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Energy consumption and demand projection of manufacturing industries in Kathmandu Valley, Nepal

by
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A THESIS
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DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING
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ABSTRACT

Sustainable Development Goal (SDG 9) targeted that industrial sector has to increase the share of energy consumption up to 25% of total energy consumption and uplift the nation from least developed country to middle by 2030. The industrial sector in Kathmandu Valley contribute vital role to achieve the goal. The objective to carry out this study is to find present status of energy consumption by industrial sector in Kathmandu Valley and the energy demand projection till 2050. However, the survey has been conducted within 250 industries to collect primary data regarding energy consumption. The collected data were compiled and analyzed using MS-Excel.

Final energy consumption by manufacturing industries in Kathmandu Valley is found 16.4 PJ which is 26% of total energy consumption by industrial sector in Nepal. This sector is still highly dependent on fossil fuel. It accounts for about 67% of total energy consumption while biomass and electricity contributes 27% and 6% respectively. Among different sub category of industries, food, beverage and tobacco industry has major contribution of energy consumption which accounts 39% of total energy consumption.

The energy demand is projected from base year 2019 to 2050 using MAED energy model tool which is categorized under bottom up model. Using this energy model, the energy demand for manufacturing industries in Kathmandu Valley is estimated to grow from 16.4 PJ in base year 2021 to 50 PJ at low growth rate (3.95%), 116 PJ at medium growth rate (7%) and 524 PJ at high growth rate (12.7%) by 2050. For policy scenario some major assumptions are that traditional boilers will be replaced by electric boiler and average growth rate will be 7%. As a result, the total energy consumption 16.4 PJ in base year is expected to rise by 106 PJ till 2050 where the share of biomass (28%) and coal (21%) in 2021 will decrease to 4% and 15% respectively by 2050.

In 2021, GHG emission by industrial sector in Kathmandu Valley was found to be 1,249.6 Gg CO_2 equivalents and it is expected to increase 3842.8 Gg CO_2 equivalents at low growth, 8890 Gg CO_2 equivalent at medium growth and 40,043 Gg CO_2 equivalents at high growth scenario by 2050. Similarly, for policy scenario the growth rate of GHG emission will be decreased to 6% such that the emission will be 6,964 Gg CO_2 equivalents till 2050.

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ABBREVIATION

CO_2	Carbon dioxide
CO	Carbon monoxide
DOI	Department of Industry
ETSAP	Energy Technology System Analysis Program
FY	Fiscal Year
GDP	Gross Domestic Product
GoN	Government of Nepal
GHG	Greenhouse gas
GVA	Gross Value of Added
GWh	Giga Watt hour
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPP	Independent Public Procurement
LEAP	Long-range Energy Alternative Planning
LPG	Liquefied Petroleum Gas
MARKAL	Market Allocation
MEAD	Model for Analysis of Energy Demand
MoF	Ministry of Finance
NEA	Nepal Electricity Authority
NISC	National Industrial Standard Classification
NPC	National Planning Commission
NO_2	Nitrous Dioxide
NPC	National Planning Commission
PJ	Peta Joule
SDG	Sustainable Development Goal
SO_2	Sulphure dioxide
TOE	Ton of Oil Equivalent
UNFCC	United Nations Framework Convention on Climate Change
WECS	Water and Energy Commission Secretariat

CHAPTER ONE: INTRODUCTION

1.1 Background

The Kathmandu Valley is composite of three districts, namely- Kathmandu, Lalitpur and Bhaktapur districts. Kathmandu Valley is considered as hub for the industries in Nepal. With the higher number of industries, the demand of energy has been also higher. Energy is one of the most essential inputs in the process of economic growth and industrial development (Dutta & Mukherjee, 2010). It is also important parameter which is used for the formulation of plan and policy. The consumption of energy is perceived as the indicator to measure level of development.

In the global outlook, the energy consumed in year 2019 was 417,972 PJ (IEA, Key World Energy Statistic 2020, 2021). Figure 1.1 shows the share of energy consumption in the world. Petroleum product accounts for 40.43% of global energy consumption which remains dominant source of energy which is followed by grid electricity (20.23%), natural gas (16.37%), coal (9.52%), biofuels and waste (10.39%), and remaining others (3%, comprise of nuclear and heat energy).

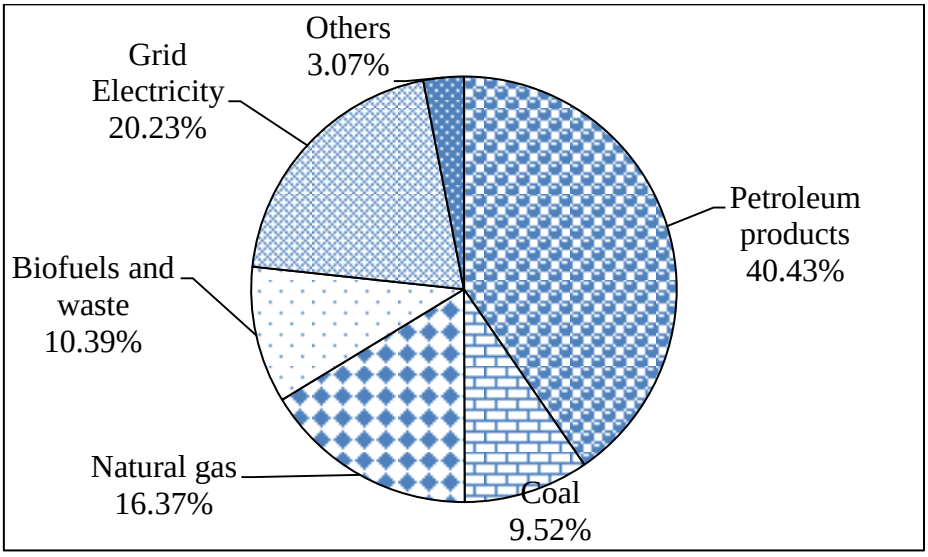


Figure 1.1: Global energy consumption (IEA,2019)

Figure 1.2 represents energy consumption in Nepal. The use of traditional fuel dominates the energy consumption at 66% followed by imported fuels (petrol, diesel, LPG, kerosene, coal and furnace oil) 27% (Finance, Economic Survey 2020/21, 2022). The excessive consumption of traditional fuels not only creates the unnecessary burden on the forests in Nepal, but also increases the greenhouse gases.

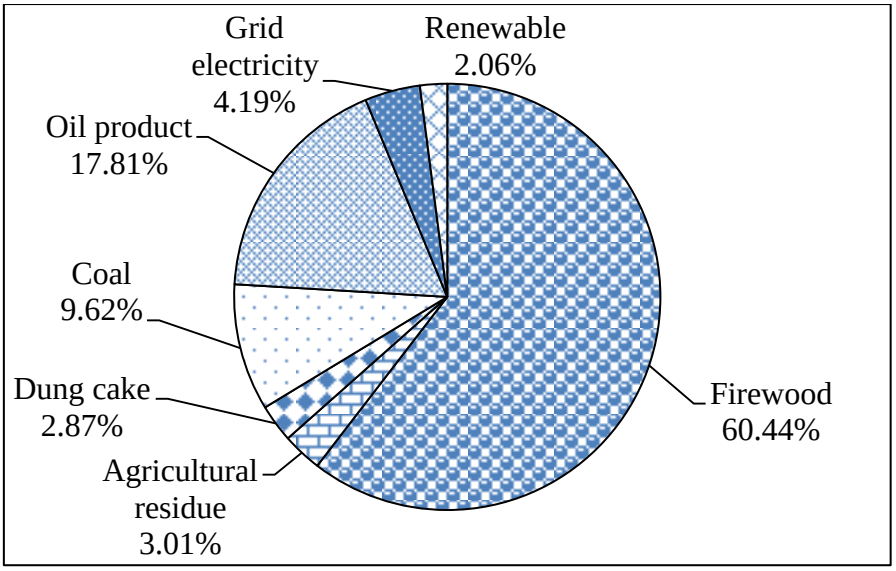


Figure 1.2: Energy consumption in Nepal (MoF, 2022)

It was found that the residential sector accounts about 80% of the overall energy consumption while the industrial sector consumes around 8% of the energy (Finance, Economic Survey 2020/21, 2022). Coal is major source of energy consumption in industrial sector in Nepal which produces enormous quantity of hazardous GHGs gases (Gyanwali & Bajrachary, 2013). However, electricity as a source of energy in industrial sector is in increasing trends (Finance, Economic Survey 2020/21, 2022).

In Kathmandu Valley, (Rajbhandari & Nakarmi, 2014) have studied that energy consumption in residential sector in 2013 was 7.5 PJ where LPG accounted for about 46% of total energy consumption followed by electricity (30%). (Bhattrai & Bajracharya, 2016) have studied that the energy consumption in transport sector in 2010 was 4.6 PJ. In 2005, the energy consumption in industrial and commercial sector was about 5 PJ and 2 PJ respectively (Shrestha & Rajbhandari, 2010).

1.2 Problem of Statement

Sustainable Development Goal (SDG) 9 targeted that industrial sector has to increase the share of energy consumption up to 25% and shift the nation from least developing country to middle by 2030 (NPC, 2017). It requires tremendous consumption of energy resources and more energy efficient technology to achieve the targeted goal. However, there are not enough study that analyzes long term plan for energy consumption and GHG emissions at local city level. The economic activities are increasing in Kathmandu Valley with increasing population and the numbers of operational industries. Therefore, it is essential to carry out long term analysis

regarding energy consumption and demand projection for industrial sector in Kathmandu Valley.

1.3 Objectives

1.3.1 Main Objective

The main objective of this thesis is to analyze energy consumption and demand projection in industrial sector of Kathmandu Valley from 2021 to 2050 using energy model tool.

1.3.2 Specific Objectives

The specific objectives of this thesis are:

- To determine the present status of energy consumption in industrial sector of Kathmandu valley
- To estimate the energy demand of all type of energy up to 2050 AD at 5 years interval in industrial sectors
- To access the emissions due to the consumption of various fuels in industrial sector

CHAPTER TWO: LITERATURE REVIEW

Energy is vital parameters for the development of any nation. Energy consumption and economy of the nation is directly related. Energy consumption is considered as a indicator to observe the development of nation. The energy demand will increase with the economic development as well as population growth of nation. Energy are obtained from various sources, it is classified into different categories. Figure 2.1 shows the classification of all the different energy sources used in Nepal according to report of economic survey.

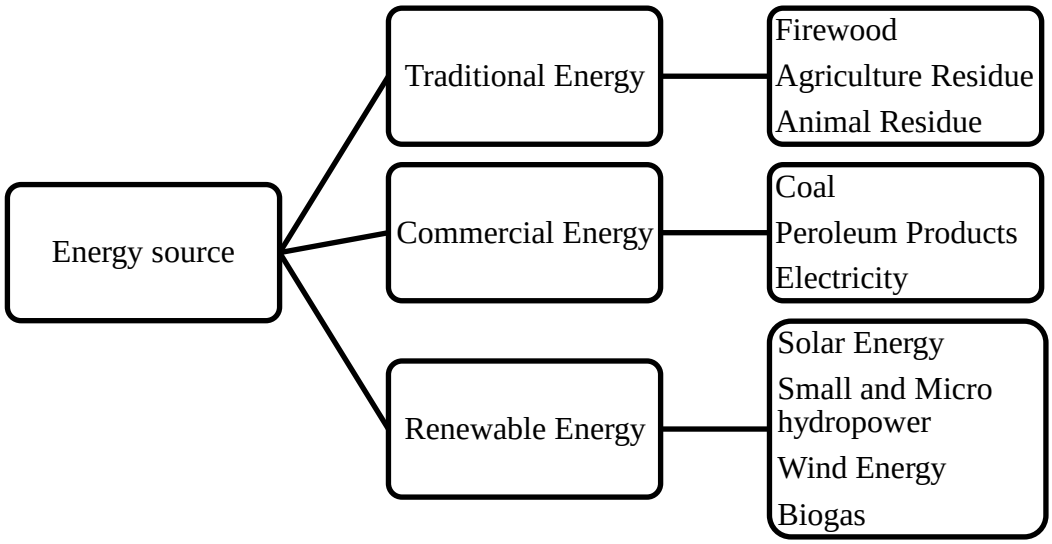


Figure 2.1: Classification of energy sources

Traditional Energy:

The traditional energies are such energy which is produced by using traditional methods and even it can be used without modern technologies. Firewood is the common source of traditional energy which is produced from forest or non-forest land. Also, agriculture residue and animal dung cake are other sources of traditional energy. These sources are used either in their primary form or secondary and tertiary forms to generate energy in the form of heat or electricity.

Commercial Energy:

Commercial energies are such energy which has market price and are traded in the market place. Coal, Petroleum products, and electricity are the example of commercial energy. These energy sources are traded among different countries at different market price.

Renewable Energy

The energies are known as renewable energy, if any primary energy is obtained from a constantly available flow of energy. Examples of renewable energy are solar energy, wind energy, biogas, micro and small hydro power.

2.1 Energy Situation of Nepal

In context of Nepal, traditiona; source of energy is still dominate which includes fuelwood, agricultural residue, animal waste and loose biomass. Figure 2.2 depicts, that the total energy consumption of Nepal from fiscal year 1999/00 to 2009/10 has been increased with annual growth rate of 2.22%. Similarly, the total energy consumption from fiscal year 2009/10 to 2019/2020 has been increased with an annual growth rate of 3.88% for s decades.

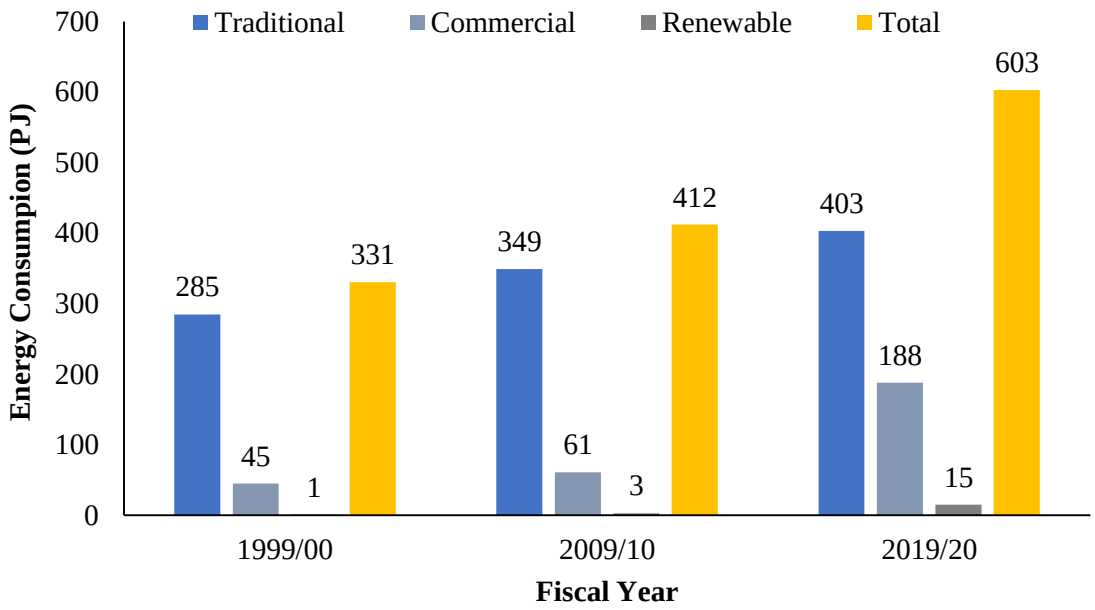
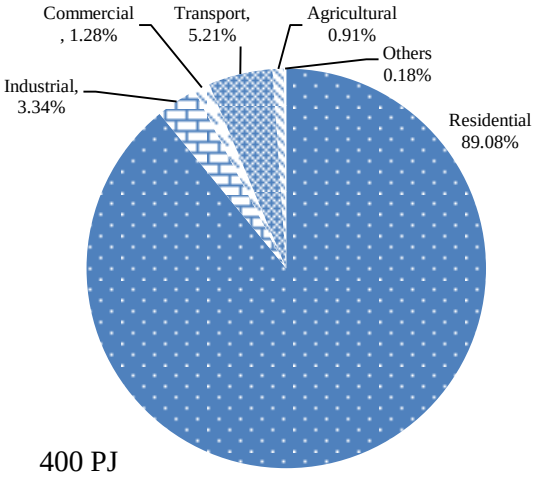


Figure 2.2: Status of energy consumption in Nepal (Economic Survey 2018/19)

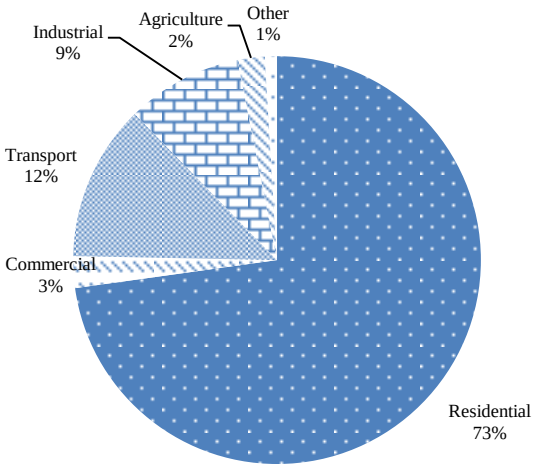
The sectoral energy consumption in fiscal year 2008/09 has major share in residential sector (89%) followed by transport (5.21%), industrial (3.34%), commercial (1.28%), and remaining by agricultural (0.91%) and others (0.18%). Similarly, the share of energy consumption in 2018/19 for residential, transportation, industrial, commercial, and agricultural sectors are 73%, 12%, 9%, 3% and 2% respectively. Construction and mining sector is included in industrial sector. By comparisons of Figure 2.3 and Figure 2.4, the share of energy consumption in residential sectors has been decreased from 89% to 73% while energy consumption in industrial and commercial sectors has

been substantially increased due to increasing establishment of factory and commercial entities



(WECS, 2010)

Figure 2.3 Sectorial energy consumption in year 2008/09



(IEA, 2022)

Figure 2.4: Sectorial energy consumption in year 2018/2019

In FY 2019/20, the consumption of electricity is highest in domestic sector accounts for 44.34% of total electricity consumption which is followed by industrial sector contributes 35.83% whereas commercial sector (7.59%), non-commercial sector (2.97%) and remaining others (9.27%) (NEA annual report, 2020).

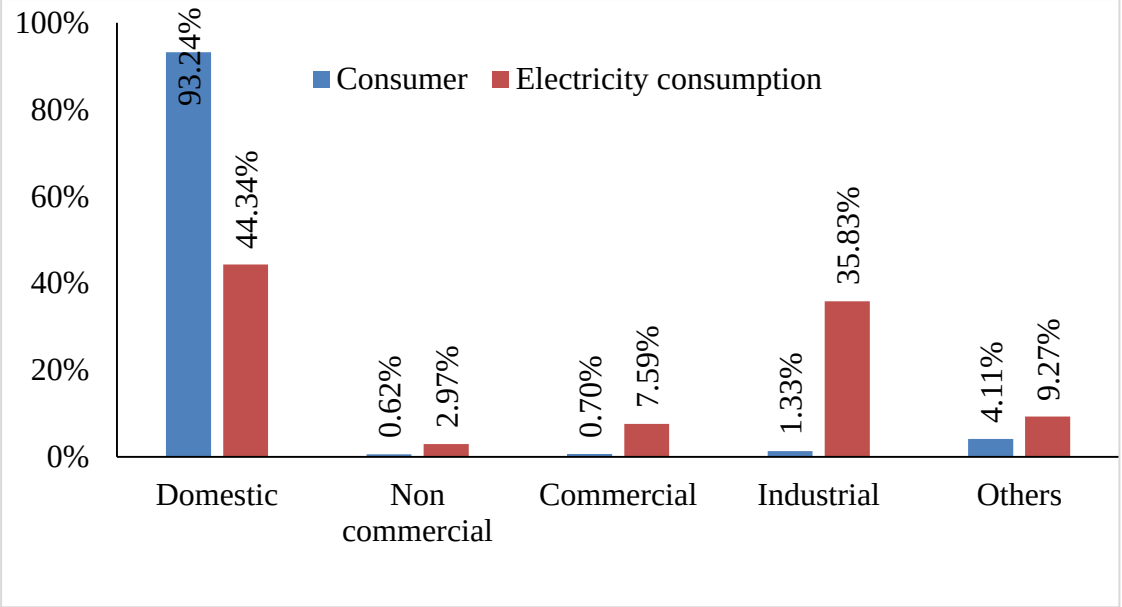


Figure 2.5: Electricity consumption pattern of economic sectors in FY 2019/20 (NEA annual report, 2019/20)

The domestic consumers contributes highest share of 93.26%, followed by 1.33% of industrial consumer, 0.70% of commercial consumer and 0.62% of Non-commercial consumer. While the rest 4.09% is the consumers from another economic sector.

Figure 2.6. represents the trend for supply of petroleum products in Nepal. The annual rate of increasing supply for diesel, petrol and aviation turbine fuel (ATF) is found to be 14.90%, 12.58% and 9.94% respectively. The consumption of diesel is high due to the infrastructure development, heavy equipment, freight vehicles, and industrial uses. In year 2015/16, import has been affected due to the border blockage issue. However, kerosene is in phase out stage so it has been decreasing with an annual rate of 11.39%.

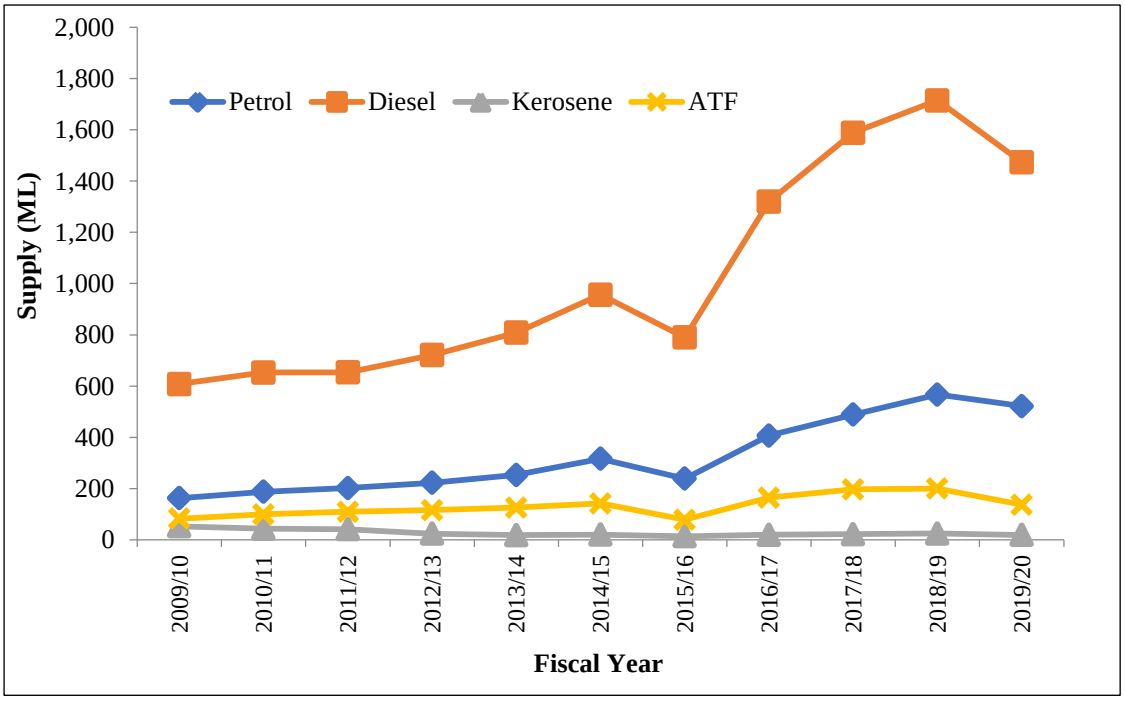


Figure 2.6: Supply of petroleum product (NOC, 2020)

In the fiscal year 2010/11 the electricity produced by NEA, IPP and import from India was 2122 GWh, 591 GWh and 639 GWh respectively. The production has been increasing with an annual growth rate of 7.25% which has reached 3021 GWh, 2991 GWh and 1729 GWh respectively in fiscal year 2020/21. The share of import from India has been increased substantially than NEA and IPP.

The total electricity available in the country is due to Nepal Electricity Authority (NEA) owned generation, Independent Power Producer (IPP), and import from India. Electricity generated by AEPC is included in NEA electricity. The electricity produced by different power producer is shown in Figure 2.7.

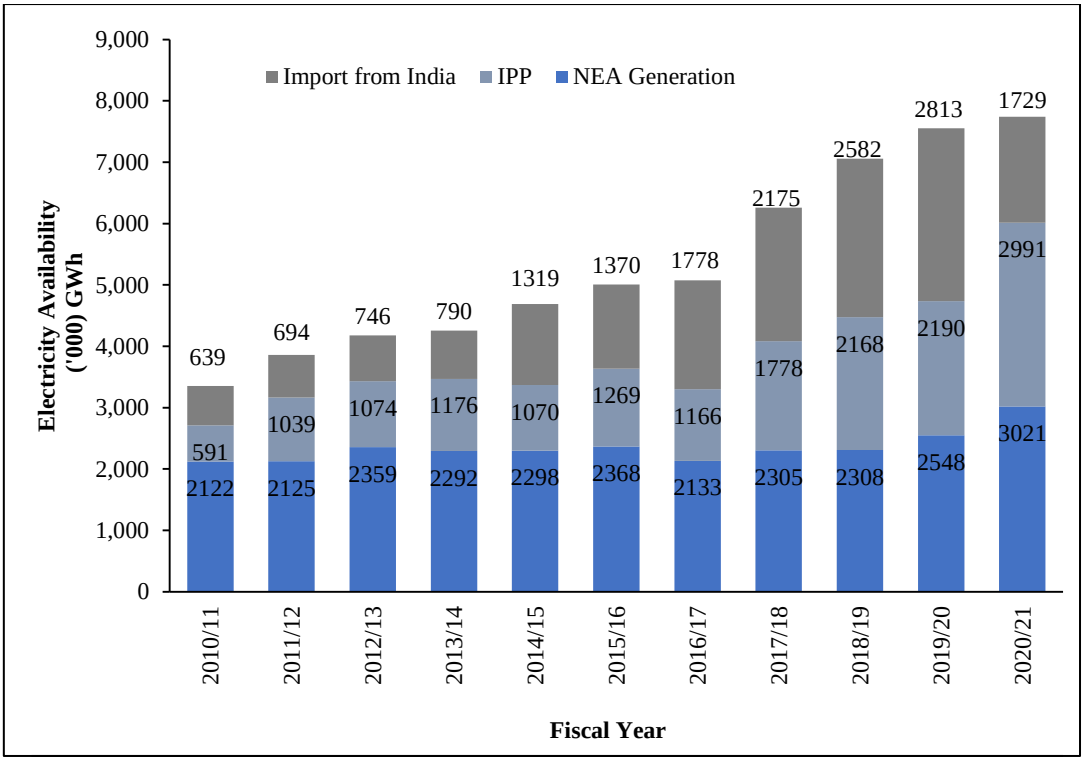


Figure 2.7: Electricity produced by different power producer (NEA, 2020)

The burning of commercial fuels like coal, oil and natural gas produces carbon dioxide which has adverse impact on greenhouse effect. The energy sector includes all fuel combustion-related emissions from energy industries, manufacturing and construction, transport and other source categories.

In 2019, International Energy Agency (IEA) has published that global energy-related CO_2 emissions were 3.3 billion tonnes out of which 33% were accounted from the advanced economies and the remaining from the rest of the world (IEA, 2020). In 2019, developed countries observed a decline in their CO2 emission by 3.2% from the 2018 level whereas there was still 2% growth in emission from the rest of the world during the same period.

Table 2.1 shows the emissions of various GHGs from different sectors in 2019 in Nepal. Transport sector contributes for higher emission of CO_2 which is followed by industrial sector. The emission of CO_2 in residential sector is significant because of higher consumption of biomass in this economic sector (GoN, 2021). Likewise, emission of Nitrous Oxide and Methane seems higher in residential sector. Thus, total CO_2 equivalent emission in residential sector is higher which indicate energy consumption in this sector is higher than other economic sectors.

Table 2.1: Emission in 2019 (in million Metric tons carbon dioxide equivalent, $mMtCO_2e$

Sectors	CO_2	CH_4	N_2O	CO_2-eq
Residential	2.09	0.41	3.57	6.07
Transport	4.73	0.40	0.01	5.15
Industrial	4.45	0.02	0.02	4.49
Commercial	0.54	0.01	0.13	0.69
Agriculture	0.78	0.00	0.00	0.78
Total	12.59	0.85	3.74	17.18

(UNFCCC, 2021)

2.2 Microeconomics

According to Central Bureau of Statistic (CBS) 2021, the total GDP of Nepal is NRs 4,851,625 million. The contribution of Bagmati Province for the GDP generation is 36.7 % of total GDP while Kathmandu Valley accounts for 30% of total GDP of Nepal (ADB, 2021). In context of Nepal, manufacturing sector accounts for 5.6% of total GDP of country while in context of Bagmati Province the composition of manufacturing sector is 5.5% of total GDP within Bagmati Province. The average annual growth rate of manufacturing and total GDP is 3.9% and 5% respectively (Finance, Economic Survey 2020/21, 2022). It illustrates that the GDP generated from manufacturing industries is unable to match the growth rate of total GDP.

2.3 Management of Process Energy

In manufacturing process energy, materials are processed to produce goods or services using energy. Energy is essential parameter in the manufacturing process such as heat energy is used to cast or forge steel, welders and machine tools are powered by electricity, moreover, furnaces and ovens are operated by using fuels. Some common industrial equioments are air compressors, motors, boilers, and refrigeration systems.

A. Process Heat

Process heat is an important manufacturing process used for drying, melting, curing, annealing, cooking, distilling, softening, and fusing various products and materials. The most common technology used for process heat are furnaces, ovens, and kilns.

B. Boiler

Boiler is a closed vessel which is used to heat water or generate steam utilized for various purposes. It is operated by burning fossil fuels, fuel wood, agriculture residue, and electricity. Boiler is generally used in manufacturing industries for cooking, dying, space heating etc.

C. Compressor

Compressed air is a major form of process energy and is used in a variety of applications, such as to drive power tools and machinery, cleaning processes, for spraying and painting applications, in drying and also in injection molding and many other applications. Compressors are operated either by using fuel or electricity.

2.4 Overview of Energy Modelling

Energy demand modelling is an indispensible module for energy planning, formulation of strategies and recommendation for energy policies (Bhattacharya, 2009). Meanwhile the early 1970s, when the policymakers concentrate in the result of the first oil crisis, the research on energy demand analysis has immensely augmented. After an inadequate understanding of the nature of energy demand and supply due to presence of external shocks in the 1970s (Pindyck, 1979), there has been a significant build-up of knowledge. In recent times, energy demand modeling has immense impacts in the developments in the energy markets as well as new policy concerns such as energy security, energy price volatility and environmental concerns.

