	176.77	199.58
Total	353.54	459.16

Likewise, in LG and efficient LG scenario, 12% of total energy can be conserved. Finally, EFF HG scenario, 25% of energy can be conserved compared to HG scenario.

Table 4-7 Comparison of final energy demand for HG and HG efficient scenarios

Scenarios	2017	2030
HG	176.77	817.31
HG efficient	176.77	641.52
Total	353.54	1458.83

The energy demand projection in efficiency scenario has shown with comparison to its corresponding growth scenario in Fig. 5.6, 5.7 and 5.8, for BAU, LG and HG scenarios respectively

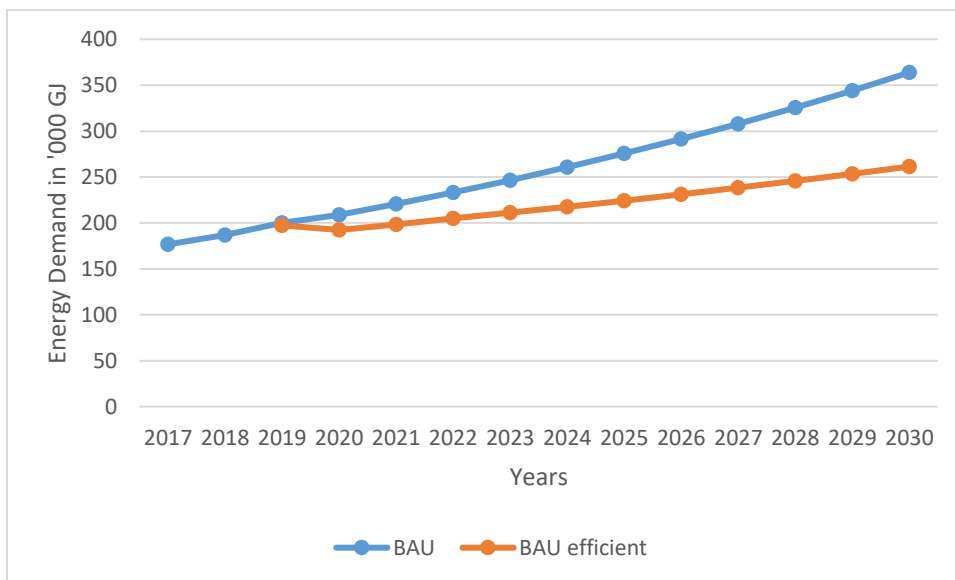


Figure 4-5: Final Energy forecast under BAU and BAU efficient scenario

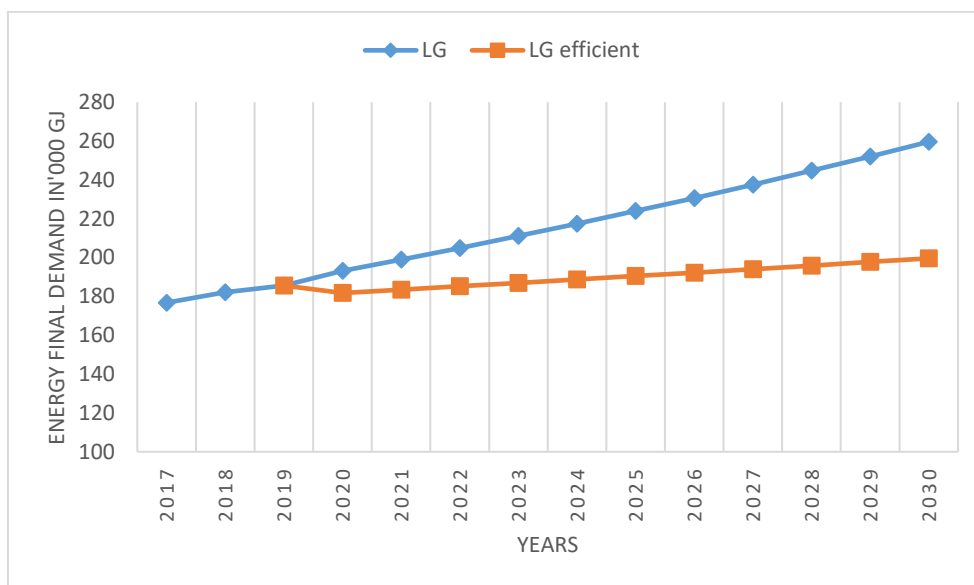


Figure 4-6: Final Energy Forecast under Low growth and low growth efficient scenario

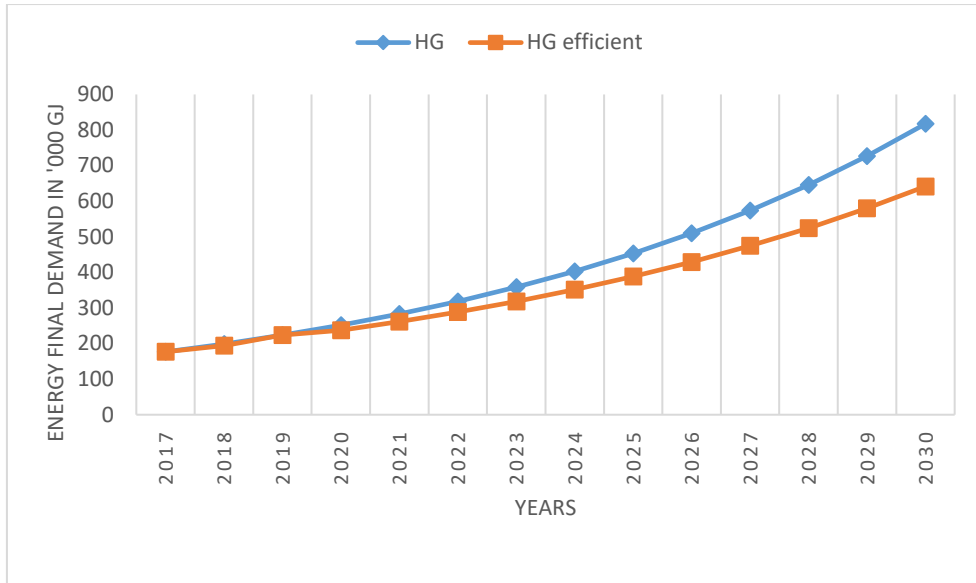


Figure 4-7: Final Energy forecast of High growth and high growth efficient scenario

