



Government of Nepal
Water and Energy Commission Secretariat
Singha Durbar, Kathmandu, Nepal

FINAL REPORT

Energy Consumption and Supply Situation in Federal System of Nepal (Bagmati Province)



Water and Energy Commission Secretariat
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EXECUTIVE SUMMARY

Global and National Energy Consumption Status

The global energy consumed in year 2018 is 416,072 PJ. Out of which, oil product (41%) has major share followed by grid electricity (19%), natural gas (16%), coal (10%), biofuels and waste (10%), and remaining others (3%, comprise of nuclear and heat energy). The outbreak of Covid-19 pandemic in 2020 has cut down the global energy demand by 4%. As a consequence, CO₂ emission has dropped down by 5.8%. According to the World Energy Trilemma Index, Nepal holds 102nd rank among 108 countries of the world. On the basis of final energy consumption, Nepal stands at 4th position among the South Asian Association for Regional Cooperation (SAARC) countries.

In Nepal, final energy consumption for year 2018/19 was 586.74 PJ which is 0.14% of global energy consumption. The consumption of traditional, commercial and renewable energy is 401.97 PJ, 172.29 PJ and 12.50 PJ respectively. Nepal is rich in fuelwood source accounting for 62.22% of major share in the total energy consumption for primary source of energy. The sectoral energy consumption in fiscal year 2011/12 for residential, industrial, commercial, transportation, and agricultural sectors were 80%, 8%, 7%, 4% and 1% respectively. The availability of electricity was found to be 6,990 GWh. The Nepal Electricity Authority (NEA), Independent Power Producer (IPP) and import from India are the three main source of electricity generation in the country. The electricity consumption in different sectors in fiscal year 2018/19 is shown in Table 1.

Table 1: Electricity consumption in different sectors

Sectors	Electricity consumption (GWh)
Domestic	2661.3
Industrial	2421.5
Commercial	465.71
Others	757.5

Provincial Overview

Bagmati Province is located at 26° 55' to 28° 23' north latitude and 83° 55' to 86° 34' east longitude. It is divided into 13 districts which are further divided into 3 metropolitan cities, 1 sub-metropolitan city, 41 municipalities and 74 rural municipalities. Geographically, 13 districts of Bagmati Province are distributed in mountain, hilly and terai region. The categorizations are 3 districts (Dolakha, Rasuwa, Sindhupalchok) in the mountain, 9 districts (Bhaktapur, Dhading, Kathmandu, Kavre, Lalitpur, Makwanpur, Nuwakot, Ramechhap, Sindhuli) in the hilly and 1 district (Chitwan) in the Terai region. The province covers an area of 20,300 sq. km, which is 13.79% of the total land of the country.

The total electricity consumed in 2019 in Bagmati Province is found to be 2,115 GWh. In Bagmati Province more than 90% of local levels are facilitated by electricity. The highest consumption is in the domestic sector followed by the industrial sector and commercial sector because Bagmati Province is densely populated and also there are greater industries and commercial enterprises.

Methodology

The task assigned is “Energy Consumption and Supply Situation in Bagmati Province”. The assignment has been carried out in six economic sectors of Bagmati Province that are residential, industrial, commercial, transportation, construction and mining, and agriculture sectors. For this, about 15,000 samples are collected from overall economic sectors of Bagmati Province.

For residential sector, the household demand is divided into two subsectors rural and urban which is further sub-divided according to the energy demand. The transport sector is divided into passenger and freight mode. The passenger mode of transportation is sub-divided into intercity and intracity. Agricultural sector is divided on the basis of farm size i.e. small, medium and large size. In commercial sector, the commercial entities are classified according to the National Standard Industrial Classification (NSIC). The industrial sector is also divided on the basis of NSIC classification while the construction and mining sector is divided into different subsectors.

The Model for Analysis of Energy Demand (MAED) model, developed by the IAEA (International Atomic Energy Agency), has been considered to project the energy demand of the province up to 2050. To develop the energy model, the total energy consumption in the base year is estimated on the basis of data obtained from various economic sectors namely, industrial, transport, service, household, agricultural, construction and mining. In MAED model, besides the reference scenario, three different scenarios on the basis of varying economic growth rate and level of energy penetration have been constructed, i.e. low economic growth rate, high economic growth rate and sustainable energy development scenarios.

Energy Supply Situation

Energy resources are divided into renewable and non-renewable energy. The renewable energy resources include solar, wind, hydro, biomass etc. The nonrenewable energy resources include petrol, diesel, kerosene, coal, etc.

Biomass is derived from organic matter such as wood, crops, waste, etc. In Bagmati Province, the total forest area is around 53.73% i.e. 1,090,876 hectares of land, which can play role in firewood production. More than 46.14% of household uses fuelwood as their primary source for cooking (CBS, 2011). Biogas is another renewable energy which is obtained from organic waste and is potential source to attain net zero emissions. The energy can also be produced by using agricultural residue such as maize and paddy residue. There is also potential production of electricity in the province. Bagmati Province has 37 IPPs with generation based on hydropower with a total capacity of about 252.27 MW. The total electricity consumption of this province is about 2249.8 GWh, in which residential sector consumes the highest share of electricity. Bagmati Province has installed a total number of 67 small and 11 large plants Improved Water Mills (IWM). It also consists of Micro Hydro Power (MHP) and Pico Hydro Power (PHP) plants with generating capacities of 860 kilowatt (kW) and 40 kW respectively. On the other hand, all the petroleum products are imported from India by a sole importer Nepal Oil Corporation (NOC) in the country.

Energy Consumption

The total energy consumption of Bagmati Province is 83.53 PJ with fuelwood occupying the major share of 32.73%. Diesel and LPG occupied share of about 21.34% and 13.68% in the total energy consumption respectively. While other fuel types such as gasoline, electricity, solar, biogas, fuelwood, agricultural residue, etc. constitute the remaining share. The residential sector is the major consumer of energy in Nepal. Following the similar trend, the residential sector of Bagmati Province also consumes the most energy. The residential sector consumes 35.30 PJ of energy, occupying the major share of 42.26% in total energy mix of the province as shown in Figure 1.

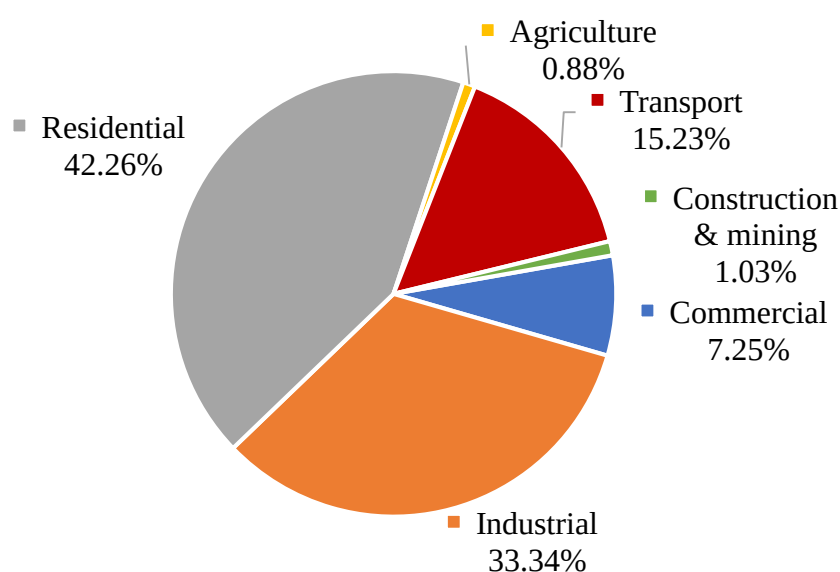


Figure 1: Energy consumption in different economic sector

The majority of energy is consumed for cooking purposes in the residential sector. Cooking alone constitutes about 64.54% share in the total residential energy consumption of the province, while other end-uses make up the remaining share. Rural residential sector consumes 16.61 PJ of energy while urban sector consumes 19.69 PJ of energy. With a share of 87.97%, fuelwood is the major source of energy in the rural residential sector while LPG plays a prominent role in the urban residential sector with a share of 37.45%. As fuelwood usage is accompanied with lower efficient technologies, the demand for energy is higher in the rural sector when compared to the urban sector.

In both the rural and urban sectors, energy demand is more for cooking than other activities. In rural sector, 10.57 PJ of energy is consumed for cooking while in urban sector 12.21 PJ of energy is consumed for cooking. The consumption of energy in the rural and urban residential sectors are shown in Table 2 and Table 3 respectively.

Table 2: Energy consumption in residential sector on the basis of end use (TJ)

End uses	Rural	Urban	Total
Cooking	10,568.9	12,213.0	22,782.2
Water boiling	117.4	693.9	811.3
Space heating	523.2	1,227.6	1,750.8

End uses	Rural	Urban	Total
Space cooling	32.0	447.8	479.8
Lighting	65.7	734.2	799.9
Electrical appliances	140.3	2,830.6	2,970.9
Social occasion	317.4	722.8	1,039.9
Food & agro processing	181.4	350.2	531.6
Animal feed preparation	3,663.9	469.7	4,133.6
Total	15,610.0	19,690.0	35,300.0

Table 3: Energy consumption in residential sector on the basis of different sources (TJ)

Energy sources	Rural	Urban	Total
Fuelwood	13,731.4	6,570.9	20,302.3
Animal dung	0.2	3.2	3.4
Agriculture residue	975.6	1,029.0	2,004.6
Kerosene	0.1	0.4	0.4
LPG	425.3	7,373.7	7,799.0
Electricity	243.6	4,390.9	4,634.5
Biogas	228.3	106.4	334.7
Briquette	0.0	6.9	6.9
Wax	0.1	-	0.1
Solar PV	4.3	20.7	25.0
Solar thermal	1.0	188.1	189.1
Total	15,610.0	19,690.0	35,300.0

In transport sector, the total energy consumption is 12.72 PJ of which the motorcycles consumed the most energy, i.e., 23.90% of total energy, trucks consumed 17.17% of total energy and the remaining percentage are consumed by buses, cars, tractors, tempos, airplanes, etc. The consumption of diesel is highest (6.22 PJ) in transport sector followed by petrol consumption (4.79 PJ) while the consumption of electricity is only 0.01425 PJ. This indicated that the consumption of petroleum products is more in this sector.

Table 4: Energy consumption in transport sector on the basis of different sources (TJ)

Transport	Energy consumed
Diesel Consumption	6,216.88
Bus	1,350.18
Car/Jeep/Van	985.68
Microbus	182.14
Minibus	336.42
Pickup	1,042.63
Tractor	135.14
Truck	2,184.69
Petrol Consumption	4,791.04
Car/Jeep/Van	1,707.45
Motorcycle	3,041.50
Tempo	42.09
Electricity Consumption	14.25
E-rickshaw	2.55
Tempo	5.57
Ropeway	6.13

Transport	Energy consumed
Aviation fuel	1,689.43
Aviation	1,689.43
LPG Consumption	15.31
Tempo	15.31
Total	12,726

Agricultural sector consumes only 0.739 PJ of energy in which 91.65% is diesel consumption, 7.43% is electricity consumption and the remaining share is of solar and petrol. In this sector tillage, irrigation and threshing are the major energy consumption processes. Tillage, irrigation and threshing consumes 0.557 PJ, 0.102 PJ and 0.7996 PJ of energy respectively.

Table 5: Energy consumption in agriculture sector on the basis of different sources (TJ)

Energy sources	Ploughing	Irrigation	Threshing	Total
Diesel	557.42	39.95	79.96	677.33
Petrol	-	0.56	-	0.56
Electricity	-	54.92	-	54.92
Solar	-	6.19	-	6.19
Total	557.42	101.62	79.96	739.00

Industrial sector consumes 27.85 PJ of energy in which 36.83% of energy is diesel consumption, 24.82% of energy is fuelwood consumption and the remaining share of energy is furnace oil, electricity, agricultural residue, petrol, kerosene, coal and LPG. Industrial sector is divided into eight different sub-categories among which the food, beverage and tobacco industries consume 15.36 PJ of energy making it the largest consumer. This sector consumes diesel the most which is 6.05 PJ while the most energy is consumed in process heat which is 12.70 PJ.

Table 6: Energy consumption in industrial sector on the basis of different sources (TJ)

Sub category	Fuelwood	Agri. residue	Coal	Kerosene	Furnace oil	Diesel	LPG	Electricity	Petrol	Briquette
Cement, bricks, concrete & clay products	1,915	70	1,604	-	-	1,382	0.05	183	17	-
Chemical products, rubber, glass & plastics	551	37	628	-	16	1,706	18	898	961	-
Electrical & electronic products	0.07	-	-	-	-	26	-	22	-	-
Food, beverage & tobacco	3,857	910	21	449	3,389	6,054	41	634	0.08	-
Mechanical engineering, iron, steel, machineries, & other metal	2	-	8	42	102	308	12	81	101	-
Paper, publication & printing, furniture & fixtures	5	0.06	-	-	1	54	5	44	28	-

Sub category	Fuelwood	Agri. residue	Coal	Kerosene	Furnace oil	Diesel	LPG	Electricity	Petrol	Briquette
Textiles, readymade garment & leather products	580	13	-	-	-	583	14	211	4	-
Miscellaneous	3	8	-	38	-	144	3	66	-	0.01
Total	6,912	1,039	2,261	529	3,508	10,257	93	2,139	1,110	0.01

Commercial sector consumes 6.06 PJ of energy in which the use of LPG is highest which is 3.46 PJ, followed by electricity (2.18 PJ). Similar to the residential sector, the majority of energy consumed for cooking purposes (i.e., 3.86 PJ) in the commercial sector of the province. Based on sub-sectors, the energy consumed in the accommodation and food services are the highest i.e. 3.91 PJ and the remaining energy is consumed in other sub-categories such as education, financial institution, health and social service, trade and retail and others. The consumption of LPG is 3.46 PJ which is the highest consumption in this sector followed by electricity.

Table 7: Energy consumption in commercial sector on the basis of different sources (TJ)

Energy resource	Cooking	Water heating	Lighting	Space heating	Space cooling	Social event	Electrical appliances	Total
Fuelwood	102	3	-	8	-	1	-	114
Kerosene	-	-	-	-	-	-	-	-
LPG	3,439	7	-	-	-	9	-	3,455
Char coal	286	-	-	-	-	0.03	-	286
Briquette	15	-	-	0.01	-	0.00	-	15
Biogas	-	-	-	-	-	0.00	-	0.00
Electricity	16	51	1	54	416	52	1,590	2,179
Solar thermal	-	10	-	-	-	-	-	10
Total	3,858	71	1	62	416	61	1,590	6,060

Construction and mining sector consumes 0.86 PJ of energy. In this sector consumption of diesel is highest which is 675.63 TJ (78.49%) while the consumption of other fuels is shown in Table 8.

Table 8: Energy consumption in construction and mining sector (TJ)

Fuel Type	Energy consumption
Diesel	675.63
Petrol	88.97
Grid electricity	11.66
Fuel wood	11.26
LPG	64.02
Coal	0.00
Kerosene	0.02
Furnace oil	9.25
Total	860.81

Socio-Economic Analysis

The major source of income in Bagmati Province is agriculture which contributes 45% of the total income followed by the business which contributes 16% of total income. The other sources of income are job/services, salary/wages, foreign employment, house rent and pension. In urban areas the income level is higher than in rural areas. Here, 24% of household heads are illiterate while only 14% of total household heads have higher education and the remaining have informal or up to secondary level education. According to the survey conducted it was found that 49% of households were found to be RCC framed, 39% found to be mud mortar with brick or stone and remaining share were found to be bamboo or wood or zinc sheet house. On the other hand, 66% of household were using 5 ampere fuse while the remaining households were using 15 ampere and 30 ampere fuses.

Scenario Development

For determining the energy demand up to year 2050, different scenarios have been considered. Those were reference economic growth scenario, low economic growth scenario, high economic growth scenario and sustainable energy development scenario.