There are different energy model based on various approach for the analysis of energy situation. Energy model portrays a simplified picture of the real energy system and actual economy (Herbst el al.2012)

2.4.1 Energy Model Approach

There are various energy model approaches has been developed which gives specific results by including substantial aspects. In general, the energy model approaches are classified into three different categories:

i. Top-Down model
ii. Bottom-Up model
iii. Hybrid model

i. Top-Down Model

Top-down model try to represent the economy as a whole on a national or regional level and to assess the aggregated effects of energy and climate policies in monetary unit. These models consider aggregate view of energy sectors and economy and are driven by economic growth, inter-industrial structural change, demographic development, and price trends, macroeconomic models try to equilibrate markets by maximizing consumer welfare using various production factors and applying feedback loops between welfare, employment, and economic growth. Few example of this model are Kuwait model, DTL, ERESME etc.

ii. Bottom-Up Model

In contrast to top-down model, this model uses business economic approach and does not consider macroeconomic impacts of energy or climate policies or related investments. Bottom-up model does not consider transaction costs but by top-down models do cover it implicitly. It takes relatively high degree of technological detail used to assess future energy demand and supply. They have been developed in various forms such as simulation or optimization models, and more recently of multi agent models. Bottom-up modelers try to identify the best technologies by assessing policies, their effects, investment, costs, and benefits, by calculating external benefits of energy efficiency measures, by identifying synergy-effects between sectors and sectorial costs and surpluses. However, if it comes to energy efficiency possibilities, most bottom-up models constrains their investment and cost determination to the conversion sector and cross cutting technologies in the final energy sectors. This fact is often overlooked and leads to questionable conclusions in cases of scenario comparisons and model comparisons (Herbst et al., 2012). Few examples of this model are MEAD, LEAP, MARKAL etc.

iii. Hybrid Model

Hybrid model is a combination of top-down and bottom-up models. It has the advantages of both top-down and bottom-up models. They partially consider the individual components contributing to the energy system while also taking into the macro-economic parameters. The advantage is that the model is flexible as well as the relation with exogenous variables are well established.

Different types of energy modeling tools are describes as below:

a. MAED (Model for Analysis of Energy Demand)

MAED is most commonly used medium to long range energy model for the projection of energy demand. The model follows the end-use demand forecasting steps typical for an engineering economy model. It depends on on the systematic development of consistent scenarios for the demand projection where the socio-economic and technological factors are considered unambiguously. Over the scenarios, the model explicitly involves structural changes and evolution in the end-use demand markets. For the conversion forms of energies, firstly, the demand is calculated in the form of useful energy then taking market penetration and end-use efficiency into consideration, final demand is derived.

b. MARKAL (Market Allocation)

MARKAL was developed by the Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency under cooperative multinational project over a period of two decades. MARKAL is a generic model incorporated by the input data to represent the evolution over a long range of usually 40 to 50 years of a specific energy system at different levels (national, regional, state or province, or community). It is the bottom-up energy model and it uses optimization methodology. The objective of this energy model is a target-oriented, incorporated with energy analysis and planning through a least cost approach. The energy demands are exogenously supplied in this model and also the energy supply are analyzed. In this model both linear as well as dynamic (non-linear) programming mathematical approaches can be employed.

c. LEAP (Long-range Energy Alternatives Planning)

LEAP stand for Long-range Energy Alternatives Planning which is a flexible modeling environment that allows developing specific applications based to particular problems at various geographical levels (cities, state, country, region or global). As LEAP is an integrated energy planning model therefore, this model can be for both the demand and supply sides of the energy system.

d. NEM (National Energy Modeling System)

NEMS was designed and developed by the US Department of Energy and it is primarily used for the preparation of Annual Energy Outlook. The sub sectors for

demand analysis are classified into four different modules (residential, commercial, industrial and transport) and each module covers the range of the regional level to a great extent.

e. WEM (World Energy Model)

WEM is a long-range energy model which is used to forecast energy demand and supply. It is generally used by International Energy Agency. The demand part of the model follows a hybrid approach where the econometric tradition is combined with the end-use methodology. An overall demand forecast is based on energy balance or accounting approach and also it covers the final demand and the energy demand for the transformation sector distinctly. The final demand is broken down into a number of sectors industry, transport, residential and services. Further disaggregation is used in each sector for example, the industrial sector considers the main sub-sectors, the transport sector is analyzed by mode and type of fuel, while the domestic and commercial sectors consider fuels by end-uses.

2.5 Policy Overview

Nepal Sustainable Development Goals, Status and Roadmaps 2016-2030

According to the Nepal Sustainable Development Goals, Status and Roadmaps 2016-2030, Nepal has set the goal to uplift from least developed countries to middle developed country which requires the rapid economic growth of above 7% over the decade.

Sustainable Development Goal (SGD) 7: Ensure access to affordable, reliable, sustainable and modern energy for all

Target: By2030,

- To rise the share of renewable energy in the global energy mix substantially
- To double improvement in energy efficiency in global rate

Sustainable Development Goal (SGD) 9: Build resilient, infrastructure, promote inclusive and sustainable industrialization and foster innovation

Target: By 2030,

- To promote inclusive and sustainable industrialization
- To increase the share of industry to 25%

Industrial Energy Consumption Survey 1996/97

- Energy survey to determine the energy consumption pattern of industrial sector by fuel and technology in both modern and traditional sector
- Potential of captive and ingeneration power

Industrial Policy (2011)

- Provisions for technical, financial support and provide incentives to industries using environment-friendly and energy-efficient technologies.
- No royalty or tax for self-dependent industries on electricity and provision to sell excess energy to the national grid
- Regulation for auditing and reporting of energy intensity of industries
- Provision to develop the capability of the Department to monitor and control pollution.

The Fifteenth Plan (Fiscal Year 2019/20-2023/24)

- Provide support and assistance towards the development of infrastructure and promotion of industries based on domestic raw materials including cement, sugar, footwear, medicine, juice, dairy, tea, cashmere, handicrafts
- Connection of industry with agriculture, tourism, education, health, and other sectors
- Establishment of industrial estates in all provinces in line with the policy of establishing at least one modern industrial estate in every province
- The establishment of environment-friendly and agriculture based industries will be emphasized.
- Relevant laws to amended and improved to extract, process, and use petroleum products and minerals.

CHAPTER THREE: METHODOLOGY

This chapter describes the methodology that has been adopted for the work from initial phase of the research till the completion. It includes literature review, questionnaire development, site selection, data collection, compilation and analysis of data, energy model development, documentation and presentation. The methodology followed for the accomplishment of study is shown in Figure 3.1.

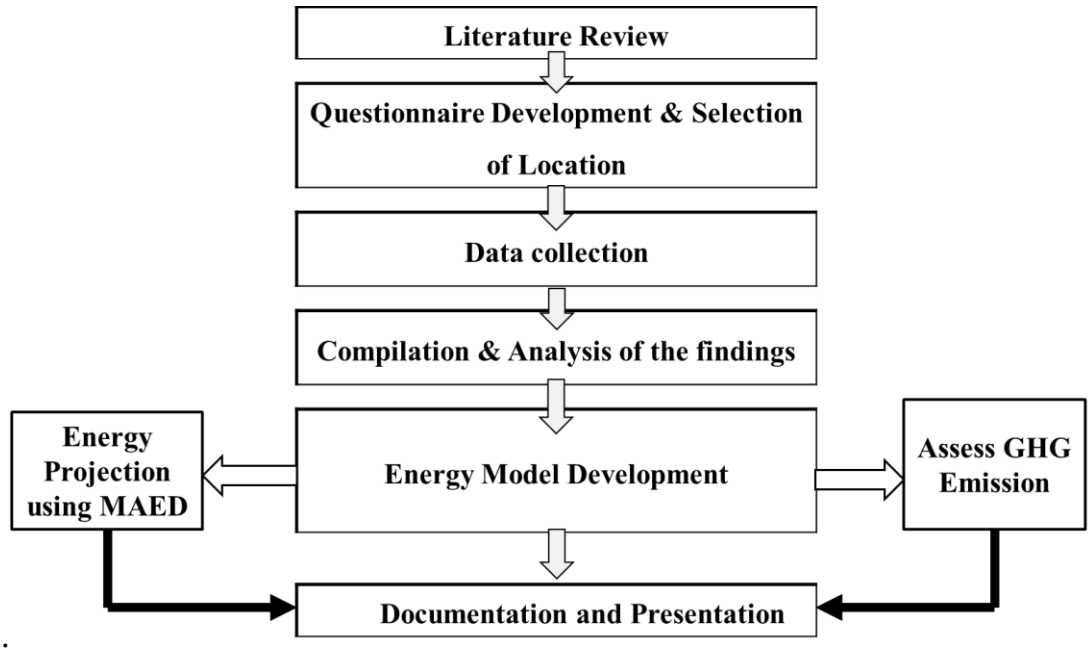


Figure 3.1: Flow diagram of Methodology

3.1 Literature Review

Literature review is a vital part for research therefore an extensive literature review was conducted to get information about various fuel used in industrial sector, end use technologies, energy modeling tools and techniques, macroeconomics and GHG emissions. Different editions of "Economic Survey Report" published by Ministry of Finance (MoF), national as well as provincial report published by Water and Energy Commission Secretariat (WECS), various statistical report published by Center Bureau of Statistic (CBS), Sustainable Development Goals published by National Planning Commission (NPC) were studied thoroughly. Similarly, to collect information about plan, policy and guidelines regarding energy resource, potential, supply, demand and consumption many relevant governmental reports as well as national and international research paper were studies.

3.2 Questionnaire Development and Selection of Location

3.2.1 Questionnaire Development

The information acquired from literature review has been used to design questionnaires. The questionnaire has included various parameters such as:

- Various fuels used ,
- Different end use technologies,
- Types of the products manufacture
- Capital of industry
- Average operation hours
- Annul energy consumption by fuel types

3.2.2 Sample Size Determination

According to Central Bureau of Statistic, there are 633 numbers of manufacturing industries in Kathmandu Valley (Kathmandu-318, Lalitpur-172 and Bhaktapur-143) (CBS, Statistical Pocket Book of Nepal 2018, 2019). It was not possible to collect energy data from all the industries in Kathmandu Valley therefore; sample size determination method was applied to calculate appropriate sample size. For proportionally determination of sample size, it was designed with 95% level of confidence with 5% marginal error and 5% non-response rate for the manufacturing industries. The sample size was calculated using Krejci and Morgan formula (Morgan K. , 1970),

$$n = \frac{\chi^2 \; x \; p \; x \; qxN}{e^2 \; (N-1) + \chi^2 x \; px \; q}$$

Where,

$\chi 2$ = chi-square for specific confidence level at 1 degree of freedom

p = probability of success

e = margin of error

N = Population size

n = required sample size

Non-response rate: Total non-response rate is assumed as 5%, which considers non-respondent and unavailable unit.

Total sample size = n±5% of n

Industrial sector has been classified into 24 categories by type of products and economic output by Nepal Standard Industrial Classification (NSIC). Nevertheless, the industries have been congregated into 8 categories based on type of output and energy activity involves so that the complexity can be ease. Table 3.1 shows the categorization for each of the industry type

Table 3.1: Categorization for each of industry type

Categorization	Inclusions from NSIC
Food, beverages, and tobacco	Manufacture of food product
	Manufacture of beverage
	Manufacture of tobacco products
Textiles, apparels and leather products	Manufacture of textiles
	Manufacture of wearing apparel
	Manufacture of leather and related products
Wood and paper products	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles and straw and plaiting materials
	Manufacture of paper and paper product
	Manufacture of furniture
Chemical, Rubber and Plastics	Manufacture of coke, refined fuel petroleum
	Manufacture of rubber and plastic products
	Manufacture of chemical and chemical product
	Manufacture of basic pharmaceutical products and pharmaceutical preparation
Mechanical engineering and machineries	Manufacture of basic metal
	Manufacture of fabricated metal products, except machinery and equipment
	Manufacture of machinery and equipment
	Manufacture of motor vehicles, trailers and semitrailers
	Manufacture of other transport equipment
	Repair and installation of machinery and equipment
Electrical Engineering	Manufacture of computer, electronic and optical products
	Manufacture of electrical equipment
Cement, Bricks and Clay products	Manufacture of other non-metallic mineral product
Other products	Printing and reproduction of recorded media
	Other manufacturing

3.2.3 Selection of Location and Field Survey

After questionnaire development, and proportionally determination of sample size, location has been selected to conduct field survey. Locations to collect data are different classification of industries categorized by Nepal Standard Industrial Classification (NSIC) within Kathmandu district. During field survey phase, primary data regarding energy consumption has been collected by interview as well as observation. Likewise, secondary data such as electricity bill, machine log book, generator log book etc. has been also collected.

3.3 Data Collection and Compilation

3.3.1 Primary Data

Primary data source is an original data source, from which the data are collected by the researcher for a specific research. The most common techniques used for the collection of primary data are self-administered surveys, interviews, field observation, and experiments. In this research, self-administered survey was conducted for the acquisition of primary data from selected industries using prepared questionnaire.

3.3.2 Secondary Data

The process of secondary data collection is acquisition of data by someone other than the actually one who uses. It portrays that the information is already available, and analyzed by someone else. In this research, the secondary data were collected from magazines, newspapers, books, journals, government publications, economical survey report, and energy survey reports. Statistical documents etc.

3.4 Compilation and Analysis of Findings

Data collected from manufacturing industries by field survey was further compiled using MS Excel. During this phase, the error and invalid data were eliminated. Then, the compiled data has been analyzed which proceed for result and conclusion

3.4.1 Determination of Present Energy Consumption

Energy consumption for industry sector was also calculated using bottom-up approach. The energy data are collected with the information of specific purpose. Such energy is summed up to get the total energy at each upper level – from per value

added to per sub-sector to sector. The general formula for approximation of energy in industry sector is

$$E_s = \sum_p \left[\sum_u \sum_f \left(\frac{E_{f,u} \times hv_f}{va_p} \right) \times VA_p \right]$$

Where,

Es = energy demand of sector s [in TJ]

$E_{f,u}$ = energy demand of fuel f for end use u

va_p = value addition of industry p

hv_f = heating value of fuel f [MJ per unit of fuel]

VA_p = Total Value addition of sub sector p

s = sector

p = subsector

u = end use

f = fuel types

3.5 Energy Model Development

Different energy model have been developed for the planning of energy. Such model includes certain aspect and gives specific results. Among the different energy models, bottom-up model has been used because this model has been developed in the form of simulation and optimization models. It also identifies best technologies by assessing policies, their effects, investment, costs, and benefits. So, the software used for the development of energy model was:

MEAD (Model for Analysis of Energy Demand)

MAED model is bottom-up model which evaluates future energy demand based on medium- to long-term scenarios of socio-economic, technological and demographic developments (IAEA, 2006). This model relates systematically the specific energy demand for producing various goods and services identified in the model, to the corresponding social, economic and technological factors that affect this demand. Energy demand is disaggregated into a several number of end-use types; each one corresponding to a given provision or to the production of a definite good. The nature and level of the demand for goods and services are a function of several determining factors which includes population growth, number of populations per dwelling,

number of electrical appliances used in households, national priorities for the development of certain industries or economic sectors, the evolution of the energy efficient technologies, market penetration of new technologies or different forms of energy etc. For these determining factors, which constitute different "scenarios", the estimated future trends are exogenously introduced.

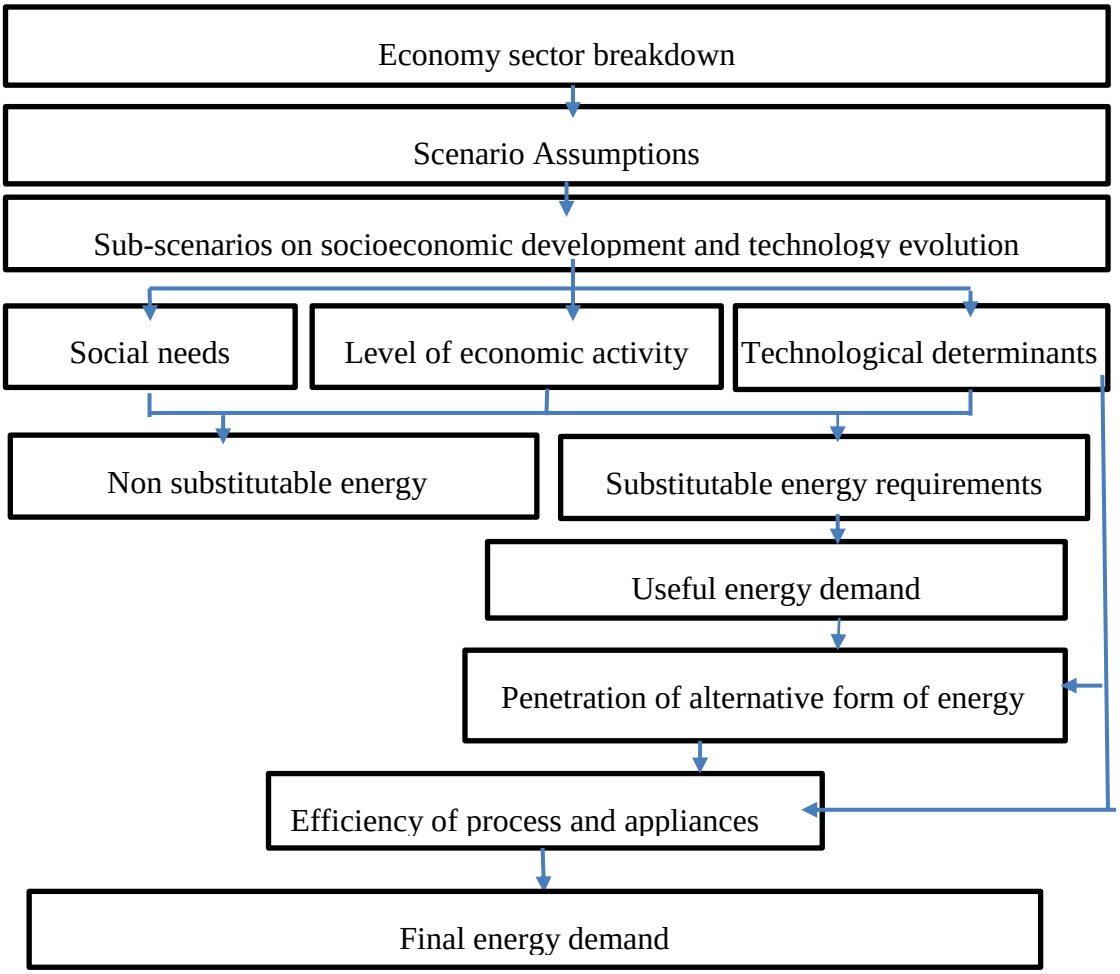


Figure 3.2: MEAD Modeling Scheme

3.5.1 Projection of Energy Demand

Projection of energy demand evaluates appropriate information for decision/policy makers regarding trend of the future energy demand for better planning and scheduling for energy supply and distribution systems. The energy projection process requires database generation of a base year that includes demand, supply, consumption and potential assessment. The projection of the energy demand up to 2050 A.D. at 5 years intervals in industrial sectors at different growth rate (high,

medium and low) was developed. MAED energy model is used to evaluate the future energy demand using MAED generic equation:

$$\mathrm{ED} = \left(\frac{\mathrm{ED}}{\mathrm{DP}}\right) \times (\mathrm{CH}) \times (\mathrm{DP})$$

Where,

ED – Represents Energy demand in future year

$\left(\frac{\mathrm{ED}}{\mathrm{DP}}\right)$ – Specific energy demand per unit of driving parameters in base year

CH – Coefficient to reflect evolution of specific energy demand per unit of driving parameters in future year

DP – Specific energy demand per unit of driving parameters in future year

3.5.2 Assessment of GHG emission

According to IPPC, emission of GHG is calculated by a general equation:

$$\mathrm{Emission} = \sum(\mathrm{EF_a} \times \mathrm{Activity_a})$$

Where, EF_a denotes emission factor (kg/TJ) and $Activity_a$ denotes energy input (TJ) using fuel type 'a'

Table 3.2 shows the emission factors used for the projection of GHG emission in Industrial sector.

Table 3.2: Emission factor (MoSTE, 2014)

Fuel	CO_2(kg/TJ)	CH_4(kg/TJ)	N_2O(kg/TJ)
Fuelwood	112,000.0	30.0	4.0
Agri Residue	0.0	2,210.0	9.7
Coal	92,600.0	10.0	1.4
Kerosene	71,900.0	3.0	0.6
Furnace oil	77,400.0	3.0	0.6
Diesel	74,100.0	3.0	0.6
LPG	0.0	0.5	2.0
Petrol	20.0		11.0

3.6 Documentation and Presentation

The findings of the research work would be presented in the form of Journal Paper and formal thesis report as per requirement of the guidelines of Institute of Engineering.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Energy Consumption in Industrial Sector

4.1.1 Industrial Sector Energy Mix in Kathmandu Valley

Final energy consumption by manufacturing industries in Kathmandu Valley is 16.4 PJ. Figure 4.1 shows the share of various fuels consumption in manufacturing industries in Kathmandu Valley. It was found that industrial sectors are highly dependent on fossil fuel. It accounts for about 67% of total energy consumption while biomass and electricity contributes 27% and 6% respectively.

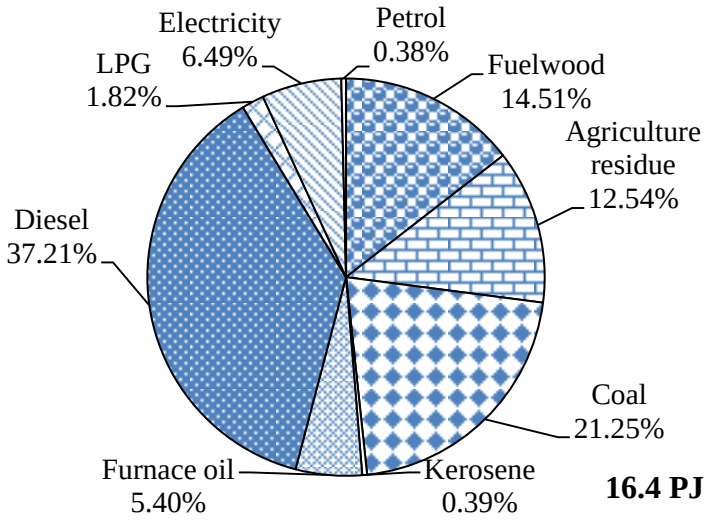


Figure 4.1: Energy Mix in Industrial Sector

Diesel is the main source of energy consumption in industrial sector. It accounts about 37.21% share of total energy consumption. After diesel, coal is most consumed energy source which contributes 21.5% share of total energy consumption. Furthermore, Fuelwood, agriculture residue, furnace oil and others occupied shares of 14.5%, 12.5%, 5.4% and 2.6% respectively.

4.1.2 Energy Consumption by End use

In industrial sector, boiler, process heat and motive power are major process under which final products are manufactured. Figure 4.2 illustrates the share of energy consumption by different end uses. It was found that 36.86% of total energy is consumed for process heat which is followed by boiler (34.84%), motive power (25.8%) and others (2%). Mostly, diesel, coal and furnace oil are used for process heat in cement, brick, food and beverage industries. It seems uses of biomass (fuel wood

and agricultural residue) are still higher for boiler. However, consumption of coal is being replaced by electricity and diesel. Moreover, diesel generators are operated due to power cut-off and unstable power supply from grid.

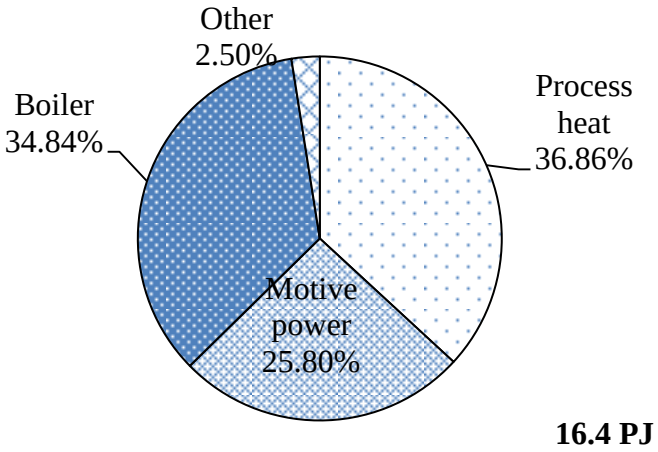


Figure 4.2: Share of energy consumption by end use

4.1.3 Energy Consumption by Industry Category wise

According to NSIC, manufacturing industries are classified in several categories among which food, beverage and tobacco (39%) consumes highest energy as shown in Figure 4.3.

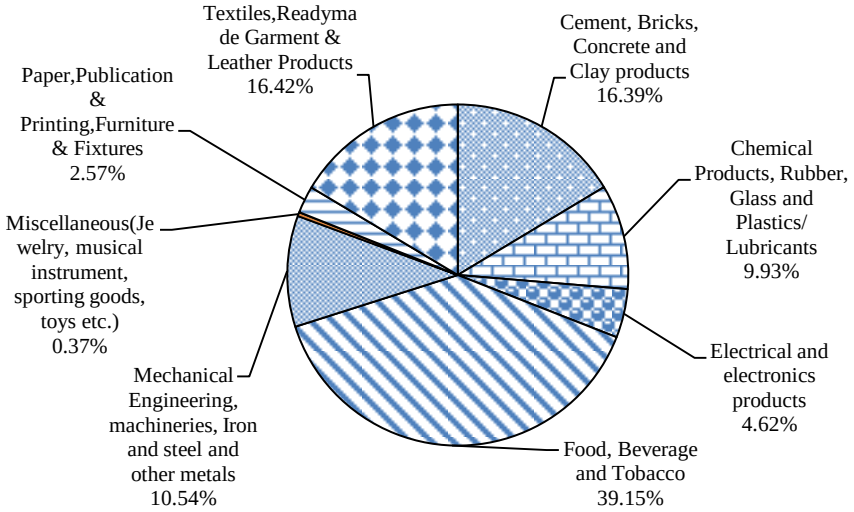


Figure 4.3: Share of energy consumption by Industrial Category wise

Then, cement, brick, concrete and clay product and textile, readymade garment and leather product both accounts about 16% of total energy consumption which is followed by mechanical engineering, iron and steel and other metal (10.5%), chemical products, rubber, glass and plastic (10%) and remaining others.

4.2 Sample Size Calculation

For determination of sample size, it was designed with 95% level of confidence with 5% marginal error and 5% non-response rate for the manufacturing industries. The sample size was calculated using Krejci and Morgan formula,

$$n = \frac{\chi^2 \; x \; p \; x \; q \; x \; N}{e^2 \; (N-1) + \chi^2 x \; px \; q}$$

Chi-square at 1 degree of freedom (χ^2) = 3.841

Probability if success (p) = 0.5

Margin of error (e) = 0.5

Population size (N) = 633

Sample number (n) = 239

Hence, total sample size = n+5% of n = 250

Using Krejci and Morgan formula and the above parameters, the sample size for 633 population numbers has been calculated which results as 250. The sample number has been distributed proportionally according to the industrial category as shown in Table 4.1

Table 4.1: Sample size on National Standard Industrial Classification

NSIC	Population Number	Sample Number
Cement, Bricks, Concrete and Clay products	85	15
Chemical Products, Rubber, Glass and Plastics	105	35
Electrical and Electronic products	9	5
Food, Beverage and Tobacco	65	29
Mechanical Engineering, machineries, Iron and steel and other metals	54	28
Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)	52	30
Paper, Publication & Printing, Furniture & Fixtures	120	48
Textiles, Readymade Garment & Leather Products	143	60
Grand Total	633	250

4.3 Energy Scenario Analysis

4.3.1 Scenario Development

In order for scenario development, different growth rate for the possible future energy demand have been considered are Low Growth Scenario, Medium Growth Scenario, High Growth Scenario and Policy Scenario. These growth rates are considered with the reference of relevant documents and report published by governmental organs. The thermal end use technologies are categorized as steam generation, furnace/direct heating and space/water heating for the required useful thermal energy demand. Likewise, the penetration various category of energy for steam generation was determined to be 1.066% electricity, 63.63% traditional fuels and the remaining was fossil fuels, for furnace/direct heat the penetration was 2.45% electricity, 9.04% traditional fuels and remaining was fossil fuel, whereas for space/water heating, 90.26% of penetration was electricity, 9.74% was traditional fuels. Present energy consumption, efficiency of end use technology, penetration of technology and economic growth are major parameters. These parameters are provided as input to MAED which results as the projection of energy demand in different energy scenario.

Low Growth Scenario

Low growth was assumed as the average growth rate of GDP for manufacturing industries of Nepal within a decade. The assumptions for this scenario are:

- Average growth rate of 3.95%
- The share of each demand technology in the supply energy for future year will be same as base year

Medium Growth Scenario

For medium growth scenario, the growth rate has been considered as the targeted growth rate of GDP by Nepal Sustainable Development Goal. The assumptions for this scenario are:

- Average growth rate of 7% (NPC, 2017)
- The share of each demand technology in the supply energy for future year will be same as base year.

High Growth Scenario

For high growth scenario, the growth rate is considered as the targeted growth of GDP for manufacturing industrial sector by the 15th plan. The assumptions of this scenario are:

- Average growth rate of 12.7% (National Planning Commission, 2020)
- The share of each demand technology in the supply energy for future year will be same as base year.

Policy Scenario

Major assumptions for policy scenario are:

- Average growth of 7%
- For boiler,
  - ❖ Penetration of 100% share of electric boiler in food beverage and tobacco by 2050
  - ❖ Penetration of 100% share of electric boiler in textile and leather by 2050
  - ❖ Penetration of 100% share of electric boiler in chemical rubber and plastic share by 2050
  - ❖ Penetration of 100% share of electric boiler in wood products and paper by 2050

4.3.1.1 Cement, Bricks, Concrete and Clay products

Low Economic Growth Scenario

Figure 4.4 depicts the growth of different energy sources in cement, brick, concrete and clay products industry at low growth rate from base year 2021 to 2050. The total energy consumption in this category shows increasing trends which is expected to grow from 2.6 PJ in 2021 to 3.8 PJ in 2025 and 8.2 PJ in 2050 which contributes for more than three folds. The contribution of coal will be higher in all the future years which will be followed by consumption of petroleum product, biomass and electricity till 2050.