#### 4.6 Carbon dioxide emissions

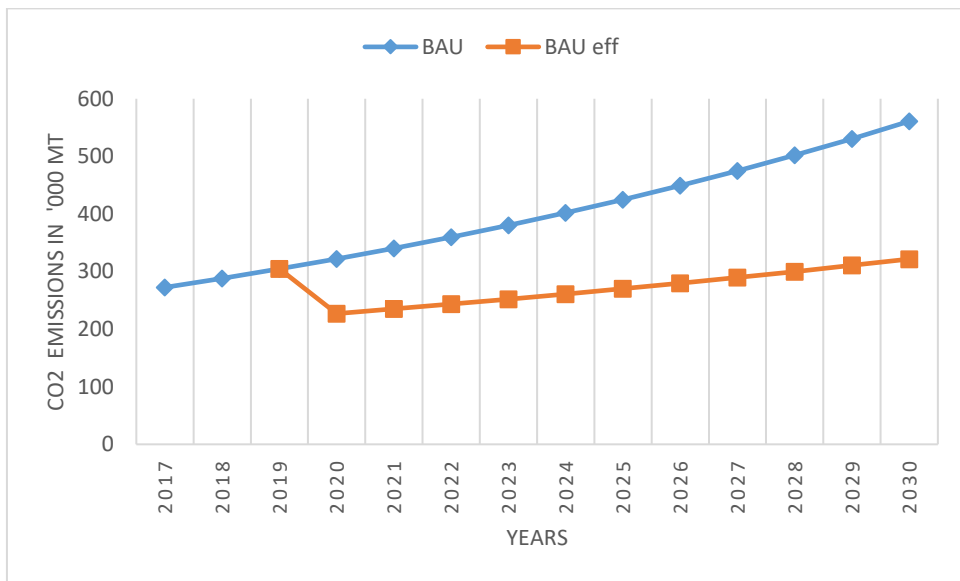


Figure 4-8: CO<sub>2</sub> emission for BAU and BAU efficient scenario

The carbon dioxide emission for different growth rates was analysed too. When there was no intervention in the growth rate, i.e. in business as usual (BAU) scenario, the carbon dioxide emission for different processes was found to be 271.48 thousand metric tonnes for the year 2017, and with the rise in the production of instant noodles, the rate of carbon emission too raised subsequently. It reached up to 560.85 thousand metric tonnes in 2030. With the efficiency measures being practiced in the BAU scenario, the

carbon dioxide emission was found to be 321.65 thousand metric tonnes in the year 2030. Hence, the reduction of the carbon dioxide emission was 239.2 thousand metric tonnes.

Table 4-8 Carbon dioxide emissions for different scenarios

Scenarios	2017	2030
BAU	272.48	560.85
BAU efficient	272.48	321.65
LG	272.48	400.15
LG efficient	272.48	227.85
HG	272.48	1,259.86
HG efficient	272.48	734.44
Total	1634.90	3504.80

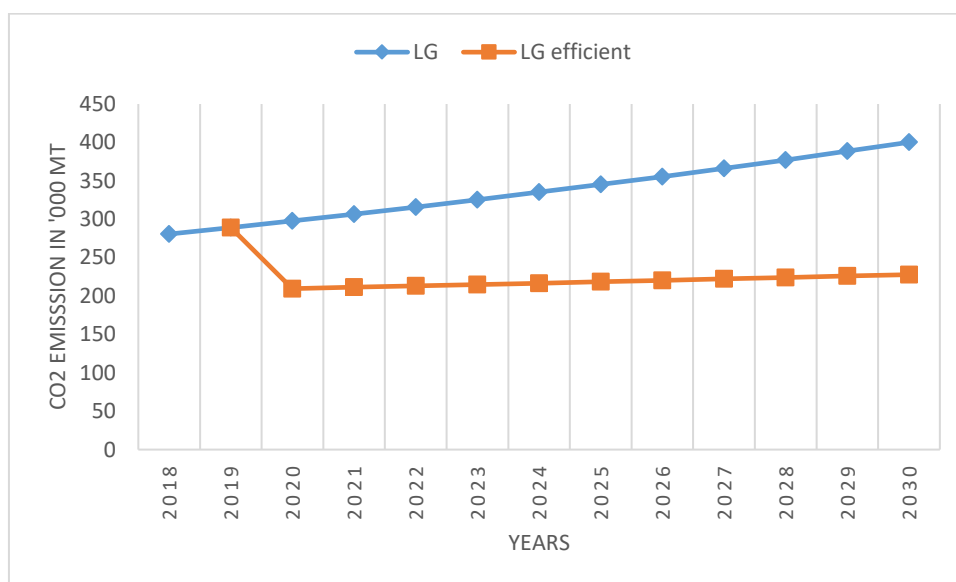


Figure 4-9: CO<sub>2</sub> emission for LG and LG efficient scenario

Likewise, with the low growth scenario, the carbon dioxide emission in the year 2018 was found to be 280.66 thousand metric tonnes which reached up to 400.15 thousand metric tonnes in the year 2030. Applying efficient practices in different end-use equipment and processes, the carbon dioxide emission was restricted to 227.85 thousand metric tonnes. So, the difference while using the efficient practices and without using the efficient practices resulted in the reduction of carbon dioxide emission by 172.3 thousand metric tonnes.