In reference economic growth scenario, the GDP is considered to be 7% per annum. In this scenario, the energy demand is expected to increase from 83.53 PJ to 115.91 PJ in 2030 and 308.75 PJ in 2050. The share of petroleum product and solid fuels is expected to grow in this scenario. Also, the consumption of energy would be more in industrial sector and would be 198.29 PJ in 2050 while the consumption of energy in agricultural, commercial, construction and mining, residential and transport sectors in the same year would be 5.26 PJ, 40.04 PJ, 6.12 PJ, 41.87 PJ and 17.17 PJ respectively. As the consumption of energy would be increasing, the demand of electricity would also increase and is expected to grow from 560 MW to 786 MW in 2030 and 2282 MW in 2050. The GHG emission would increase during the period and is expected to reach to 8029.0 tons in 2050 from 3248.6 tons in 2021.

The GDP growth rate in low economic growth scenario is assumed to be 4.8%. The demand of energy is expected to reach 108.83 PJ in 2030 and 196.89 PJ in 2050 from 83.53 PJ in 2021. The consumption of all the energy is expected to grow as the energy demand depends on population growth and GDP. The energy demand in Industrial sector is estimated to increase to 110.06 PJ in 2050 from 27.85 PJ in 2021. The energy demand in other sectors i.e. agricultural, commercial, construction and mining, residential and transport are considered to increase to 2.92 PJ, 22.06 PJ, 3.40 PJ, 41.87 PJ and 16.59 PJ respectively in year 2050. The installed power plant capacity requirement in 2030 would be 700 MW and would reach to 1419 MW in 2050. The GHG emission would increase to 3681.0 tons in 2030 and finally to 5553.8 tons in 2050.

In high economic growth rate scenario, the GDP is considered to be 10.8%. At this GDP the demand of energy is expected to increase to 139.64 PJ in 2030 and 743.75 PJ in 2050. The energy demand in agricultural, commercial, construction and mining, industrial, residential and transport sectors are expected to reach 14.46 PJ, 106.69 PJ, 16.85 PJ, 545.52 PJ, 41.87 PJ and 18.34 PJ respectively in 2050. The power generation capacity requirement is expected

to grow to 1409 MW in 2030 and 5480 MW in 2050 while the emission would reach to 4451.5 tons in 2030 and 17,771.9 tons in 2050.

Sustainable Energy Development (SED) scenario is developed on the basis of the Sustainable Development Goals (SDG) and Second National Determined Contribution (SNDC). In this scenario, the GDP is assumed to be 7% while the penetration of energy is assumed according to the SNDC. The energy demand is expected to reach 97.65 PJ in 2030 and 214.47 PJ in 2050 from 83.53 PJ in 2021 in SED scenario. In this scenario, the consumption of electricity is assumed to be growing, replacing the demand of fossil fuels and biomass. The demand of electricity is expected to grow from 9.03 PJ in the base year, 2021 to 25.87 PJ in 2030 and 123.79 PJ in 2050 while the demand of other fuels is expected to decrease. As in this scenario, electricity is expected to be replacing other sources of energy, as a result the power plant capacity requirement would grow dramatically. The power plant capacity requirement would be 1982 MW in 2030 while this requirement would grow to 6347 MW in 2050. Therefore, in this scenario, the GHG emission is expected to reduce to 2685.9 tons in 2030 and to 1208.5 tons in 2050.

Hence, in reference scenario, the total energy demand in the year 2030 is expected to be 115.91 PJ while this demand would increase to 308.75 PJ in 2050. In the SED scenario the demand is expected to be 97.65 PJ in 2030 and 214.47 PJ in 2050. In the year 2030, the reference scenario would use only 13.9% of total energy as renewable energy while in the SED scenario, the share of renewable energy is 27.98%. Similarly, the share of renewable energy would increase and reach 60% in 2050 in the SED scenario. On the other hand, the ratio of net import of petroleum products to total energy would be 41.6% which would be in increasing order in the reference scenario and in decreasing order in the SED scenario.

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ABBREVIATION

AEPC	Alternative Energy Promotion Center
CBS	Central Bureau of Statistic
CO ₂	Carbon Dioxide
COPs	Conference of Parties
CREF	Center For Renewable Energy Fund
DoI	Department of Industry
DOTM	Department of Transport and Management
EDC	Electricity Development Center
EIA	Environment Impact Assessment
FY	Fiscal Year
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GJ	Giga Joule
GoN	Government of Nepal
GWh	Gigawatt hour
IAEA	International Atomic Energy Agency
IBG	Institutional Biogas
IEA	International Energy Agency
IEE	International Environment Examination
IPP	Independent Power Producer
ISPS	Institutional Solar Power System
IWM	Improved Water Mill
LCED	Low Carbon Economic Development Strategy
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MAED	Model For Analysis of Energy Demand
MHP	Micro Hydropower
MW	Mega Watt
NA	Not Available
NAP	National Adaption Plan
NEA	Nepal Electricity Authority
NGO	Non-Governmental Organization
NOC	Nepal Oil Corporation
NPC	National Planning Commission
NSIC	National Standard Industrial Classification
OECD	Organization for Economic Co-operation and Development
PHP	Pico Hydropower
PJ	Peta Joule
PV	Photovoltaic
RFP	Request for Proposal
RETs	Renewable Energy Technologies

SAARC	South Asian Association for Regional Corporation
SEDS	Sustainable Energy Development Scenario
SNDC	Second Nationally Determined Contribution
SPSS	Statistical Package for Social Science
TJ	Tera Joule
TOR	Terms of Reference
UNFCC	United Nations Framework Convention on Climate Change
WECS	Water and Energy Commission Secretariat

CHAPTER ONE: INTRODUCTION

1.1 Background

The analysis of the supply and demand of energy resources helps to understand the current energy status of the nation along with plan and formulate policy in the energy sector for sustainable development. In Nepal, traditional sources of energy like fuelwood, agricultural residue, animal dung etc. still holds a majority share of energy use for cooking and space heating. The use of commercial energy like coal, petroleum and electricity are continuously increasing. In terms of technology, renewable energy technologies like solar photovoltaic system are continuously increasing in the urban areas of the country. In economic and residential/domestic sectors electricity along with traditional sources are generally utilized. In commercial and industrial sectors electricity supplied from national grid, solar PV system and diesel generator are the most commonly used sources of energy. Along with this, petroleum products like petrol, diesel, aviation fuel etc. lead the energy share in transportation sector. While the share of electricity is also increasing in recent years with the introduction of electric vehicle. In agriculture sector, the use of petroleum product is continuously replacing the traditional methods of farming. The construction/mining sector generally uses petroleum products along with electricity. Hence, actual field-based information can help the country to achieve maximum benefits from the energy resources with minimum emission.

The data and information related to the demand and supply of the energy resources and technology gives the overall status. It helps in the formation of the sustainable plans and policies, and creates a scientific basis for the academic researcher. The existing energy supply and demand scenario along with the driving factors is the basis for the development of energy demand projection model. The energy demand projection model forecasts the future energy demand and helps the plan to ensure that for all fuels there is a reliable and economic supply without any interruption.

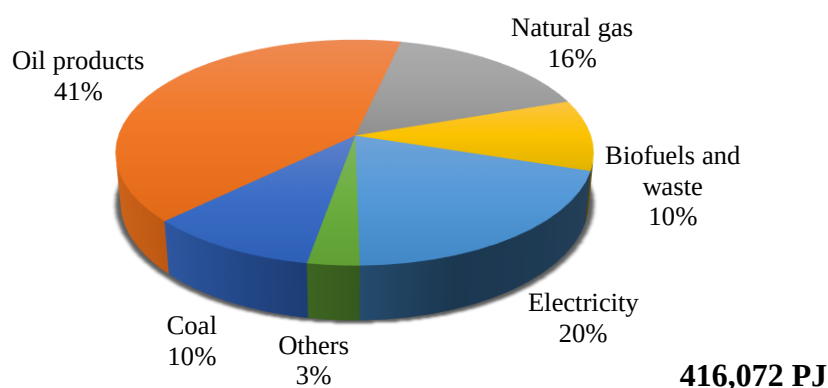
Water and Energy Commission Secretariat (WECS) since its establishment has been engaged in conducting field surveys to collect energy resources and consumption data and information from primary sources of different energy consuming sectors. It has already completed the Sectorial Energy Supply/Demand Profiles at the regional level and Residential Energy Supply/Demand Profiles at the district level during 1990-1995 which were compiled and further updated in 1997/98. Similarly, the industrial survey, commercial survey and transport survey were completed in 1997/98, 1998/99 and 2000/2001 respectively. Based on these survey energy demand and supply situations, WECS has published energy sector synopsis report in regular basis. Energy Consumption and Supply Situation of Nepal, 2011/12 is the latest survey carried out by WECS.

With the change in demographic, socio-economic and technology intervention the demand and supply situation also changes. So, after the formation of federal system within the country, WECS has started energy consumption, supply and demand survey to collect and compile energy related information in different provinces of the country. Within this, WECS has already collected the energy consumption, supply and demand data of province-1 and province-2 in fiscal year 2075/76 and currently has launched an assignment namely, “Energy Consumption and Supply in Federal System of Nepal (Bagmati Province)” with the aim of determining the existing situation of energy consumption and supply situation of the energy resources of Bagmati Province as well as forecast

energy demand up to 2050 A.D. at different growth rates based on consultation with National Planning Commission (NPC). This project further intends to analyze the information in terms of physiographic regions i.e. Mountain, Hill and Inner Terai.

1.2 Global Energy Consumption Status

The global energy consumed in year 2018 was 416,072 PJ. Out of which, oil product (41%) has major share followed by grid electricity (19%), natural gas (16%), coal (10%), biofuels and waste (10%), and remaining others (3%, comprise of nuclear and heat energy).



(IEA, 2020)

Figure 1.1: Global energy consumption status

The outbreak of COVID-19 pandemic has dropped down global energy demand by 4% in 2020. As a consequence, oil has been hardest hit due to restriction on mobility which has fallen by 9% throughout the year. Similarly, the demand of coal has been dropped by 4% but, the usage of renewable energy has been seemed to increase by 3%. Such energy consumption pattern has resulted in a drop down of CO₂ by 5.8%. Meanwhile, in 2021, it has been projected that the global energy demand will rebound by 4.6% therefore CO₂ emission will also rebound by 4.8%. In context of Nepal, import of petroleum product was declined by 10% in 2020. Meanwhile, the electricity consumption increased by 2% compared to previous 2019 due to the impact of COVID-19 pandemic. However, the energy consumption can rebound rapidly when the pandemic ends.

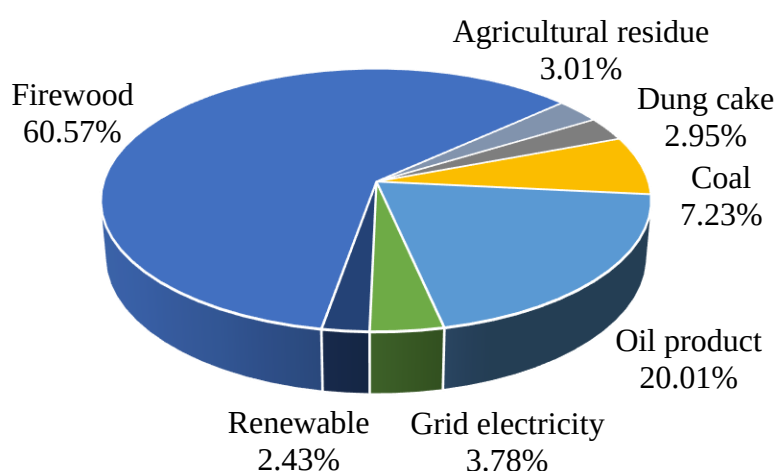
World Energy Trilemma Index published by world energy council indicates the development of energy situation of the country. The Energy Trilemma Index can be helpful for countries and energy stakeholders in an on-going dialogue to determine what areas of energy policies need to improve and examples from other countries that may help to determine which options might be more suitable for the development of a country. In 2020, the overall scores for top ten ranks remain dominated by OECD (Organization for Economic Co-operation and Development) countries, which illustrate the benefit of longstanding active energy policies. The countries that stand for top three ranks are Switzerland, Sweden and Denmark have overall scores of 84 and above. The countries that stand for top ten ranks have a strong European flavors with Canada, the United States and New Zealand breaking the European monopoly. The top three countries that followed the path since 2000 in order to improve their overall Trilemma performance are Cambodia, Myanmar and Kenya. Even though, these countries have low overall ranks, they have made

considerable and sustainable efforts to improve their energy systems. Nepal stands at 102nd ranked with about 40 score among 108 countries.

SAARC Energy Outlook 2030 describes the contrasting economic profile, energy consumption pattern and energy portfolio among SAARC (South Asian Association for Regional Corporation) countries. India is the largest country among SAARC countries by economy and energy consumption. In 2018, total energy consumption of India is 34,122 PJ which is increasing with annual growth rate of 4.5%. About 65% of total energy consumption is accounted for coal demand due to the growth of industrial and commercial sectors. However, renewable energy is also increasing because of intervention of government policies while, Afghanistan is one of the poorest country in the world where only 35% of the country is electrified and only 10% of rural region is electrified. The population of Afghanistan are still consuming fuelwood, charcoal, animal and agricultural residue as major primary source of energy for cooking and heating purpose. Similarly, major populations are using kerosene, candle and biogas for lighting purpose. Ultimately, final energy consumption of the country in 2018 has been seemed only 180 PJ. Among SAARC countries, Nepal stands in 4th position on the basis of total energy consumption i.e. 586 PJ.

1.3 National Energy Consumption Status

Nepal is a landlocked nation spread over 147,181 sq. km and surrounded by China in the north and by India in the south, east, and west. Overall energy consumption for year 2020/21 is found to be 605.62 PJ. In Nepal, firewood is the pre-dominant energy source which accounts 60.57% of the major share of energy consumption as the primary source of energy. Secondly, oil product holds 20.01% of share which is mainly dependent on imported fuels. Similarly, remaining share of energy consumption is accounted by coal (7.23%), grid electricity (3.78%), dung cake (2.95%), agricultural residue (3.01%), and renewable (2.43%). Nepal is still dependent upon fuelwood as the primary source of energy with minimum share of renewable energy.



(MoF, 2021)

Figure 1.2: National energy consumption status in fiscal year 2020/21

1.4 Objectives

The specific objectives are outlined below:

- To review plans, policies, rules and regulations relevant to energy.
- To provide training to field enumerators and supervisors.
- To determine the present scenario of energy consumption and supply throughout the Bagmati Province in regards to all economic and all fuel types at different physiographic regions.
- To estimate the energy supply and demand of all type of energy up to 2050 at 5 years interval in all economic sector with different growth rate at different physiographic regions.
- To identify potential of different energy resource and the cost of energy resources in each economic sector in each sample unit.
- To prepare energy flow diagram (Sankey chart) along with most appropriate and relevant models for energy demand forecast.
- To identify the costs of all energy resources in each economic sector in each sample unit.
- To analyze and report per capita and per economic sector energy consumption for different economic sectors and physiographic regions at different growth rates.

1.5 Scope of Work

The assignment has been carried out systematically using appropriate methods and methodology. The scope of work in order to fulfill the consulting assignment as indicated in Request for Proposal (RFP) include:

- Review of existing plans, policies, rules, regulations and guidelines related to energy.
- Development of detailed methodology and work plan for energy demand and supply survey, analysis and projection.
- Conduction of pilot survey and pre-testing of questionnaire for different economic sector.
- Determination of sample size at 95% level of confidence, 5% margin error and at 5% non-response rate for different economic sector. In case of population size up to 750 in industrial sector, thirty-three percent thresholds shall be used.
- Conduction of energy survey to collect primary data at local levels in local units which later be converted to the standard unit.
- Collection of energy supply and resource data, different growth scenarios and other relevant information from the secondary sources.
- Assessment of the demand, supply and consumption of energy resource and potential of the Bagmati Province.
- Analysis of total energy consumption of all districts of Bagmati Province in all economic sectors by each fuel type, end uses and energy technologies/devices.
- Development of energy demand forecast model of Bagmati Province at different physiographic regions (Hill, Mountain and Terai) for all economic sectors and with different growth scenarios up to 2050 AD by using freely available software/model.