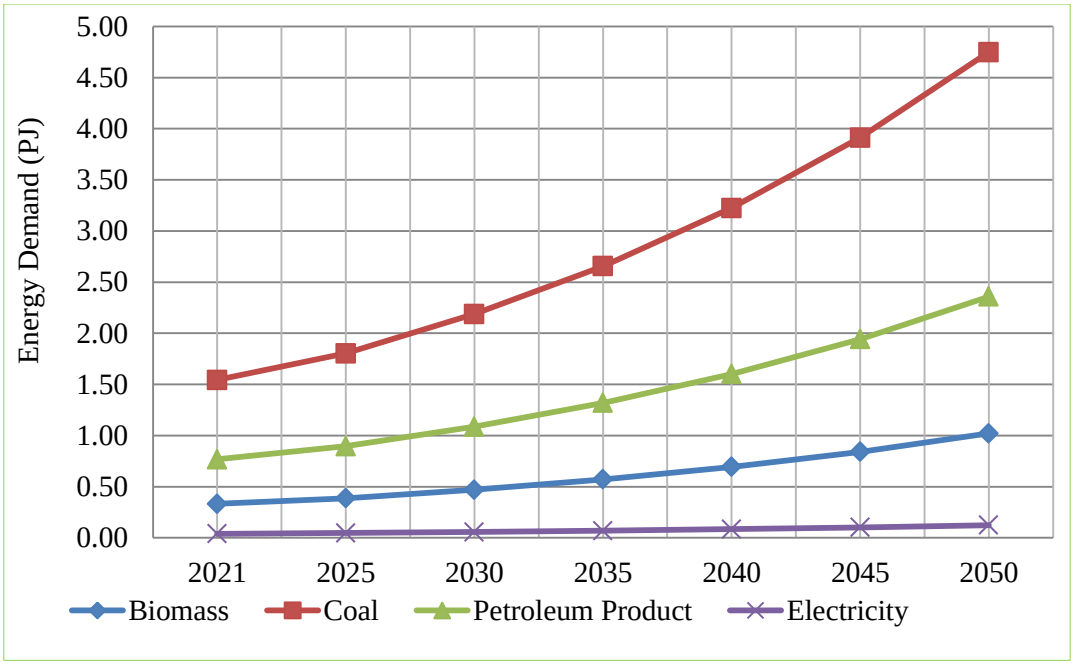


Figure 4.4: Fuel consumption trend at low growth scenario in cement, brick, concrete and clay products industries

Figure 4.5 shows the trends of GHG emission by industrial sector for low economic growth rate scenario. GHG emission was 227 thousand metric tons in base year 2021 and would increase to 322 thousand metric tons in 2030 and again this would increase to 698 thousand metric tons in 2050.

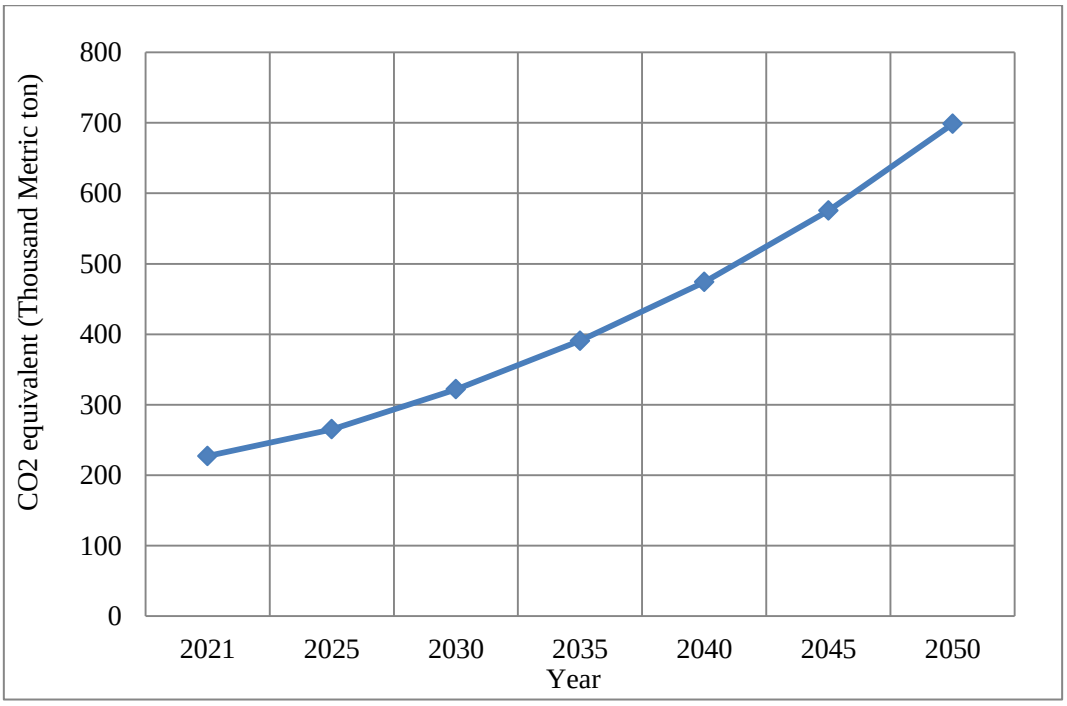


Figure 4.5: GHG emission trend at low growth scenario in cement, brick, concrete and clay products industries

Medium Economic Growth Scenario

Figure 4.6 shows the growth of different energy sources in cement, brick, concrete and clay products at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 2.6 PJ in 2021, 4.9 PJ in 2025 and 19.0 PJ in 2050. Coal has highest share in all year followed by petroleum product, biomass and electricity.

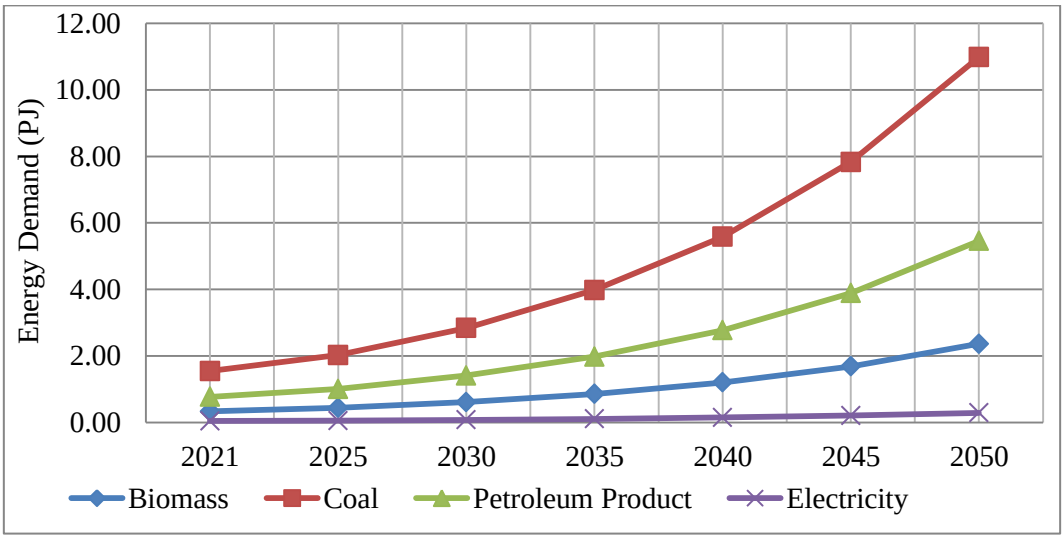


Figure 4.6 Fuel consumption trend at medium growth scenario in cement, brick, concrete and clay products industries

The trend of GHG emission for low economic growth rate scenario is shown in Figure 4.7. GHG emission was 227 thousand metric tons and would increase to 417 thousand metric tons in 2030 and again this would increase to 1,616 thousand metric tons in 2050.

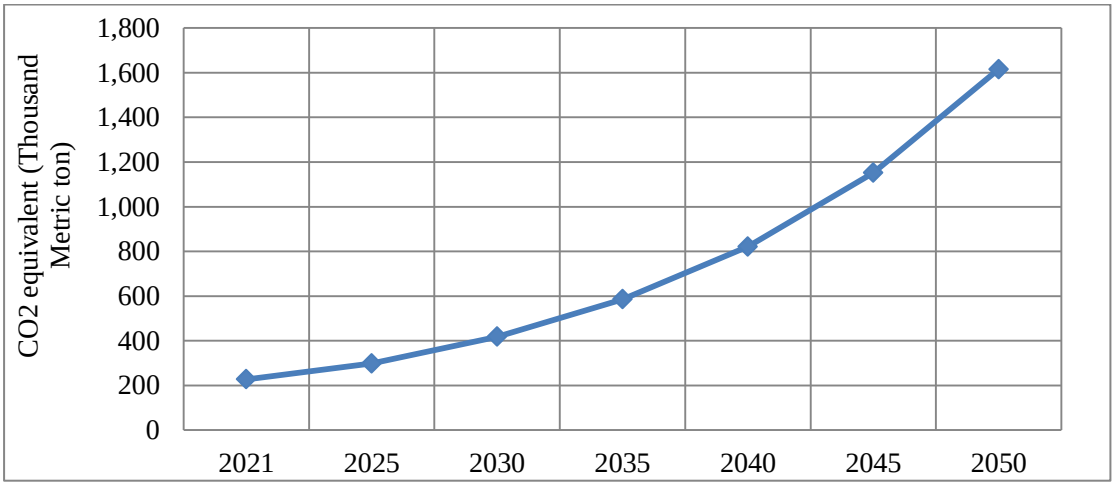


Figure 4.7: GHG emission trend at medium growth scenario in cement, brick, concrete and clay products industries

High Economic Growth Scenario

Figure 4.8 represents the growth of different energy sources in cement, brick, concrete and clay products at high growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 2.6 PJ in 2021, 7.8 PJ in 2025 and 86.0 PJ in 2050. Coal has highest share in all year followed by petroleum product, biomass and electricity.

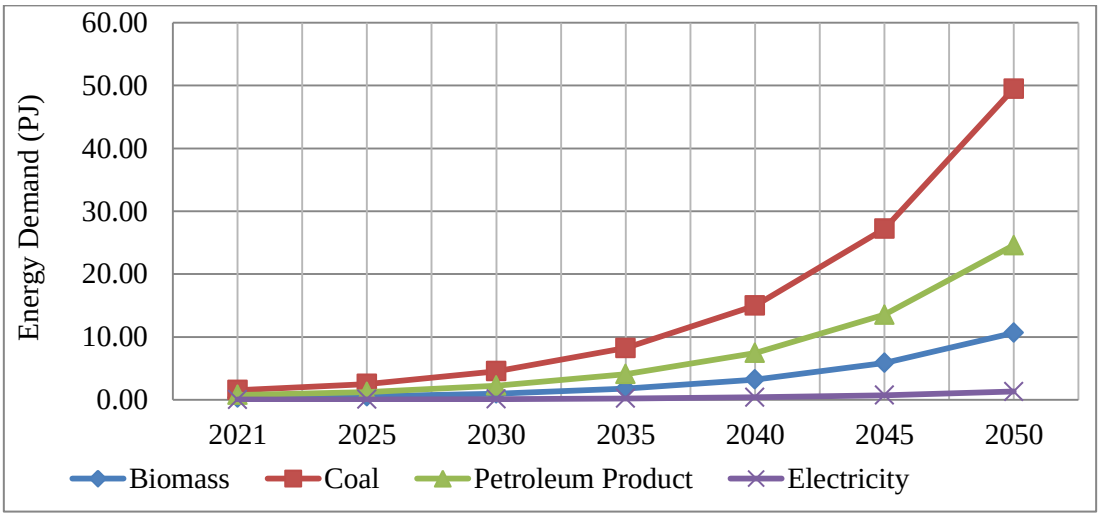


Figure 4.8 Fuel consumption trend at high growth scenario in cement, brick, concrete and clay products industries

Figure 4.9 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 227 thousand metric tons and would increase to 417 thousand metric tons in 2030 and again this would increase to 1,616 thousand metric tons in 2050.

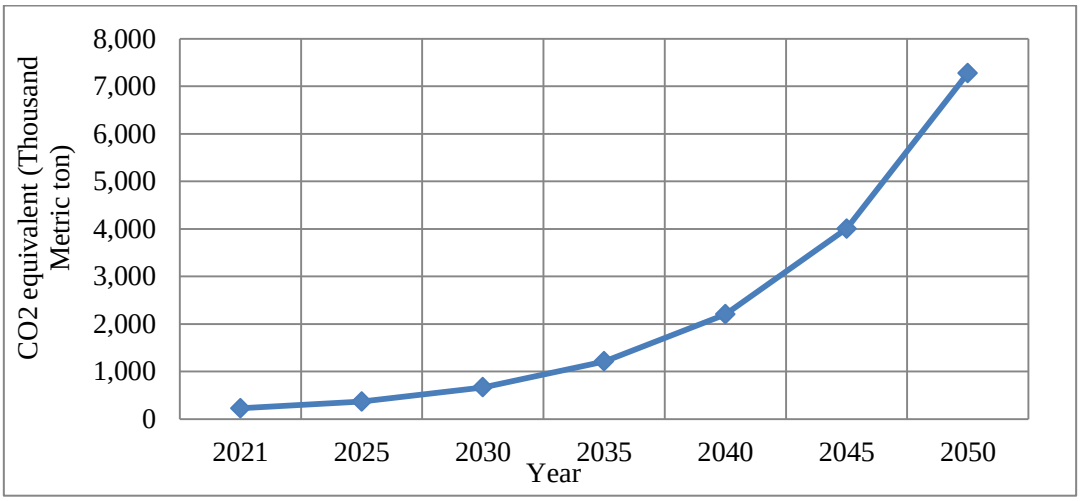


Figure 4.9: GHG emission trend at high growth scenario in cement, brick, concrete and clay products industries

4.3.1.2 Chemical Products, Rubber, Glass and Plastics

Low Economic Growth Scenario

Figure 4.10 depicts the growth of different energy sources in Chemical Products, Rubber, Glass and Plastics industries at low growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 1.6 PJ in 2021, 2.3 PJ in 2025 and 5.0 PJ in 2050 which contributes for more than three folds. Petroleum products has highest share in all year followed by biomass, electricity and coal.

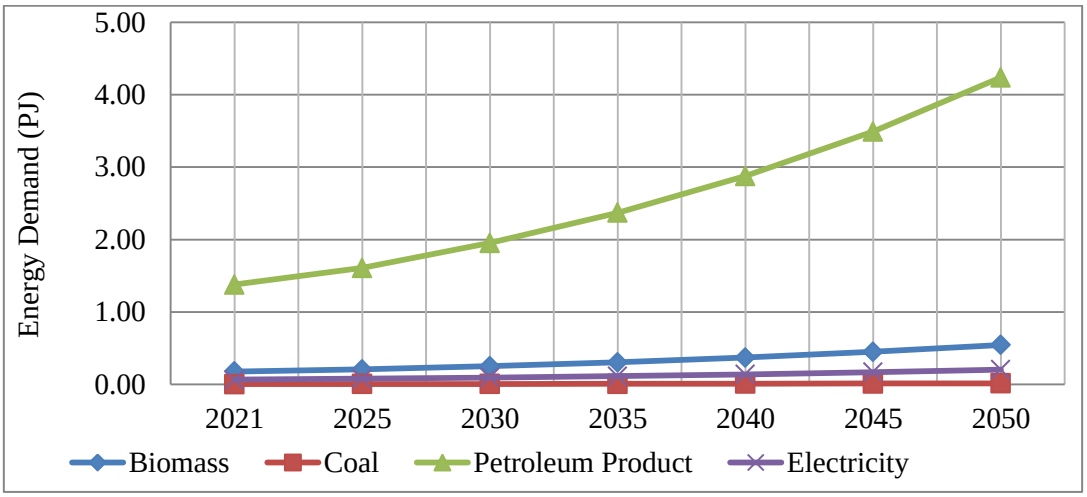


Figure 4.10: Fuel consumption trend at low growth scenario in Chemical Products, Rubber, Glass and Plastics industries

Figure 4.11 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 111 thousand metric tons and would increase to 157 thousand metric tons in 2030 and again this would increase to 341 thousand metric tons in 2050.

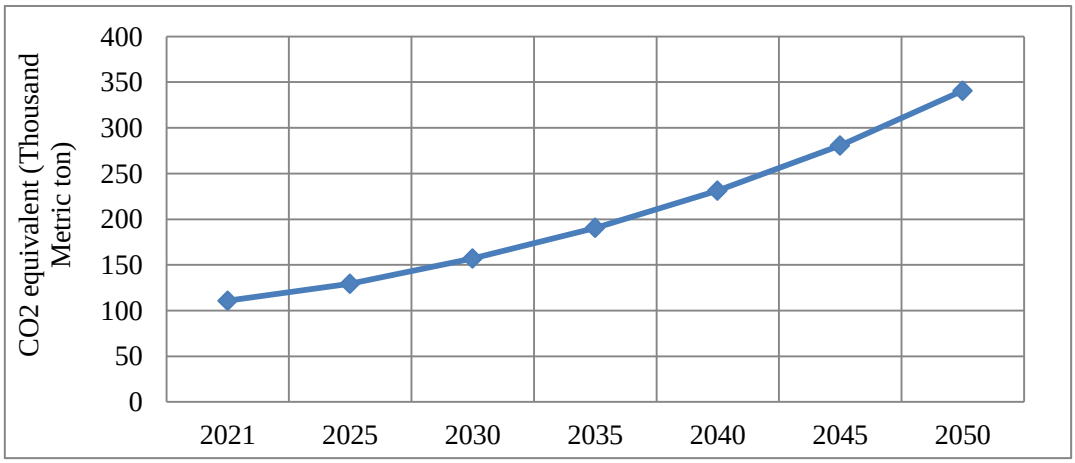


Figure 4.11: GHG emission trend at low growth scenario in Chemical Products, Rubber, Glass and Plastics industries

Medium Economic Growth Scenario

Figure 4.12 shows the growth of different energy sources in Chemical Products, Rubber, Glass and Plastics industries at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 1.6 PJ in 2021, 3.0 PJ in 2025 and 11.5 PJ in 2050. Petroleum products has highest share in all year followed by biomass, electricity and coal.

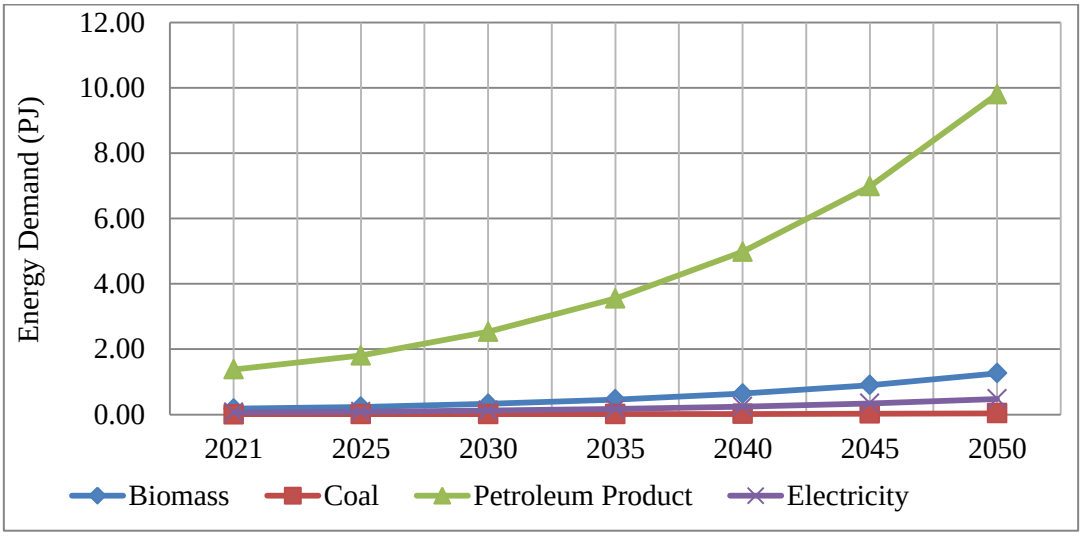


Figure 4.12: Fuel consumption trend at medium growth scenario in Chemical Products, Rubber, Glass and Plastics industries

Figure 4.13 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 111 thousand metric tons and would increase to 204 thousand metric tons in 2030 and again this would increase to 788 thousand metric tons in 2050.

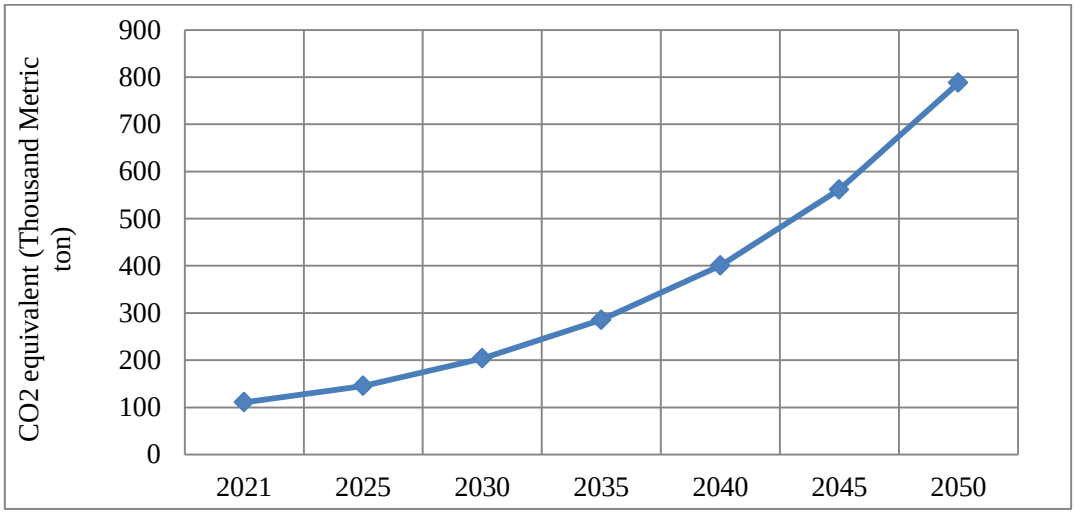


Figure 4.13: GHG emission trend at medium growth scenario in Chemical Products, Rubber, Glass and Plastics industries

High Economic Growth Scenario

Figure 4.14 represents the growth of different energy sources in Chemical Products, Rubber, Glass and Plastics industries at high growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 2.6 PJ in 2021, 4.8 PJ in 2025 and 52.0 PJ in 2050. Petroleum products has highest share in all year followed by biomass, electricity and coal.

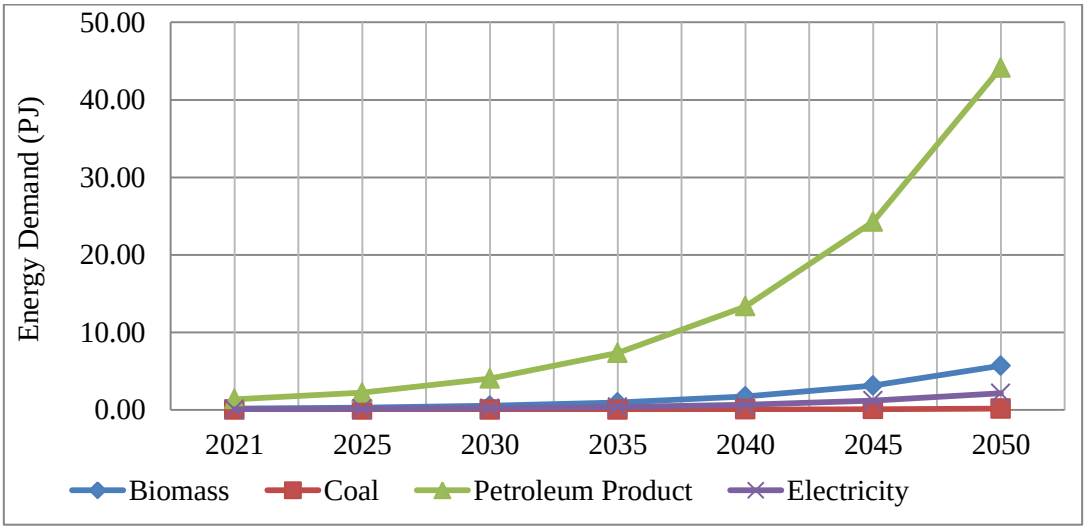


Figure 4.14: Fuel consumption trend at high growth scenario in Chemical Products, Rubber, Glass and Plastics industries

Figure 4.15 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 111 thousand metric tons and would increase to 325 thousand metric tons in 2030 and again this would increase to 3,549 thousand metric tons in 2050.

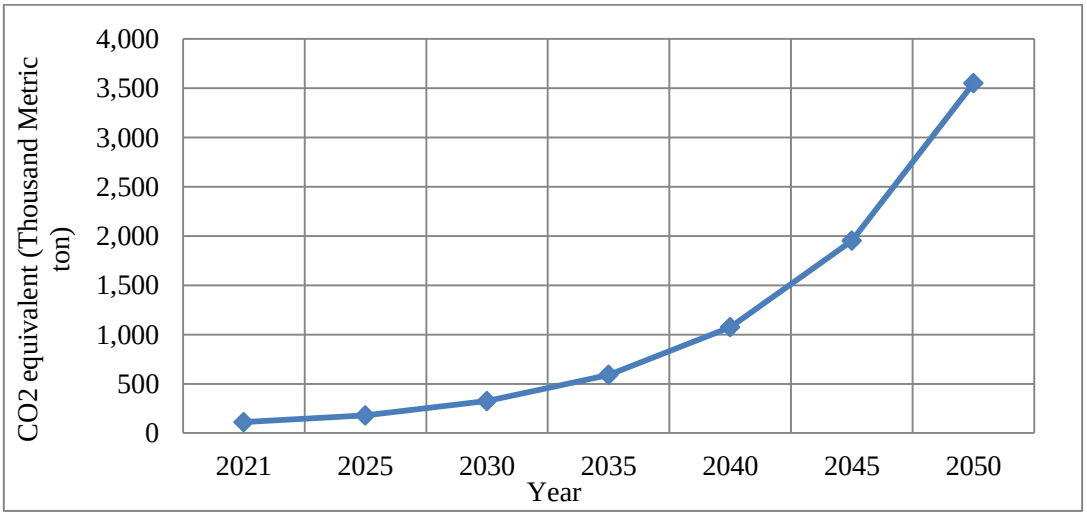


Figure 4.15: GHG emission trend at high growth scenario in Chemical Products, Rubber, Glass and Plastics industries

Policy Scenario

Energy consumption in Chemical Products, Rubber, Glass and Plastics industries for policy scenario is shown in Figure 4.16. It seems that the demand of petroleum product will increase rapidly while share of coal is completed reduced. The trends of petroleum products and biomass are expected to grow at average growth rate of 6.8% and 6.7% respectively. Likewise, the demand of electricity is predicted to grow at average growth rate of 10%.

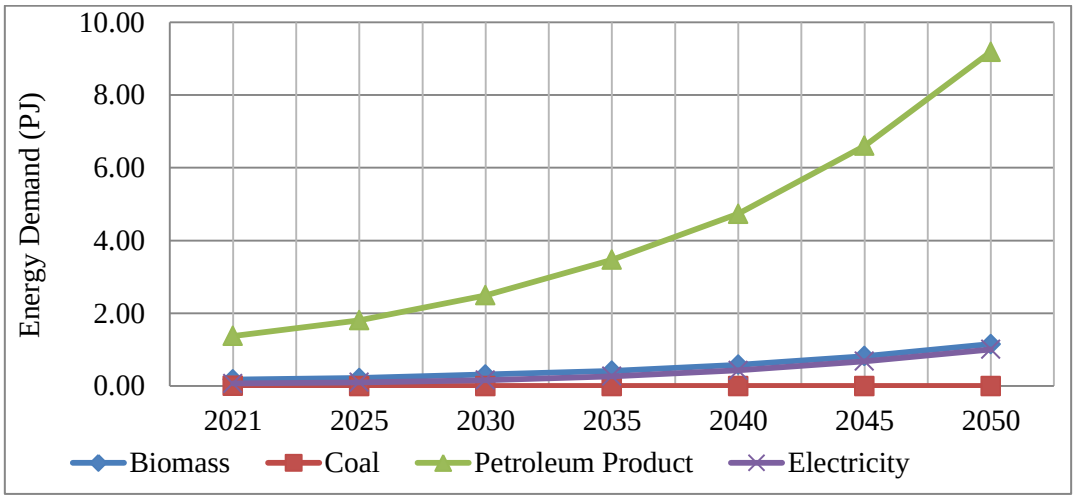


Figure 4.16: Fuel consumption trend at policy scenario in Chemical Products, Rubber, Glass and Plastics industries

Figure 4.17 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 111 thousand metric tons and would increase to 198 thousand metric tons in 2030 and again this would increase to 725 thousand metric tons in 2050.

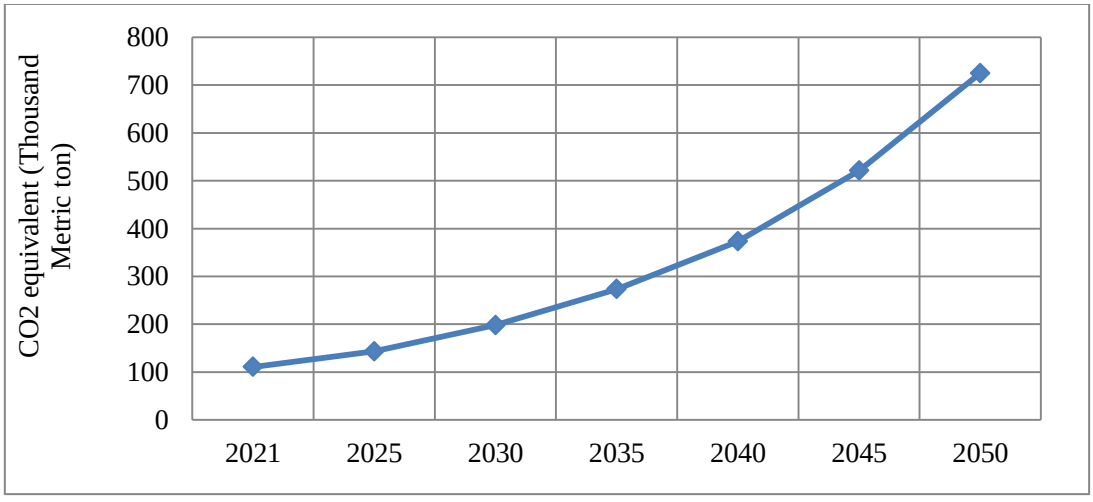


Figure 4.17: GHG emission trend at policy scenario in Chemical Products, Rubber, Glass and Plastics industries

4.3.1.3 Electrical and Electronic products

Low Growth Scenario

Figure 4.18 depicts the growth of different energy sources in Electrical and Electronics products industries at low growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.76 PJ in 2021, 1.08 PJ in 2025 and 2.3 PJ in 2050 which contributes for more than three folds. The trends of petroleum products and electricity are growing rapidly.