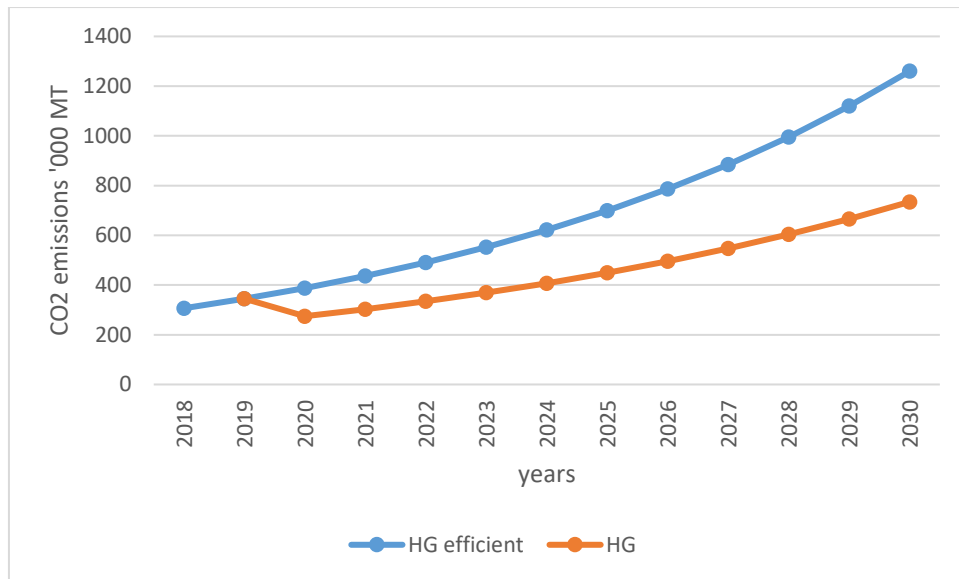


Figure 4-10: CO<sub>2</sub> emission for HG and HG efficient scenario

During the analysis using the high growth rate, the carbon dioxide emission was found to be 306.64 thousand metric tonnes in the year 2018 and this reached up to 1259 thousand metric tonnes in the year 2030. Under the efficient scenario, the emission was confined to a mere 734.55 thousand metric tonnes showing a significant reduction in the emission by 524.45 thousand metric tonnes

Analysing all these scenarios, it was found that if the efficient measures were implemented, then the energy demand as well as the carbon dioxide emissions would also reduce by a significant amount which resulted in the rise of profit margin with a cleaner environment.

#### 4.7 Savings Potential

After the creation of the model and generation of various scenarios, the savings potential for electrical and thermal energy was found to be as

Table 4-9 :Saving Potential under different Scenarios

Scenario	Electrical energy saving potential in '000 GJ	Thermal energy saving potential in '000 GJ
BAU	21.6	83.58
Low Growth	29.147	60.323
High Growth	97.47	182.47

## CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

### 5.1 Conclusion

Nepal is considered third largest per capita consumer of the instant noodles in the world. With the growing popularity Instant noodles not only in domestic circuit but also in the international circuit, as Nepalese noodles are being consumed in more than 40 countries of the world, the energy demand is also bound to rise. The increase of the domestic demand and its fulfillment, in future perspective, expects more noodles industries to commence the noodles production.

Currently, Nepal is producing about 103.6 thousand metric tonnes of Instant Noodles every year with the potential of producing 160 thousand metric tonnes of instant noodles. With various industries trying to expand their production capacity, it is quite necessary to evaluate the efficient measures that can be implemented to reach the demand with low energy consumption.

The production of Noodles reaches 213.24 thousand metric tonnes under business as usual scenario and under low growth scenario and high growth scenarios, it reaches 152.14 thousand metric tonnes and 479.01 thousand metric tonnes.

For the base year 2017, the final energy demand was 176.77 thousand GJ and it was predicted to become 363.84 thousand GJ in the year 2030 under BAU condition. However, with the low growth and high growth scenarios, it would reach 199.58 thousand GJ and 817.31 thousand GJ respectively in the year 2030.

Expecting certain improvements in different end-use process and increment in the efficiency of various equipment the demand will subside by a bit in each scenario discussed above. For BAU efficient scenario, the energy demand will become 261.48 thousand GJ, for Low growth efficient 199.58 thousand GJ and for high growth efficient 641.52 thousand GJ. This would lead to a saving of 29.15 thousand GJ of electrical energy in BAU approach with the potential of saving 21.6 thousand GJ of electrical energy under low growth approach and about 97.15 thousand GJ of electrical energy under high growth scenario. In terms of percentage about 8.01% of electrical energy can be saved under BAU with 8.32 % under low growth and about 11.88% under high growth scenario.

Similarly, about 60.32 thousand GJ of thermal energy will be saved under BAU approach with the potential of saving 83.58 thousand GJ of thermal energy under low growth scenario and about 182.47 thousand GJ of thermal energy under high growth

scenario. In terms of percentage about 16.5% of thermal energy can be saved in Low growth conditions. Likewise, about 20.6% of thermal energy can be saved under business as usual and about 22.32% of thermal energy can be saved under high growth. In terms of CO<sub>2</sub> emissions, 272.48 thousand metric tonnes of carbon dioxide has been emitted from the Noodles Industries with the prediction of it reaching 560.85 thousand metric tonnes in year 2030. Using different efficient measures, the emission can be limited to 321.46 thousand metric tonnes of carbon dioxide. Thus, with proper measures being taken a significant amount of energy can be saved along with the reduction in the GHG emissions.

Hence, with the certain improvements in the end-use processes and increasing the efficiency in certain equipment, a significant portion of electrical and thermal energy can be saved in the Instant Noodle Processing Industry.

## **5.2 Recommendations**

Based on the findings of this research, recommendations for the management of energy consumption in Noodles industrial sectors are as follows:

1. Use of more efficient devices can help in the reduction of significant amount of energy in different end-use devices and processes.
2. Switching other fuels to electricity is highly recommended for sustainable development and significant energy savings and GHG emission reduction.

## **5.3 Further Research Areas**

This research is intended to find the energy saving potential along with the energy consumption pattern of Noodles Processing Industries. Further research can be carried out to find the out the energy saving potential of food and snack processing industries. Likewise, various large companies like C.G. Foods, Himshree and Asian Thai foods have established their plant in various locations like in the hilly and terai regions and even in different countries as well, so a comparative study can be done in order to analyze the energy consumption pattern and saving potential for those different locations.

Further, this research has not focused on the financial aspect of the energy savings, so a study can also be done considering the financial aspect of including the efficient devices and adopting the efficient measures in Instant Noodles Industries.