- Conduction of consultation workshop between client, consultant and stake holders before energy survey and after each output.

1.6 Technology Transfer

The transfer of technology is a key factor which happens from starting of the assignment to the completion of work among stakeholders. The major objective of the skill transfer program was to enable the concerned personnel and their representatives to understand and adopt the process required for the energy planning in provincial and local level. In each stage/phase of the assignment, the transfer of knowledge occurs between the concerned parties. The necessary information has been collected by the consultant while the consultant has presented the outputs obtained in each phase of work. It means, there is transfer of knowledge among consultant members, clients, experts and other stakeholders during performing the assignment. Obviously, transfer of knowledge has enhance the skill, knowledge and experience of all the concerned stakeholders. For the transfer of knowledge, both structured and informal approaches and methods has been practiced. The consultant has tried to provide opportunities for all the stakeholders to present their views, experiences and concerns to achieve the goals of the assignment.

The client, experts and stakeholders has given valuable comments and suggestions which has been assisted in achieving the aim of the assignment in an efficient way. Not only this, the methodology was shaped with the help of knowledge transferred from the experts, clients and other stakeholders. The consultant members got feedbacks on sampling, survey methods, energy modeling etc. which has been assisted in saving time, reducing cost and minimizing risks. The training on energy demand projection model have familiarized the participant with the energy modelling software. Pros and cons related to the selected software were discussed thoroughly. The participants were also provided with the leaflets and manuals regarding the used energy modelling tools.

1.7 Limitations

The major limitations in this study are listed below.

- Different variants of COVID-19 halted the energy survey.
- Lack of recent secondary data as well as district wise historical data.
- Change in location of industries caused difficulty in data collection.
- Vehicles in Kathmandu valley creates ambiguity as intracity and intercity.
- Respondents hesitation and unwillingness to provide data is the major constrain.
- Ambiguity in classification of cottage industry as manufacturing industry as the energy consumption in cottage industry is negligible while compared to other industry
- Lack of information regarding the energy demand regarding the manual/animal drought power especially in agriculture sector.

CHAPTER TWO : LITERATURE REVIEW

Energy is vital in day-to-day life and for the development of the nation. Energy and economy are directly related to each other. Energy consuming economic sectors are divided into six categories. The type of fuels, technologies, and end user varies from one sector to another. Similarly, energy in itself can be classified as renewable and non-renewable energy sources. Renewable energy is energy from sources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Non-renewable energy is those whose supplies are in limited amount. Renewable energy is divided into conventional renewable energy and new renewable energy. Conventional renewable energy is further divided into traditional biomass and modern biomass while new renewable energy category includes the solar energy, wind energy, geothermal, hydropower, hydrogen fuel cell etc. The traditional biomass means fuelwood, animal waste and agriculture residue while modern biomass are biogas, biofuel, briquette, etc. All the fossil fuels such as petroleum product, coal, natural gas, are non-renewable energy. The categorization of source of energy is represented in Figure 2.1.

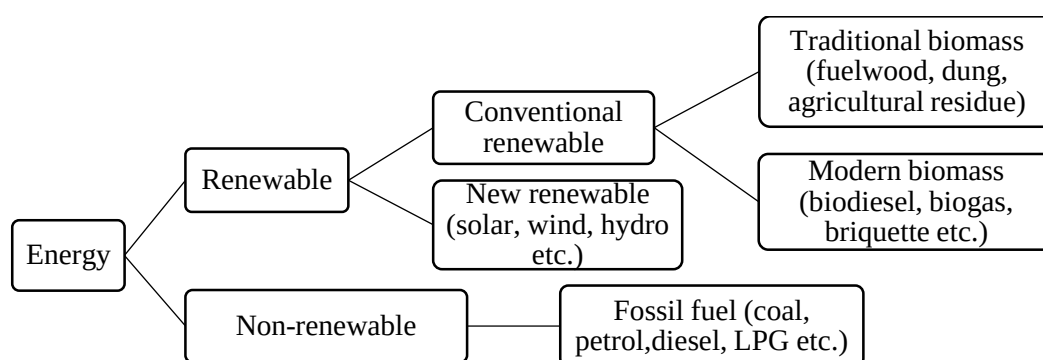


Figure 2.1: Classification of energy resource

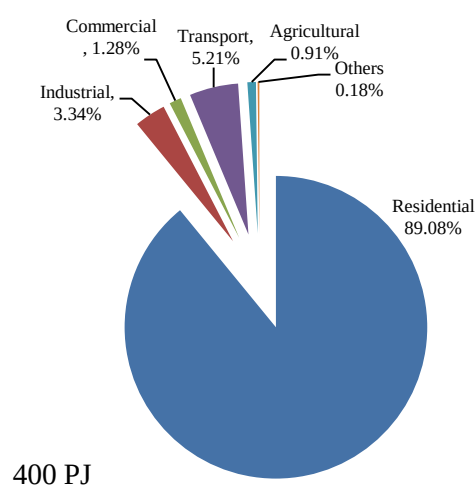
2.1 Energy Demand and Supply Situation of Nepal

The energy consuming economic sectors are classified into six categories:

- Residential sector
- Commercial sector
- Agricultural sector
- Industrial sector
- Transport sector
- Construction and mining sector

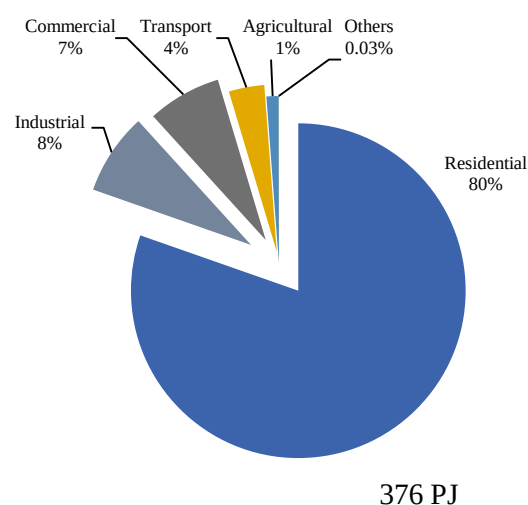
The sectoral energy consumption in fiscal year 2008/09 has major share in residential sector (89%) followed by transport (5.21%), industrial (3.34%), commercial (1.28%), and remaining by agricultural (0.91%) and others (0.18%). Similarly, the share of energy consumption in 2011/12 for residential, industrial, commercial, transportation, and agricultural sectors are 80%, 8%, 7%, 4% and 1% respectively. Construction and mining sector is included in industrial sector. By comparisons of Figure 2.2 and Figure 2.3, the share of energy consumption in residential sectors has been decreased from 89% to 80% while energy consumption in industrial and commercial

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



400 PJ

(WECS, 2010)



376 PJ

(WECS, 2014)

Figure 2.2: Sectorial energy consumption in year 2008/09

Figure 2.3: Sectorial energy consumption in year 2011/2012

Energy consumption is still dominated by the traditional source of energy which includes fuelwood, agricultural residue, animal waste and loose biomass. Figure 2.4 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 10 years.

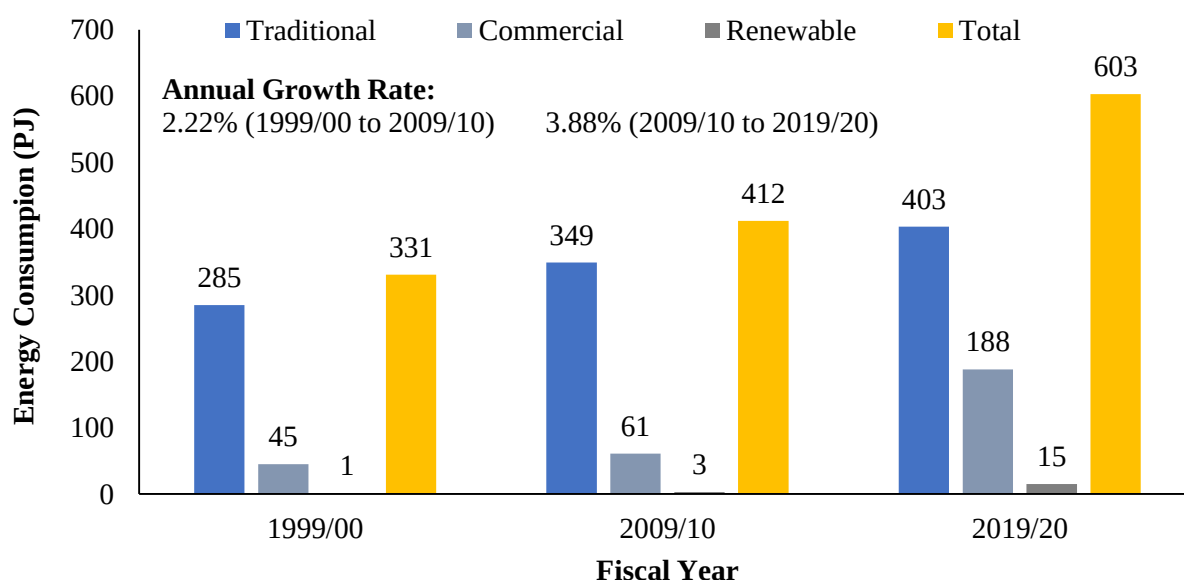
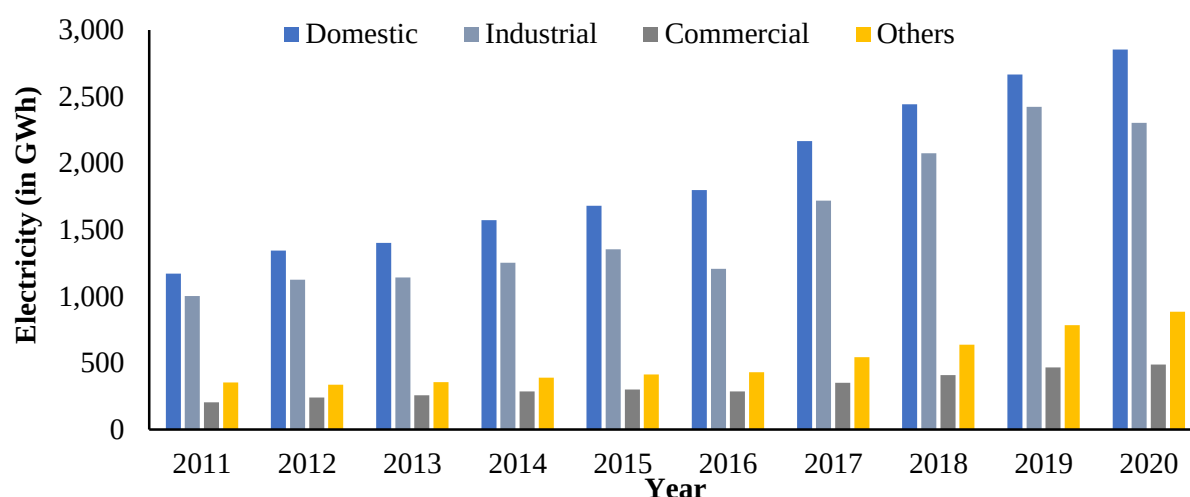


Figure 2.4: Status of energy consumption in nepal

(MoF, 2021)

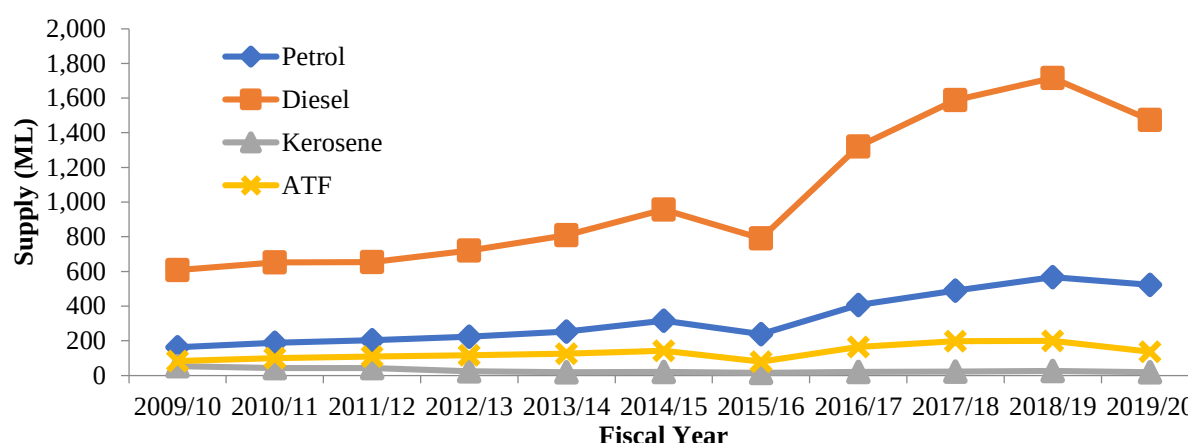
The energy consumption from electricity in fiscal year 2011 in different economic sectors; domestic, industrial, commercial and others are 1169.35 GWh, 1001.90 GWh, 351.38 GWh, and 3204.18 GWh respectively. The consumption in each sectors is increasing exponentially with a growth rate of domestic (9.5%), industrial (8.01%), commercial (9.06%) and others (9.76%) which has touched 2852.3 GWh, 2301.5 GWh, 885.71 GWh, and 487.5 GWh respectively in 2020.



(NEA, 2021)

Figure 2.5: Sectoral energy consumption from electricity in nepal

The trend for supply of petroleum products in Nepal is shown in Figure 2.6. 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%.

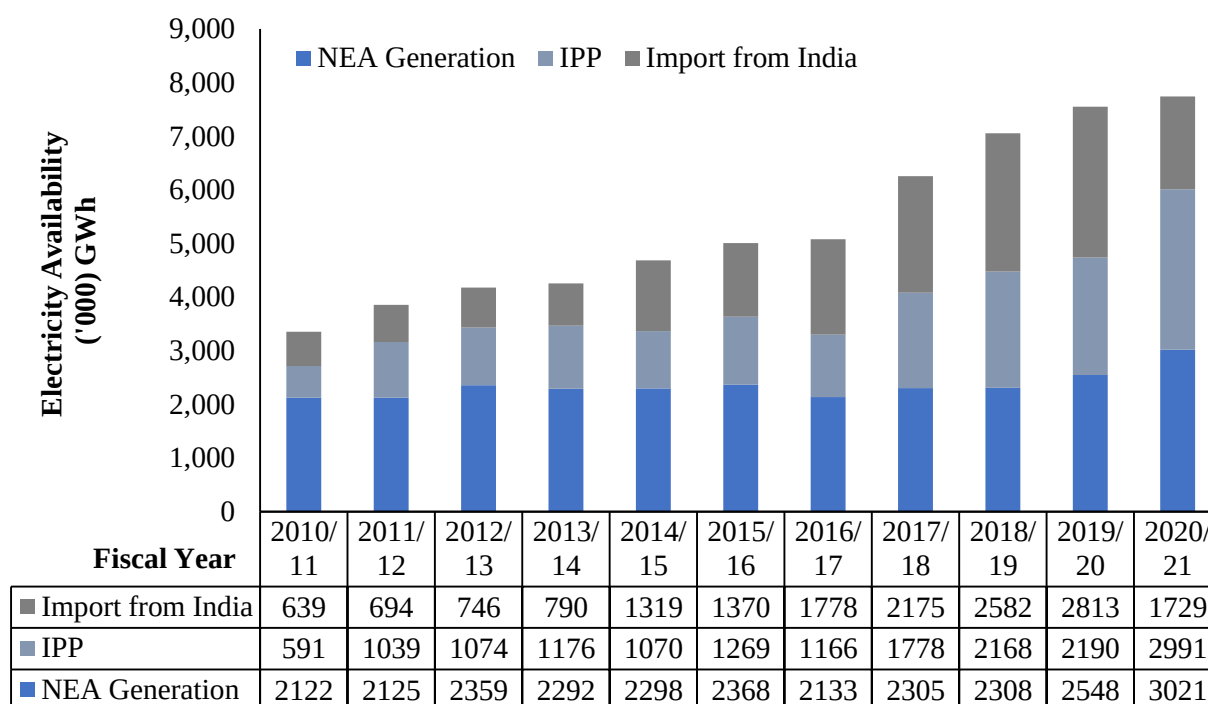


(NOC, 2021)

Figure 2.6: Supply of petroleum product

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.