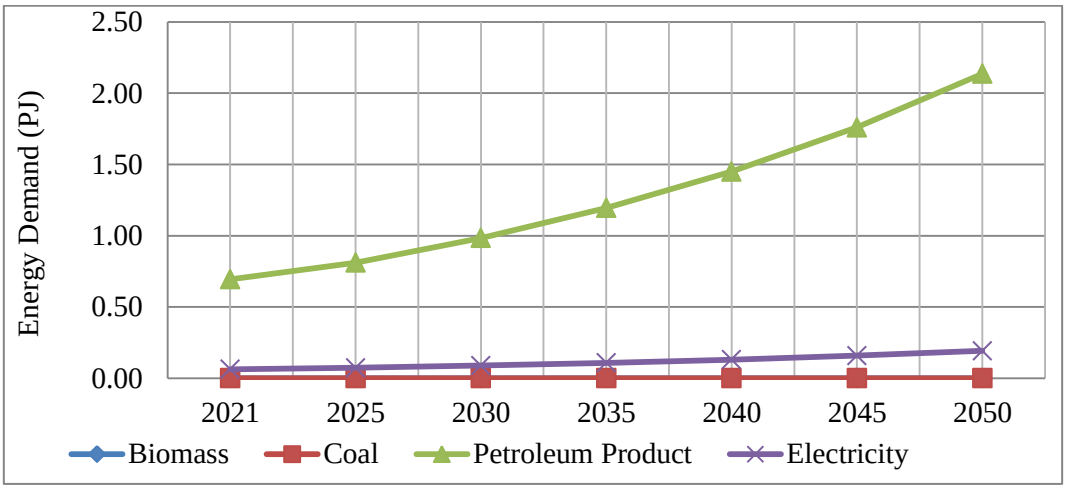


Figure 4.18: Fuel consumption trend at low growth scenario in Electrical and Electronics products industries

Figure 4.19 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 52 thousand metric tons and would increase to 73 thousand metric tons in 2030 and again this would increase to 159 thousand metric tons in 2050.

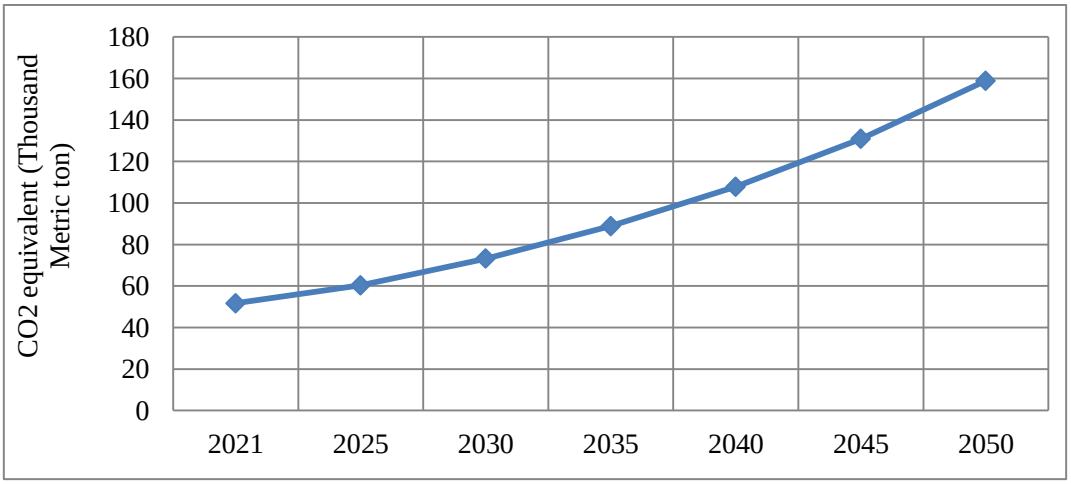


Figure 4.19: GHG emission trend at low growth scenario in Electrical and Electronics products industries

Medium Growth Scenario

Figure 4.20 shows the growth of different energy sources in in Electrical and Electronics products industries at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.76 PJ in 2021, 1.3 PJ in 2025 and 5.3 PJ in 2050.

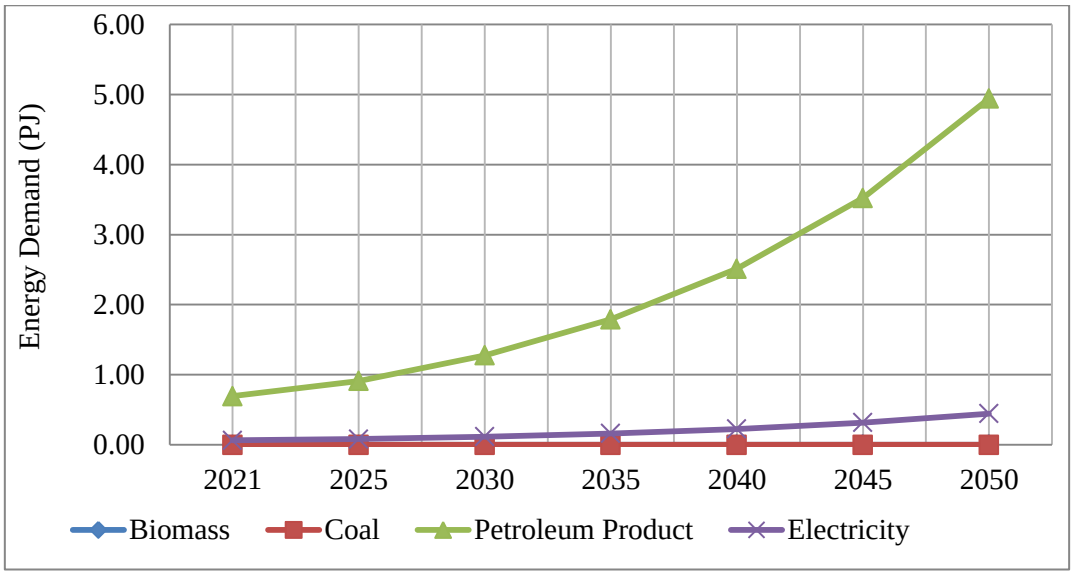


Figure 4.20: Fuel consumption trend at medium growth scenario in Electrical and Electronics products industries

Figure 4.21 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 52 thousand metric tons and would increase to 95 thousand metric tons in 2030 and again this would increase to 367 thousand metric tons in 2050.

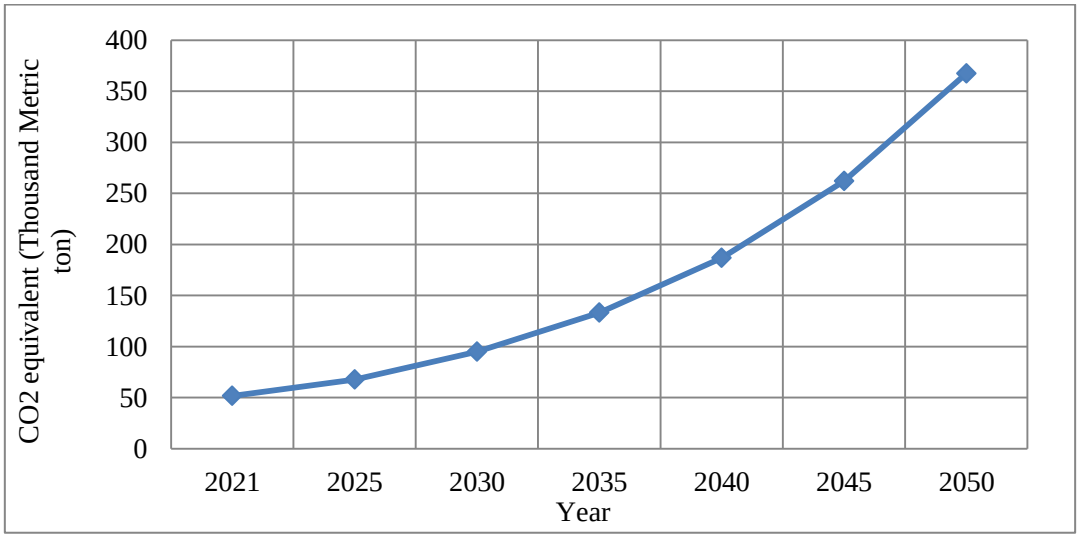


Figure 4.21: GHG emission trend at medium growth scenario in Electrical and Electronics products industries

High Growth Scenario

Figure 4.22 represents the growth of different energy sources in in Electrical and Electronics products industries at high growth rate from base year to 2050. The total energy demand in this category is expected to grow from 0.76 PJ in 2021, 2.2 PJ in 2025 and 24.2 PJ in 2050.

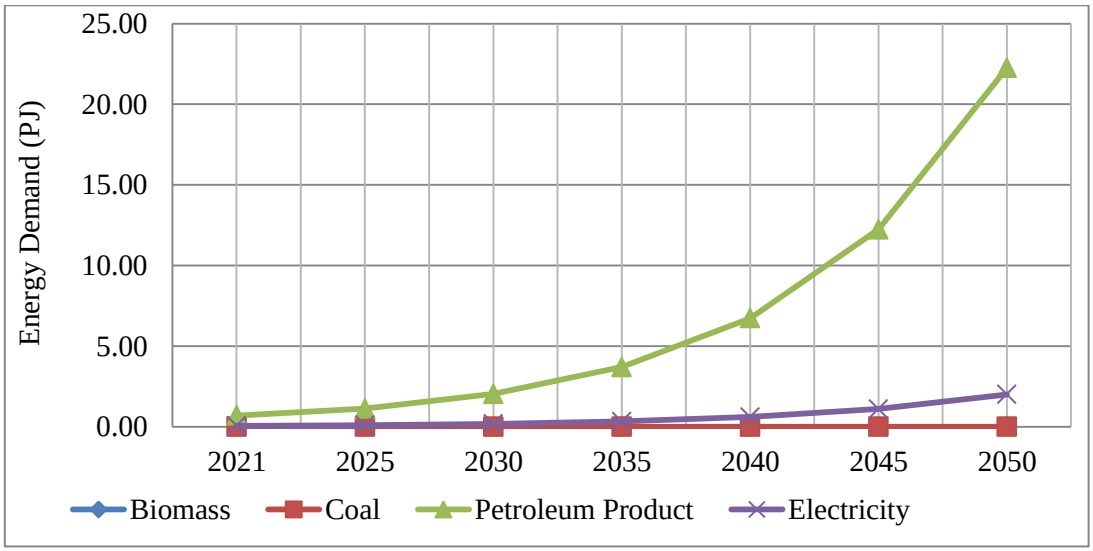


Figure 4.22: Fuel consumption trend at high growth scenario in Electrical and Electronics products industries

Figure 4.23 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 52 thousand metric tons and would increase to 152 thousand metric tons in 2030 and again this would increase to 1,655 thousand metric tons in 2050.

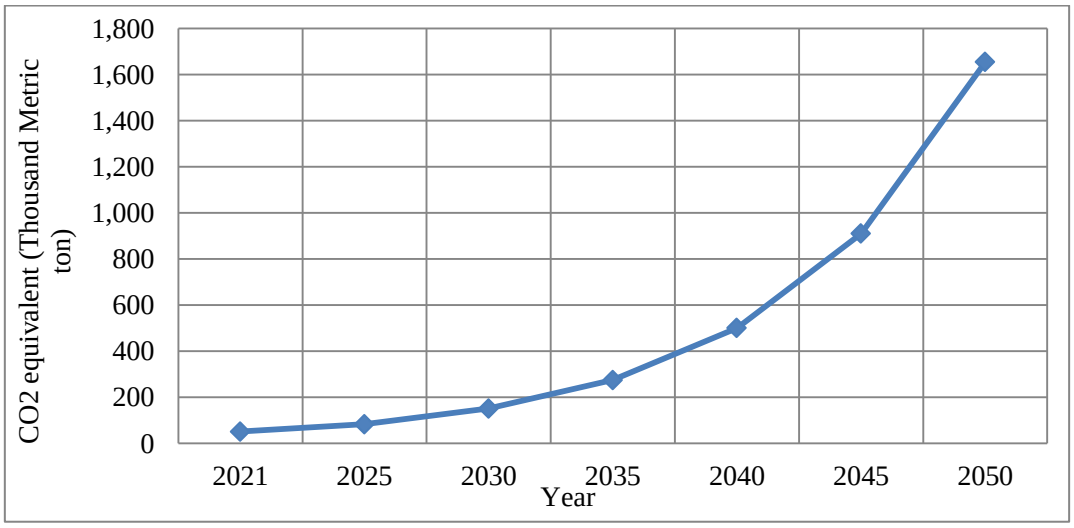


Figure 4.23: GHG emission trend at high growth scenario in Electrical and Electronics products industries

4.3.1.4 Food, Beverage and Tobacco

Low Economic Growth Scenario

Figure 4.24 depicts the growth of different energy sources in Food, Beverage and Tobacco industries at low growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 6.4 PJ in 2021, 9.1 PJ in 2025 and 19.7 PJ in 2050 which contributes for more than three folds. Biomass has highest share in all year followed by petroleum product, coal and electricity.

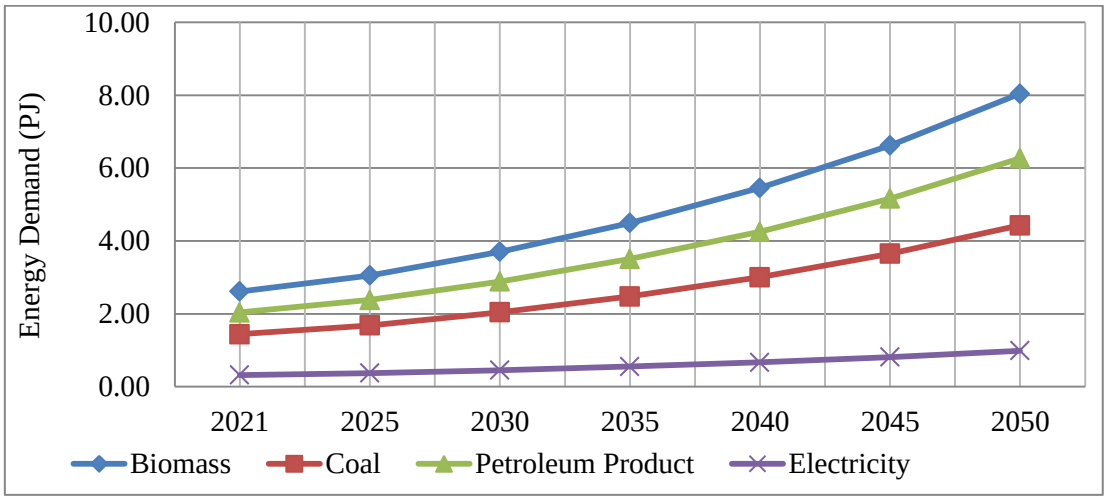


Figure 4.24: Fuel consumption trend at low growth scenario in Food, Beverage and Tobacco industries

Figure 4.25 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 533 thousand metric tons and would increase to 755 thousand metric tons in 2030 and again this would increase to 1,639 thousand metric tons in 2050.

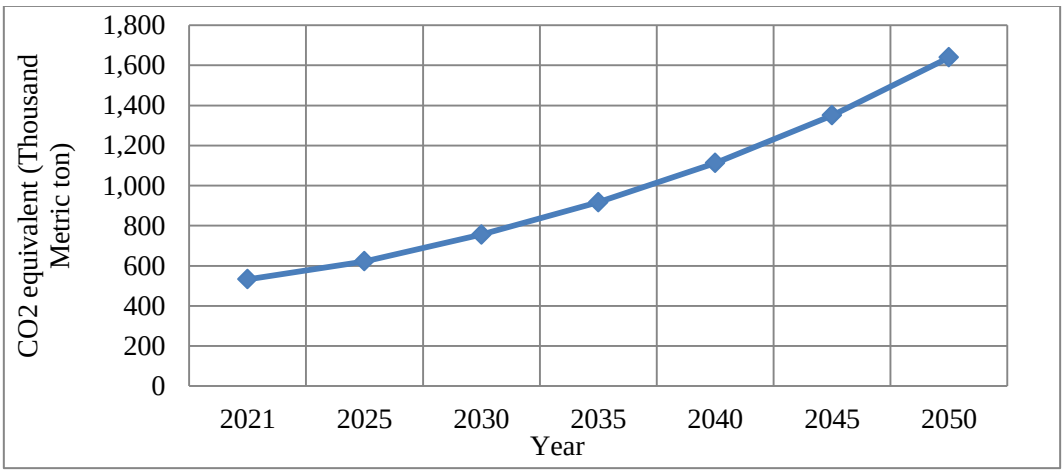


Figure 4.25: GHG emissions trend at low growth scenario in Food, Beverage and Tobacco industries

Medium Economic Growth Scenario

Figure 4.26 shows the growth of different energy sources in Food, Beverage and Tobacco industries at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 6.4 PJ in 2021, 11.7 PJ in 2025 and 45.6 PJ in 2050.

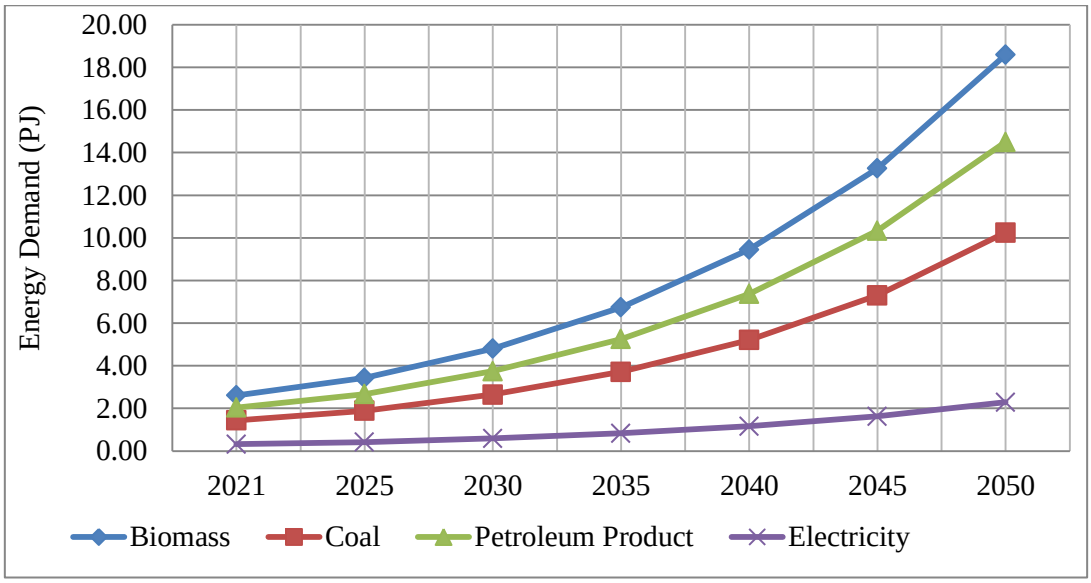


Figure 4.26: Fuel consumption trend at medium growth scenario in Food, Beverage and Tobacco industries

Figure 4.27 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 533 thousand metric tons and would increase to 980 thousand metric tons in 2030 and again this would increase to 3,791 thousand metric tons in 2050.

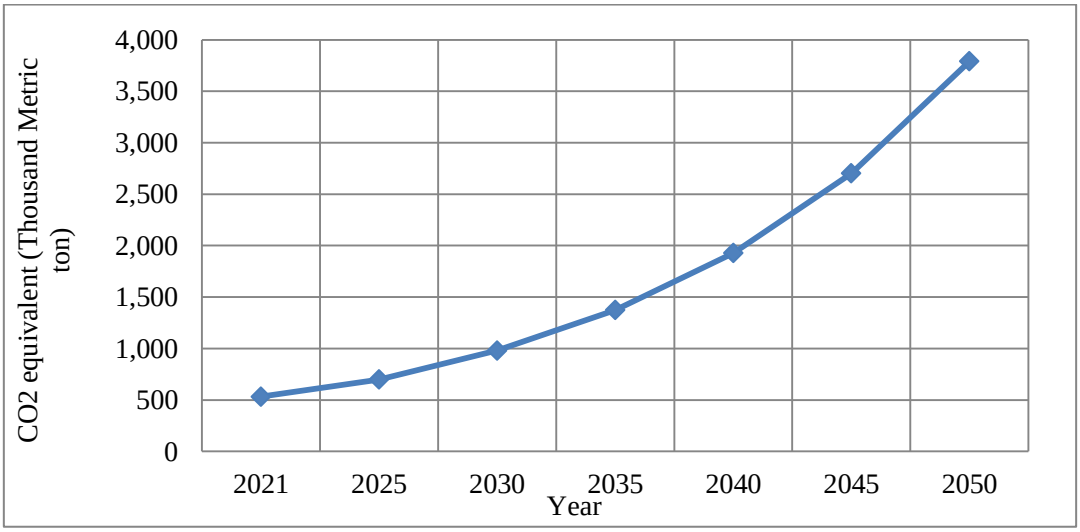


Figure 4.27: GHG emissions trend at medium growth scenario in Food, Beverage and Tobacco industries

High Economic Growth Scenario

Figure 4.28 represents the growth of different energy sources in Food, Beverage and Tobacco industries at high growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 6.4 PJ in 2021, 18.8 PJ in 2025 and 20.5 PJ in 2050.

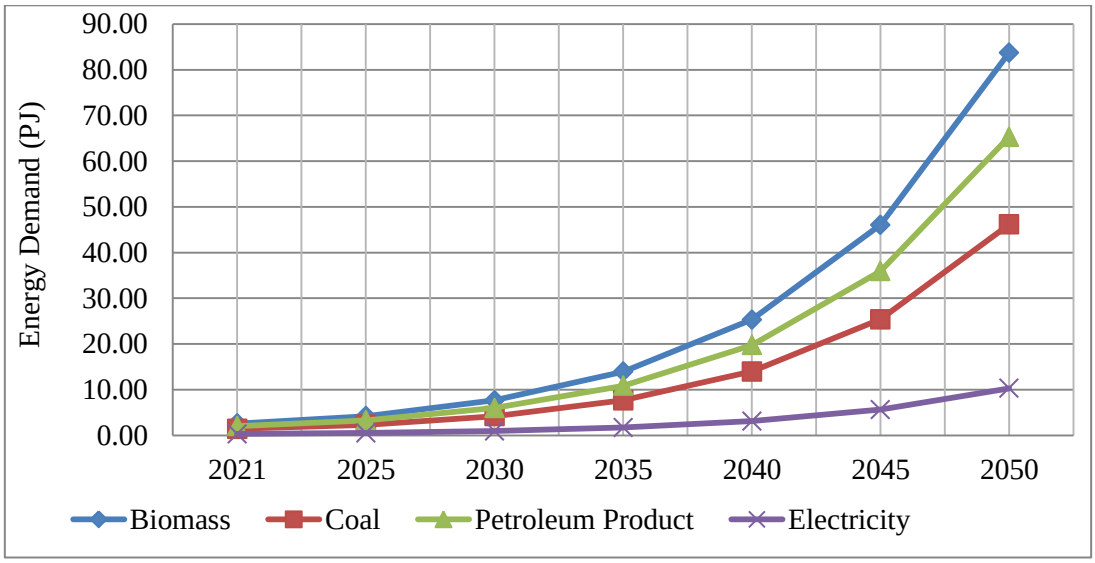


Figure 4.28: Fuel consumption trend at high growth scenario in Food, Beverage and Tobacco industries

Figure 4.29 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 533 thousand metric tons and would increase to 1,563 thousand metric tons in 2030 and again this would increase to 17,077 thousand metric tons in 2050.

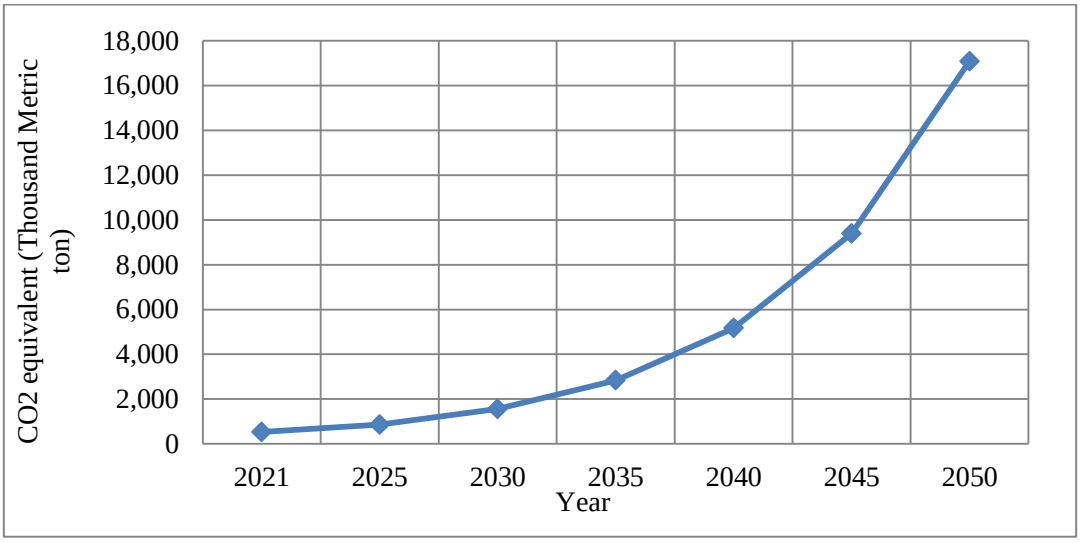


Figure 4.29: GHG emissions trend at high growth scenario in Food, Beverage and Tobacco industries

Policy Scenario

Energy consumption in Food, Beverage and Tobacco industries for policy scenario is shown in Figure 4.30. It seems that the demand of petroleum product will increase rapidly while share of coal and biomass is completed substituted. The trends of petroleum products and electricity are expected to grow at average growth rate of 9.9% and 11% respectively.

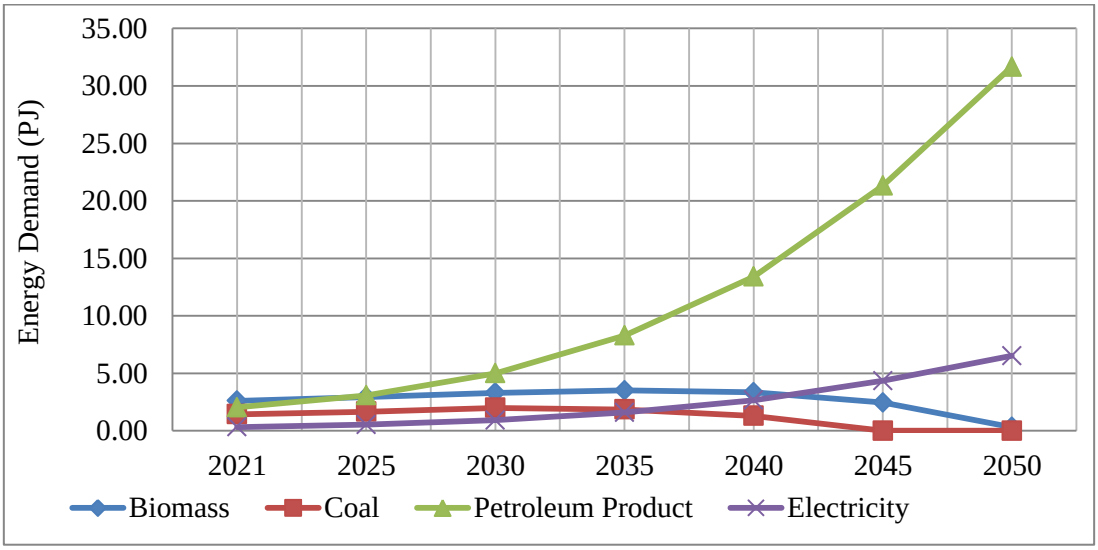


Figure 4.30: Fuel consumption trend at policy scenario in Food, Beverage and Tobacco industries

Figure 4.31 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 533 thousand metric tons and would increase to 888 thousand metric tons in 2030 and again this would increase to 2,384 thousand metric tons in 2050.

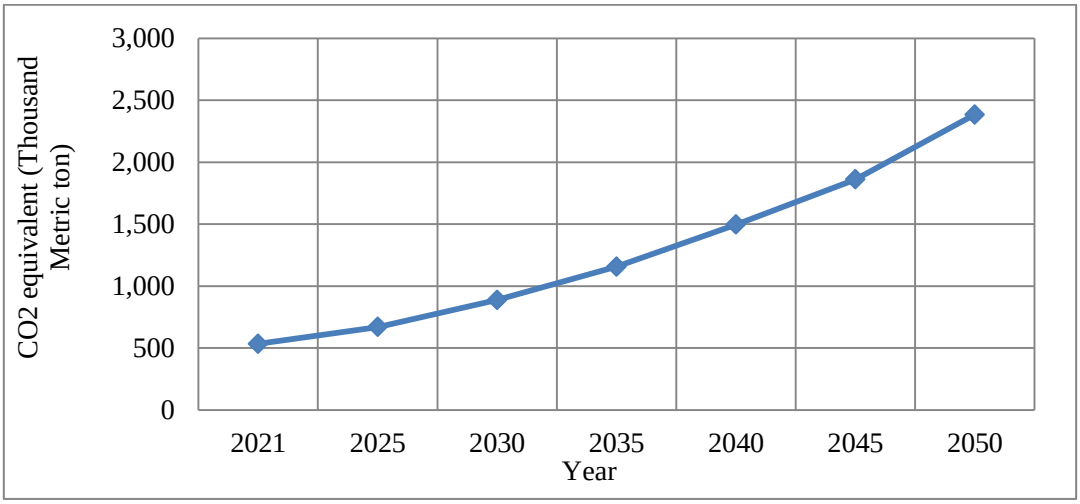


Figure 4.31: GHG emissions trend at policy scenario in Food, Beverage and Tobacco industries

4.3.1.5 Mechanical Engineering, machineries, Iron and steel and other metals

Low Economic Growth Scenario

Figure 4.32 depicts the growth of different energy sources in Mechanical Engineering, machineries, Iron and steel and other metals industries at low growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 1.7 PJ in 2021, 2.4 PJ in 2025 and 5.3 PJ in 2050 which contributes for more than three folds. Petroleum product has highest share in all year followed by coal, electricity and biomass.