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**APPENDIX A: NAME OF THE INSTANT NOODLE INDUSTRIES IN  
NEPAL**

	Name of Establishments	Address	Capital	Products with their capacity
1	NEPAL THAI FOODS PVT. LTD.	Lalitpur	49,700,000	1550 M.T.
2	C.G. FOODS ENTERPRISES PVT.LTD	Bardiya	247,000,000	8000 MT,
3	HIM SHREE FOODS PVT. LTD.	Kaski	142,050,000	5812 MT
4	EVEREST NOODLES PVT. LTD.	Kaski	1,23,00,000	1275 MT
5	POKHARA NOODLES PVT. LTD.	Kaski	22,577,000	7650 PACKET
6	MORANG NOODLES	Morang	49,598,000	1275 MT.
7	HIMALAYAN AGRO HEALTH FOODS	Kathmandu	12,557,151	180 MT.
8	FAST FOODS NEPAL PVT.LTD	Nawalparasi	150,000,000	6750 MT
9	AUPAM FOODS PVT.LTD	Kaski	57,600,000	750 MT
10	MOOYUR NOODLES PVT.LTD	Morang	55,872,000	1275 MT
11	HIMALAYA NOODLES PVT.LTD	Lalitpur	50,000,000	1200 MT
12	SMART FOOD & SNACKS PVT.LTD	Chitwan	100,000,000	1500 MT
13	SHIV SHAKTI SNACKFOODS PVT. LTD.	Chitwan	246,000,000	12600 M.T.
14	YASHODA FOODS PVT. LTD.	Rupandehi	245,000,000	10000 M.T.

	Name of Establishments	Address	Capital	Products with their capacity
15	MULTY FOOD PVT.LTD	Kathmandu	80,000,000	11250 MT
16	DRAGON NOODLES PVT.LTD	Chitwan	67,422,000	1530 MT
17	ANOMOL FOODS PRODUCTS PVT.LTD	Morang	25,000,000	15000000 PACKETS
18	BIDDYA INTERNATIONAL (NEPAL) PVT. LTD.	Jhapa	65,722,000	1200 MT
19	ASIAN THAI FOODS PVT. LTD.	Sunsari & Nawalparasi	52,000,000	1200 MT and 10000 MT
20	JAGADAMBA FOODS	Rupandehi	92,600,000	INSTANT NOODLES 14500 MT, BROKEN NOODELS 500 MT
21	QUALITY FOODS NEPAL PVT.LTD	Morang	100,000,000	7000 MT

## APPENDIX B: QUESTIONNAIRE

Name of the establishment	
Address	
Contact person	
Designation	
Production Capacity	

### 1. Energy Consumption in Lighting System

A. End Use Equipment				
Description	Quantity	Rated Power		Daily operating hours
		Power	Efficiency	
1. Lamps				
a) Florescent				
b) CFL				
c) Incandescent				
d) Halogen				
e) Others				

#### B. Fuel Used

Description	Annual Consumption		Description	Annual Consumption
1. Electricity			2. Diesel	
3. Others				

### 2. Energy Used in Motive Power

#### A. End Use Equipment

Description	Quantity	Rated Power		Annual Consumption
		Power	Efficiency	
1. Automobiles				
a. Diesel Engine				
b. Petrol Engine				
2. IC Engines				
3. EC Engines				
4. Motors				
a. Electric				
b. Pneumatic				
c. Hydraulic				

#### B. Fuel Used

Description	Annual Consumption		Description	Annual Consumption
1. Electricity			2. Diesel (KL)	

### 3. Energy Consumption in Boiler

A. End Use Equipment				
Description	Make	Rated Power		Annual Consumption
		Power	Efficiency	
1. Boilers				
a.				
b.				
c.				

### B. Fuel Used

Description	Annual Consumption		Description	Annual Consumption
1. Fuel wood			2. Diesel	
3. Rice Husk			4. Furnace Oil	
5. Kerosene			6. Others	

### 4. Energy Consumption in Process Heat

A. End Use Equipment				
Description	Quantity	Rated Power		Annual Consumption
		Power	Efficiency	
1. Fuel Fired Heating				
a.				
b.				
c.				
2. Steam Heating				
a.				
b.				
c.				
3. Hot Oil/ Water/Air Heating				
a.				
b.				
c.				
Electrical Heating				
a.				
b.				

**B. Fuel Used**

Description	Annual Consumption		Description	Annual Consumption
1. Fuel wood			2. Diesel	
3. Coal			4. Furnace Oil	
5. Electricity			6. Others	

**5. Energy Consumption in other Equipment**

A. End Use Equipment				
Description	Quantity	Rated Power		Daily Operating hours
		Power	Efficiency	
1. Computers				
2. Fans				
3. Refrigerators				
4				
5				
6				

**B. Fuel Used**

Description	Annual Consumption		Description	Annual Consumption
1. Electricity			2. Diesel	
3. Others				

**6. Annual Consumption of Fuel and Electricity (Yearly basis)**

Description	Unit	Annual Quantity				
		2014	2015	2016	2017	2018
1. Electricity	Tonnes					
2. Diesel	KL					
3. Furnace Oil	KL					
4. Rice Husk	Tonnes					
5. Fuel wood	Tonnes					
5. Kerosene	KL					
6. Petrol	KL					

**APPENDIX C: DATA COLLECTION FROM SURVEYED  
INDUSTRIES**

Name	Lighting (GJ)	Motor drives (GJ)	Boiler (GJ)	Process heat (GJ)	Others (GJ)
Jagadamba	321.81	11763.06	28781.75	2717.50	827.51
Quality	735.66	6348.86	21102.85	4621.70	887.73
Asian	588.80	8258.56	20125.72	2971.00	1545.87
Yasodha	221.60	1362.53	3441.23	596.79	411.03
Morang	152.71	954.48	1893.16	715.86	327.26
Himalaya	176.50	2118.02	10001.74	2059.18	453.00
Himshree	545.66	5287.78	10456.88	2372.23	1081.33
Pokhara	121.67	1419.51	3389.44	538.83	324.46
Everest	83.19	738.33	1776.75	229.29	145.59
Anupam	19.83	491.14	1226.82	227.29	28.71
Anmol	108.00	1257.60	4690.56	942.00	205.20
Smart foods	106.00	413.56	1692.82	253.84	110.02
<b>Total</b>	<b>3181.43</b>	<b>40413.43</b>	<b>108579.72</b>	<b>18245.51</b>	<b>6347.71</b>