(NEA, 2021)

Figure 2.7: Availability of electricity in Nepal

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.

2.2 Emission Situation of Nepal

Energy use and consumption emits more GHGs worldwide than any other anthropogenic activities. Burning fossil fuels such as coal, oil and natural gas converts carbon in the fuel to CO₂, the predominant gas contributing to the greenhouse effect. The energy sector includes all fuel combustion-related emissions from energy industries, manufacturing and construction, transport and other source categories. Energy efficiency improvement and fuel-switching from fossil fuels to electricity in transport, residential/domestic, commercial and agriculture sectors offer deep decarbonization to achieve net zero target.

According to International Energy Agency (IEA), global energy-related CO₂ emissions in 2019 were 3.3 billion tonnes of which 33% contribution were 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.

For 1994, total GHGs emission from energy and non-energy was estimated at 29,347,000 tonnes CO₂-eq. while it declined to 24,541,000 tonnes CO₂-eq. for 2000. It again increased to 30,011,000

tonnes CO₂-eq. in 2008. The net GHG emissions of 31,998,910 tonnes CO₂-eq. was estimated for Nepal in the base year 2011 which accounts for 0.060% of Nepal's contribution to the global emission of the total 53,197,386,480 tonnes CO₂-eq. (Olivier and Janssens-Maenhout, 2014). The GHG gas emission and removal from various sector is shown in Table 2.1.

Table 2.1: Nepal's GHG emission and removal for 2011

Sector	CO ₂ (Tonnes)	CH ₄ (Tonnes)	N ₂ O (Tonnes)	CO ₂ -eq. (Tonnes)
Energy	4,678,200	3,54,590	3,890	14,702,850
Industrial processes and product use	355,400		3.5	379,800
Agricultural forest and land use	-12,371,790	8,82,360	21,120	15,982,160
Waste	2,360	12,350	1,220	922,530

(MoPE, 2017)

The sectoral data of GHG emission in 2011 is shown in Table 2.2. The major GHG emission is contributed by combined industrial, construction and mining sectors among all economic sectors.

Table 2.2: Nepal's GHG emission and removal from energy sector in 2011

Economic sector	CO ₂ (Tonnes)	CH ₄ (Tonnes)	N ₂ O (Tonnes)	CO ₂ -eq (Tonnes)
Residential	300,740	5.60	0.69	301,090
Commercial	129,300	4.92	0.99	129,710
Transport	1,708,910	274.28	84.55	1,740,970
Agricultural	299,530	12.14	2.43	300,560
Industrial	2,239,710	321.69	55.56	2,264,310
Construction and mining				

(MoPE, 2017)

Nepal, as a member to the United Nations Framework Convention on Climate Change (UNFCCC), pursues and supports efforts to limit temperature rise to well below 2°C leading to 1.5°C above pre- industrial levels in order to reduce the risks and adverse impacts of climate change. Nepal believes that the cumulative impacts of Nationally Determined Contributions (NDCs) submitted to the UNFCCC would greatly contribute to limit temperature rise to safe levels and make this planet livable. Nepal has prepared its NDC in the process of implementing the decisions of the Conference of the Parties (COPs) through a broad-based stakeholder consultation process.

2.3 Energy Situation of Bagmati Province

Bagmati Province, established by the constitution of Nepal as of 20 September 2015, is one of the seven provinces of Nepal. The province is located at 26° 55' to 28° 23' north latitude and 83° 55' to 86° 34' east longitude in the map. Hetauda is its provincial headquarter and the country's capital Kathmandu also lies in this province. Mostly, the province is geographically distributed with hilly, mountainous and terai districts with hosts mountain peaks including Gaurishankar, Langtang, Jugal, and Ganesh. The map of Bagmati Province according to physiographic region is shown in Figure 2.8

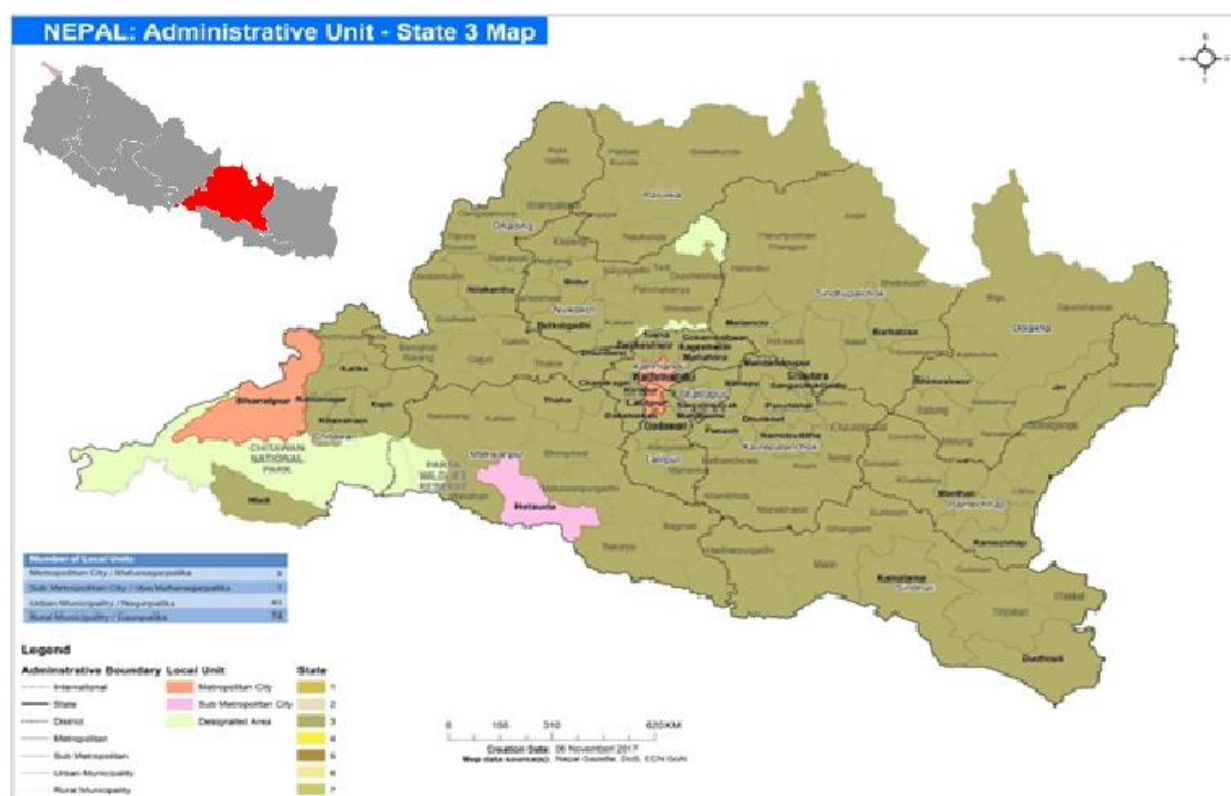


Figure 2.8: Map of Bagmati Province

Bagmati Province is divided into 13 districts which are further divided into 3 metropolitan city, 1 sub-metropolitan city, 41 municipalities and 74 rural municipalities. Geographically, 13 districts of Bagmati Province are distributed in mountain, hilly and terai region. The categorizations are 3 districts (Dolakha, Rasuwa, Sindhupalchok) in the mountain, 9 districts (Bhaktapur, Dhading, Kathmandu, Kavre, Lalitpur, Makwanpur, Nuwakot, Ramechhap, Sindhuli) in the hills and 1 district (Chitwan) in the terai region. The province covers an area of 20,300 sq. km, which is 13.79% of the total land of country. The forest covers about 59.27% area of the province while the agricultural land covers an area of about 24.34% of the area of province. Bagmati Province is surrounded by Province 1 in the east, Gandaki Province in the west, Madhesh Province and India in the south, and China in the north.

Table 2.3 shows the number of local levels fully electrified, partially electrified and not electrified. It seems more than 90% of local levels are facilitated by electricity.

Table 2.3: Electrification status in Bagmati Province

Particulars	Electrification Status			
	Fully Electrified	Partially Electrified	Not Electrified	Total
Metropolitan	3			3
Sub-Metropolitan	1			1
Municipalities	34	7		41
Rural Municipalities	44	25	5	74
Total	82	32	5	119

(NEA, 2020)

2.4 Macroeconomic

According to Central Bureau of Statistic (2021), revised GDP in Bagmati Province is Rs. 1,454,775.90 million in fiscal year 2020/21, which is 32.7% of share contributed over national GDP. Bagmati Province has highest share of GDP among other provinces. The growth rate in fiscal year 2020/21 is -3.6%, however, it has been predicted that the growth rate of GDP will be increased to 4.7% by upcoming fiscal year 2021/22. Wholesale and retail stands with highest share of 24.6% by GDP whereas water supply and waste management stands with lowest share 0.3% (CBS, 2021).

Table 2.4: Provincial gross value added by industrial division in Bagmati Province

	Industrial classification	2020/21
A	Agriculture, forestry and fishing	162,304
B	Mining and quarrying	7,191
C	Manufacturing	68,271
D	Electricity, gas ,steam and air conditioning supply	14,909
E	Water supply; sewerage, waste management and remediation activities	4,770
F	Construction	53,946
G	Wholesale and retail trade ; repair of motor vehicles and motorcycles	330,580
H	Transportation and storage	95,742
I	Accommodation and food service activities	23,124
J	Information and communication	25,300
K	Financial and insurance activities	163,222
L	Real estate activities	238,095
M	Professional, scientific and technical activities	26,459
N	Administrative and support service activities	20,727
O	Public administration and defence; compulsory social security	51,768
P	Education	63,536
Q	Human health and social work activities	16,638
R,S, T,U	Arts, entertainment and recreation; Other service activities; and Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	10,235
	<i>Gross Domestic Product(GDP) at basic prices</i>	<i>1,376,814</i>
	Taxes less subsidies on products	230,836
	<i>Gross Domestic Product(GDP)</i>	<i>1,607,651</i>

(CBS, 2021)

2.5 Institutional Set-up Overview

The Government of Nepal is consolidating its institution to ensure implementation of energy plan, policy and strategy. Along with developing various plans, policies and strategy, it has also set up various institutions to regulate the energy supply, demand and consumption of the nation. These

institutions are also responsible for energy demand projection, assessment of energy potential, development of subsidy policy, development and implementation of energy plan and policies.

Ministry of Energy, Water Resources and Irrigation

The Ministry of Energy, Water Resources and Irrigation is a governmental body of Nepal that governs the development and implementation of energy including its conservation, regulation and utilization. It furthermore executes electricity projects including hydropower projects. Due to the importance of water resources in Nepal, the ministry focuses on the development and utilization of hydropower.

Water and Energy Commission Secretariat

The Water and Energy Commission (WEC) was established by GoN in 1975 with the objective of developing the water and energy resources in an integrated and accelerated manner. Consequently, a permanent secretariat of the WEC was established in 1981 and was given the name, Water and Energy Commission Secretariat (WECS). The primary responsibility of the WECS is to assist GoN, different ministries relating to Water Resources and other related agencies in the formulation of policies and planning of projects in the water and energy resources sector.

Alternative Energy Promotion Centre

Alternative Energy Promotion Centre (AEPC) is a Government institution established in November 3, 1996, under the Ministry of Science and Technology with the objective of developing and promoting renewable/alternative energy technologies in Nepal. The mission of AEPC is to make renewable energy the mainstream resource through increased access, knowledge and adaptability contributing to the improved living conditions of people in Nepal.

Nepal Electricity Authority

Nepal Electricity Authority (NEA) was created in August 16, 1985 under the Nepal Electricity Authority Act, 1984, through the merger of the Department of Electricity of Ministry of Water Resources, Nepal Electricity Corporation and related Development Boards. To remedy the inherent weakness associated with these fragmented electricity organizations with overlapping and duplication of works, merger of this individual organization became necessary to achieve efficiency and reliable service. The primary objective of the NEA is to generate, transmit and distribute adequate, reliable and affordable power by planning, constructing, operating and maintaining all generation, transmission and distribution facilities in Nepal's power system both interconnected and isolated.

Nepal Electricity Regulatory Commission

It was formed by the government of Nepal with the aim to make the generation, transmission, distribution or trade of electricity simple, systematic and transparent, to balance the demand and supply of electricity, to regulate electricity tariff, to protect the rights and interests of electricity consumers, to make the electricity market competitive and to make electricity service reliable, accessible and maintain its quality.

Department of Electricity Development

The Department of Electricity Development previously known as Electricity Development Center (EDC) was established in July 16, 1993 is responsible for assisting the Ministry in implementation of overall government policies related to power/electricity sector. The major functions of the Department are to ensure transparency of regulatory framework, accommodate, promote and facilitate private sector's participation in power sector by providing "One Window" service and license to power projects.

Nepal Oil Corporation

Nepal Oil Corporation (NOC) is a government owned organization established in 1970 with the aim to import, store and distribute petroleum products throughout the country.

2.6 Policy and Strategy Overview

Nepal has aimed to achieve the sustainable development goals set by the United Nations and reach the level of medium income countries by 2030 A.D. Among the sustainable development goals, the seventh goal is aimed to ensure the accessibility of affordable, reliable, sustainable and modern energy for all whereas the twelfth goal is aimed to promote sustainable and accountable production and use. To achieve these goals, it is necessary to establish policy, legal and institutional framework that ensures the availability of affordable and reliable energy and its efficient use.

National Energy Efficiency Strategy

The National Energy Efficiency Strategy was developed by the Ministry of Energy, Water Resources and Irrigation and approved by the cabinet meeting of the Government of Nepal (GoN) in November 18, 2018 with the vision to assist in energy security by increasing the energy access through efficient use of available energy. This strategy was developed to promote energy efficiency by effectively implementing energy efficiency programmes through establishing policy, legal and institutional frameworks. The goal of the strategy is to double the average improvement rate of energy efficiency in Nepal from 0.84% which existed during the period of 2000-2015 to 1.68% per year in 2030.

Energy Policy

Nepal has energy policy of maximizing hydropower utilization to meet domestic demand of electricity and to accelerate the renewable energy sector in Nepal along with mitigating adverse environmental impacts. The goal of this policy is to provide access to energy efficient technologies through various subsidy mechanisms. Under this policy Nepal intends to expand its energy mix focusing on renewable energy by 20% by diversifying its energy consumption pattern to more industrial and commercial sectors.

Biomass Energy Strategy

This strategy was formulated in 2017 to address the need of an appropriate strategy for supporting the environment conservation through the sustainable production of biomass energy for proper and efficient utilization of available biomass resources and thereby contributing to forest conservation; for reducing the import of fossil fuel by reducing the increasing dependency on LPG; for contributing to appropriate energy mix by developing modern biomass energy; for

supporting the management of municipal waste by generating energy from the waste; for encouraging the energy supply services; and for reducing the existing regional imbalances prevailing in the supply and demand of biomass energy

Renewable Energy Subsidy Policy

Renewable Energy Subsidy Policy, 2016 has provisions of subsidies for the promotion of biomass energy technologies such as biogas, improved cook stoves, gasifiers, etc. Subsidy provision for biogas has been made for domestic biogas and energy from wastes (energy from commercial, institutional, community and municipal wastes). Similarly, subsidy has been provisioned for metallic improved cooking stoves, gasifiers for cooking, room heating, drying for fruits, vegetables and grains at domestic, institutional, and commercial level; and also for electrification through biomass energy. From gender equality and social inclusion point of view, additional subsidy has been provisioned for the groups identified for necessary support.

Rural Energy Policy

This policy has been formulated in 2006 as it was felt that there is an absence of the overall rural energy policy, although the Tenth Plan, Poverty Reduction Strategy Paper, Millennium Development Goal, etc. provides general guideline for the rural energy development. The goal of this policy is to contribute to rural poverty reduction and environmental conservation by ensuring access to clean reliable and appropriate energy in the rural areas by reducing dependency on traditional source of energy.