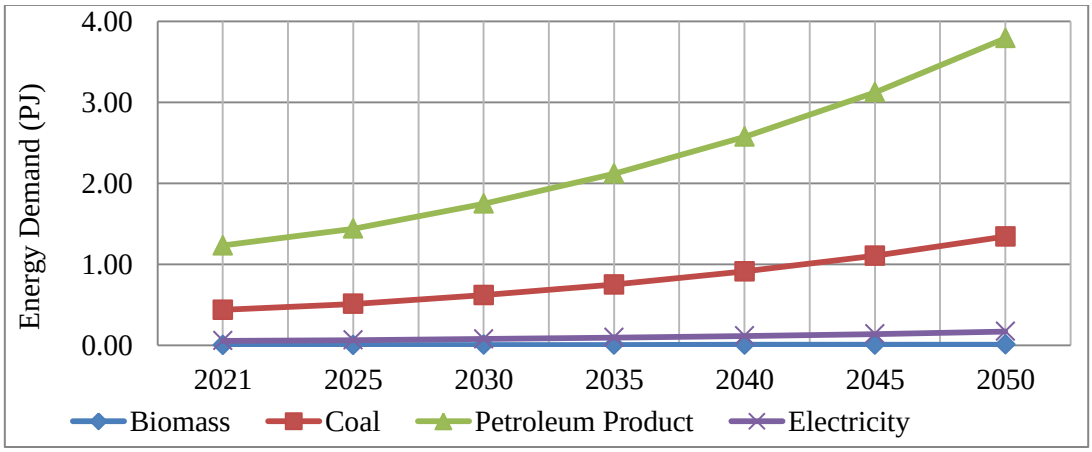


Figure 4.32: Fuel consumption trend at low growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals industries

Figure 4.33 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 134 thousand metric tons and would increase to 190 thousand metric tons in 2030 and again this would increase to 412 thousand metric tons in 2050.

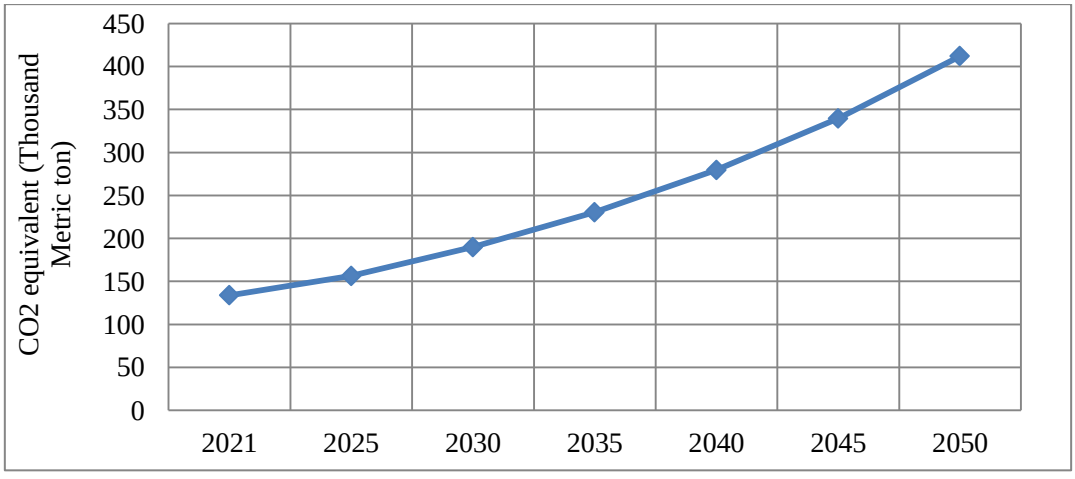


Figure 4.33: GHG emissions trend at low growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals industries

Medium Economic Growth Scenario

Figure 4.34 shows the growth of different energy sources in Mechanical Engineering, machineries, Iron and steel and other metals industries at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 1.7 PJ in 2021, 3.2 PJ in 2025 and 12.3 PJ in 2050.

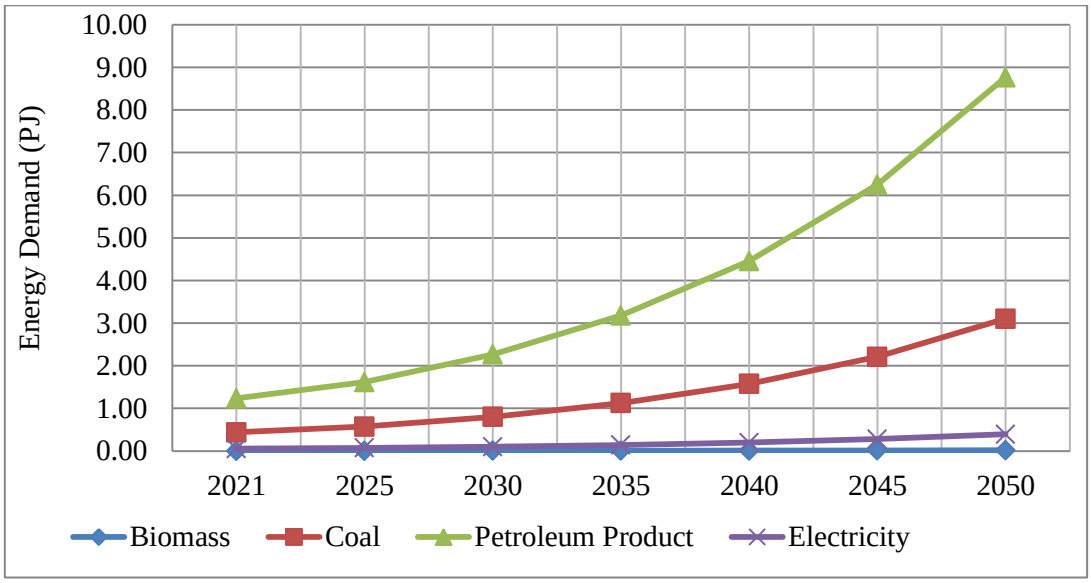


Figure 4.34: Fuel consumption trend at medium growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals industries

Figure 4.35 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 134 thousand metric tons and would increase to 246 thousand metric tons in 2030 and again this would increase to 953 thousand metric tons in 2050.

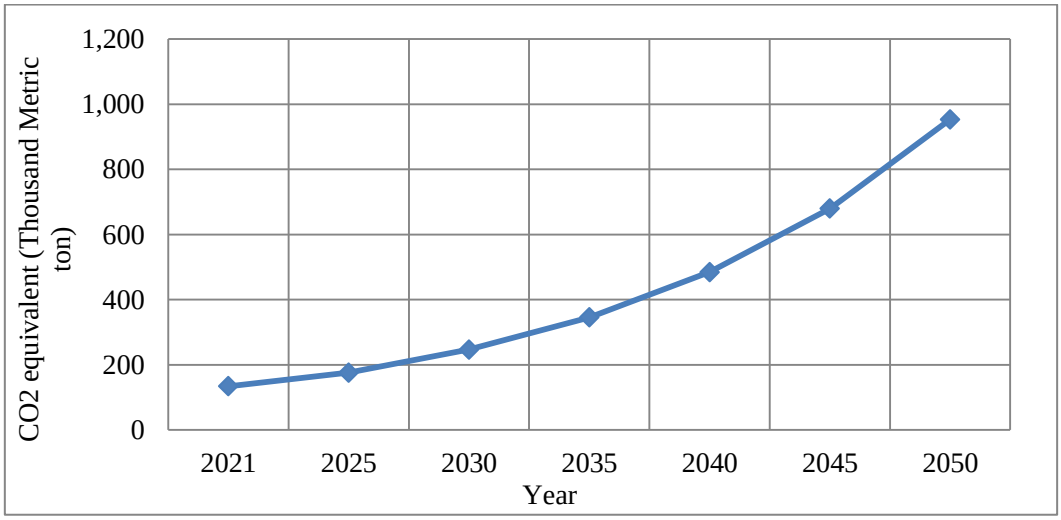


Figure 4.35: GHG emissions trend at medium growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals industries

High Economic Growth Scenario

Figure 4.36 represents the growth of different energy sources in Mechanical Engineering, machineries, Iron and steel and other metals industries at high growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 2.6 PJ in 2021, 5.0 PJ in 2025 and 55.3 PJ in 2050.

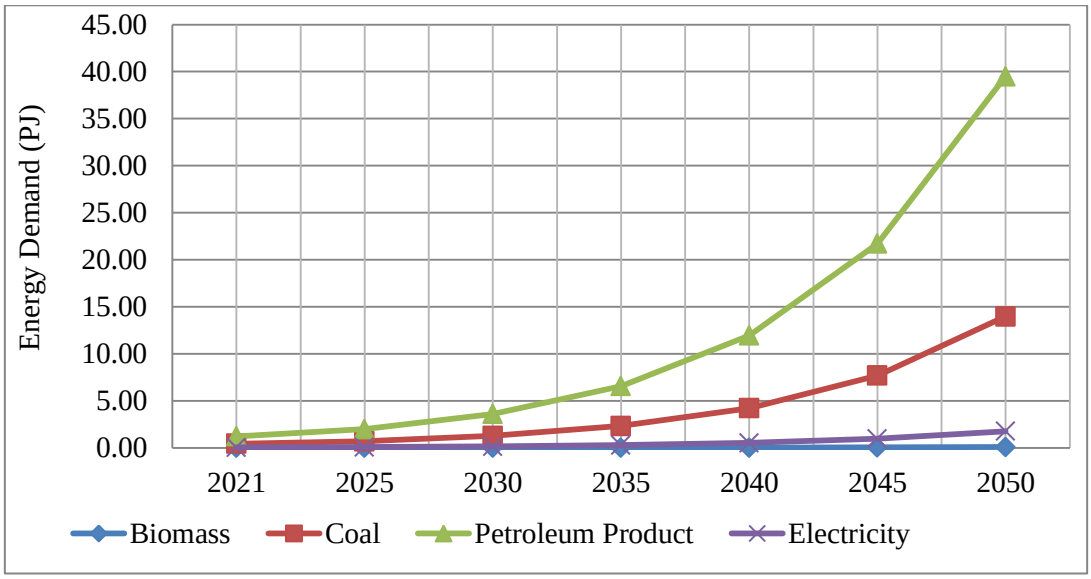


Figure 4.36: Fuel consumption trend at high growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals industries

Figure 4.37 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 134 thousand metric tons and would increase to 393 thousand metric tons in 2030 and again this would increase to 4,294 thousand metric tons in 2050.

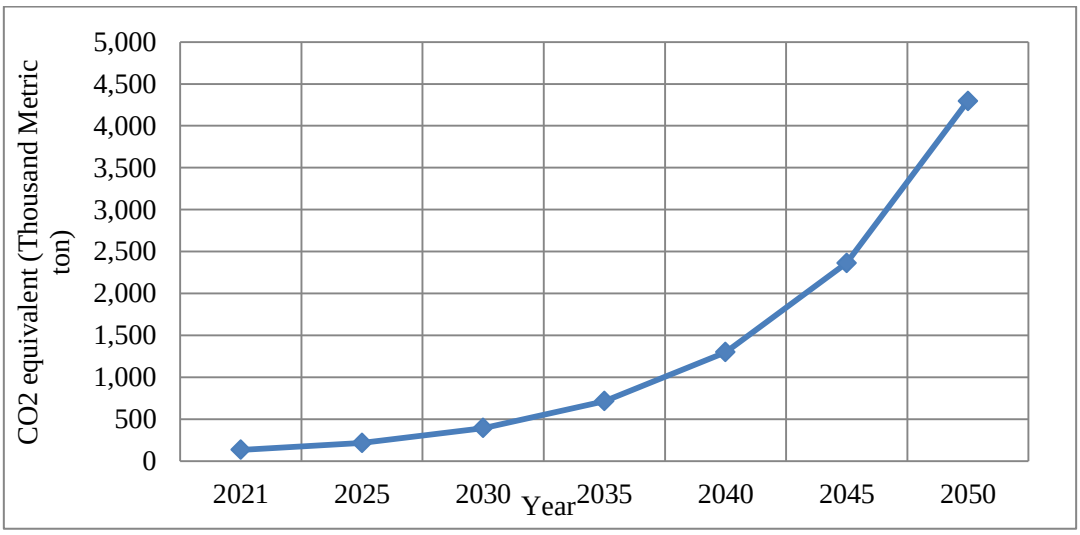


Figure 4.37: GHG emissions trend at high growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals industries

4.3.1.6 Paper, Publication & Printing, Furniture & Fixtures

Low Economic Growth Scenario

Figure 4.38 depicts the growth of different energy sources in Paper, Publication & Printing, Furniture & Fixtures industries at low growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.42 PJ in 2021, 0.6 PJ in 2025 and 1.3PJ in 2050 which contributes for more than three folds. The share of biomass is highest in all year followed by electricity and petroleum products.

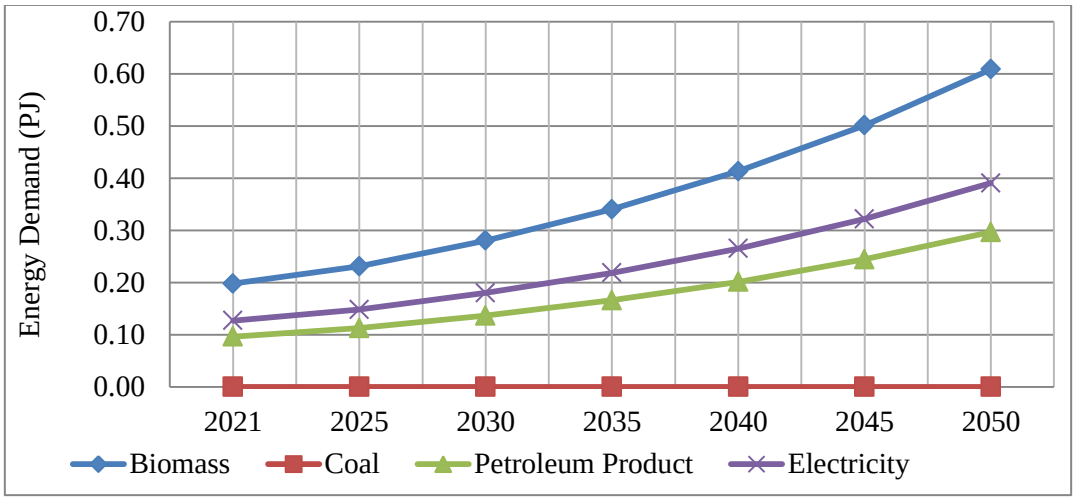


Figure 4.38: Fuel consumption trend at low growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

Figure 4.39 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 23 thousand metric tons and would increase to 33 thousand metric tons in 2030 and again this would increase to 72 thousand metric tons in 2050.

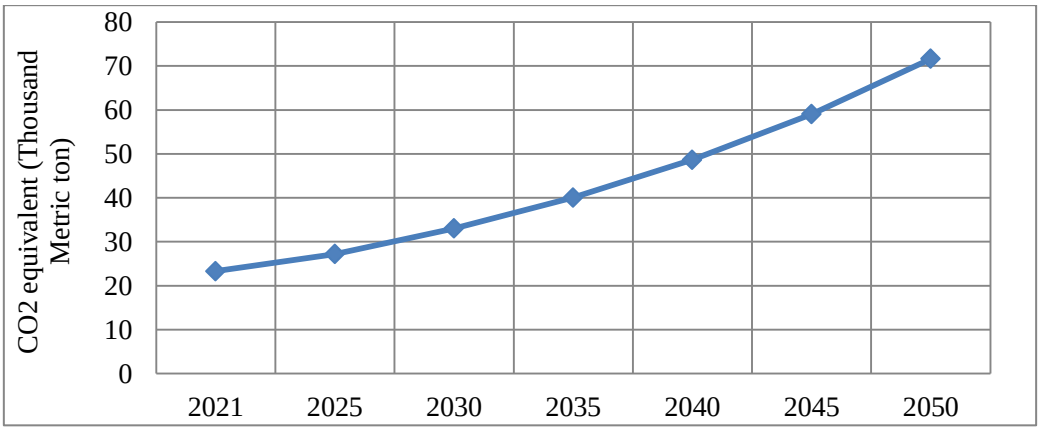


Figure 4.39: GHG emissions trend at low growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

Medium Economic Growth Scenario

Figure 4.40 shows the growth of different energy sources in Paper, Publication & Printing, Furniture & Fixtures industries at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.42 PJ in 2021, 0.74 PJ in 2025 and 2.5 PJ in 2050.

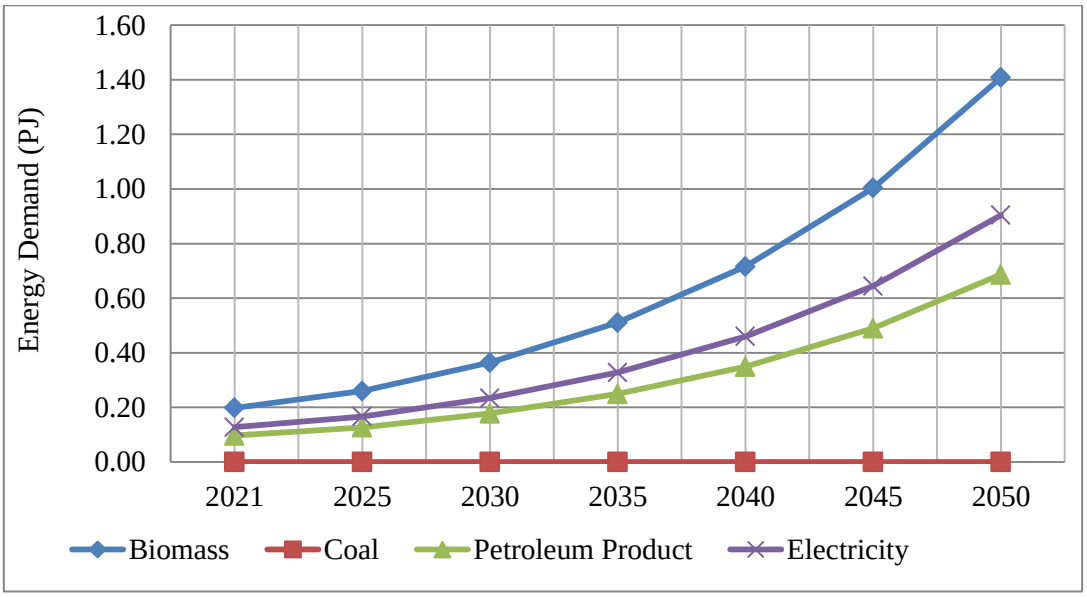


Figure 4.40: Fuel consumption trend at medium growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

Figure 4.41 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 23 thousand metric tons and would increase to 43 thousand metric tons in 2030 and again this would increase to 166 thousand metric tons in 2050.

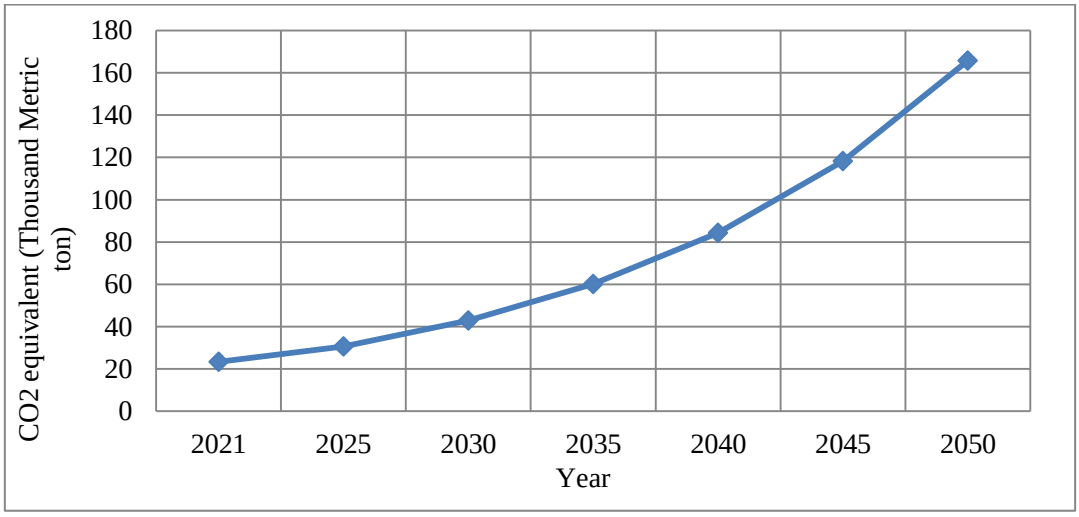


Figure 4.41: GHG emissions trend at medium growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

High Economic Growth Scenario

Figure 4.42 represents the growth of different energy sources in Paper, Publication & Printing, Furniture & Fixtures industries at high growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.42 PJ in 2021, 1.2 PJ in 2025 and 12.5 PJ in 2050.

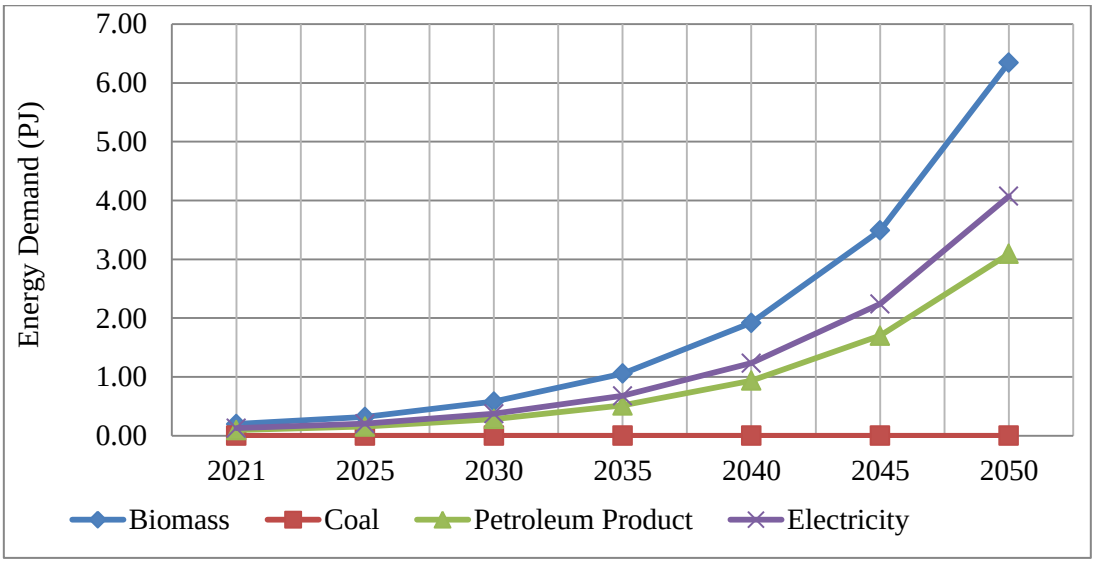


Figure 4.42: Fuel consumption trend at high growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

Figure 4.43 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 23 thousand metric tons and would increase to 68 thousand metric tons in 2030 and again this would increase to 747 thousand metric tons in 2050.

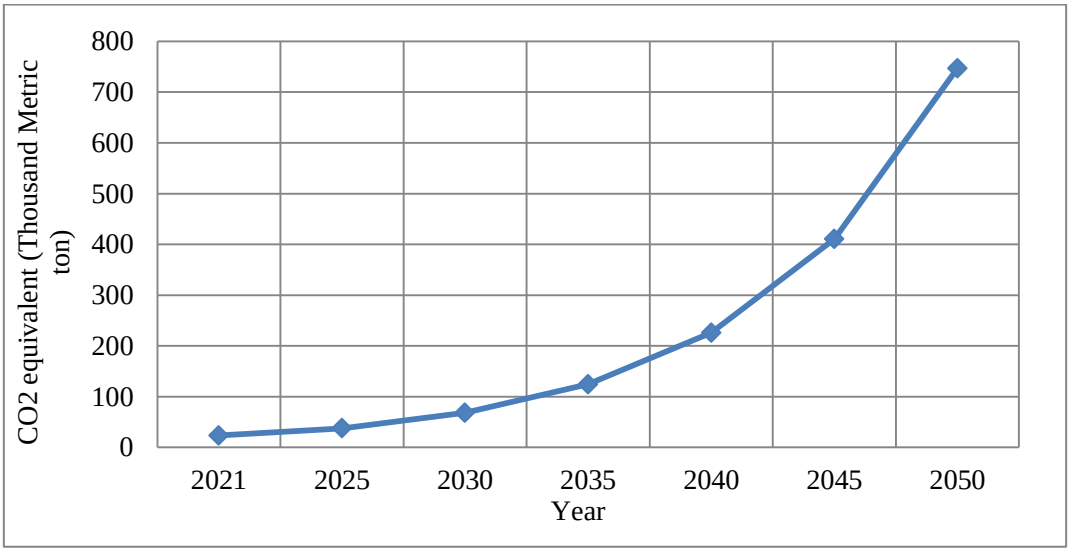


Figure 4.43: GHG emissions trend at high growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

Policy Scenario

Energy consumption in in Paper, Publication & Printing, Furniture & Fixtures industries for policy scenario is shown in Figure 4.44. It seems that the demand of petroleum product and electricity will increase rapidly while share of coal and biomass is completed replaced. The trends of petroleum products and electricity are expected to grow at average growth rate of 10% and 8% respectively.

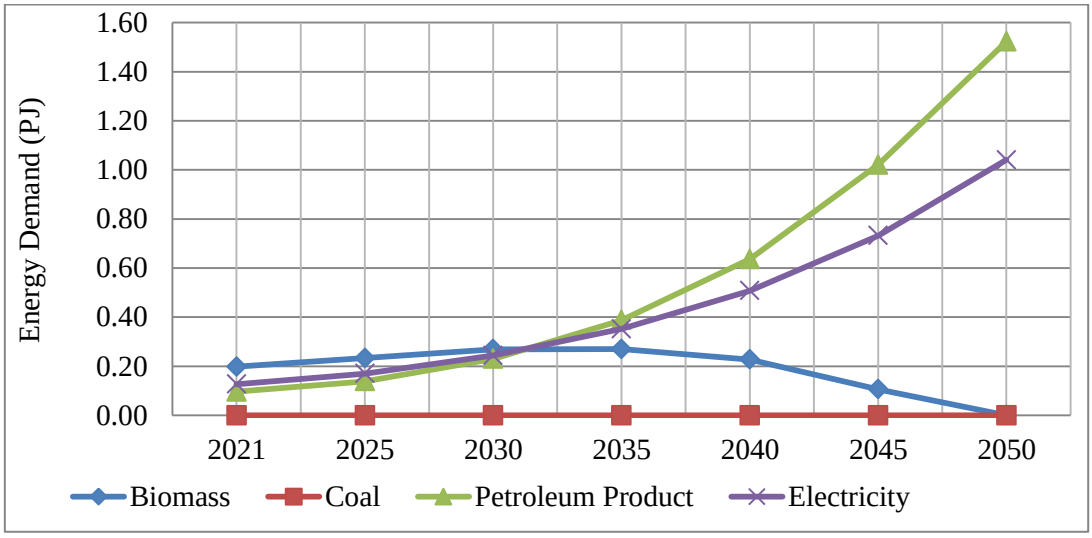


Figure 4.44: Fuel consumption trend at policy growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

Figure 4.45 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 23 thousand metric tons and would increase to 38 thousand metric tons in 2030 and again this would increase to 94 thousand metric tons in 2050.

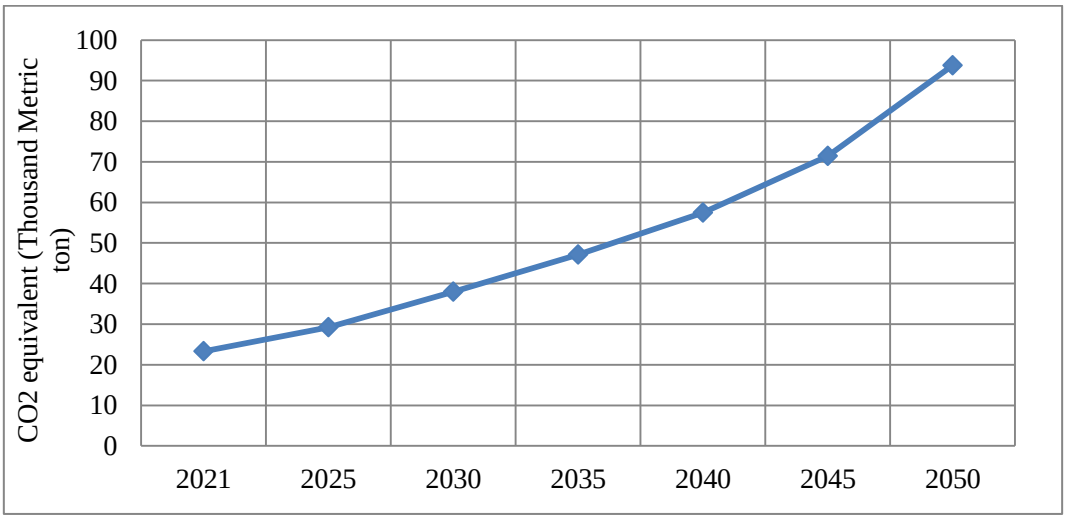


Figure 4.45: GHG emissions trend at policy growth scenario in Paper, Publication & Printing, Furniture & Fixtures industries

4.3.1.7 Textiles, Readymade Garment & Leather Products

Low Economic Growth Scenario

Figure 4.46 depicts the growth of different energy sources in Textiles, Readymade Garment & Leather Products industries at low growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 2.7 PJ in 2021, 3.8 PJ in 2025 and 8.2 PJ in 2050 which contributes for more than three folds. Coal has highest share in all year followed by petroleum product, biomass and electricity.

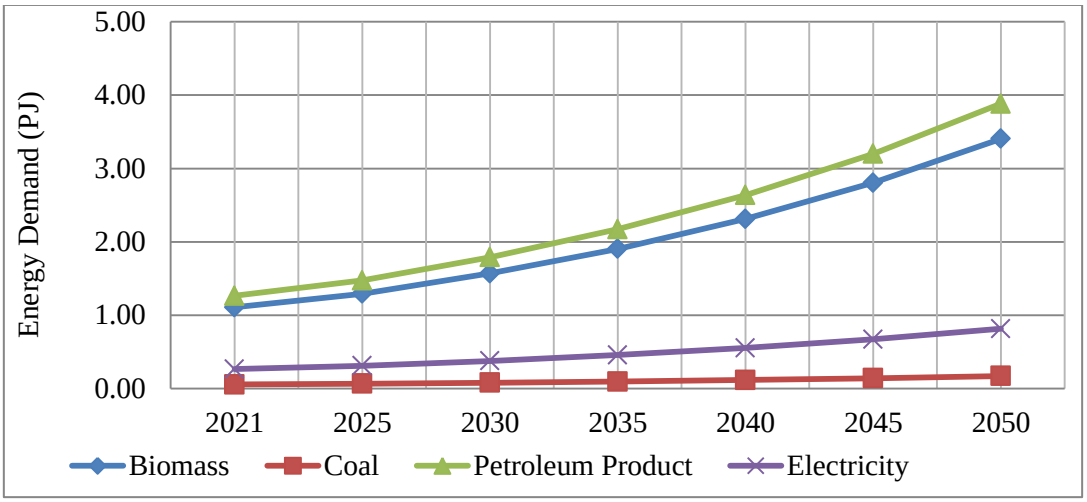


Figure 4.46: Fuel consumption trend at low growth scenario in Textiles, Readymade Garment & Leather Products industries

Figure 4.47 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 167 thousand metric tons and would increase to 236 thousand metric tons in 2030 and again this would increase to 513 thousand metric tons in 2050.