**APPENDIX D: CALCULATION OF ELASTICITY OF END-USE  
FOOD AND BEVERAGE INDUSTRIES**

Log linear regression Analysis

Year	End use service demand (Et)	Value addition in year t (Vat)	VAt/VA0	ln(Et)	ln(VA/Vt)
2001	4618896	356472700	0.675287	12.6426	-0.39262
2002	3383299	388685900	0.736310	12.3313	-0.3061
2003	2075821	416111400	0.788264	11.8428	-0.23792
2004	2844597	430356100	0.815249	12.15787	-0.20426
2005	3072164	453112200	0.858357	12.23483	-0.15274
2006	3210418	485739100	0.920164	12.27885	-0.0832
2007	3477612	503225700	0.953290	12.35879	-0.04784
2008	3808522	476432600	0.902534	12.44969	-0.10255
2009	4170328	476642200	0.902931	12.54044	-0.10211
2010	9105134	486900900	0.922365	13.32129	-0.08081
2011	9158851	499648900	0.946514	13.32717	-0.05497
2012	9616791	509632500	0.965427	13.37596	-0.03519
2013	10616716	522642500	0.990072	13.47488	-0.00998
2014	10597015	523585900	0.991859	13.47302	-0.00817
2015	23994030	520978600	0.986920	14.29025	-0.01317
2016	26394030	527883200	0.977557	14.38559	-0.0227
2017	29821119	540002400	1.000000	14.50766	0

	Intercept	X Variable1
Coefficients	13.13	1.36
Standard Error	0.18	0.49
t Stat	71.26	2.8
P-value	0	0.01

The log-linear regression analysis calculated the elasticity of end use Food and beverages demand as to be 1.36.

## APPENDIX E: FINAL ENERGY DEMAND RESULTS FOR DIFFERENT SCENARIOS

Energy Demand Final Units
Scenario: LG, All Fuels
Units: Thousand Gigajoules

Branches	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
<b>Lighting</b>	<b>3.18</b>	<b>3.28</b>	<b>3.38</b>	<b>3.48</b>	<b>3.58</b>	<b>3.69</b>	<b>3.80</b>	<b>3.91</b>	<b>4.03</b>	<b>4.15</b>	<b>4.28</b>	<b>4.40</b>	<b>4.54</b>	<b>4.67</b>
Electricity	2.23	2.29	2.36	2.43	2.51	2.58	2.66	2.74	2.82	2.91	2.99	3.08	3.18	3.27
DG sets	0.95	0.98	1.01	1.04	1.07	1.11	1.14	1.17	1.21	1.25	1.28	1.32	1.36	1.40
<b>Motor Drives</b>	<b>40.41</b>	<b>41.63</b>	<b>42.87</b>	<b>44.16</b>	<b>45.49</b>	<b>46.85</b>	<b>48.26</b>	<b>49.70</b>	<b>51.19</b>	<b>52.73</b>	<b>54.31</b>	<b>55.94</b>	<b>57.62</b>	<b>59.35</b>
Electricity	28.29	29.14	30.01	30.91	31.84	32.80	33.78	34.79	35.84	36.91	38.02	39.16	40.33	41.54
DG sets	12.12	12.49	12.86	13.25	13.65	14.06	14.48	14.91	15.36	15.82	16.29	16.78	17.29	17.80
<b>Process heat</b>	<b>18.25</b>	<b>18.79</b>	<b>19.36</b>	<b>19.94</b>	<b>20.54</b>	<b>21.15</b>	<b>21.79</b>	<b>22.44</b>	<b>23.11</b>	<b>23.81</b>	<b>24.52</b>	<b>25.26</b>	<b>26.01</b>	<b>26.79</b>
Direct heating	2.74	2.82	2.90	2.99	3.08	3.17	3.27	3.37	3.47	3.57	3.68	3.79	3.90	4.02
Indirect heating	15.51	15.97	16.45	16.95	17.46	17.98	18.52	19.07	19.65	20.24	20.84	21.47	22.11	22.78
<b>Boiler</b>	<b>108.58</b>	<b>111.84</b>	<b>115.19</b>	<b>118.65</b>	<b>122.21</b>	<b>125.87</b>	<b>129.65</b>	<b>133.54</b>	<b>137.55</b>	<b>141.67</b>	<b>145.92</b>	<b>150.30</b>	<b>154.81</b>	<b>159.45</b>
Rice husk	86.86	89.47	92.15	94.92	97.77	100.70	103.72	106.83	110.04	113.34	116.74	120.24	123.85	127.56
Furnace oil	16.29	16.78	17.28	17.80	18.33	18.88	19.45	20.03	20.63	21.25	21.89	22.54	23.22	23.92
Firewood	3.26	3.36	3.46	3.56	3.67	3.78	3.89	4.01	4.13	4.25	4.38	4.51	4.64	4.78
Electric	2.17	2.24	2.30	2.37	2.44	2.52	2.59	2.67	2.75	2.83	2.92	3.01	3.10	3.19
<b>Others</b>	<b>6.35</b>	<b>6.54</b>	<b>6.73</b>	<b>6.94</b>	<b>7.14</b>	<b>7.36</b>	<b>7.58</b>	<b>7.81</b>	<b>8.04</b>	<b>8.28</b>	<b>8.53</b>	<b>8.79</b>	<b>9.05</b>	<b>9.32</b>
Electricity	4.44	4.58	4.71	4.86	5.00	5.15	5.31	5.46	5.63	5.80	5.97	6.15	6.34	6.53
DG sets	1.90	1.96	2.02	2.08	2.14	2.21	2.27	2.34	2.41	2.48	2.56	2.64	2.72	2.80
<b>Total</b>	<b>176.77</b>	<b>182.07</b>	<b>187.53</b>	<b>193.16</b>	<b>198.95</b>	<b>204.92</b>	<b>211.07</b>	<b>217.40</b>	<b>223.92</b>	<b>230.64</b>	<b>237.56</b>	<b>244.69</b>	<b>252.03</b>	<b>259.59</b>