National Adaptation Plans

In 2015, Nepal launched a process to formulate and implement National Adaptation Plan (NAP) to address medium and long-term adaptation needs and reduce climate vulnerabilities by shifting to the use of clean renewable energy in different economic sector. The different economic sectors include domestic/residential sector, Industrial sector, commercial sector, transport sector and construction and mining sector. This will also promote integration of climate change adaptation into sectoral policies, strategies, plans and programs. The NAP will be developed through country driven, extensive consultation, participatory and transparent approaches and concerned ministry-led Thematic Working Groups.

Nepal Sustainable Development Goals, Status and Roadmaps 2016-2030

The National planning prepared the Nepal Sustainable Development Goals, Status and Roadmaps 2016-2030 with the goal of advancing Nepal from least developed countries which requires the rapid economic growth of above 7% over the decade. It highlights major issue and challenges along the route to meets the sustainable development goals. It emphasizes the sectors related to clean energy, agriculture and tourism

Second Nationally Determined Contribution

Goal: Formulation of Long-term low GHG emission development strategy by 2021 to achieve net-zero GHG emission by 2050.

Target:

Energy generation

- By 2030, 15% of total energy demand is ensured to be supplied from clean energy sources by expansion of the energy sources from 1,400 MW to 15,000 MW.

Transportation sector

- In 2025, sales of electric vehicle will be 25% of all private passenger vehicle sales, comprising of two-wheeler and 20% of all four-wheeler public passenger vehicle sales excluding e-rickshaws and electric tempos. As a consequence, there will be decrease in fossil fuel energy demand from 40 PJ to 36 PJ. This target will mitigate CO₂ eq. emission from 2,988 Gg to 2,734 Gg CO₂ eq.
- By 2030, electric vehicles sales will increase to cover 90% of all private passenger (two wheeler and 60% of four-wheeler public passenger vehicle excluding e-rickshaw and e-tempos. Thus, mitigation of emission will be from 3,640 Gg CO₂ eq. to 2,619 Gg CO₂ eq.
- By 2030, develop 200 km of electric rail network to use as public travelling as well as freight transportation

Residential cooking and biogas

- By 2025, install 500,000 improved cook stoves, rural area will be focused
- By 2025, install an additional 200,000 households biogas plants and 500 large scale biogas plants
- By 2030, ensure 25% of households use electricity as primary source for cooking purpose

The combined target of residential cooking and biogas can reduce emission by about 11% in 2025 while by 23 % in 2030.

Nepal's Energy Sector Vision 2050 A.D.

Energy vision 2050 was formulated in 2013 with the vision to explore potential energy resources available in the country in order to meet energy demand sustainably. It envisions to reduce the dependence on imported petroleum products by substituting it with indigenously available hydropower and other renewable energy resources. It identifies hydropower as the lead energy resources to meet the long-term energy demand of all sectors in the country. Electrification in all major sectors demands power capacity of 4,100 MW, 11,500 MW, and 31,000 MW by 2020, 2030 and 2050 respectively. To achieve the target, GDP shares of the energy sector should approximately be 2.4%.

Sustainable Development Goals

Goal: Ensure access to affordable, reliable, sustainable, and modern energy for all

Target:

- By 2030, ensure universal access to affordable, reliable and modern energy services
- By 2030, increase substantially the share of renewable energy in the global mix
- By 2030, double the global rate of improvement in the energy efficiency

- By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology and promote investment in energy infrastructure and clean energy technology.
- By 2030, expand infrastructure and update technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries and small island developing states.

Goal: Ensure sustainable consumption and production pattern

Target:

- Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking lead, taking into account the development and capabilities of developing countries.
- By 2030, achieve the sustainable management and efficient use of natural resources
- By 2020, achieve the environmentally sound management of chemical and all wastes
- By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuses.
- Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production

Others supporting policy and documents are listed below

Table 2.5: Supporting policy and documents

Key Plans, Policies, programs	Features
Hydropower Development Policy 1992, Hydropower Development Policy 2001, Water Resources Act 1992 and Electricity Act 1992	• Emphasize foreign private sector investment to develop hydropower to meet the existing demand • Provision for developing hydropower through a transparent procedure to attract foreign and domestic private sectors investment, • To create an independent regulatory body
Forest Act (1993)	• Provision to convey every part of National Forest to consumer in the form of a community forest for well development, better management, and efficient utilization of the forest.
Motor Vehicle and Transport Management Act (1993)	• Authorized act for vehicles to pass the roadworthiness test for registration and operation process - the test identify pollution and age of vehicles. • Rule to impose penalties for violating the regulations and on the spot check and to pay fine for vehicles that are not roadworthy • Roles and responsibilities, and institutional setup of Department and Transport Management Committee
Update and Compilation of Regional Energy Consumption Profile 1995/96	• Compilation of regional and district level data and analysis of energy survey in different economic sector from 1990-1995
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 in generation power
Detailed Energy Consumption Survey in Transport Sector of Nepal (2000)	• Conduction of energy survey to determine the energy consumption behaviour of Transport sector by fuel and technology

Key Plans, Policies, programs	Features
Forest Sector Policy (2000)	- Promotion of community forestry by delegating forest protection and management to consumer groups. - Development and promotion of alternative energy sources and adoption of energy efficient improved cookstove
Hydropower Development Policy (2001)	Generation of electricity at low cost by utilizing the water resources available in the country mobilizing resources from the private sector, government and bilateral and regional cooperation.
National Transport Policy (2002)	- Co-operating policies and programs that mitigates emission from the transport sector. - Provisions to restrict polluting vehicles restrict the operation of vehicles in urban core areas and development of cycle tracks. - Provision to exclude heavy tax on non-polluting vehicles - Formation of Road Transport Authority for road transport management - Incorporation of National Transport Board to coordinate authorities relating to transport
Rural Energy Policy (2006)	- Support for renewable energy technologies in rural areas without grid power supply - Provision of institutional setup and a Rural Energy Fund - Provision to provide rural renewable energy subsidy, and mobilize the private sector, financial institutions, NGOs, and local organizations.
Nepal Energy Efficiency Program	- Demonstration of energy efficiency in household and industries - Advocacy and pilot audit projects in energy-intensive industries. - Establishment and capacity development of the Energy Efficiency Centre
Nepal Rural and Renewable Energy Program	- Single program modality for the effectiveness of RE projects and activities. - Targets for various RETs
Solid Waste Management Act (2011)	- An authorized act of providing responsibility to the Local Body for solid waste management. - Co-operation with the private sector, community and non-governmental organizations, and local body - Instruction and methodology for segregation of solid waste at source, and promotion of 3R principles. - Permission for the private sector to develop and operate sanitary landfill sites, following EIA and IEE. - Authorized rules to form Solid Waste Management Council - Act to incorporate a Solid Waste Management Technical Support Centre
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 - Ordinance for auditing and reporting of energy intensity of industries - Provision to build the capacity of the Department to monitor and control pollution.
Energy Consumption and Supply Situation of Nepal, 2011/12	Present pattern of energy consumption in all economic sectors namely the residential/ domestic sector, industrial sector, transport sector, commercial/business sector, agricultural sector and others by physiographic and development regions.

Key Plans, Policies, programs	Features
Environment-friendly Vehicle and Transport Policy (2014)	• Development and extension of environment-friendly and electric vehicles and transportation. • Rules and regulation to allow conversion of technically feasible motor vehicles into electric vehicles. • Aim to achieve exceeding 20% of vehicle fleets to be environment-friendly vehicles by 2020. • Construction of safe cycle tracks and efficient charging stations for electric vehicles to reduce emission. • Tax reduction and the provision of low interest loans for private consumers to purchase environment-friendly vehicles
National Urban Development Strategy (2015)	• Priority to dense settlements over scattered areas and incorporation of land use and transportation planning. • Development of infrastructure for smart cities • Preparation of institutional mechanism and coordination capacity to address issues related to urban transport and land use, and • Development of transport management plan, and promotion of sustainable urban public transport, and non-motorized transport and pedestrianization • Mobilization of finance for urban development, including alternative sources and private sector partnership.
National Urban Policy (2012)	
Subsidy Policy for Renewable Energy (2015)	• Obvious subsidies and financial arrangement/guidelines • Rules and regulation of total metering policy for urban solar energy. • Rules for tax exemption for importing solar energy systems, net metering equipment, and LED lights
Urban Solar Energy System Subsidy and Loan Guidelines (2015)	
The current situation and future road map of Water, Energy, and Irrigation (2019/20)	• Rules and regulation regarding energy in all government level • Set goal for electricity consumption of 700 kWh per consumer within first 5 year and 1500 kWh per consumer in next 10 years by shifting from other source of energy toward electricity • Conduction of “Ujjwal for Education and Health” program • Penetration of mix energy consumption for energy security by prioritizing connection of renewable energy to grid • Discouraging uses of inefficient technologies • Encourage marginalized group to raise living standard providing renewable energy free of cost • Providing opportunity of investment in energy sector to public • Tariff structure for different economic sector on the basis of time and season • Development of High Tension transmission (400KV) line from east-west • Establishment of international trade of electricity
15 th Plan Approach paper 2017/18-2022/23	• Develop hydropower by attracting domestic and international investment • Expand domestic and cross-border transmission line to make reliable and effective electricity distribution system • Promote smart meters and smart grid for making electricity services reliable and reducing electricity leakage • Promote “every house energy house” concept by net metering for rooftop solar PV and grid connection through net payment

Key Plans, Policies, programs	Features
	• Promote “every house one electric stove” concept for energy efficiency, reduction of indoor air pollution and premature mortality rate, increasing domestic electricity demand and energy security in the country • Develop standard for electric cook stoves and to make them accessible to households for energy efficiency and replacing fossil fuels
• National Renewable Energy Framework, 2017	• Speed up the transition from subsidy centred model to credit-focused model along with a better subsidy mechanism • Improve availability and technology of renewable energy

CHAPTER THREE : METHODOLOGY

The systematic methodological flow diagram as shown in the Figure 3.1 will be followed throughout the assignment to maintain high quality of work throughout the project. Various assessments will be done in different stages of the work to ensure that the assignment is carried out systematically and is on time. Any obstacle during the assignment will be handled by both formal and informal approach.

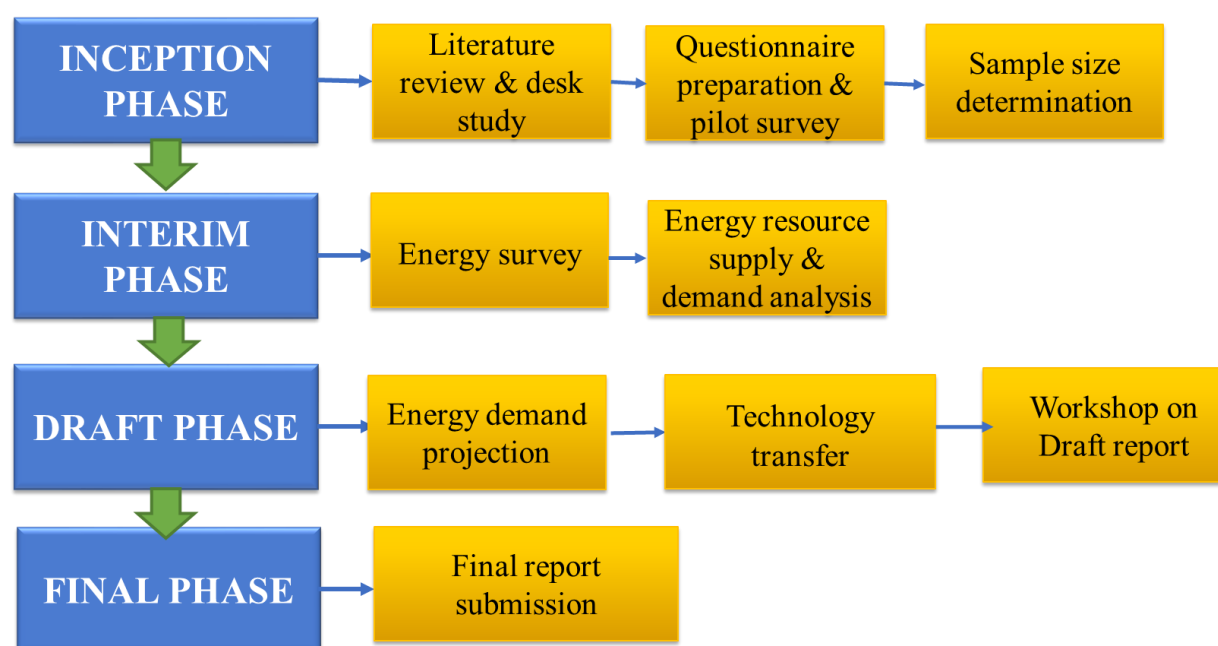


Figure 3.1: Methodological approach

The team of Multiscope Solution Pvt. Ltd. has completed the assignment systematically along with maintaining high quality of work. The assignment has commenced immediately after signing the contract. The consultant initiated its preliminary work which included a meeting among its team members so that every member of the assignment is clear about their role and duties in the assignment. If necessary, the consultant will make arrangement to include client and stakeholder.

The consultation workshop will be organized in different phases after the submission of different reports. The client may invite experts and concerned professionals in the Workshop. The comments, suggestions and feedbacks from the client and stake holders will be incorporated into different reports. Also, different output of this assignment will be compared with previous published reports and journals. The assignment will be carried through out six energy economic sectors namely domestic/residential sector, industrial sector, commercial sector, agricultural sector, transportation sector and construction & mining sector. Each economic sector will be further classified into sub sectors:

3.1.1.1 Residential Sector

Household is the sample unit for residential sector which is disaggregated into rural and urban, metropolitan, sub-metropolitan, municipalities, rural municipalities, and roof types of houses as represented in Figure 3.2.

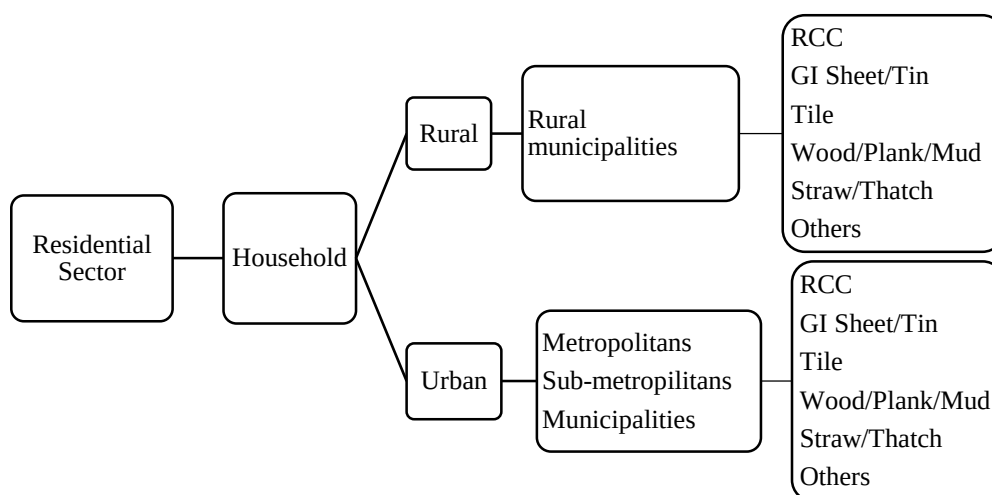


Figure 3.2: Disaggregation of residential sector

3.1.1.2 Transport Sector

For transport sector, vehicle is considered as the sample unit which is classified into two group i.e. passenger (intercity and intracity) and freight vehicle. Passenger vehicle consist of motorcycles, cars, jeeps, vans, buses, micro buses, mini buses, tempos, e-rickshaws, airways and ropeways whereas freight vehicles consist of lorries, trucks, mini trucks, tractors, cargo vans, ropeways and airways.