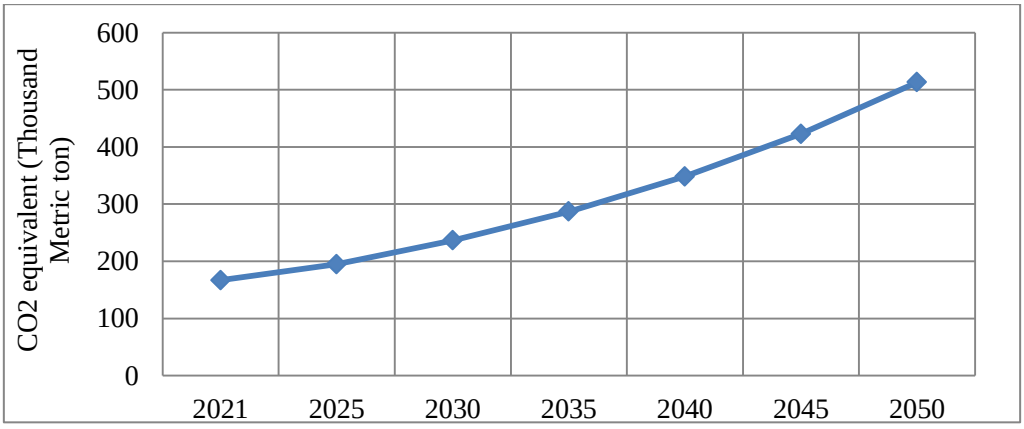


Figure 4.47: GHG emissions trend at low growth scenario in Textiles, Readymade Garment & Leather Products industries

Medium Economic Growth Scenario

Figure 4.48 shows the growth of different energy sources in Textiles, Readymade Garment & Leather Products industries at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 2.7 PJ in 2021, 4.8 PJ in 2025 and 16.6 PJ in 2050.

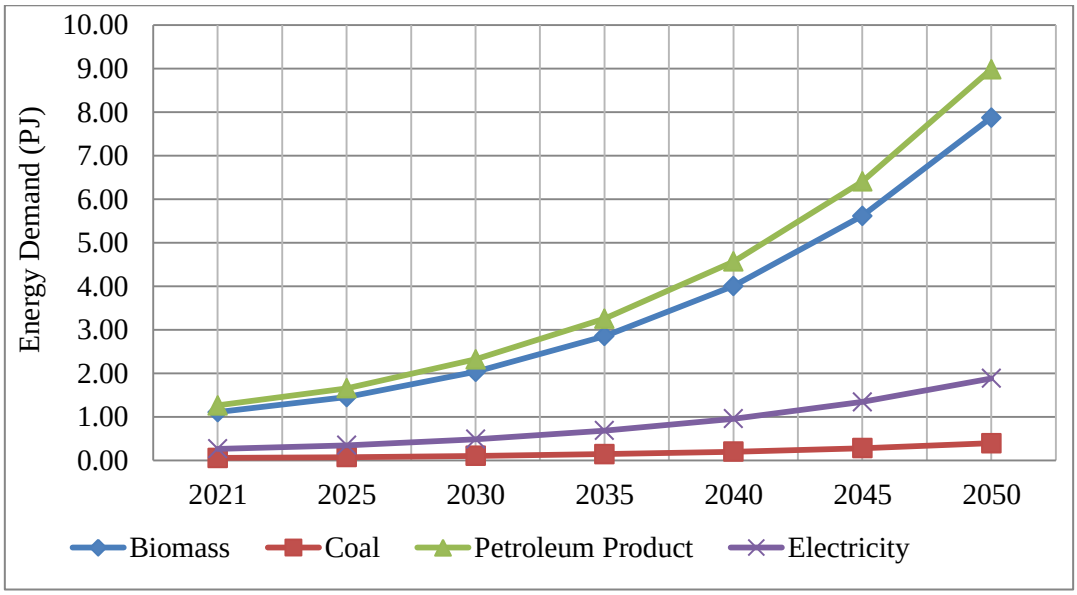


Figure 4.48: Fuel consumption trend at medium growth scenario in Textiles, Readymade Garment & Leather Products industries

Figure 4.49 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 167 thousand metric tons and would increase to 307 thousand metric tons in 2030 and again this would increase to 1,187 thousand metric tons in 2050.

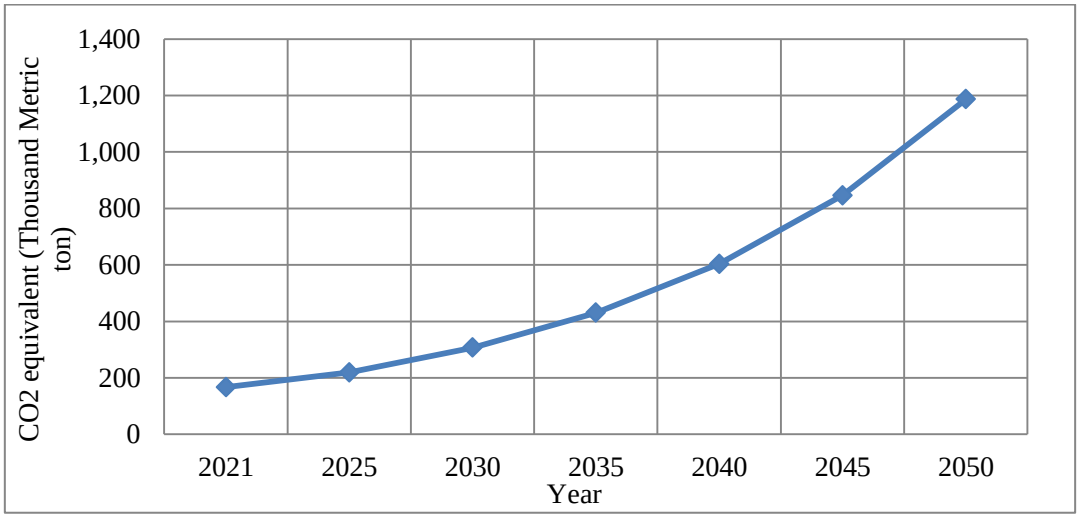


Figure 4.49: GHG emissions trend at medium growth scenario in Textiles, Readymade Garment & Leather Products industries

High Economic Growth Scenario

Figure 4.50 represents the growth of different energy sources in Textiles, Readymade Garment & Leather Products industries at high growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 2.6 PJ in 2021, 7.8 PJ in 2025 and 86.0 PJ in 2050. Coal has highest share in all year followed by petroleum product, biomass and electricity.

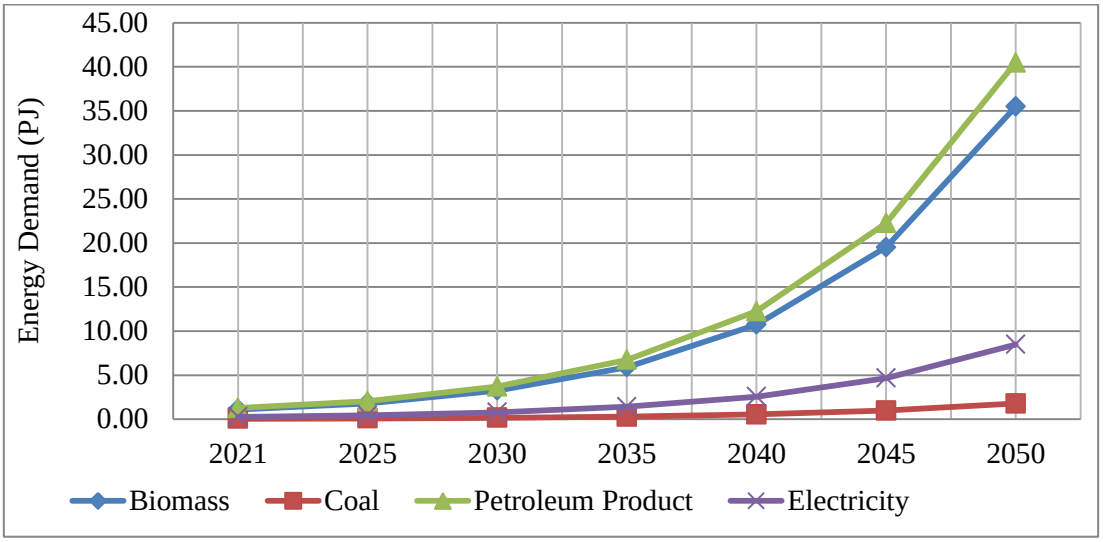


Figure 4.50: Fuel consumption trend at high growth scenario in Textiles, Readymade Garment & Leather Products industries

Figure 4.51 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 167 thousand metric tons and would increase to 489 thousand metric tons in 2030 and again this would increase to 5,346 thousand metric tons in 2050.

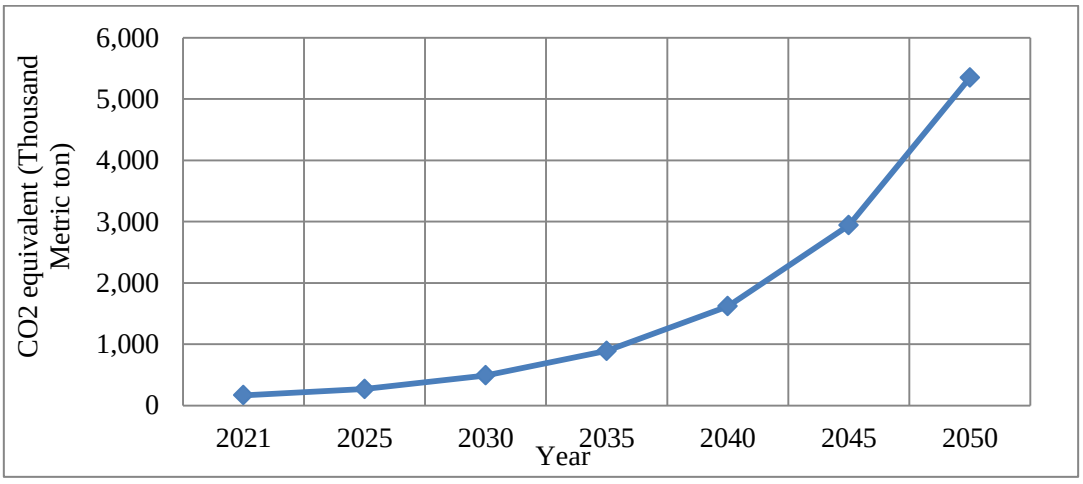


Figure 4.51: GHG emissions trend at high growth scenario in Textiles, Readymade Garment & Leather Products industries

Policy Scenario

Energy consumption in Textiles, Readymade Garment & Leather Products industries for policy scenario is shown in Figure 4.52. It seems that the demand of petroleum product and electricity will increase rapidly while share of coal and biomass is completed replaced. The trends of petroleum products and electricity are expected to grow at average growth rate of 8% and 11% respectively.

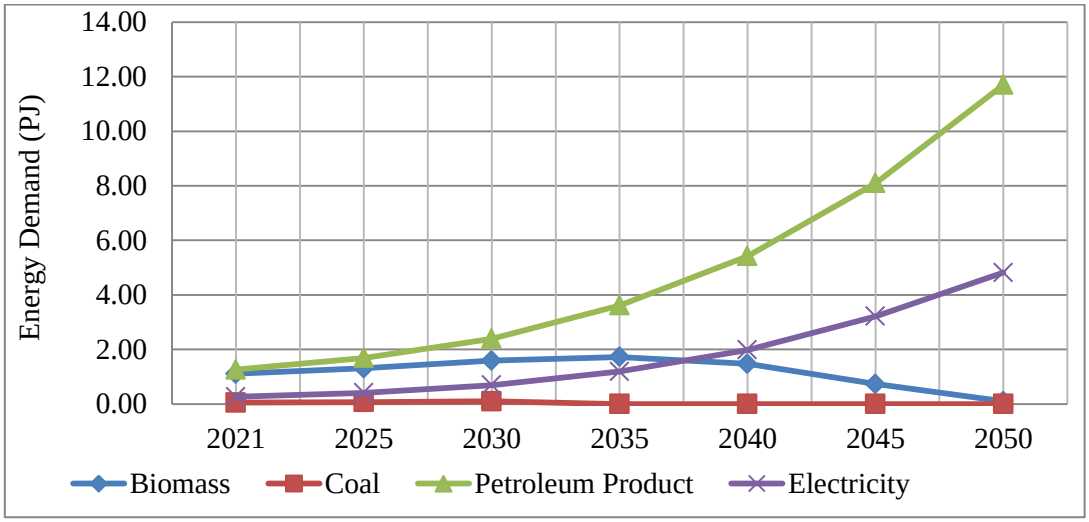


Figure 4.52: Fuel consumption trend at policy growth scenario in Textiles, Readymade Garment & Leather Products industries

Figure 4.53 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 167 thousand metric tons and would increase to 275 thousand metric tons in 2030 and again this would increase to 804 thousand metric tons in 2050.

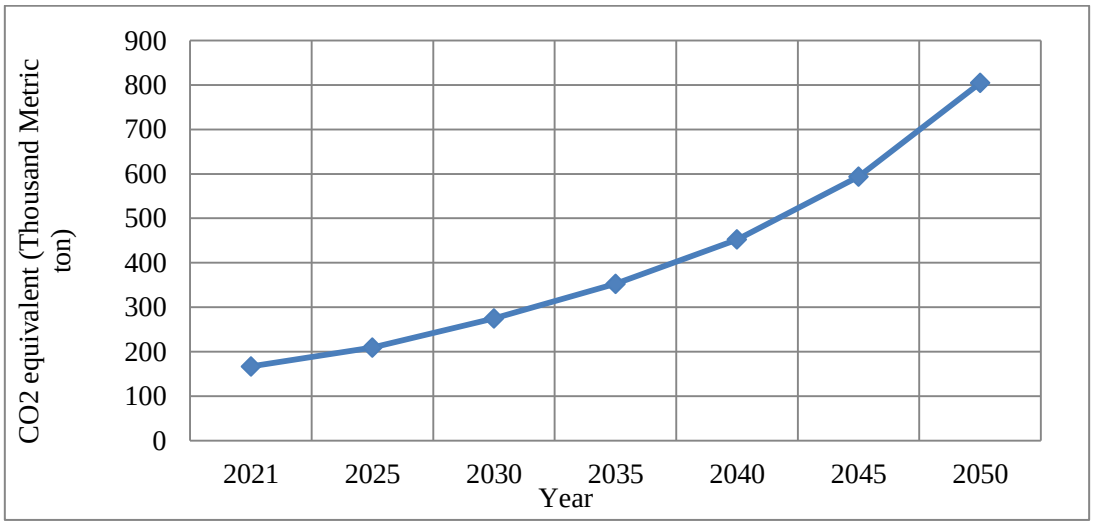


Figure 4.53: GHG emissions trend at policy scenario in Textiles, Readymade Garment & Leather Products industries

4.3.1.8 Miscellaneous

Low Economic Growth Scenario

Figure 4.54 depicts the growth of different energy sources in Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.) industries at low growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.06 PJ in 2021, 0.08 PJ in 2025 and 0.18 PJ in 2050 which contributes for more than three folds. Petroleum products has highest share in all year followed electricity.

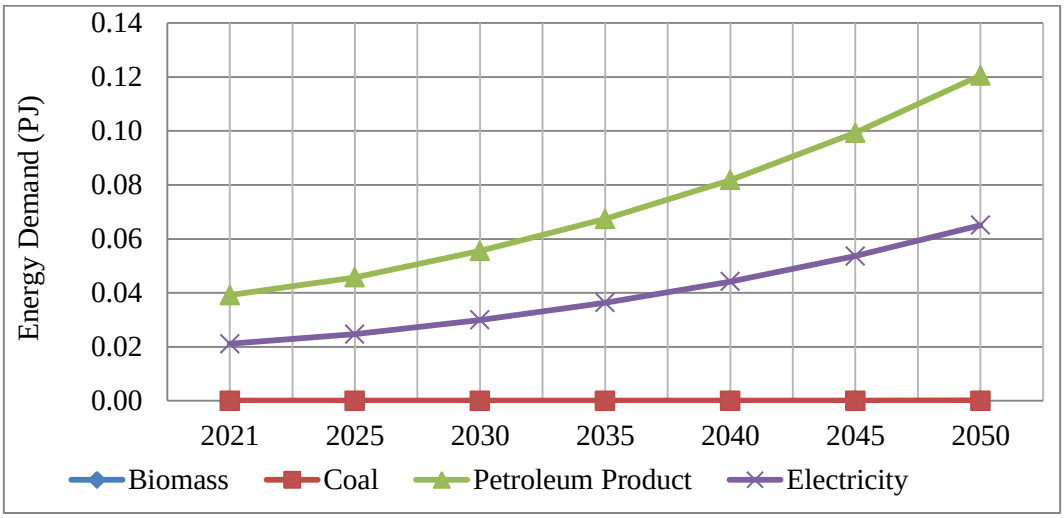


Figure 4.54: Fuel consumption trend at low growth scenario in Miscellaneous products industries

Figure 4.55 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 3 thousand metric tons and would increase to 4 thousand metric tons in 2030 and again this would increase to 9 thousand metric tons in 2050.

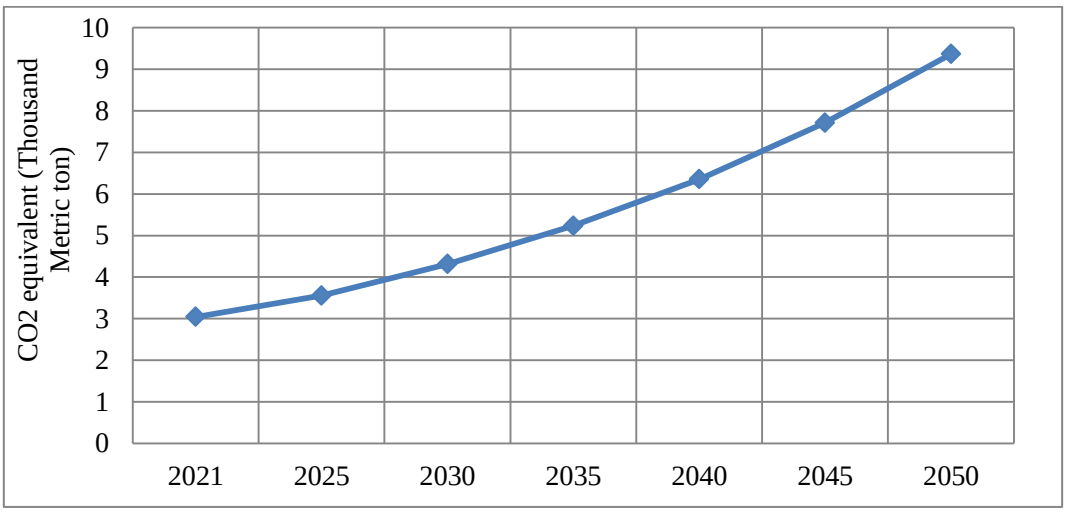


Figure 4.55: GHG emissions trend at low growth scenario in miscellaneous products industries

Medium Economic Growth Scenario

Figure 4.56 shows the growth of different energy sources in Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.) industries at medium growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.06 PJ in 2021, 0.1 PJ in 2025 and 0.4 PJ in 2050.

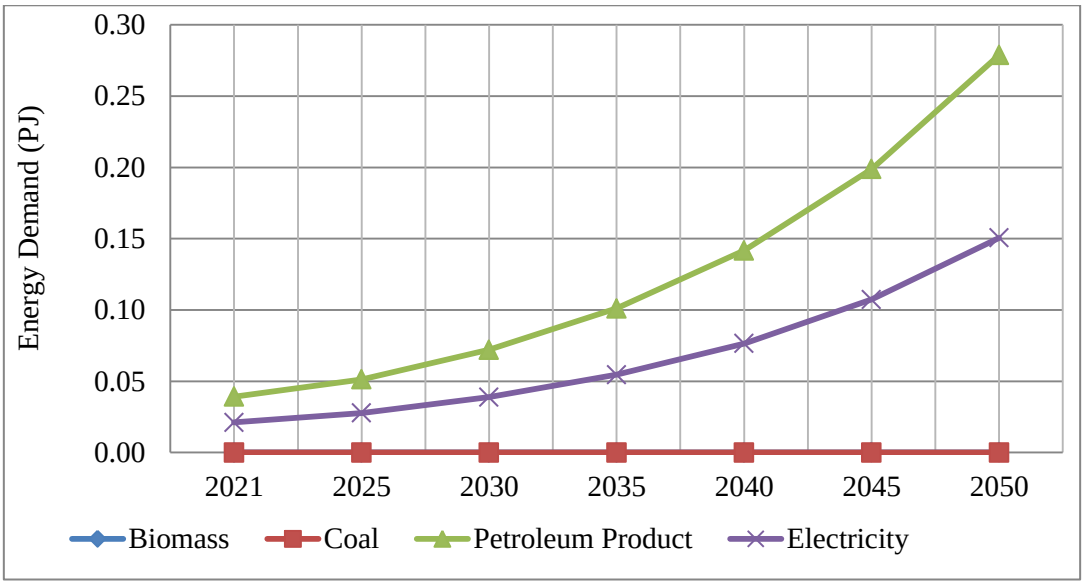


Figure 4.56: Fuel consumption trend at medium growth scenario in Miscellaneous products industries

Figure 4.57 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 3 thousand metric tons and would increase to 6 thousand metric tons in 2030 and again this would increase to 22 thousand metric tons in 2050.

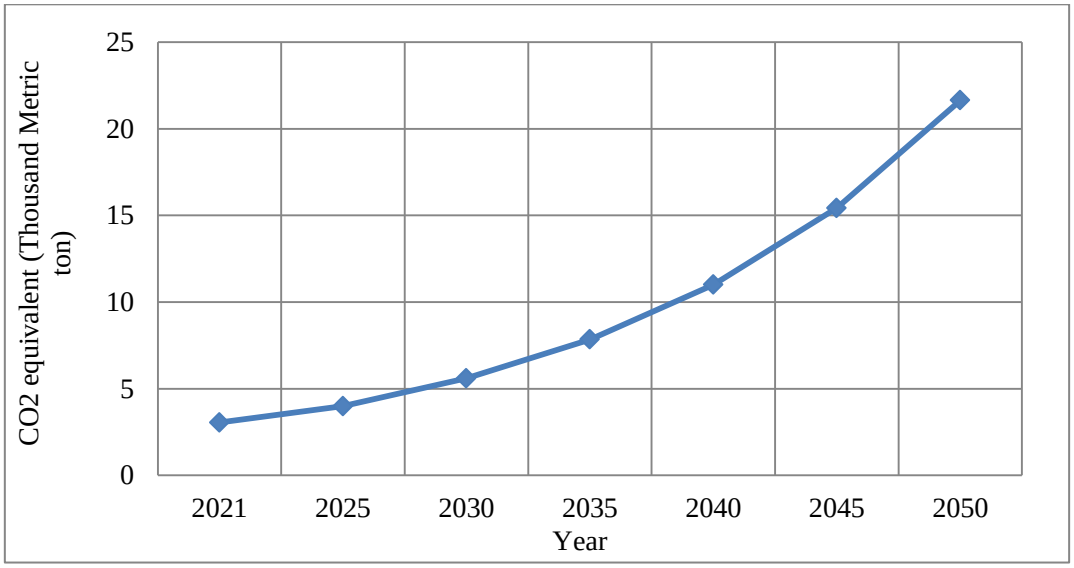


Figure 4.57: GHG emissions trend at medium growth scenario in miscellaneous products industries

High Economic Growth Scenario

Figure 4.58 represents the growth of different energy sources in Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.) industries at high growth rate from base year to 2050. The total energy consumption in this category is expected to grow from 0.06 PJ in 2021, 0.08 PJ in 2025 and 1.9 PJ in 2050.

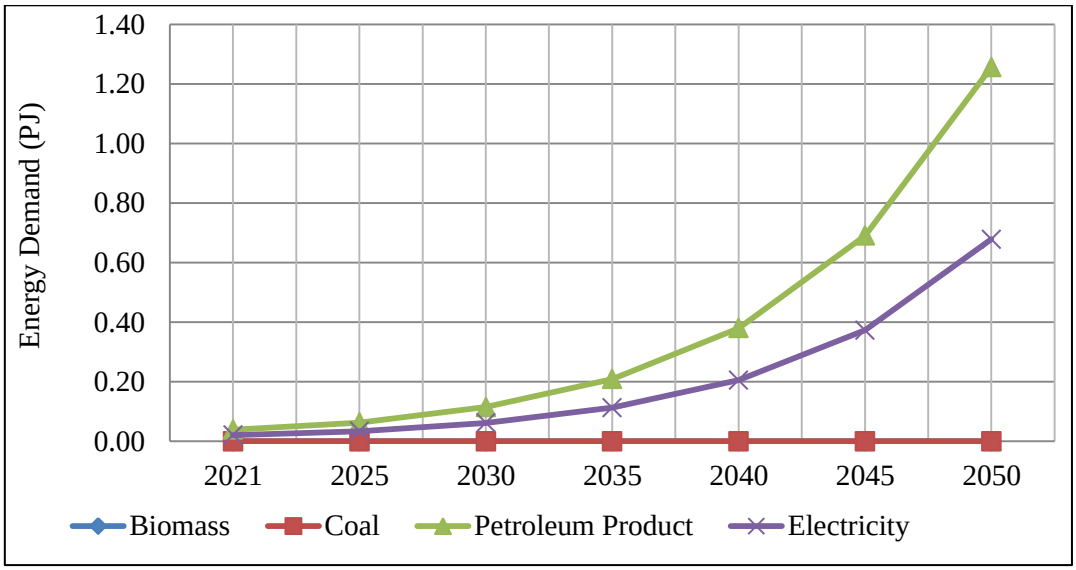


Figure 4.58: Fuel consumption trend at high growth scenario in Miscellaneous products industries

Figure 4.59 shows the trends of GHG emission for low economic growth rate scenario. GHG emission was 3 thousand metric tons and would increase to 9 thousand metric tons in 2030 and again this would increase to 97 thousand metric tons in 2050.

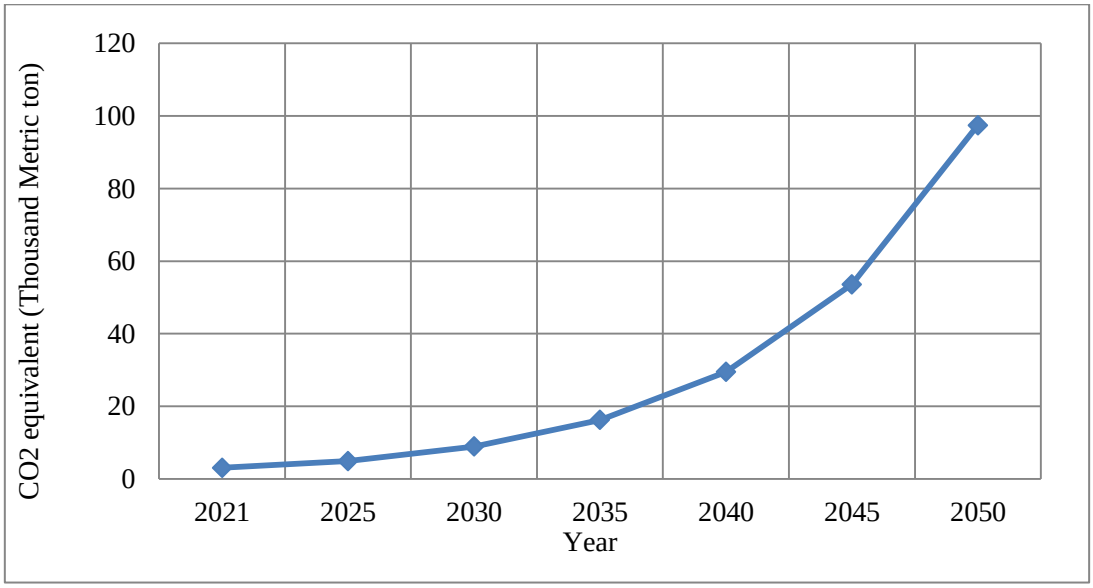


Figure 4.59: GHG emissions trend at high growth scenario in miscellaneous products industries

4.3.2 Total Energy Demand

Low Economic Growth Scenario

Table 4.2 depicts the total energy demand of various fuels for low economic growth rate from base year 2021 to 2050. The total energy demand for industrial sector from base year 2021 to 2050 is expected to grow at average annual growth rate of 3.95% from 16 PJ in 2021, 23 PJ in 2030 and 50 PJ in 2050 which has increased in more than three folds.

Table 4.2: Fuel consumption at low growth scenario by overall Industrial sector (PJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	2.38	2.77	3.37	4.09	4.96	6.02	7.31
Agriculture residue	2.05	2.40	2.91	3.53	4.29	5.21	6.32
Coal	3.48	4.06	4.93	5.99	7.27	8.82	10.70
Kerosene	0.06	0.08	0.09	0.11	0.13	0.16	0.20
Furnace oil	0.88	1.03	1.25	1.52	1.85	2.24	2.72
Diesel	6.20	7.24	8.79	10.66	12.94	15.71	19.07
LPG	0.30	0.35	0.42	0.51	0.62	0.75	0.91
Electricity	0.96	1.12	1.36	1.65	2.00	2.43	2.95
Petrol	0.06	0.07	0.09	0.11	0.13	0.16	0.19
Total	16.38	19.12	23.21	28.17	34.19	41.50	50.37

Figure 4.60 shows the trends of consumption of different category of energy sources. The demand of petroleum product is expected to be higher in all the year which is followed by biomass, coal and electricity.