Energy Demand Final Units														
Scenario: BAU, All Fuels														
Branch: Demand														
Units: Thousand Gigajoules														
Branches	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
<b>Lighting</b>	<b>3.18</b>	<b>3.36</b>	<b>3.56</b>	<b>3.76</b>	<b>3.97</b>	<b>4.20</b>	<b>4.44</b>	<b>4.69</b>	<b>4.96</b>	<b>5.24</b>	<b>5.54</b>	<b>5.86</b>	<b>6.19</b>	<b>6.55</b>
Electricity	2.23	2.35	2.49	2.63	2.78	2.94	3.11	3.28	3.47	3.67	3.88	4.10	4.34	4.58
DG sets	0.95	1.01	1.07	1.13	1.19	1.26	1.33	1.41	1.49	1.57	1.66	1.76	1.86	1.96
<b>Motor Drives</b>	<b>40.41</b>	<b>42.72</b>	<b>45.16</b>	<b>47.74</b>	<b>50.46</b>	<b>53.35</b>	<b>56.39</b>	<b>59.61</b>	<b>63.02</b>	<b>66.61</b>	<b>70.42</b>	<b>74.44</b>	<b>78.69</b>	<b>83.18</b>
Electricity	28.29	29.90	31.61	33.42	35.33	37.34	39.47	41.73	44.11	46.63	49.29	52.11	55.08	58.23
DG sets	12.12	12.82	13.55	14.32	15.14	16.00	16.92	17.88	18.90	19.98	21.13	22.33	23.61	24.95
<b>Process heat</b>	<b>18.25</b>	<b>19.29</b>	<b>20.39</b>	<b>21.55</b>	<b>22.78</b>	<b>24.08</b>	<b>25.46</b>	<b>26.91</b>	<b>28.45</b>	<b>30.07</b>	<b>31.79</b>	<b>33.61</b>	<b>35.53</b>	<b>37.55</b>
Direct heating	2.74	2.89	3.06	3.23	3.42	3.61	3.82	4.04	4.27	4.51	4.77	5.04	5.33	5.63
Indirect heating	15.51	16.39	17.33	18.32	19.37	20.47	21.64	22.88	24.18	25.56	27.02	28.57	30.20	31.92
<b>Boiler</b>	<b>108.58</b>	<b>114.78</b>	<b>121.33</b>	<b>128.26</b>	<b>135.59</b>	<b>143.33</b>	<b>151.51</b>	<b>160.16</b>	<b>169.31</b>	<b>178.98</b>	<b>189.19</b>	<b>200.00</b>	<b>211.42</b>	<b>223.49</b>
Rice husk	86.86	91.82	97.07	102.61	108.47	114.66	121.21	128.13	135.45	143.18	151.36	160.00	169.13	178.79
Furnace oil	16.29	17.22	18.20	19.24	20.34	21.50	22.73	24.02	25.40	26.85	28.38	30.00	31.71	33.52
Firewood	3.26	3.44	3.64	3.85	4.07	4.30	4.55	4.80	5.08	5.37	5.68	6.00	6.34	6.70
Electric	2.17	2.30	2.43	2.57	2.71	2.87	3.03	3.20	3.39	3.58	3.78	4.00	4.23	4.47
<b>Others</b>	<b>6.35</b>	<b>6.71</b>	<b>7.09</b>	<b>7.50</b>	<b>7.93</b>	<b>8.38</b>	<b>8.86</b>	<b>9.36</b>	<b>9.90</b>	<b>10.46</b>	<b>11.06</b>	<b>11.69</b>	<b>12.36</b>	<b>13.07</b>
Electricity	4.44	4.70	4.97	5.25	5.55	5.87	6.20	6.55	6.93	7.32	7.74	8.18	8.65	9.15
DG sets	1.90	2.01	2.13	2.25	2.38	2.51	2.66	2.81	2.97	3.14	3.32	3.51	3.71	3.92
<b>Total</b>	<b>176.77</b>	<b>186.86</b>	<b>197.53</b>	<b>208.81</b>	<b>220.73</b>	<b>233.34</b>	<b>246.66</b>	<b>260.74</b>	<b>275.63</b>	<b>291.37</b>	<b>308.01</b>	<b>325.60</b>	<b>344.19</b>	<b>363.84</b>

Energy Demand Final Units														
Scenario: HG, All Fuels														
Branch: Demand														
Units: Thousand Gigajoules														
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Branches	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lighting	3.18	3.58	4.03	4.53	5.10	5.73	6.45	7.26	8.16	9.18	10.33	11.62	13.08	14.71
Electricity	2.23	2.51	2.82	3.17	3.57	4.01	4.51	5.08	5.71	6.43	7.23	8.14	9.15	10.30
DG sets	0.95	1.07	1.21	1.36	1.53	1.72	1.93	2.18	2.45	2.75	3.10	3.49	3.92	4.41
Motor Drives	40.41	45.47	51.15	57.54	64.73	72.83	81.93	92.17	103.69	116.65	131.24	147.64	166.09	186.86
Electricity	28.29	31.83	35.80	40.28	45.31	50.98	57.35	64.52	72.58	81.66	91.86	103.35	116.27	130.80
DG sets	12.12	13.64	15.34	17.26	19.42	21.85	24.58	27.65	31.11	35.00	39.37	44.29	49.83	56.06
Process heat	18.25	20.53	23.09	25.98	29.23	32.88	36.99	41.61	46.81	52.67	59.25	66.66	74.99	84.36
Direct heating	2.74	3.08	3.46	3.90	4.38	4.93	5.55	6.24	7.02	7.90	8.89	10.00	11.25	12.65
Indirect heating	15.51	17.45	19.63	22.08	24.84	27.95	31.44	35.37	39.79	44.77	50.36	56.66	63.74	71.71
Boiler	108.58	122.15	137.42	154.60	173.92	195.66	220.12	247.64	278.59	313.42	352.59	396.67	446.25	502.03
Rice husk	86.86	97.72	109.94	123.68	139.14	156.53	176.10	198.11	222.87	250.73	282.07	317.33	357.00	401.63
Furnace oil	16.29	18.32	20.61	23.19	26.09	29.35	33.02	37.15	41.79	47.01	52.89	59.50	66.94	75.30
Firewood	3.26	3.66	4.12	4.64	5.22	5.87	6.60	7.43	8.36	9.40	10.58	11.90	13.39	15.06
Electric	2.17	2.44	2.75	3.09	3.48	3.91	4.40	4.95	5.57	6.27	7.05	7.93	8.93	10.04
Others	6.35	7.14	8.03	9.04	10.17	11.44	12.87	14.48	16.29	18.32	20.61	23.19	26.09	29.35
Electricity	4.44	5.00	5.62	6.33	7.12	8.01	9.01	10.13	11.40	12.83	14.43	16.23	18.26	20.54
DG sets	1.90	2.14	2.41	2.71	3.05	3.43	3.86	4.34	4.89	5.50	6.18	6.96	7.83	8.80
Total	176.77	198.86	223.72	251.69	283.15	318.54	358.36	403.15	453.55	510.24	574.02	645.77	726.50	817.31