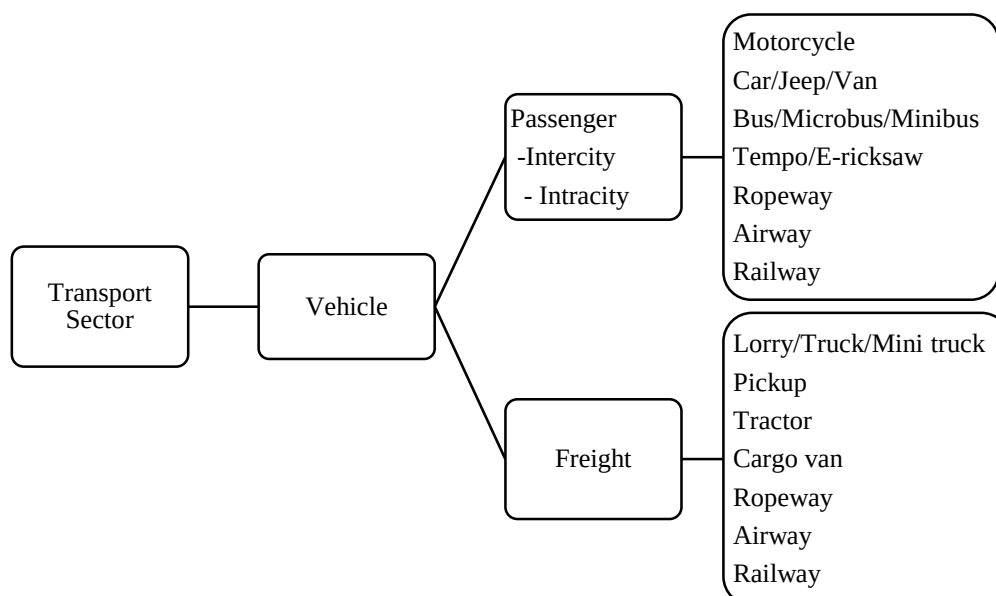


Figure 3.3: Disaggregation of transport sector

3.1.1.3 Agriculture Sector

Farm size is considered as the sample unit in agricultural sector. Farm is further categorized into small (up to 0.5 hectare), medium (0.5 to 2 hectare) and large (2 hectare above) as shown in Figure 3.4.

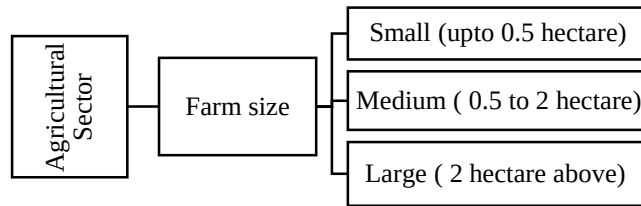


Figure 3.4: Disaggregation of agricultural sector

3.1.1.4 Commercial Sector

In commercial sector, relevant entities are classified according to National Standard Industrial Classification (NSIC) as portrayed in Figure 3.5.

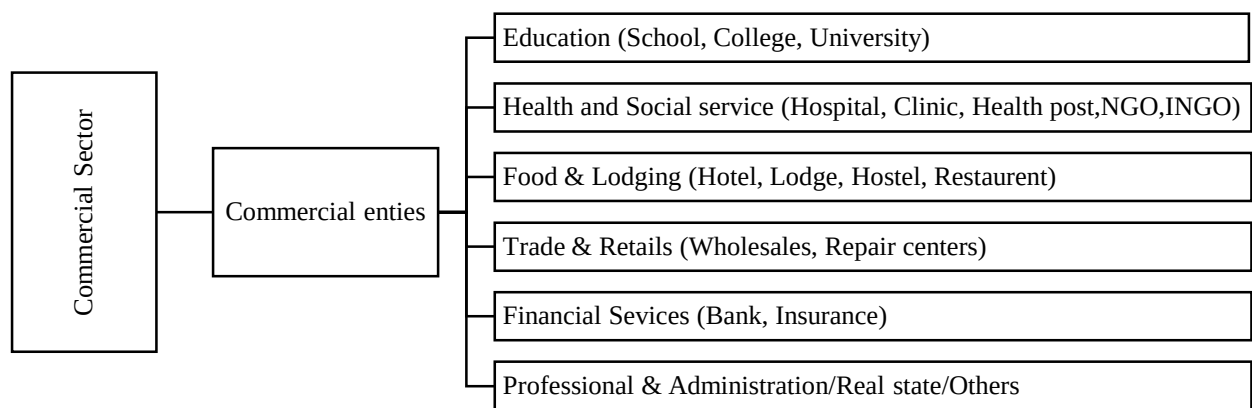


Figure 3.5: Disaggregation of commercial sector

3.1.1.5 Industrial Sector

Factory is the sample unit for industrial sector which is further classified into different sub-sector on the basis of NSIC as shown in Figure 3.6.

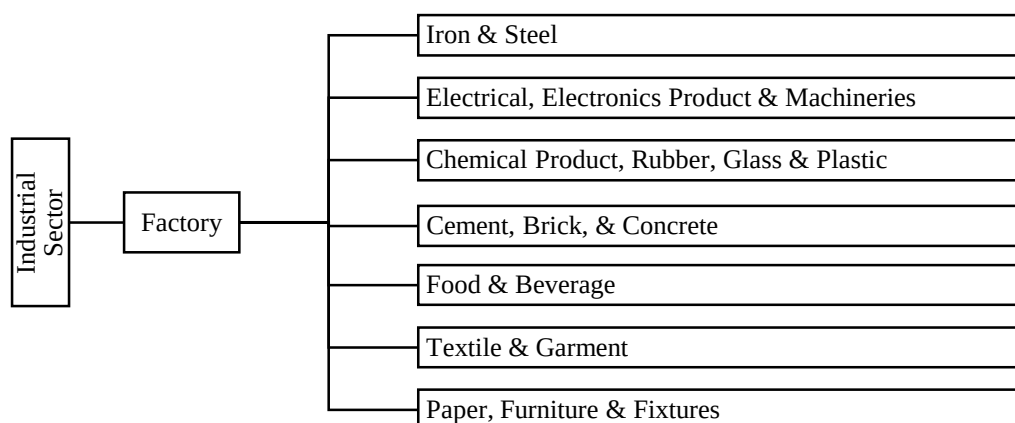


Figure 3.6: Disaggregation of industrial sector

3.1.1.6 Construction and Mining Sector

Construction site and mining site are considered as sample unit for construction and mining sector. These sites are further disaggregated into sub sectors as shown in Figure 3.7.

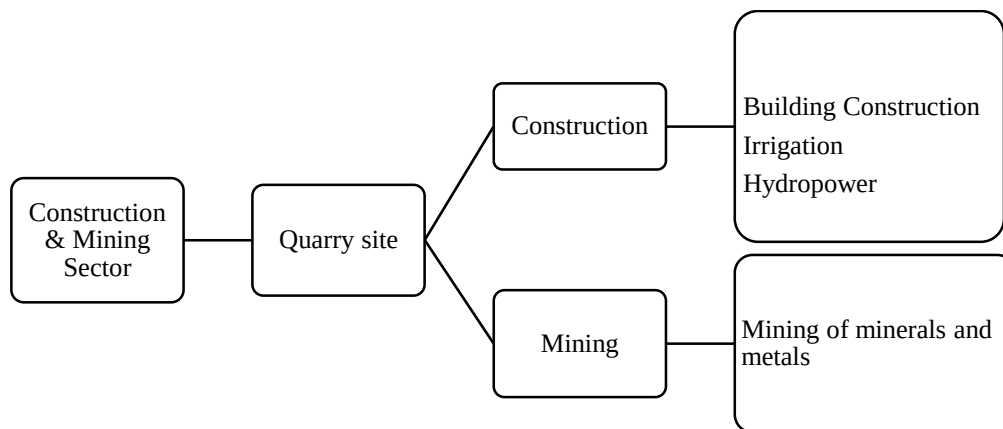


Figure 3.7: Disaggregation of construction and mining sector

Based on the methodological flowchart and details of activities to be conducted for different economic sector developed, the consultant will conduct various tasks grouped under following phases:

- Inception phase
- Interim phase
- Draft phase
- Final phase

3.2 Inception Phase

In the inception phase, consultant has commenced the preparatory work immediately after signing of contract. The main aim of the inception phase is to conduct literature review along with sampling, planning and scheduling so that the assignment can be completed systematically without any hindrance.

Initially, various literatures related to plan, policies, guidelines related to energy are collected from various institutions and have been thoroughly reviewed. Also, a round table meeting between the team members, client and stakeholders will be organized to fine tune the methodology and work schedule and also build mutual understanding about the roles between the consultant and the client.

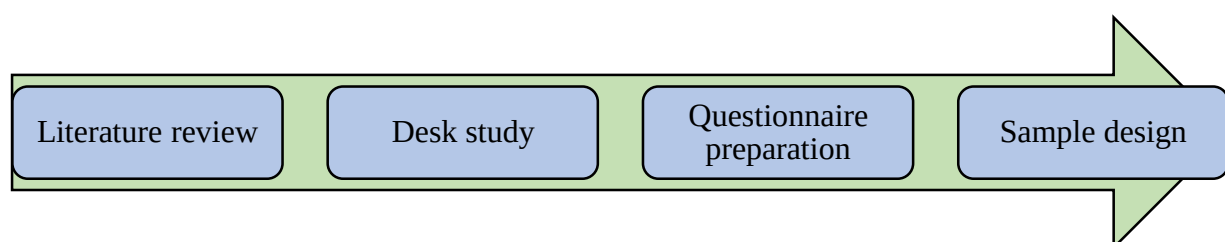


Figure 3.8: Tasks in inception phase

3.2.1 Literature Review

The team members from MSPL have followed steps as in Figure 3.8 to collect and review relevant documents, literatures, plans, policies and guidelines regarding energy resource, potential, supply, demand and consumption from various secondary sources and institution in coordination with the Water and Energy Commission Secretariat (WECS). Previous reports and journals including WECS survey reports regarding the energy consumption have been reviewed. The information collected will help to understand the energy scenario of different economic sectors in the proposed province i.e. Bagmati Province and thus assist in development of the appropriate questionnaire along with work plan and methodology. Different Energy models and tools used for the energy demand projection at different growth rate have been reviewed thoroughly and the most appropriate will be selected.

3.2.2 Desk Study

The related reports enlisted in Table 3.1 have been reviewed during desk study. The exploratory study has been conducted in parallel with the literature review for available design software, identification of relevant models of energy demand. Master plan along with fine tuning the methodology, work schedules and work division has been developed in this phase which in case helped in smooth and systematic completion of the assignment. In order to maintain superiority, a quality assurance plan has also been developed.

Table 3.1: List of literature reviewed relevant to energy

S.N.	Reports for references
1.	Update and Compilation of Regional Energy Consumption Profile 1995/96 report of WECS
2.	Industrial Energy Consumption Survey 1996/97 reports of WECS
3.	Detailed Energy Consumption Survey in Transport Sector of Nepal (2000) report of WECS
4.	Energy Consumption and Supply Situation of Nepal, 2011/12 reports of WECS.
5.	Electricity Demand Forecast Report (2014-2040) report published by WECS
6.	Third National Communication report, MoPE, 2017
7.	National Economic Census, CBS, 2018
8.	Nepal Electricity Authority Annual Report, 2019/20
9.	Economic Survey, MoF, 2019/20
10.	Energy Demand Projection 2030 report published by Investment Board of Nepal

3.2.3 Questionnaires Preparation

The information acquired from literature review and desk study along with review of the relevant reports has been used to prepare questionnaires for conduction of energy survey in different economic sectors. The questionnaire developed for different economic sector were varied according to preliminary findings via. literature review and desk study. The prepared questionnaires were approved by the client and any relevant changes were made accordingly.

The questionnaires have been tested for complete understanding of the survey guidelines and identifying the problems that have occurred during field visits. A field visit to areas within Kathmandu valley has been carried out for pre-testing purposes. Incorporating the suggestions

received from client and stakeholders, final questionnaires will be prepared for the field survey. The sample questionnaire prepared for each economic sector has been attached at annex 6.

3.2.4 Pilot Survey

Pilot survey has been conducted to gather data for each economic sector in order to pre-test the prepared questionnaire. Kathmandu, Lalitpur and Bhaktapur districts are considered for the location of sample unit. On the basis of analysis of collected data using excel, modifications have been made on the questionnaires.

3.2.5 Sampling Design

Sampling is the method used to identify the number of samples and sample unit from a population using statistical method such that it possesses the characteristics of the population. Sampling has been done to identify the sample size and sample units in each economic sector. The sample size for residential/domestic, industrial, commercial, agricultural and constructions & mining sector has been identified using the information at district and province level while that of transport sector at zonal level.

Sampling has been designed on the basis of total population size. In case of population size up to 750, thirty-three percent threshold has been used to determine sample size. However, in case of population size more than 750, sampling has been designed with 95% level of confidence, 5% margin error and 5% non-response rate for all economic sectors. The sample size has been calculated using Krejcie-Morgan formula

$$n = \frac{z^2 \times p \times q \times N}{e^2 (N - 1) + z^2 \times p \times q}$$

Where,

z^2 = Z square for specific confidence level (95%) = 3.841.

p = probability of success = 0.5

q = 1-p = probability of unsuccessful = 0.5

e = margin of error

N = Population size

n = required sample size

Non-response rate: Total non-response rate is assumed as 5%,

Hence, total sample size = $n + 5\% \text{ of } n$

3.2.5.1 Residential Sector

In residential sector, household is considered as sample unit whereas district is taken as location for sampling. Sample has been collected on the basis of house roof types (Straw, Tin, Tile, RCC, Wood, Mud and others) which were categorized on the basis of CBS classification. The population size is projected population for 2021 which has been incorporated from “Nepal Statistical Year Book 2019” published by CBS in 2020. The calculated household and samples size for residential sector are listed in Table 3.2.

Table 3.2: Sample size for residential sector

District	Population Size (Households in 2021)	Sampling Size
Mountain (Subtotal)	128,983	1,189
Dolakha	47,870	400
Rasuwa	11,362	388
Sindhupalchok	69,751	401
Hill (Subtotal)	878,639	3612
Bhaktapur	70,946	401
Dhading	78,663	401
Kathmandu	276,054	403
Kavrepalanchok	83,932	401
Lalitpur	97,394	402
Makwanpur	96,214	402
Nuwakot	65,734	401
Ramechhap	45,073	400
Sindhuli	64,629	401
Terai (Subtotal)	153,662	402
Chitwan	153,662	402
Total	1,161,284	5,203

(CBS, 2020)

As shown in Table 3.3, sample has been collected in urban and rural part in each district for residential sector. The sample has been distributed proportionally on the basis of population size in order to avoid biasness on collection of sample.

Table 3.3: Sample size in urban and rural residential sector

District	Urban		Rural	
	Population size	Sample size	Population size	Sample size
Bhaktapur	430,408	402	-	-
Chitwan	695,203	378	26,965	24
Dhading	87,277	107	235,474	294
Dolakha	50,622	100	122,104	300
Kathmandu	2,017,532	403	-	-
Kavreplanchowk	218,162	246	148,717	155
Lalitpur	519,525	366	28,876	36
Makwanpur	235,114	186	225,939	216
Nuwakot	95,311	137	167,670	263
Ramechhap	65,347	148	105,273	252
Rasuwa	-	-	45,554	388
Sindhuli	142,490	175	157,627	225
Sindhupalchowk	108,290	165	154,562	236
Total	4,665,281	2,812	1,418,761	2,390

3.2.5.2 Commercial Sector

Each district is considered as the location for estimation of sample size. The total population size of commercial sector is 238,822 while the total estimated sample size is 4,954. The population size has been included from “National Economic Census 2018” published by CBS in 2021. The sample size will be proportionally distributed according to population of different types of commercial entities as classified by National Standard Industrial Classification (NSIC). Sector includes wholesales & retailer, accommodation & food service, financial & insurance education human health and social work, real state, professional, technical, scientific and other services.