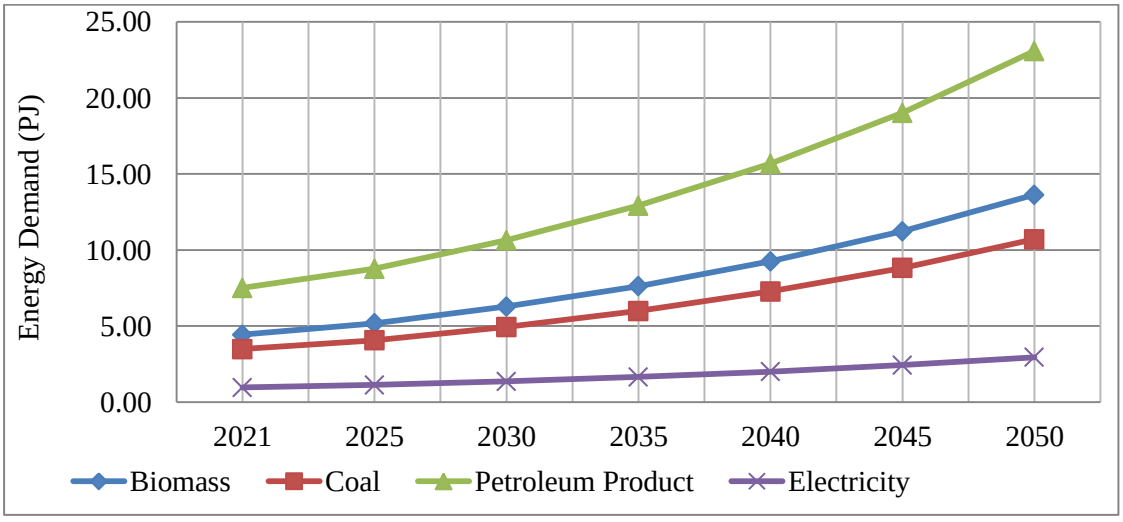


Figure 4.60: Fuel consumption trend at low growth scenario by overall Industrial sector

Figure 4.61 shows the GHG emission for low economic growth rate scenario. GHG emission was 1,249.6 thousand metric tons and would increase to 1770.8 thousand metric tons in 2030 and again this would increase to 3842.8 thousand metric tons in 2050.

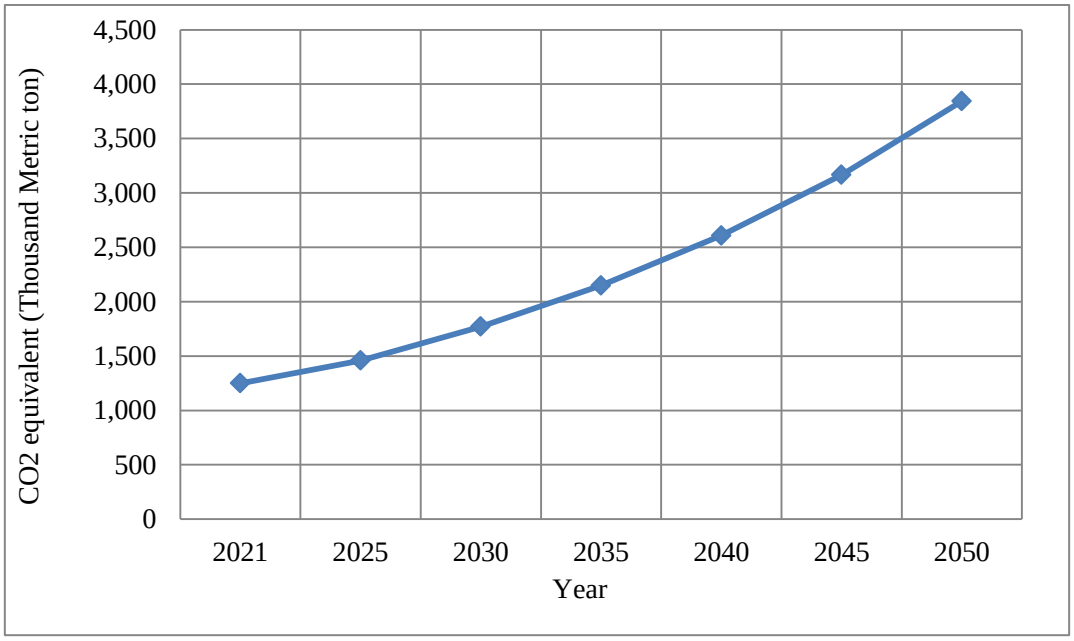


Figure 4.61: GHG emission at low growth scenario by overall Industrial sector

Medium Economic Growth Scenario

Table 4.3 represents the total energy demand of various fuels types for medium economic growth rate from base year 2021 to 2050. The total energy demand for industrial sector from base year 2021 to 2050 is expected to grow at average annual growth rate of 7% from 16 PJ in 2021, 30 PJ in 2030 and 116 PJ in 2050.

Table 4.3: Fuel consumption trend at medium growth scenario by overall Industrial sector (PJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	2.38	3.11	4.37	6.13	8.59	12.05	16.91
Agriculture residue	2.05	2.69	3.78	5.30	7.43	10.42	14.61
Coal	3.48	4.56	6.40	8.98	12.59	17.66	24.76
Kerosene	0.06	0.08	0.12	0.17	0.23	0.33	0.46
Furnace oil	0.88	1.16	1.63	2.28	3.20	4.48	6.29
Diesel	6.20	8.13	11.40	15.99	22.42	31.45	44.11
LPG	0.30	0.39	0.55	0.77	1.08	1.51	2.12
Electricity	0.96	1.26	1.76	2.47	3.47	4.86	6.82
Petrol	0.06	0.08	0.11	0.16	0.22	0.31	0.44
Total	16.38	21.47	30.11	42.23	59.23	83.07	116.52

Figure 4.62 shows the trends of consumption of different category of energy sources. The demand of petroleum product is expected to be higher in all the year which is followed by biomass, coal and electricity.

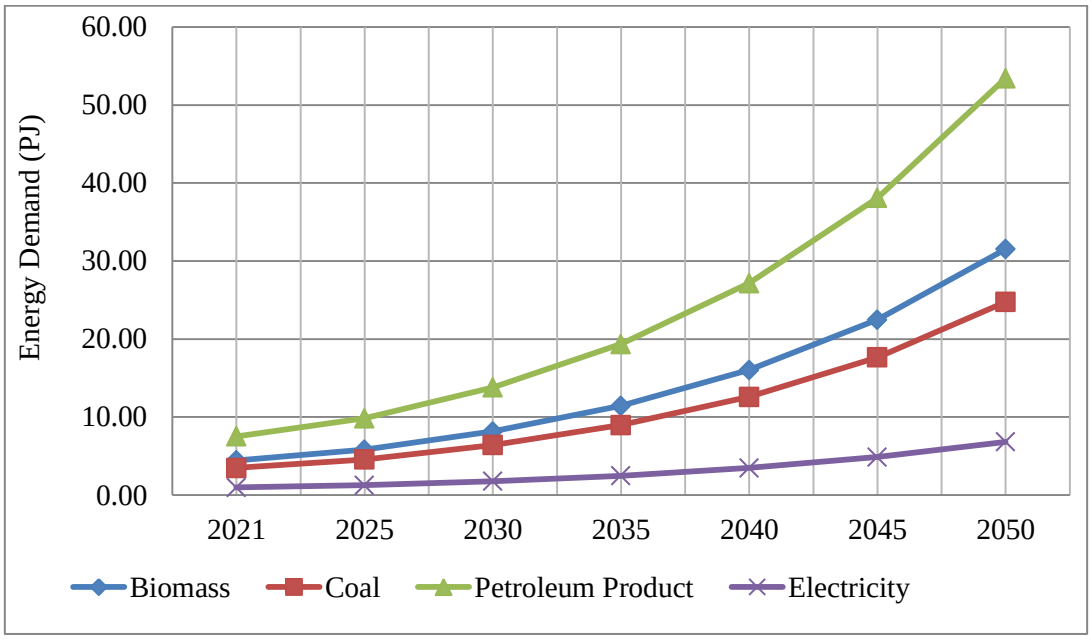


Figure 4.62: Fuel consumption trend at medium growth scenario by overall Industrial sector

Figure 4.63 shows the GHG emission for medium economic growth rate scenario. GHG emission was 1,249.6 thousand metric tons and would increase to 2297 thousand metric tons in 2030 and again this would increase to 8890 thousand metric tons in 2050.

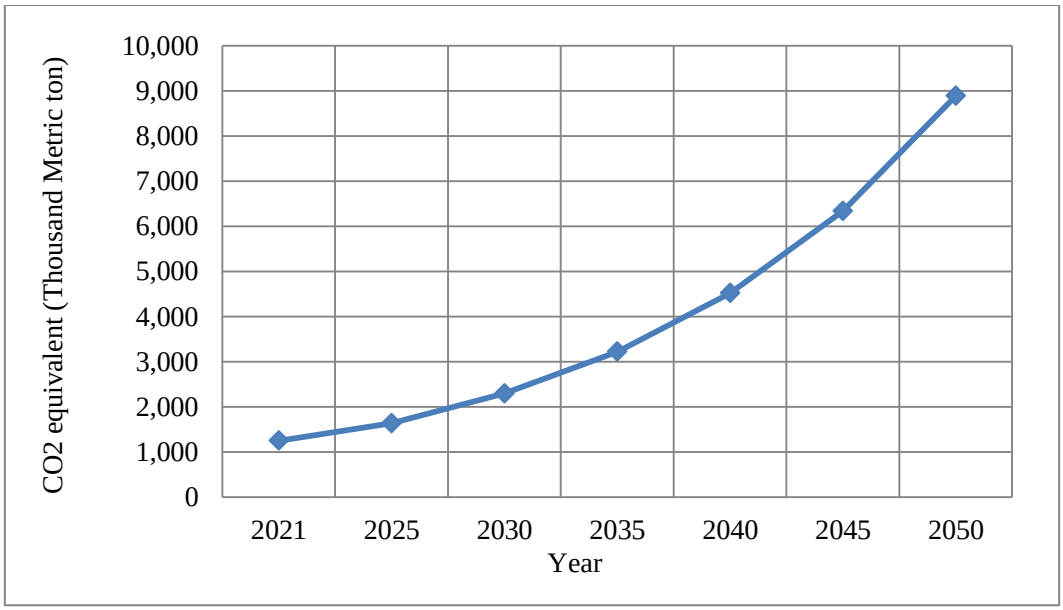


Figure 4.63: GHG emission at medium growth scenario by overall Industrial sector

High Economic Growth Scenario

Table 4.4 represents the total energy demand of various fuels types for high economic growth rate from base year 2021 to 2050. The total energy demand for industrial sector from base year 2021 to 2050 is expected to grow at average annual growth rate of 12.7% from 16 PJ in 2021, 30 PJ in 2030 and 116 PJ in 2050.

Table 4.4: Fuel consumption trend at high growth scenario by overall Industrial sector (PJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	2.38	3.83	6.97	12.67	23.04	41.89	76.16
Agriculture residue	2.05	3.31	6.03	10.95	19.92	36.21	65.83
Coal	3.48	5.62	10.21	18.56	33.75	61.35	111.55
Kerosene	0.06	0.10	0.19	0.34	0.63	1.14	2.07
Furnace oil	0.88	1.43	2.59	4.71	8.57	15.58	28.33
Diesel	6.20	10.00	18.18	33.06	60.11	109.28	198.69
LPG	0.30	0.48	0.87	1.59	2.88	5.24	9.53
Electricity	0.96	1.55	2.81	5.11	9.30	16.90	30.73
Petrol	0.06	0.10	0.18	0.33	0.60	1.09	1.99
Total	16.38	26.42	48.04	87.34	158.78	288.69	524.87

Figure 4.64 shows the trends of consumption of different category of energy sources. The demand of petroleum product is expected to be higher in all the year which is followed by biomass, coal and electricity

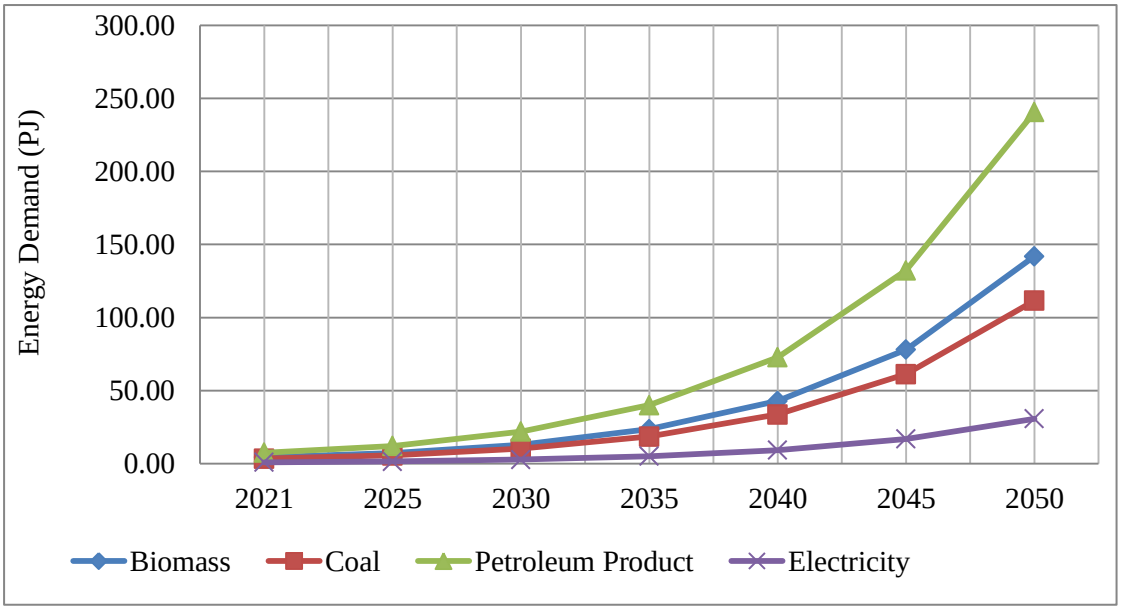


Figure 4.64: Fuel consumption trend at high growth scenario by overall Industrial sector

Figure 4.65 shows the GHG emission for high economic growth rate scenario. GHG emission was 1,249.6 thousand metric tons and would increase to 3665 thousand metric tons in 2030 and again this would increase to 40,043 thousand metric tons in 2050.

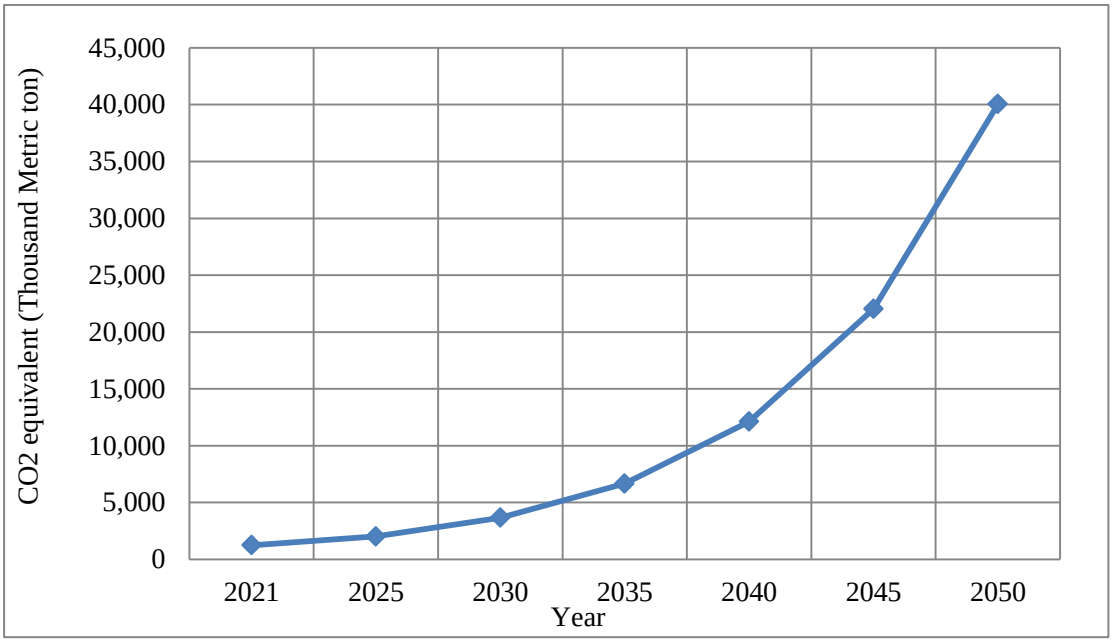


Figure 4.65: GHG emission at high growth scenario by overall Industrial sector

Policy Scenario

Table 4.5 represents the total energy demand of various fuels types for the policy scenario from the base year 2021 to 2050. The total energy demand for industrial sector from base year 2021 to 2050 is expected 16 PJ in 2021, 29 PJ in 2030 and 106 PJ in 2050.

Table 4.5: Fuel consumption trend at policy scenario by overall Industrial sector

Fuel Types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	2.38	2.83	3.41	3.94	4.39	3.82	2.17
Agriculture residue	2.05	2.31	2.69	2.84	2.45	2.00	1.79
Coal	3.48	4.32	5.73	6.97	8.47	10.04	14.09
Kerosene	0.06	0.08	0.12	0.17	0.23	0.33	0.46
Furnace oil	0.88	1.16	1.62	2.28	3.20	4.48	6.29
Diesel	6.20	8.59	12.75	19.45	29.37	44.29	64.22
LPG	0.30	0.38	0.53	0.74	1.04	1.45	2.04
Electricity	0.96	1.45	2.34	3.87	6.24	9.89	14.67
Petrol	0.06	0.08	0.12	0.17	0.25	0.36	0.51
Total	16.38	21.20	29.32	40.43	55.62	76.66	106.24

Figure 4.66 shows the trends of consumption of different category of energy sources for policy scenario. The demand of petroleum product is expected to be higher in all the year which is followed by electricity. While the trend of biomass consumption is expected to decrease from 4.4 PJ in 2021 to 3.9 PJ in 2050 due to replacement of traditional boiler by electric boiler.

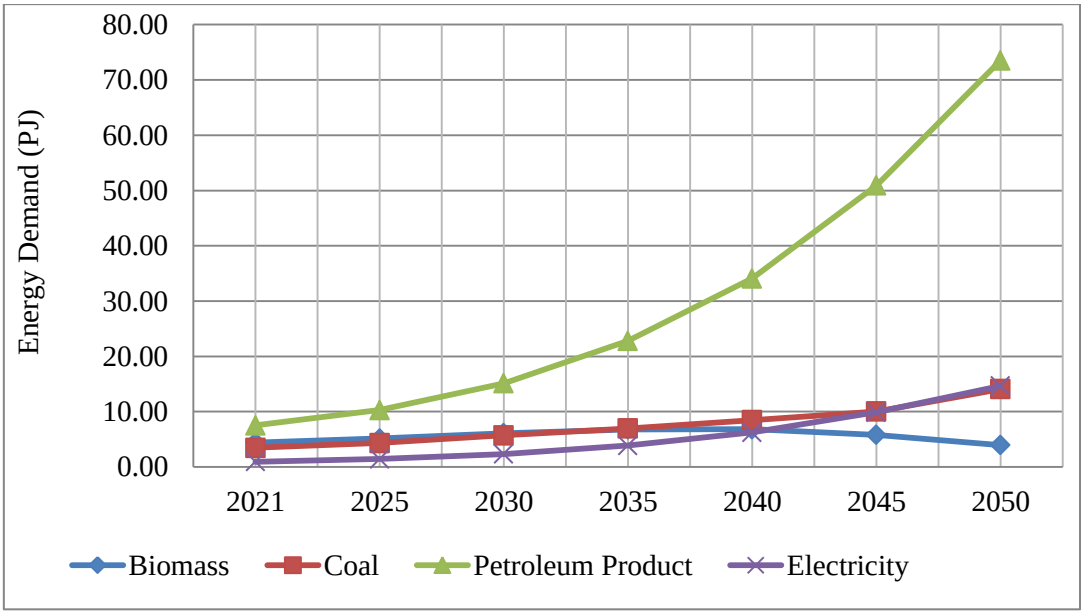


Figure 4.66: Fuel consumption trend at policy scenario by overall Industrial sector

Figure 4.67 shows the GHG emission for policy scenario. GHG emission was 1,249.6 thousand metric tons and would increase to 2163 thousand metric tons in 2030 and again this would increase to 6,964 thousand metric tons in 2050.

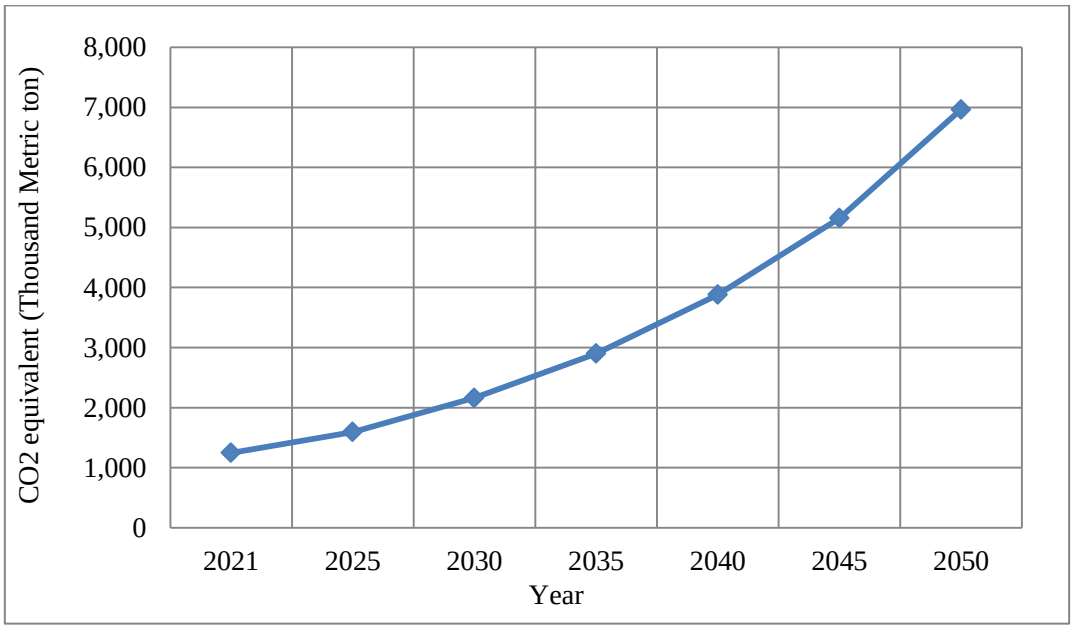


Figure 4.67: GHG emission at policy scenario by overall Industrial sector

4.4 Financial Analysis

4.4.1 Carbon Trading

Carbon trading is a system which sets a target to mitigate the emission where emission trading is designed in such a way that target can be met without actual reduction taking place. In this process, credits are bought and sold that permits a company and other entities to emit certain quantity of carbon dioxide and other greenhouse gases. ERPA (Emission Reduction Payment Agreement) is a legal contract abides by two parties that allow one party to convey verified carbon credit to another. As per ERPA, Nepal will receive $5 for each tonne of carbon dioxide emission reduction.

Table 4.6: Cumulative carbon trading benefits

Particulars	2025	2030	2035	2040	2045	2050
GHG Reduction (000' tonne)	43	134	321	637	1,183	1,925
Benefits ($)	214,043	669,522	1,605,175	3,183,169	5,914,735	9,623,316

4.5 Result Validation

Energy intensity is the indicator which measures the efficiency of particular economic sector. It is calculated by taking ratio of energy demand to gross domestic product (GDP). Furthermore, GHG emission per GVA is calculated as another indicator on order to validate the accuracy of result obtained. It has been calculated numerically taking ratio of GHG emission to the gross value added (GVA) by industrial categorization. As shown in Table 4.7, the obtained results are compared among Nepal, Province 1 and Province 2.

Table 4.7: Comparison of energy intensity and GHG emission per GVA

Particulars	Nepal	Province 1	Province 2	Kathmandu Valley
Energy consumption per GVA in Industrial sector (KJ/NRs)	479	851	596	442
GHG emission by Industrial sector per GVA (g/NRs)	40	34	66	46

(IEA, Energy Statistics Data Browser, 2022), (WECS, 2021)

For industrial sector, energy intensity for Kathmandu Valley is calculated and compared with energy intensity of Nepal, Province 1 and Province 2 as shown in Figure 4.68. With comparison, the energy intensity for Province 1 seems greater due to operation of large number of energy intensive industries of iron and steel as well as brick industries. Nevertheless, the energy intensities are much comparable among Nepal, Province 2 and Kathmandu Valley.

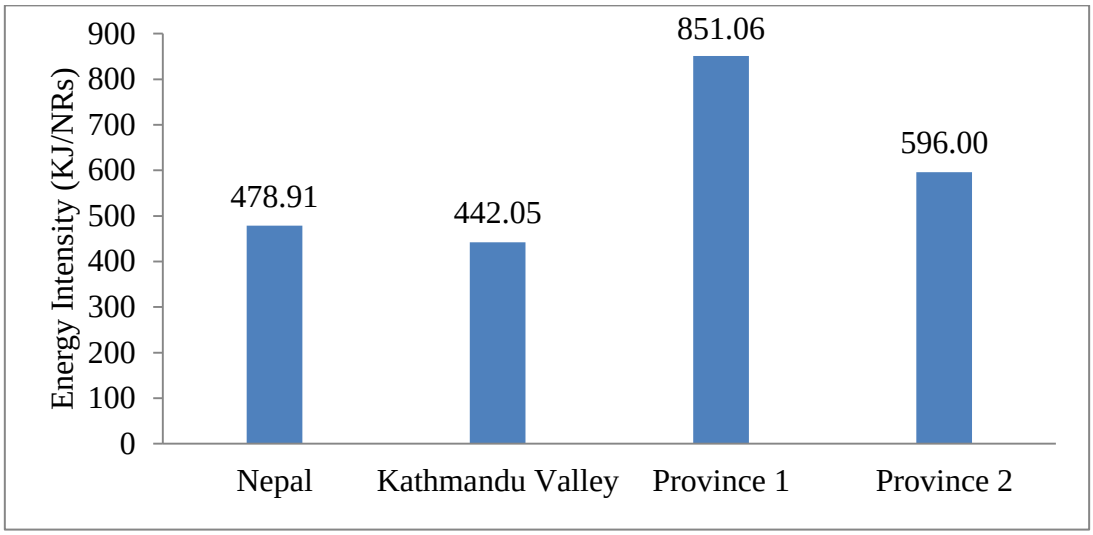


Figure 4.68: Comparison of energy intensity (IEA, 2022) (WECS, 2021)

Figure 4.69represents the comparison of GHG emission per GVA among Nepal, Province 1 and Province 2. It indicated the Province 1 has higher GHG emission per GVA because large number of steel and iron industries as well as brick industries is in operation within this province. However, the value is much comparable among Nepal, Province 2 and Kathmandu Valley.

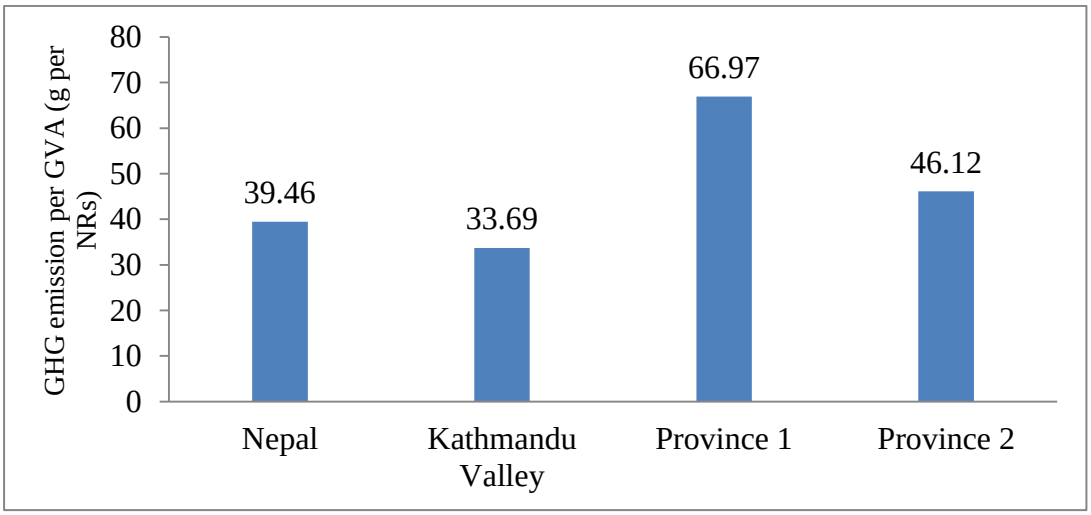


Figure 4.69: Comparison of GHG emission per GVA (WECS, 2021), (GoN, 2021)

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Following conclusion has been drawn from the study are as follow:

- Total energy consumption of manufacturing industrial sector in Kathmandu Valley is 16.4 PJ. Industrial sector accounts 67%, 27% and 6% share of total energy consumption fossil fuel, biomass and electricity respectively.
- 36.86% of total energy is consumed for process heat which is followed by boiler (34.84%), motive power (25.8%) and others (2%)
- Among several categories of industries, food, beverage and tobacco has major energy consumption types which accounts 39% of total energy consumption.
- The energy demand for manufacturing industries in Kathmandu Valley is estimated to grow from 16.4 PJ in 2021 to 50 PJ at low growth rate (3.95%), 116 PJ at medium growth rate (7%) and 524 PJ at high growth rate (12.7%).
- GHG emission in 2021 was 1,249.6 thousand metric tons and it is expected to increase by 2050 at low growth, medium growth, high growth and policy scenario is 3842.8 thousand metric tons, 8890 thousand metric tons, 40,043 thousand metric tons and increase to 6,964 thousand metric tons respectively

5.2 Recommendations

Following recommendations have been made from the study:

- The target should be set to increase the share of energy consumption to 25% for industrial sector by 2030
- For the energy demand of 16.4 PJ in industrial sector in Kathmandu Valley, energy supply projection should be developed.
- Energy intensity of Industrial sector in Kathmandu Valley is 442 KJ/NRs which should be decreased by penetration of energy efficient technology
- Further study should be carried out to develop scenario in which traditional end use technology of process heat and motive power will completely be replaced by electric power technology
- Industrial sector of Kathmandu Valley contributes about 30% share of total energy consumption by industrial sector in Nepal therefore, taking reference of this model, energy model for other local city can be developed.

- Penetration of renewable energy is recommended to reduce 33.69 g/NRs GHG emissions per GVA to zero emission.

5.3 Future Research Area

This research study represents energy consumption and demand projection of industrial sector in Kathmandu Valley. Further research can be conducted to find energy consumption in other economic sector such as residential sector, transport sector, commercial sector, agriculture sector and construction and mining sector in different local cities, local level government, districts, and provinces.

REFERENCE

ADB. (2021). *Nepal Macroeconomic Update.* Kathmandu: Asian Development Banl.

Bhandari, S., & Bajcharya, T. (2016). The Effects of Economy of Scale of Production on Energy Mix and GHGs Emission for Biscuit Industries of Nepal:A Case Study of Nebico Food Pvt. Ltd. *IOE Graduate Conference.* Kathmandu.

Bhatta, R. P., & Bhattrai, N. (2017). Study on Grid Integrated Solar PV for Balaju Industrial District, Kathmandu, Nepal. *IOE Graduate Conference.* Kathmandu.

Bhattacharya, S. C. (2009). Modelling energy demand of developing countries:Are the specific features. *Elsavier*.

Bhattacharyya, S. C. (2011). *Energy Economics.* Spring.