Energy Demand Final Units														
Scenario: HG efficient, All Fuels														
Branch: Demand														
Units: Thousand Gigajoules														
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
<b>Branches</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>	<b>2024</b>	<b>2025</b>	<b>2026</b>	<b>2027</b>	<b>2028</b>	<b>2029</b>	<b>2030</b>
<b>Lighting</b>	<b>3.18</b>	<b>3.18</b>	<b>3.17</b>	<b>3.15</b>	<b>3.13</b>	<b>3.11</b>	<b>3.11</b>	<b>3.11</b>	<b>3.11</b>	<b>3.12</b>	<b>3.13</b>	<b>3.14</b>	<b>3.16</b>	<b>3.18</b>
Electricity	2.23	2.70	3.17	3.15	3.13	3.11	3.11	3.11	3.11	3.12	3.13	3.14	3.16	3.18
DG sets	0.95	0.48	-	-	-	-	-	-	-	-	-	-	-	-
<b>Motor Drives</b>	<b>40.41</b>	<b>40.27</b>	<b>40.07</b>	<b>39.90</b>	<b>39.73</b>	<b>39.56</b>	<b>39.39</b>	<b>39.22</b>	<b>39.05</b>	<b>38.87</b>	<b>38.70</b>	<b>38.53</b>	<b>38.36</b>	<b>38.19</b>
Electricity	28.29	34.21	40.07	39.90	39.73	39.56	39.39	39.22	39.05	38.87	38.70	38.53	38.36	38.19
DG sets	12.12	6.06	-	-	-	-	-	-	-	-	-	-	-	-
<b>Process heat</b>	<b>18.25</b>	<b>18.17</b>	<b>18.08</b>	<b>18.00</b>	<b>17.92</b>	<b>17.84</b>	<b>17.76</b>	<b>17.68</b>	<b>17.59</b>	<b>17.51</b>	<b>17.43</b>	<b>17.35</b>	<b>17.27</b>	<b>17.19</b>
Direct heating	2.74	2.72	2.71	2.69	2.67	2.66	2.64	2.63	2.61	2.59	2.58	2.56	2.55	2.53
Indirect heating	15.51	15.45	15.38	15.31	15.25	15.18	15.12	15.05	14.98	14.92	14.85	14.79	14.72	14.66
<b>Boiler</b>	<b>108.58</b>	<b>108.05</b>	<b>107.52</b>	<b>106.99</b>	<b>106.45</b>	<b>105.92</b>	<b>105.37</b>	<b>104.83</b>	<b>104.29</b>	<b>103.74</b>	<b>103.19</b>	<b>102.64</b>	<b>102.08</b>	<b>101.52</b>
Rice husk	86.86	64.82	64.50	64.17	63.84	63.52	63.19	62.87	62.54	62.22	61.89	61.56	61.24	60.91
Furnace oil	16.29	21.61	21.50	21.39	21.28	21.17	21.06	20.96	20.85	20.74	20.63	20.52	20.41	20.30
Firewood	3.26	3.01	2.76	2.51	2.26	2.00	1.75	1.50	1.25	1.00	0.75	0.50	0.25	-
Electric	2.17	18.62	18.77	18.92	19.07	19.22	19.36	19.51	19.64	19.78	19.92	20.05	20.18	20.30
<b>Others</b>	<b>6.35</b>	<b>6.32</b>	<b>6.29</b>	<b>6.27</b>	<b>6.24</b>	<b>6.21</b>	<b>6.19</b>	<b>6.16</b>	<b>6.13</b>	<b>6.11</b>	<b>6.08</b>	<b>6.05</b>	<b>6.03</b>	<b>6.00</b>
Electricity	4.44	5.37	6.29	6.27	6.24	6.21	6.19	6.16	6.13	6.11	6.08	6.05	6.03	6.00
DG sets	1.90	0.95	-	-	-	-	-	-	-	-	-	-	-	-
<b>Total</b>	<b>176.77</b>	<b>176.00</b>	<b>175.14</b>	<b>174.31</b>	<b>173.48</b>	<b>172.64</b>	<b>171.82</b>	<b>170.99</b>	<b>170.17</b>	<b>169.35</b>	<b>168.53</b>	<b>167.71</b>	<b>166.90</b>	<b>166.08</b>