Table 3.4: Sample size for commercial sector

District	Population Size	Sampling Size
Mountain (Subtotal)	13,714	1,064
Dolakha	5,291	376
Rasuwa	1,193	305
Sindhupalchok	7,230	383
Hill (Subtotal)	200,171	3,493
Bhaktapur	15,883	394
Dhading	9,355	387
Kathmandu	110,976	402
Kavrepalanchok	11,379	390
Lalitpur	22,566	397
Makwanpur	13,110	392
Nuwakot	6,727	382
Ramechhap	4,284	370
Sindhuli	5,891	379
Terai (Subtotal)	24,937	397
Chitwan	24,937	397
Total	238,822	4,954

(CBS, 2021)

3.2.5.3 Transportation Sector

The locations for the calculation of sample size are Janakpur Zone, Narayani Zone and Bagmati Zone. Total numbers of registered vehicles are 1,997,095 while 169,621 vehicles are registered in 2075/76. Thus, the sample size of numbers of vehicle is 1,207. Bus, minibus, car, jeep, van, tempo, e-rickshaw and motorcycle are categorized as passenger vehicles whereas lorry, truck, mini truck, pickup, tractor and cargo van are categorized under freight vehicles. Airplane and cable cars are also included in the vehicle category.

Table 3.5: Sample size for transportation sector

Zone	Population size	Sample size
Janakpur	12,580	391
Narayani	71,052	401

Zone	Population size	Sample size
Bagmati	85,989	402
Total	169,621	1,194

(DOTM, 2019)

3.2.5.4 Industrial Sector

A manufacturing factory with a specific product is considered as the sample unit for the industrial sector. District is the ultimate location for estimation of sample size. Industries are categorized according to NSIC. Different manufacturing industries are iron and steel, engineering, machineries and other metals, electrical and electronic products, petrochemical and chemical products, rubber, glass and plastics, cement, bricks, concrete and clay products, food, drink and tobacco, textiles, readymade garment and leather products, furniture and fixtures, paper, publication and printing, and miscellaneous (jewelry, musical instruments, sporting goods, toys etc.). This sector has been classified into 24 categories by type of products and economic output by Nepal Standard Industrial Classification (NSIC). These categories represent specific outputs. Thus, for simplicity of energy analysis, the industries have been grouped into 8 categories based on type of output and energy activity they utilize. Table 3.6 shows the categorization for each of the industry type.

Table 3.6: Industrial sector categorization

Adopted 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

Total population size of industrial sector is 1,690 while sample estimated is 514. Furthermore, the sample size segregated on the basis of NSIC has been included in annex 6.

Table 3.7: Sample size for industrial sector

District	Population Size	Sampling Size
Mountain (Subtotal)	13	4
Dolakha	5	2
Rasuwa	4	1
Sindhupalchok	4	1
Hill (Subtotal)	1560	471
Bhaktapur	84	28
Dhading	23	8
Kathmandu	1,021	293
Kavrepalanchok	64	21
Lalitpur	267	88
Makwanpur	89	29
Nuwakot	12	4
Ramechhap	18	6
Sindhuli	6	2
Terai (Subtotal)	117	39
Chitwan	117	39
Total	1,690	514

(DOI, 2021)

3.2.5.5 Construction and Mining Sector

Construction and mining site is considered as the sample unit for the energy consumption survey. District is considered as the ultimate location for estimation of sample size. Total population size and mining size of construction and mining industry are 162 and 54 respectively. Moreover, National pride construction projects are also identified in the sample design.

Table 3.8: Sample size for construction and mining sector

District	Population Size	Sampling Size
Mountain (Subtotal)	8	4
Dolakha	1	1
Rasuwa	2	1
Sindhupalchok	5	2
Hill (Subtotal)	148	48
Bhaktapur	6	2
Dhading	4	2
Kathmandu	75	25
Kavrepalanchok	3	1
Lalitpur	53	18

District	Population Size	Sampling Size
Makwanpur	6	2
Nuwakot	3	1
Ramechhap	3	1
Sindhuli	1	1
Terai (Subtotal)	6	2
Chitwan	6	2
Total	162	54

(DOI, 2021)

3.2.5.6 Agriculture Sector

The sample unit for the energy consumption survey in agricultural sector is farm size. The farm size is categorized as small (up to 0.5 hectare), medium (0.5 to 2 hectare) and large (above 2 hectare) on the basis of area. The equipment such as iron plough, power tiller, tractor, thresher, pumping set and motors, has major contribution on farming and consumes enormous energy. District is considered as the ultimate location for determination of sample size. The counted total population size is 298,926 whereas the sample size is 3,714. Sample size on the basis of classification of farm size is incorporated in annex 3.

Table 3.9: Sample size for agricultural sector

District	Population Size	Sampling Size
Mountain (Subtotal)	523	181
Dolakha	282	98
Rasuwa	84	29
Sindhupalchok	157	54
Hill (Subtotal)	135,336	3,131
Bhaktapur	13,037	392
Dhading	7,991	385
Kathmandu	23,433	397
Kavrepalanchok	45,291	400
Lalitpur	8,609	386
Makwanpur	18,782	395
Nuwakot	2,315	346
Ramechhap	105	36
Sindhuli	15,773	394
Terai (Subtotal)	163,067	402
Chitwan	163,067	402
Total	298,926	3,714

(CBS, 2013)

3.2.6 Inception Report

The inception report has been prepared and submitted within a month after signing contract. A consultation workshop between the consultant, client and stakeholders has been conducted to discuss the inception report. The shortcoming of the report has been fixed by incorporating comments from the consultation workshop and a final and revised inception report will be submitted to the client.

Five hard copies of the report including a soft copy have been submitted to WECS for its approval. All pages of the hard copy will be authenticated by the consultant with official signature and official stamps.

3.3 Interim Phase

The interim phase has been commenced after the approval of final inception report along with the methodology and work plan by the client. The estimated duration of this phase was around six months. All the field work for energy survey, data collection and data analysis has been completed in this phase of work. The step involved in this phase is shown in Figure 3.9.

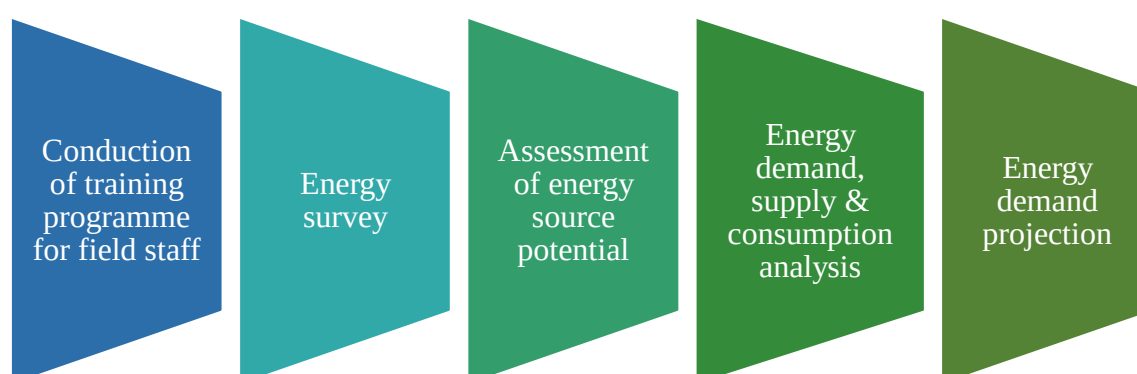


Figure 3.9: Steps in interim phase

3.3.1 Data Collection

As the energy survey has been conducted for different economic sectors the unit of data collection is different. The information regarding the data collected is shown in Table 3.10.

Table 3.10: Information collected/analyzed

Economic sector	Sample unit	Data collected/ analyzed
Residential/ Domestic sector	Household	• Energy consumption by fuel/technology • Socio economic information like household size, distance from the nearest market, distance from the forests, distance from the highway/accessible road, access to grid electricity etc. • Access to other energy form like biogas, solar, micro hydro etc. • Specific energy consumption per capita • Energy production within the household • Commercial production of the energy resources

Economic sector	Sample unit	Data collected/ analyzed
Industrial sector	Single factory with particular product	- Type of industry and economic output - Energy consumption by industrial output, cost, labor etc. - Specific energy consumption of products (per tonne/kl of product) - Energy production potential if any
Commercial sector	Commercial entity	- Type of institution and economic output - Energy consumption per capita - Energy consumption per sample unit - Energy consumption per factor of expansion
Transport sector	Vehicle	- Major driving factors affecting the energy consumption - Number of vehicles (operational and non-operational) registered in different Zones in Bagmati Province - Energy consumption, owner's information, its type, capacity etc. - Average kilometers of each vehicle type in a day/week/month/year - Total fuel consumption by each transport mode - Numbers of petrol pumps supplying the petroleum product - Future energy demand in each type of transport mode at different growth scenario - Supply of fuel used in the transport sector
Agricultural sector	Farm	- Energy consumption (type, amount and specific use) - Farm size/ type of product produced - Specific energy consumption (per ha/biggha/ropani) - Energy production potential - Technology used
Construction and mining sector	Construction/mini ng/quarry site	- Energy consumption, supply and demand forecast of all on going National Pride Project under province level - Inventory of construction sector projects, mining industries and equipment - Specific energy consumption of construction and mining sector

3.3.2 Interim Report

An interim progress report has been submitted every two months during the interim phase and has included data collected, processed and analyzed data/model along with entire completed questionnaire sheet in its original form. The final interim report has been submitted after the completion of Interim phase.

3.4 Draft Phase

The draft phase was commenced after the completion of the interim phase. The estimated duration of this phase was around three months. All the tasks involved with the technology transfer, training program in operation of energy demand was completed in this phase of work. In this phase of work, a draft report was prepared that included all the data collected, analyzed, energy demand projection models at different growth rate along with detailed methodology taken, work plan etc. The report will also cover text, table, picture based on the findings of the survey work.

3.4.1 Training in Operation of Energy Demand Projection Model

The complete developed model of future energy demand projection of all economic sectors by each energy resources type at different growth scenarios (socio economic, technology and demography) of Bagmati Province has been submitted during the draft phase of work. Energy demand was projected up to 2050 by using MAED software as mentioned in above section. The consultant conducted training program for the operation of energy demand projection model. Clients has the participants in the training program so that the model can be handled effectively in future. The program was conducted for approximately seven days.

3.4.2 Interaction Workshop on Draft Report

The consultant had organized interaction workshop on the preparation of Draft Report among related stakeholders of Bagmati Province. Moreover, the client had invited experts and professionals for the comment and suggestion on Draft Report. Such comments and suggestions provided during the workshop was incorporated in the Draft Report. All the cost and expenses in the conduction of workshop has been borne by the consultant.

3.4.3 Draft Report

The draft report has been submitted after the completion of draft phase and includes all the data involved with this assignment along with any other information and technology transfer. The Draft Report covers the method of sampling and list of sample units with its detail information. The consultation workshop was conducted to discuss possible improvements that could be made on the Draft reports. The final Draft report has been submitted by incorporating comments from the Draft workshop.

Five hard copies of the report including a soft copy has been submitted to WECS for its approval. All pages of the hard copy are authenticated by the consultant with official signature and official stamps.

3.5 Final Phase

Final report has been prepared and submitted within this phase. The estimated duration of this phase is one month after the submission and approval of the Draft Report. The Consultant has prepared the Final Report incorporating all the comments and suggestions, if any. Ten hard copies and a soft copy of Final Report has been submitted to WECS. The consultant has submitted all data, analyzed database files and has completed energy demand projection model including all the results/findings along with all the filled in questionnaires, proof of field visit and any other documents relevant to the assignment.

CHAPTER FOUR : ENERGY SCENARIO DEVELOPMENT

4.1 Introduction on Scenario-Based Approach

Scenario based planning is a planning technique which was introduced in 1970. This method is a new method that helps in forecasting. This method is not accurate to predict the future but develops the strategies to solve the upcoming problems. Different approaches have been developed for scenario planning and all the approaches are differing in their details. Traditional scenario planning suffers from a number of weaknesses. So to overcome them scenario-based approach was developed by modifying the traditional approach (Wulf, Meisner, & Stubner, 2010).

4.2 Major Assumptions/Options for Demand (Supply) Analysis

4.2.1 Economy and Population Growth

In this study, certain driving factors were required such as economic and demographic parameters. The agricultural, commercial and industrial activities were assumed to be dependent on respective gross value added (GVA) while, the residential sector is dependent on population and the transport sector was dependent on both economic and demographic parameters. Therefore, for this study of GVA, economic and demographic parameters were calculated. The total population of Bagmati Province along with urban and rural population for demographic requirement along with GDP and its growth rate has been taken from CBS (Central Bureau Statistics).

4.2.2 Energy Sector Parameters

The major driving factors of energy sector are dependent on economic and demographic parameters. Table 4.1 illustrates the driving factors for different sectors that consume energy. In the residential sector, the driving factor is population. So the increment in population will increase the energy consumption in residential sector, while the increment in GDP and population will directly affect the energy demand in transport sector. Similarly, the driving factors for agricultural, construction and mining, commercial and industrial sectors are listed below in the table.

Table 4.1: Driving factors for different energy sectors

Sectors	Driving factors
Residential	Population
Transport	GDP and Population
Agricultural	GDP
Construction and Mining	GDP
Commercial	GDP
Industrial	GDP

4.3 Scenario Development

The scenario development is essential for the energy forecasting and comparison for the various models. During this study, three scenarios have been developed based on the forecasted economic growth rate. The growth rate for the scenario are based on reports published by the various governmental bodies. The scenarios developed along with the growth rate considered for different scenarios are presented in Table 4.2. For low growth scenarios, the average of the GDP growth rate of Bagmati Province over the two out of the last three years has been considered. Similarly,

for reference growth scenarios, the economic growth rate as targeted by SDG 7 and SNDC has been considered. Also, for the high growth rate, the GDP growth rate as targeted by the Provincial Ministry of Bagmati Province is considered.

Table 4.2: Growth rate in different scenarios

S.N.	Scenarios	GDP growth rate
1.	Low Economic Growth	4.8%
2.	Reference Economic Growth	7%
3.	High Economic Growth	10.8%

4.4 Use of Energy Modelling Tools

Energy modelling tools like LEAP (Low Emissions Analysis Platform), MAED (Model for Analysis of Energy Demand), TIMES (The Integrated MARKAL-EFOM1 System) etc. are available for modeling of future demand scenario of energy of Nepal. At first, the database is generated for a base year which includes energy consumption, supply and resource assessment then the demand is projected under various circumstances. The energy scenario provides a framework for future energy demand and forecast the energy consumption in future under specific conditions. This helps the policymakers to provide the pathway for the development of energy at national and provincial level. This has provided the idea for the replacement of the energy technologies with more efficient fuel in a sustainable manner.

The energy system analysis was done from the bottom-up approach. The base year was taken as 2021 for energy demand analysis and the energy scenario is developed till 2050. For the base year, energy model was developed by doing the data collection. This included the demand analysis, supply analysis and resource analysis. The scenario development was done in MAED. MAED is one of the energy modelling tools which provides a rigid framework to evaluate the future energy demand but it lacks a least-cost optimization for economic resource mobilization. The end use categories in MAED are residential, industrial, commercial, transport, agricultural and construction and mining and these categories are again divided into different other sub-categories.

4.4.1 Model for Analysis of Energy Demand (MAED)

MAED¹ is one of the energy modeling tools developed by the IAEA (International Atomic Energy Agency). MAED model evaluated future energy demand based on medium to long term scenarios for socio-economic, technological and demographic developments. The starting point for using the MAED model is construction of base year energy consumption. This requires compiling and reconciling necessary data from different sources, deriving and calculating various input parameters and adjusting them. Then in next stem, the future scenario is developed viewing the country situation and objectives.

The model focuses exclusively on energy demand, and even more specifically on demand for specified energy services. The various energy forms, i.e. electricity, fossil fuels, and renewable energy would compete for a given end-use category of energy demand. This demand is specifically calculated in useful energy terms and then converted into final energy, taking into account the

¹ It should be noted that this analysis has considered MAED-2.

market penetration rates and the efficiency of each alternative energy source, both specified as scenario parameters. Non-substitutable energy uses such as motor fuels for cars, electricity for specific uses (electrolysis, lighting etc.) are calculated directly in terms of final energy.