Bhattrai, D., & Bajracharya, D. (2016). Road Transportation Energy Demand and Environmental Emission: Acase Study of Kathmandu Valley. *Hydro Nepal*.

CBS. (2019). *Statistical Pocket Book of Nepal 2018.* Kathmandu: Government of Nepal Central Bureau of Statistic.

CBS. (2021). *National Economic Census 2019.* Kathmandu, Nepal: Central Buerue of Statistic.

DoI. (2020). *Industrial Statistic 2019/20.* Kathmandu: Department of Industry.

DOI. (2020). *Industrial Statistic 2019/20.* Kahmandu: Department of Industry.

Dutta, M., & Mukherjee, S. (2010). An outlook into energy consumption in large scale industries in India:. *Energy Policy, Elsavier*, 7286-7298.

Finance, M. o. (2021). *Economic Survey 2020/21*. Kathmandu, Nepal: Ministry of Finance.

Finance, M. o. (2022). *Economic Survey 2020/21*. Kathmandu: Ministry of Finance.

Gautam, P., Bhattrai, N., & Bajrachary, I. (2017). Energy Demand and Emissions Mitigation Potential of Mass Transport Vehicle: A Case Study of Ring Road Kathmandu Valley. *IOE Graduate Conference.* Kathmandu.

GoN. (2021). *Nepal's Long Term Strategy for Net Zero Emission.* Kathmandu: Government of Nepal.

Gyanwali, K., & Bajrachary, T. (2013). Demand Side Management in Industrial Sector of Nepal. *IOE Graduate Conference*, (pp. 112-120). Kathmandu.

Herbst, A. T. (2012). Introduction to Energy System Modelling. *Swiss Journal of Economics and Statistic*.

IAEA. (2006). *Model for Analysis of Energy Demand (MAED-2).* Vienna: International Atomic Energy Agency.

IEA. (2021). *Key World Energy Statistic 2020.* International Energy Agency.

IEA. (2021). *Largest end uses of energy by sector, selected IEA countries.* Paris: International Energy Agency.

IEA. (2022). *Energy Statistics Data Browser.* Retrieved from www.iea.org: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser

Joshi, S. B., & Poudel, L. (2017). Energy Efficiency Improvement Potential of Dairy Development Coorporation: Kathmandu Valley Supply Scheme. *IOE Graduate Conference.* Kathmandu.

Khem Gyanwali, T. R. (2013). Demand Side Management in Industrial Sector of Nepal. *Proceedings of IOE Graduate Conference*, (pp. 112-120). Kathmandu.

Kothari, C. (2004). *Research Methodology: Methods and Techniques.* New Delhi: New Age International Publishers.

M Dutta, S. M. (2010). An outlook into energy consumption in large scale industries in India:. *Energy Policy, Elsavier*, 7286-7298.

Morgan, K. &. (1970). *Determining Sample Size for Research Activities.*

MoSTE. (2014). *Nepal Second National Communication To United Nations Framework Convention on Climate Change.* Kathmandu: Government of Nepal, Ministry of Science,Technology and Environment.

National Planning Commission. (2020). *The Fifteenth Plan.* Kathmandu: Government of Nepal, National Planning Commission.

Nawraj Bhattarai, I. B. (2015). Industrial Sector's Energy Demand Projections and Analysis of Nepal for Sustainable National Energy Planning Process of the Country. *Journal of the Institute of Engineering*.

NEEP/GIZ. (2012). *Baseline Study of Selected Sector Industries to assess The potential for more Efficient use of Energy*. Kathmandu.

Nepal, G. o. (2014). *Statistical information on Nepalese agriculture (2070–2071). Ministry of Agricultural Development, Agri-Business Promotion and.* Kathmandu, Nepal: Agri-Business Promotion and Statistics Division.

NPC. (2017). *Nepal's Sustainable Development Goals - Status and Roadmap: 2016-2030.* Kathmandu: Government of Nepal, National Planning Commission.

Pokheral, S. (2006). An econometric analysis of energy consumption in Nepal. *Elsevier*.

Rajbhandari, U. S., & Nakarmi, A. M. (2014). Energy Consumption and Scenario Analysis of Residential Sector Using Optimization Model – A Case of Kathmandu Valley. *Proceedings of IOE Graduate Conference*, 476-483.

Rajput, R. K. (2007). *A Text Book Manufacturing Technology*. New Delhi: Laxmi Publication.

Report, A. (2020). Retrieved from Nepal Electricity Authority: www.nea.org.np

Sah, D. P., Chaudhary, S., & et.al. (2019). Status of Brick Kilns Stack Emission in Kathmandu Valley of Nepal. *Journal of Advanced Research in Civil and Environmental Engineering*, 1-9.

Shrestha, A., Ghimire, A., Singh, A., & et. al. (2016). Energy Use in Nepalese Cement Industries: Case of Udayapur Cement Industries Limited. *International Journal of Scientific and Engineering Research*.

ANNEXES

Annex 1: Questionnaire: Industrial Sector

Date:……..

Information of respondent and location

Question	Description
Name of respondent	
Contact number	
District	

General Information of the organization

Name of company	……
Establishment date	……
Company categorization	☐ Mechanical Engineering, machineries, Iron and steel and other metals ☐ Electrical and electronic products ☐ Chemical products, Rubber, Glass and Plastics ☐ Cement, Bricks, Concrete and Clay products ☐ Food, Beverage and Tobacco ☐ Textiles, Readymade Garment and leather products ☐ Paper, Publication and Printing, Furniture and Fixtures ☐ Miscellaneous (Jewelry, musical instruments, Sporting goods, toys
Product manufacture	……
Quantity produced last year	……units
Number of person directly engaged in industry	……..person
Total Capital of industry	NRs…….
The approximate revenue generated in the last year	NRs……

Energy Source Information

Energy sources	Annual fuel requirement
Fuelwood	……Tons
Agriculture residue	……Tons
Animal waste	……Tons
Coal	……Tons
Briquette	……Tons
Kerosene	……Kilo liters
Furnace oil	……Kilo liters
Petrol	……Kilo liters
Diesel	……Kilo liters
LPG	……Cylinders
Electricity	……kWh
Solar PV (Solar home system)	……kWp
Solar water heater	…… Liter

Energy consumption by end-use

Lighting			
Equipment	Number	Average watt	Hours per day
Halogen Flood light			
Filament bulb			
Tube light			
CFL			
LED			

Others (Specify name) …….……)			

Space cooling

Equipment	Number	Average watt	Operation hours per day
Fan			
Cooler			
Air conditioner			

Space heating

Equipment	Number	Average watt	Operation hours per day
Electric heater			
AC			
Fuelwood	……kg		
Briquette	……kg		

Boiler

Energy Source	Fuel consumption per year	Operation hour per day
Fuelwood	……..... Tons	
Agriculture residue	……..... Tons	
Coal	……..... Tons	
Kerosene	……..... Kilo liters	
Furnace oil	……..... Kilo liters	
Diesel	……..... Kilo liters	
LPG	……..... Cylinder	
Electricity	……..... kWh	

Process heat

Energy Source	**Fuel consumption per year**	**Operation hour per day**
Fuelwood	……..... Tons	
Agriculture residue	……..... Tons	
Briquettes	……..... Tons	
Coal	……..... Tons	
Kerosene	……..... Kilo liters	
Furnace oil	……..... Kilo liters	
Diesel	……..... Kilo liters	
LPG	……..... Cylinder	
Electricity	……..... kWh	

Motive power

Energy Source	Fuel consumption per year	Operation hour per day
Petrol	……..... Kilo liters	
Diesel	……..... Kilo liters	
Electricity	……..... kWh	

In-generation power	
Capacity of generator	……..... kVA
Duration of operation	……..... Hours per day
	……..... Days per year
Petrol	……..... Kilo liters
Diesel	……..... Kilo liters

Annex 2: Fuel consumption by end use wise

(in TJ)

End use	Fuelwood	Agriculture residue	Coal	Kerosene	Furnace oil	Diesel	LPG	Electricity	Petrol	Total
Lighting	-	-	-	-	-	-	-	58	-	58
Space heating	1	-	-	-	-	-	-	13	-	14
Space cooling	-	-	-	-	-	-	-	8	-	8
Process heat	303	252	1,980	65	884	2,214	286	53	-	6,036
Motive power	-	-	-	-	-	3,280	-	887	59	4,226
Boiler	2,072	1,802	1,501	-	0	275	11	45	-	5,706
Ingeneration	-	-	-	-	-	326	-	-	4	330
Total	2,376	2,054	3,481	65	884	6,095	297	1,063	63	16,378

ANNEX 3: Sub-category wise energy consumption by end use

(in TJ)

Industries	Lighting	Space heating	Space cooling	Process heat	Motive power	Boiler	Ingeneration	Total
Cement, Bricks, Concrete and Clay products	6	1	0	1,878	798	-	1	2,684
Chemical Products, Rubber, Glass and Plastics/ Lubricants	7	2	4	1,202	231	159	23	1,627
Electrical and electronics products	2	4	1	338	399	-	13	757
Food, Beverage and Tobacco	8	2	2	236	1,976	4,068	120	6,413
Mechanical Engineering, machineries, Iron and steel and other metals	3	0	1	1,590	77	-	55	1,726
Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)	1	0	0	39	20	-	1	60
Paper, Publication & Printing, Furniture & Fixtures	3	1	0	6	161	208	42	422
Textiles, Readymade Garment & Leather Products	27	3	0	747	564	1,271	77	2,690
Total	58	14	8	6,036	4,226	5,706	330	16,378

Annex 4: Fuel consumption by Industrial categories wise

(in **TJ**)

Industries	Fuelwood	Agriculture residue	Coal	Kerosene	Furnace oil	Diesel	LPG	Electricity	Petrol	Briquette	Total
Cement, Bricks, Concrete and Clay products	141	191	1,544	-	-	751	-	40	16	-	2,684
Chemical Products, Rubber, Glass and Plastics/ Lubricants	140	37	5	-	0	1,133	138	171	2	-	1,627
Electrical and electronics products	0	-	-	-	-	695	-	63	-	-	757
Food, Beverage and Tobacco	1,714	899	1,440	63	1	1,968	6	321	0	-	6,413
Mechanical Engineering, machineries, Iron and steel and other metals	3	-	436	0	844	368	4	55	15	-	1,726
Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)	-	-	-	-	39	1	0	21	-	-	60
Paper, Publication & Printing, Furniture & Fixtures	129	69	-	1	-	60	6	127	30	-	422
Textiles, Readymade Garment & Leather Products	250	857	55	-	-	1,120	143	265	0	-	2,690
Total	2,376	2,054	3,481	65	884	6,095	297	1,063	63	-	16,378

Annex 5: Fuel demand at low growth scenario in Cement, Bricks, Concrete and Clay products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	141	164	199	242	294	357	433
Agriculture Residue	191	223	271	329	400	485	589
Coal	1,544	1,803	2,188	2,656	3,224	3,913	4,749
Kerosene	0	0	0	0	0	0	0
Furnace oil	0	0	0	0	0	0	0
Diesel	751	877	1,064	1,292	1,568	1,903	2,310
LPG	0	0	0	0	0	0	0
Electricity	40	47	57	70	84	102	124
Petrol	16	18	22	27	33	40	49
Total	2,684	3,133	3,803	4,616	5,603	6,800	8,253

Annex 6: Fuel demand at medium growth scenario in Cement, Bricks, Concrete and Clay products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	141	185	259	363	509	714	1,001
Agriculture Residue	191	251	352	494	692	971	1,362
Coal	1,544	2,024	2,839	3,981	5,584	7,832	10,985
Kerosene	-	-	-	-	-	-	-
Furnace oil	-	-	-	-	-	-	-
Diesel	751	985	1,381	1,937	2,716	3,810	5,344
LPG	-	-	-	-	-	-	-
Electricity	40	53	74	104	146	205	288
Petrol	16	21	29	41	57	80	113
Total	2,684	3,518	4,934	6,920	9,705	13,612	19,092

ANNEX 7: Fuel Demand at Low Growth Scenario in Cement, Bricks, Concrete and Clay products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	141	227	413	751	1,365	2,481	4,511
Agriculture Residue	191	309	561	1,021	1,856	3,374	6,134
Coal	1,544	2,491	4,529	8,234	14,970	27,217	49,484
Kerosene	-	-	-	-	-	-	-
Furnace oil	-	-	-	-	-	-	-
Diesel	751	1,212	2,203	4,005	7,282	13,240	24,071
LPG	-	-	-	-	-	-	-
Electricity	40	65	119	216	392	712	1,295
Petrol	16	26	46	84	154	279	507
Total	2,684	4,329	7,871	14,310	26,018	47,304	86,003

ANNEX 8: Fuel demand at low growth scenario in Food, Beverage and Tobacco

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	1,714	2,001	2,429	2,948	3,578	4,343	5,271
Agriculture Residue	899	1,050	1,274	1,547	1,877	2,279	2,766
Coal	1,440	1,682	2,041	2,477	3,007	3,650	4,430
Kerosene	63	74	90	109	132	160	194
Furnace oil	1	1	1	1	2	2	2
Diesel	1,968	2,298	2,789	3,385	4,108	4,986	6,052
LPG	6	7	9	10	13	15	19
Electricity	321	375	455	552	670	813	987
Petrol	0	0	0	0	0	0	0
Total	6,413	7,487	9,088	11,030	13,387	16,249	19,722

ANNEX 9: Fuel demand at medium growth scenario in Food, Beverage and Tobacco

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	1,714	2,247	3,151	4,420	6,199	8,694	12,194
Agriculture Residue	899	1,179	1,653	2,319	3,252	4,562	6,398
Coal	1,440	1,888	2,648	3,714	5,209	7,306	10,247
Kerosene	63	83	116	163	229	321	450
Furnace oil	1	1	1	2	3	4	6
Diesel	1,968	2,579	3,618	5,074	7,117	9,981	13,999
LPG	6	8	11	16	22	31	43
Electricity	321	421	590	828	1,161	1,628	2,284
Petrol	0	0	0	0	0	0	0
Total	6,413	8,406	11,789	16,535	23,191	32,527	45,621

Annex 10: Fuel demand at high growth scenario in Food, Beverage and Tobacco

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	1,714	2,765	5,027	9,140	16,618	30,213	54,931
Agriculture Residue	899	1,451	2,638	4,796	8,719	15,852	28,821
Coal	1,440	2,324	4,224	7,681	13,964	25,388	46,159
Kerosene	63	102	185	337	613	1,114	2,026
Furnace oil	1	1	2	4	8	14	26
Diesel	1,968	3,174	5,772	10,493	19,078	34,686	63,063
LPG	6	10	18	32	59	107	195
Electricity	321	518	942	1,712	3,112	5,659	10,288
Petrol	0	0	0	0	0	0	0
Total	6,413	10,345	18,808	34,195	62,171	113,034	205,507

Annex 11: Fuel demand at policy scenario in Food, Beverage and Tobacco

(in TJ)

	2021	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Fuelwood	1,714	2,060	2,485	2,920	3,303	2,407	255
Agriculture Residue	899	876	826	592	38	53	74
Coal	1,440	1,657	1,992	1,863	1,306	-	-
Kerosene	63	83	116	163	229	321	450
Furnace oil	1	1	1	1	1	2	3
Diesel	1,968	2,988	4,873	8,110	13,163	20,971	31,173
LPG	6	7	10	14	20	28	39
Electricity	321	537	918	1,596	2,670	4,351	6,527
Petrol	0	0	0	0	0	1	1
Total	6,413	8,209	11,221	15,260	20,731	28,133	38,522

Annex 12: Fuel demand at low growth in Chemical Products, Rubber, Glass

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	140	164	199	241	293	355	431
Agriculture Residue	37	44	53	64	78	94	115
Coal	5	6	7	9	10	13	15
Kerosene	-	-	-	-	-	-	-
Furnace oil	0	0	0	0	0	1	1
Diesel	1,238	1,445	1,754	2,129	2,584	3,136	3,806
LPG	138	162	196	238	289	351	426
Electricity	67	78	95	115	140	169	206
Petrol	1	2	2	2	3	3	4
Total	1,627	1,900	2,306	2,799	3,397	4,123	5,004

Annex 13: Fuel demand at medium growth in Chemical Products, Rubber, Glass

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	140	184	258	362	507	711	998
Agriculture Residue	37	49	69	96	135	189	265
Coal	5	7	9	13	18	25	36
Kerosene	-	-	-	-	-	-	-
Furnace oil	0	0	0	1	1	1	1
Diesel	1,238	1,622	2,275	3,191	4,476	6,278	8,805
LPG	138	181	254	357	500	702	985
Electricity	67	88	123	172	242	339	476
Petrol	1	2	2	3	5	7	9
Total	1,627	2,133	2,991	4,195	5,884	8,253	11,575

Annex 14: Fuel demand at high growth in Chemical Products, Rubber, Glass

(inTJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	140	226	411	748	1,360	2,472	4,495
Agriculture Residue	37	60	109	199	361	657	1,195
Coal	5	8	15	27	49	88	161
Kerosene	-	-	-	-	-	-	-
Furnace oil	0	0	1	1	2	4	7
Diesel	1,238	1,997	3,630	6,600	12,000	21,817	39,665
LPG	138	223	406	738	1,342	2,439	4,435
Electricity	67	108	196	357	648	1,179	2,143
Petrol	1	2	4	7	13	23	42
Total	1,627	2,625	4,772	8,676	15,774	28,680	52,142

Annex 15: Fuel demand at policy scenario in Chemical Products, Rubber, Glass

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	140	170	245	321	450	631	886
Agriculture Residue	37	49	69	96	135	189	265
Coal	5	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-
Furnace oil	0	0	0	1	1	1	1
Diesel	1,238	1,624	2,233	3,107	4,219	5,884	8,173
LPG	138	181	254	357	500	702	985
Electricity	67	99	161	265	428	679	1,007
Petrol	1	2	4	7	12	19	29
Total	1,627	2,127	2,966	4,153	5,745	8,106	11,346

Annex 16: Fuel demand at low growth scenario in Electrical and electronics products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	0	0	0	0	0	0	0
Agriculture Residue	-	-	-	-	-	-	-
Coal	-	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-
Furnace oil	-	-	-	-	-	-	-
Diesel	695	811	984	1,195	1,450	1,760	2,136
LPG	-	-	-	-	-	-	-
Electricity	63	73	89	108	131	158	192
Petrol	-	-	-	-	-	-	-
Total	757	884	1,073	1,302	1,581	1,919	2,329

Annex 17: Fuel demand at medium growth scenario in Electrical and electronics products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	0	0	0	0	0	0	1
Agriculture Residue	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0
Furnace oil	0	0	0	0	0	0	0
Diesel	695	910	1,277	1,791	2,512	3,523	4,942
LPG	0	0	0	0	0	0	0
Electricity	63	82	115	161	226	317	445
Petrol	0	0	0	0	0	0	0
Total	757	993	1,392	1,952	2,738	3,841	5,387

Annex 18: Fuel demand at high growth scenario in Electrical and electronics products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	0	0	0	0	1	1	2
Agriculture Residue	-	-	-	-	-	-	-
Coal	-	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-
Furnace oil	-	-	-	-	-	-	-
Diesel	695	1,121	2,037	3,704	6,734	12,244	22,260
LPG	-	-	-	-	-	-	-
Electricity	63	101	183	333	606	1,102	2,003
Petrol	-	-	-	-	-	-	-
Total	757	1,222	2,221	4,038	7,341	13,347	24,266

Annex 19: Fuel demand at low growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	3	3	4	4	5	6	8
Agriculture Residue	-	-	-	-	-	-	-
Coal	436	509	618	750	910	1,105	1,341
Kerosene	0	0	0	0	0	0	1
Furnace oil	844	986	1,197	1,452	1,763	2,140	2,597
Diesel	368	430	522	634	769	934	1,133
LPG	4	5	6	8	9	11	14
Electricity	55	64	78	95	115	139	169
Petrol	15	17	21	25	31	37	45
Total	1,726	2,015	2,446	2,968	3,603	4,373	5,308

Annex 20: Fuel demand at medium growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	3	3	5	7	9	13	18
Agriculture Residue	-	-	-	-	-	-	-
Coal	436	572	802	1,124	1,577	2,212	3,102
Kerosene	0	0	0	0	1	1	1
Furnace oil	844	1,107	1,552	2,177	3,054	4,283	6,008
Diesel	368	483	677	950	1,332	1,869	2,621
LPG	4	6	8	12	16	23	32
Electricity	55	72	101	142	199	279	391
Petrol	15	19	27	38	53	74	104
Total	1,726	2,262	3,173	4,450	6,241	8,754	12,278

Annex 21: Fuel demand at high growth scenario in Mechanical Engineering, machineries, Iron and steel and other metals

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	3	4	7	13	24	45	81
Agriculture Residue	-	-	-	-	-	-	-
Coal	436	703	1,279	2,325	4,227	7,686	13,974
Kerosene	0	0	1	1	2	3	6
Furnace oil	844	1,362	2,477	4,503	8,187	14,885	27,062
Diesel	368	594	1,081	1,965	3,572	6,494	11,807
LPG	4	7	13	24	44	79	144
Electricity	55	89	161	293	534	970	1,763
Petrol	15	24	43	78	142	258	469
Total	1,726	2,784	5,062	9,203	16,732	30,420	55,307

Annex 22: Fuel demand at low growth scenario in Paper, Publication & Printing, Furniture & Fixtures

(inTJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	129	150	182	221	269	326	396
Agriculture Residue	69	81	98	119	145	176	213
Coal	-	-	-	-	-	-	-
Kerosene	1	1	2	2	3	3	4
Furnace oil	-	-	-	-	-	-	-
Diesel	60	70	84	102	124	151	183
LPG	6	7	8	10	12	14	17
Electricity	127	148	180	219	265	322	391
Petrol	30	35	43	52	63	76	93
Total	422	492	597	725	880	1,068	1,296

Annex 23: Fuel demand at medium growth scenario in Paper, Publication & Printing, Furniture & Fixtures

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	129	169	236	332	465	652	915
Agriculture Residue	69	91	127	179	251	352	493
Coal	-	-	-	-	-	-	-
Kerosene	1	2	2	3	4	6	9
Furnace oil	-	-	-	-	-	-	-
Diesel	60	78	109	154	215	302	424
LPG	6	7	10	15	20	29	40
Electricity	127	167	234	328	460	645	904
Petrol	30	39	55	78	109	153	214
Total	422	553	775	1,087	1,524	2,138	2,999

Annex 24: Fuel demand at high growth scenario in Paper, Publication & Printing, Furniture & Fixtures

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	129	207	377	686	1,247	2,267	4,122
Agriculture Residue	69	112	203	370	672	1,222	2,222
Coal	-	-	-	-	-	-	-
Kerosene	1	2	4	6	12	21	39
Furnace oil	-	-	-	-	-	-	-
Diesel	60	96	175	317	577	1,049	1,908
LPG	6	9	17	30	55	100	181
Electricity	127	205	373	678	1,232	2,240	4,072
Petrol	30	49	88	160	292	531	965
Total	422	680	1,236	2,248	4,087	7,430	13,508

Annex 25: Fuel demand at Policy scenario in Paper, Publication & Printing, Furniture & Fixtures

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	129	151	173	162	114	53	0
Agriculture Residue	69	82	96	108	114	53	-
Coal	-	-	-	-	-	-	-
Kerosene	1	2	2	3	4	6	9
Furnace oil	-	-	-	-	-	-	-
Diesel	60	94	166	294	500	823	1,241
LPG	6	2	3	4	6	9	12
Electricity	127	170	244	352	508	732	1,040
Petrol	30	41	59	86	125	183	261
Total	422	542	743	1,010	1,371	1,859	2,563

Annex 26: Fuel demand at low growth scenario in Textiles, Readymade Garment & Leather Products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	250	292	354	430	522	634	769
Agriculture Residue	857	1,001	1,214	1,474	1,789	2,171	2,635
Coal	55	64	78	95	115	140	170
Kerosene	0	0	0	0	0	0	0
Furnace oil	0	0	0	0	0	0	0
Diesel	1,120	1,308	1,587	1,927	2,338	2,838	3,445
LPG	143	167	202	245	298	361	439
Electricity	265	309	375	455	553	671	814
Petrol	0	0	0	0	0	0	0
Total	2,690	3,140	3,812	4,626	5,615	6,815	8,272

Annex 27: Fuel demand at medium growth scenario in Textiles, Readymade Garment & Leather Products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	250	328	460	645	904	1268	1779
Agriculture Residue	857	1,123	1,575	2,210	3,099	4,347	6,096
Coal	55	72	101	142	200	280	393
Kerosene	0	0	0	0	0	0	0
Furnace oil	0	0	0	0	0	0	0
Diesel	1,120	1,468	2,059	2,888	4,051	5,681	7,968
LPG	143	187	262	368	516	724	1,015
Electricity	265	347	487	683	957	1,343	1,883
Petrol	0	0	0	0	0	1	1
	0	0	0	0	0	0	0
Total	2,690	3,526	4,945	6,935	9,727	1,3643	19,135

Annex 28: Fuel demand at high growth scenario in Textiles, Readymade Garment & Leather Products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	250	403	733	1,334	2,424	4,408	8,014
Agriculture Residue	857	1,382	2,513	4,569	8,308	15,104	27,461
Coal	55	89	162	294	535	973	1,769
Kerosene	-	-	-	-	-	-	-
Furnace oil	-	-	-	-	-	-	-
Diesel	1,120	1,807	3,285	5,973	10,859	19,742	35,894
LPG	143	230	418	761	1,383	2,515	4,572
Electricity	265	427	776	1,412	2,566	4,666	8,483
Petrol	0	0	0	1	1	2	3
Total	2,690	4,339	7,889	14,343	26,077	47,410	86,197

Annex 29: Fuel demand at policy scenario in Textiles, Readymade Garment & Leather Products

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	250	259	242	171	3	4	6
Agriculture Residue	857	1,047	1,349	1,554	1,468	730	92
Coal	55	71	99	-	-	-	-
Kerosene	-	-	-	-	-	-	-
Furnace oil	-	-	-	-	-	-	-
Diesel	1,120	1,509	2,146	3,260	4,925	7,401	10,727
LPG	143	179	251	352	493	691	970
Electricity	265	409	692	1,193	1,983	3,218	4,819
Petrol	0	0	0	1	1	3	4
Total	2,690	3,474	4,779	6,530	8,874	12,048	16,618

Annex 30: Fuel demand at low growth scenario in Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	0	0	0	0	0	0	0
Agriculture Residue	-	-	-	-	-	-	-
Coal	-	-	-	-	-	-	-
Kerosene	-	-	-	-	-	-	-
Furnace oil	39	45	55	66	80	98	119
Diesel	1	1	1	1	1	2	2
LPG	0	0	0	0	0	0	0
Electricity	21	25	30	36	44	54	65
Petrol	-	-	-	-	-	-	-
Total	60	70	86	104	126	153	186

Annex 31: Fuel demand at medium growth scenario in Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)

(in TJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	0	0	0	0	0	0	0
Agriculture Residue	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0
Furnace oil	39	51	71	99	139	196	274
Diesel	1	1	1	2	2	3	4
LPG	0	0	0	0	0	0	0
Electricity	21	28	39	55	77	107	151
Petrol	0	0	0	0	0	0	0
Total	60	79	111	156	218	306	429

Annex 32: Fuel demand at high growth scenario in Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)

(inTJ)

Fuel types	2021	2025	2030	2035	2040	2045	2050
Fuelwood	0	0	0	0	0	0	0
Agriculture Residue	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0
Furnace oil	39	62	113	206	374	680	1,236
Diesel	1	1	2	3	6	11	20
LPG	0	0	0	0	0	0	1
Electricity	21	34	62	113	205	373	678
Petrol	0	0	0	0	0	0	0
Total	60	97	177	322	585	1,064	1,934

Annex 33: Total GHG emission at different scenario in manufacturing industries in Kathmandu Valley

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	1,249.51	1,458.94	1,770.76	2,149.23	2,608.58	3,166.12	3,842.82
Medium growth scenario	1,249.51	1,637.85	2,297.17	3,221.90	4,518.88	6,337.96	8,889.32
High growth scenario	1,249.51	2,015.74	3,664.83	6,663.05	12,114.15	22,024.82	40,043.48
Policy scenario	1,249.51	1,595.04	2,163.26	2,900.86	3,882.24	5,155.01	6,964.65

Annex 34: GHG emission at different scenario in Cement, Bricks, Concrete and Clay products

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	227	265	322	391	474	575	698
Medium growth scenario	227	298	417	586	821	1,152	1,616
High growth scenario	227	366	666	1,211	2,202	4,003	7,277

Annex 35: GHG emission at different scenario in Food, Beverage and Tobacco industry

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	533	622	755	917	1,112	1,350	1,639
Medium growth scenario	533	698	980	1,374	1,927	2,703	3,791
High growth scenario	533	860	1,563	2,842	5,166	9,393	17,077
Policy scenario	533	668	888	1,156	1,496	1,860	2,384

Annex 36: GHG emission at different scenario in Chemical Products, Rubber, Glass and Plastic industry

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	111	129	157	190	231	281	341
Medium growth scenario	111	145	204	286	401	562	788
High growth scenario	111	179	325	591	1,074	1,952	3,549
Policy scenario	111	143	198	273	373	521	725

Annex 38: GHG emission at different scenario in Paper, Publication & Printing, Furniture & Fixtures

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	23	27	33	40	49	59	72
Medium growth scenario	23	31	43	60	84	118	166
High growth scenario	23	38	68	124	226	411	747
Policy scenario	23	29	38	47	57	71	94

Annex 39: GHG emission at different scenario in Textiles, Readymade Garment & Leather Products

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	167	195	236	287	348	423	513
Medium growth scenario	167	219	307	430	603	846	1,187
High growth scenario	167	269	489	890	1,617	2,941	5,346
Policy scenario	167	209	275	352	452	594	804

Annex 40: GHG emission at different scenario in Mechanical Engineering, machineries, Iron and steel and other metals

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	134	156	190	230	280	340	412
Medium growth scenario	134	176	246	345	485	680	953
High growth scenario	134	216	393	714	1,299	2,362	4,294

Annex 41: GHG emission at different scenario in Electrical and Electronics Products

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	52	60	73	89	108	131	159
Medium growth scenario	52	68	95	133	187	262	367
High growth scenario	52	83	152	275	501	911	1,655

Annex 42: GHG emission at different scenario in Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)

(in '000 metric ton CO_2 equivalent)

Scenario	2021	2025	2030	2035	2040	2045	2050
Low growth scenario	3	4	4	5	6	8	9
Medium growth scenario	3	4	6	8	11	15	22
High growth scenario	3	5	9	16	29	54	97

Annex 43: ORIGINALITY REPORT

ENERGY CONSUMPTION AND DEMAND PROJECTION OF MANUFACTURING INDUSTRIES IN KATHMANDU VALLEY

ORIGINALITY REPORT

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