Energy Demand Final Units														
Scenario: LG efficient, All Fuels														
Branch: Demand														
Units: Thousand Gigajoules														
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
<b>Branches</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>	<b>2024</b>	<b>2025</b>	<b>2026</b>	<b>2027</b>	<b>2028</b>	<b>2029</b>	<b>2030</b>
<b>Lighting</b>	<b>3.181</b>	<b>3.167</b>	<b>3.141</b>	<b>3.103</b>	<b>3.055</b>	<b>2.995</b>	<b>2.986</b>	<b>2.986</b>	<b>2.995</b>	<b>3.014</b>	<b>3.042</b>	<b>3.079</b>	<b>3.126</b>	<b>3.181</b>
Electricity	2.227	2.692	3.141	3.103	3.055	2.995	2.986	2.986	2.995	3.014	3.042	3.079	3.126	3.181
DG sets	0.954	0.475	-	-	-	-	-	-	-	-	-	-	-	-
<b>Motor Drives</b>	<b>40.413</b>	<b>40.289</b>	<b>40.165</b>	<b>40.040</b>	<b>39.916</b>	<b>39.792</b>	<b>39.667</b>	<b>39.543</b>	<b>39.419</b>	<b>39.294</b>	<b>39.170</b>	<b>39.046</b>	<b>38.921</b>	<b>38.797</b>
Electricity	28.289	34.246	40.165	40.040	39.916	39.792	39.667	39.543	39.419	39.294	39.170	39.046	38.921	38.797
DG sets	12.124	6.043	-	-	-	-	-	-	-	-	-	-	-	-
<b>Process heat</b>	<b>18.25</b>	<b>18.16</b>	<b>18.08</b>	<b>17.99</b>	<b>17.91</b>	<b>17.83</b>	<b>17.74</b>	<b>17.66</b>	<b>17.58</b>	<b>17.49</b>	<b>17.41</b>	<b>17.33</b>	<b>17.24</b>	<b>17.16</b>
Direct heating	2.74	2.70	2.67	2.63	2.59	2.56	2.52	2.49	2.45	2.41	2.38	2.34	2.31	2.27
Indirect heating	15.51	15.46	15.41	15.37	15.32	15.27	15.22	15.17	15.13	15.08	15.03	14.98	14.94	14.89
<b>Boiler</b>	<b>108.58</b>	<b>108.02</b>	<b>107.50</b>	<b>107.02</b>	<b>106.58</b>	<b>106.17</b>	<b>105.80</b>	<b>105.46</b>	<b>105.17</b>	<b>104.91</b>	<b>104.68</b>	<b>104.50</b>	<b>104.35</b>	<b>104.24</b>
Rice husk	86.86	64.95	64.75	64.55	64.35	64.15	63.95	63.74	63.54	63.34	63.14	62.94	62.74	62.54
Furnace oil	16.29	21.65	21.58	21.52	21.45	21.38	21.32	21.25	21.18	21.11	21.05	20.98	20.91	20.85
Firewood	3.26	2.78	2.33	1.93	1.56	1.23	0.94	0.69	0.48	0.31	0.17	0.08	0.02	-
Electric	2.17	18.65	18.84	19.03	19.22	19.41	19.59	19.78	19.96	20.14	20.32	20.50	20.67	20.85
<b>Others</b>	<b>6.35</b>	<b>5.86</b>	<b>6.31</b>	<b>6.29</b>	<b>6.27</b>	<b>6.25</b>	<b>6.23</b>	<b>6.21</b>	<b>6.19</b>	<b>6.17</b>	<b>6.15</b>	<b>6.13</b>	<b>6.11</b>	<b>6.09</b>
Electricity	4.44	5.38	6.31	6.29	6.27	6.25	6.23	6.21	6.19	6.17	6.15	6.13	6.11	6.09
DG sets	1.90	0.48	-	-	-	-	-	-	-	-	-	-	-	-
<b>Total</b>	<b>176.77</b>	<b>175.50</b>	<b>175.20</b>	<b>174.45</b>	<b>173.73</b>	<b>173.03</b>	<b>172.43</b>	<b>171.86</b>	<b>171.35</b>	<b>170.88</b>	<b>170.46</b>	<b>170.08</b>	<b>169.75</b>	<b>169.47</b>

Energy Demand Final Units														
Scenario: BAU efficient, All Fuels														
Branch: Demand														
Units: Thousand Gigajoules														
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Branches	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lighting	3.18	2.76	2.53	2.49	2.65	3.00	2.99	2.99	3.00	3.01	3.04	3.08	3.13	3.18
Electricity	2.23	2.35	2.53	2.49	2.65	3.00	2.99	2.99	3.00	3.01	3.04	3.08	3.13	3.18
DG sets	0.95	0.42	-	-	-	-	-	-	-	-	-	-	-	-
Motor Drives	40.41	40.20	39.98	39.76	39.54	39.33	39.11	38.89	38.67	38.45	38.24	38.02	37.80	37.58
Electricity	28.29	34.17	39.98	39.76	39.54	39.33	39.11	38.89	38.67	38.45	38.24	38.02	37.80	37.58
DG sets	12.12	6.03	-	-	-	-	-	-	-	-	-	-	-	-
Process heat	18.25	18.12	17.99	17.87	17.74	17.62	17.49	17.37	17.24	17.11	16.99	16.86	16.74	16.61
Direct heating	2.74	2.69	2.65	2.61	2.57	2.53	2.48	2.44	2.40	2.36	2.32	2.27	2.23	2.19
Indirect heating	15.51	15.43	15.34	15.26	15.17	15.09	15.01	14.92	14.84	14.76	14.67	14.59	14.51	14.42
Boiler	108.58	108.10	107.61	107.14	106.66	106.19	105.72	105.25	104.78	104.32	103.86	103.41	102.95	102.50
Rice husk	86.86	64.80	64.45	64.10	63.74	63.39	63.04	62.69	62.34	61.99	61.64	61.29	60.94	60.59
Furnace oil	16.29	21.60	21.48	21.37	21.25	21.13	21.01	20.90	20.78	20.66	20.55	20.43	20.31	20.20
Firewood	3.26	2.99	2.73	2.47	2.21	1.95	1.70	1.45	1.20	0.95	0.71	0.47	0.23	-
Electric	2.17	18.71	18.96	19.21	19.46	19.71	19.96	20.21	20.46	20.71	20.96	21.21	21.47	21.72
Others	6.35	6.31	6.28	6.25	6.21	6.18	6.14	6.11	6.07	6.04	6.01	5.97	5.94	5.90
Electricity	4.44	5.37	6.28	6.25	6.21	6.18	6.14	6.11	6.07	6.04	6.01	5.97	5.94	5.90
DG sets	1.90	0.95	-	-	-	-	-	-	-	-	-	-	-	-
Total	176.77	175.49	174.40	173.50	172.80	172.30	171.45	170.60	169.77	168.95	168.14	167.34	166.55	165.78

**APPENDIX F: CARBON DIOXIDE EMISSIONS FOR DIFFERENT SCENARIOS**

Carbondioxide Emission						
Branches: All fuels						
Unit: Thousand Metric Tonnes						
	BAU	BAU efficient	LG	LG efficient	HG	HG efficient
2017	272.48	272.48	272.48	272.48	272.48	272.48
2018	288.04	211.72	280.66	206.18	306.54	225.59
2019	304.49	219.14	289.08	207.82	344.86	248.82
2020	321.88	226.92	297.75	209.57	387.97	274.55
2021	340.25	234.98	306.68	211.33	436.46	302.94
2022	359.68	243.32	315.88	213.10	491.02	334.27
2023	380.22	251.96	325.36	214.89	552.40	368.83
2024	401.93	260.90	335.12	216.70	621.45	406.97
2025	424.88	270.16	345.17	218.52	699.13	449.05
2026	449.14	279.75	355.53	220.35	786.52	495.48
2027	474.79	289.69	366.19	222.21	884.84	546.71
2028	501.90	299.97	377.18	224.07	995.44	603.24
2029	530.56	310.62	388.50	225.95	1119.88	665.61
2030	560.85	321.65	400.15	227.85	1259.86	734.44