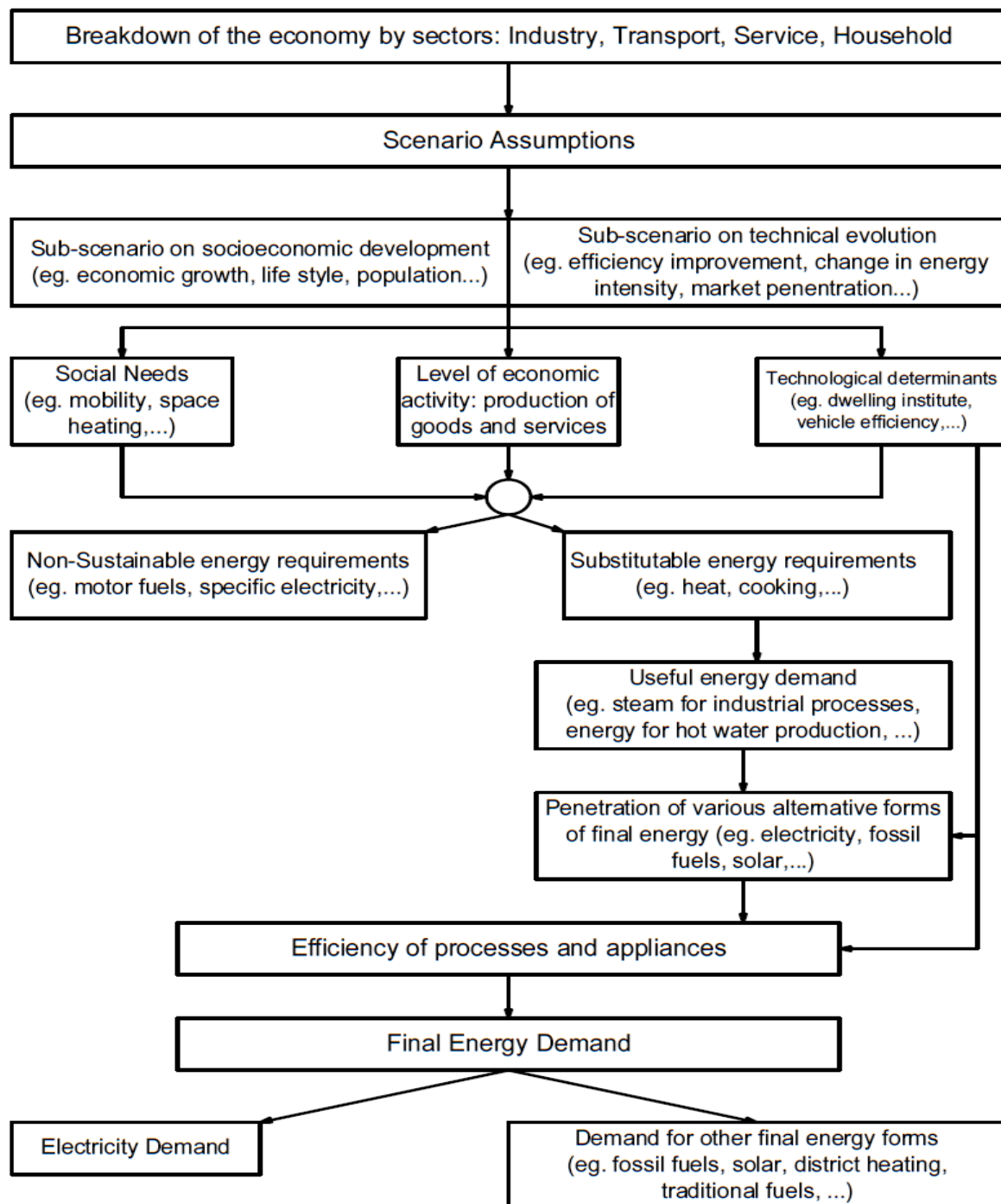


Figure 4.1: Scheme used to project useful and final energy demand in Module 1 of MAED

CHAPTER FIVE : ENERGY SUPPLY SITUATION

With the depletion of fossil fuels, energy supply situation plays an important role for the energy planners and policy makers alike. Energy resources can be divided into renewable energy resources and non-renewable energy resources. In terms of R/P ratio (reserve/production) ratio, the energy resources with R/P ratio of 100 and above are categorized into renewable energy and resources with those R/P ratios below 100 are categorized into nonrenewable energy resources. The examples of nonrenewable energy sources are petrol, diesel, kerosene etc. while solar wind, biomass, hydro etc. fall under renewable energy resources. The detail categorization of energy resources is shown in Figure 5.1.

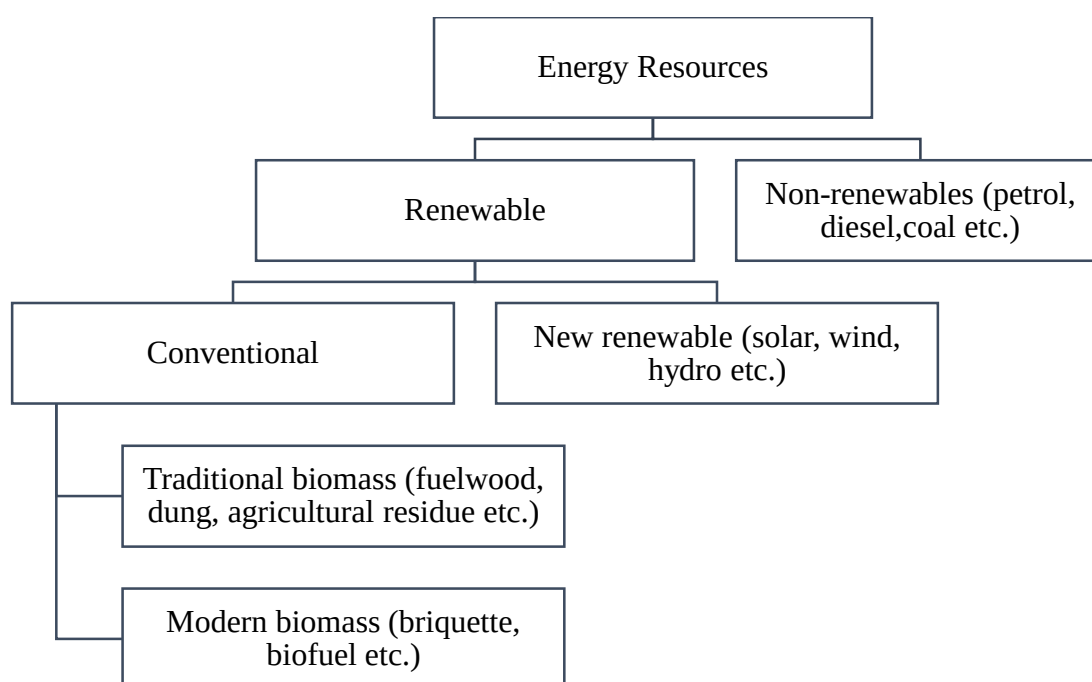


Figure 5.1: Classification of energy

5.1 Solid Biomass

Biomass is the renewable energy source which is derived from organic matter such as wood, crops, waste etc. Generally, fuelwood is considered as the solid biomass. The combustion of these solid biomass results in production of heat energy which can be used directly for cooking purposes or indirectly for electricity production and so on. In Bagmati Province the total area of forest is around 53.73% (including other wooded land) and supports different type of vegetation like deciduous, coniferous and alpine forests and woodland. If managed properly these forest can have a significant role in firewood production.

These forest are mostly located in rural municipalities in case of Bagmati Province. 73.3% of the forest is located in rural municipalities where households utilize fuelwood from forest for cooking and heating purpose in traditional manner hence releasing greenhouse gases in the atmosphere. The efficient management of fuelwood along with the use of improved and modern technology can reduce the GHG emission significantly.

5.2 Physical Environment

Bagmati Province consists of 3 physiographic zones i.e. Terai, Hills and Mountain. There is one district in Terai, 9 districts in Hilly region and 3 districts in the Mountain. The elevation varies from 141m at Golaghat in Chitwan to 7,422m at Ganesh Himal. There are geographical regions from Chure, mid hills to high mountains. Hence, the biodiversity within Bagmati Province covers large area of forests and animals.

Terai region consists of recent and post-pleistocene alluvial deposits that form a piedmont plain (Carson et al., 1986). The lower Chure is largely composed of very fine-grained sediments such as variegated mudstone, siltstone and shale with smaller amounts of fine-grained sandstone (Upreti, 1999). The middle Chure has thick beds of multi-storied sandstone alternating with subordinate beds of mudstone. The upper Chure is characterized by very coarse sediments such as loose boulder conglomerates. Dominant soil texture found in Middle Mountains region ranges from fragmented sandy to loamy/boulderly, loamy, loamy skeletal as per the diverse land forms. High Mountains soils are rocky mostly derived from phyletic, schist, gneiss and quartzite of different ages. High Himal physiographic region is characterised by rocky soils originated from gneiss, schist, limestone and shale of different ages (Pariyar, 2008).

The Terai comprises of a narrow belt of flat and fertile land in the southernmost part of the country around 200m meters above from the sea level. The altitude of below 1000m signifies that the forest here lies in the tropical zone. Climate in the Terai is hot in summer and warm in winter. Plant species which grow in Terai, generally need hot temperature and high moisture in soil. *Shorea robusta* (sal), *Adina cordifolia*, *Aegle marmelos*, *Albizia* spp., *Anthocephalus chinensis*, *Anogeissus latifolia*, *Butea frondosa*, *Dillenia pentagyna*, *Dillenia indica*, etc. are the vegetation found in the forests in Terai.

Altitude of Hilly region vary from 1000 m to 3000 m and climate comprises of subtropical and temperate ecological zone of Nepal. It has subtropical to temperate monsoonal climate and is characterized by a great variety of terrain types and intensive farming on hillside terraces. The dominant soil types include Precambrian phyllite, quartzite, schist, granite, and limestone. The zone has the greatest diversity of ecosystems and species in Nepal.

In the Mountain region (3000m and above) the climate is cold with snow covering throughout the year and hence very few vegetation survives in this region. The vegetation in this region are mostly alpine forests (upto 5000m) and as the elevation further increases (above 5000m) the type of forest found becomes Nival forest. The forests in the alpine zone are characterized by the presence of various stunted bushes. The main species are *Rhododendron setosum*, *R. anthopogon*, *R. lepidotum*, *Potentilla fruiticosa*, *Ephedra gerardiana*, *Berberis* spp. and *Cotonneseaster acuminate*. In river valleys *Hippophae* spp. and *Salix* spp. along with *Saxifraga*, *Arenaria* and *Androsace* species and alpine grasses are found. The Nival zone consists of the permanent snowfields, rocks, glaciers and ice on the high Himalayan ranges in the north. The area lies under permanent snow and is mostly without vegetation except for some Lichens on exposed rocky places and few flowering plants such as *Stellaria decumbens*. This zone also supports species like *Androsace*, *Sassurea*, *Primula*, and *Arenaria* that complete their life cycle within three to four months during the rainy season.

5.3 Forest

In Bagmati Province, 1,090,876 hectares (ha) is covered by forest, this equates to 53.73% of the total land area. The type of forest varies according to the elevation of the region, i.e., from tropical forest (below 1000 m) to Nival forest (above 5000 m). Different types of vegetation located in different districts of the Bagmati Province are shown in Table 5.1.

Table 5.1: Vegetations in Bagmati Province

District	Soft wood		Hard wood
	Conical leaves	Flat leaves	Flat leaves
Mountain region			
Rasuwa	Chir Pine, Blue Pine, West Himalayan Spruce, West Himalayan Fir, Tecote Pine	Nepalese Alder, Himalayan Ash	Walnut, Brown Oak, Himalayan Cherry, Himalayan White Pine
Dolakha	Chir Pine, Blue Pine, West Himalayan Spruce, West Himalayan Fir, Tecote Pine	Nepalese Alder, Himalayan Ash	Black Juniper
Kavrepalanchowk	Chir Pine, Tecote Pine	Nepalese Alder, Himalayan Ash, Mango Tree, Lebbek Tree, Eucalyptus	Kattus, Sal tree, Albizia Lebbek, Himalayan Pine, Champaca, Cutch tree
Hilly region			
Sindhupalchowk	Chir Pine, Tecote Pine	Nepalese Alder, Himalayan Ash, Mango Tree, Lebbek Tree, Eucalyptus	Sal Tree, Kattus, Himalayan pine
Dhading	Chir Pine	Nepalese Alder, Himalayan Ash, Mango Tree, Lebbek Tree, Eucalyptus	Sal Tree, Kattus, Himalayan pine
Ramechhap	Chir Pine, Blue Pine	Nepalese Alder, Himalayan Ash, Mango Tree, Lebbek Tree, Eucalyptus	Sal Tree, Karma Tree, Kino tree, Sisso tree, Albizia, Bot dhangero, Black Plum tree, Jackfruit, Glaucous Oak, Brown Oak
Kathmandu	Chir Pine	Nepalese Alder, Himalayan Ash, Lebbek Tree, Eucalyptus	Kattus, Glaucous Oak, Brown Oak, Banjh Oak
Lalitpur	Chir Pine	Nepalese Alder, Himalayan Ash, Lebbek Tree, Eucalyptus	Kattus, Glaucous Oak, Brown Oak, Banjh Oak

District	Soft wood		Hard wood
	Conical leaves	Flat leaves	Flat leaves
Bhaktapur	Chir pine	Nepalese Alder, Himalayan Ash, Lebbek Tree, Eucalyptus	Kattus, Glauous Oak, Brown Oak, Banjh Oak
Nuwakot	Chir pine	Nepalese Alder, Himalayan Ash, Lebbek Tree	Sal Tree, Karma Tree, Kino tree, Sisso tree, Albizia, Bot dhango, Black Plum tree, Jackfruit, Glauous Oak, Brown Oak
Makwanpur	Chir pine	Bombax tree, Burflower Tree, Dabdabe tree	Sal Tree, Karma Tree, Kino tree, Sisso tree, Albizia, Bot dhango, Black Plum tree, Jackfruit, Glauous Oak, Brown Oak
Sindhuli	Chir pine	Bombax tree, Burflower Tree, Dabdabe tree	Sal Tree, Karma Tree, Kino tree, Sisso tree, Albizia, Bot dhango, Black Plum tree, Jackfruit
Terai region			
Chitwan	Chir pine	Bombax tree, Burflower Tree, Dabdabe tree	Sal Tree, Karma Tree, Kino tree, Sisso tree, Albizia, Bot dhango, Black Plum tree, Jackfruit

Similarly, different medicinal herbs are available in 5 districts (Sindhuli, Kavrepalanchowk, Sindhupalchowk, Rasuwa and Nuwakot) of Bagmati Province. The medicinal herbs like *Aconitum heterophyllum*, *Phyllanthus emblica*, *Juglans regia*, *Neopicrorhiza scrophulariiflora* etc are available in large quantities in Bagmati Province.

5.3.1 Forest Management

Overall, 53.73% of the total area of Bagmati Province is covered by forest, other wooded land (OWL), national park and conservation area. There are five national parks/conservation areas managed for the protection of vegetation and animals in the province. These national parks are Chitwan National Park, Parsa National Park, Shivapuri Nagarjun National Park, Langtang National Park and Gaurishankar Conservation Area. These parks cover a total land area of 608,541 hectares (MoITFE, 2075).

Table 5.2: National park and conservation area in Bagmati Province

S.N.	Protected area	Core area (km ²)	Buffer zone area (km ²)	Total area(km ²)
1.	Chitwan National Park	763.30	470.45	1,233.75
2.	Parsa National park	72.90	192.15	265.05
3.	Shivapuri Nagarjun National park	159.00	118.61	277.61
4.	Langtang National Park	1,710.00	420.00	2,130.00
5.	Gaurishankar Conservation area	2179.00	0.00	2179.00
Total		4884.2	1201.21	6085.41

(MoITFE, 2075)

Most of the forests in the regions are community forests followed by leased and private forest. Different types of forest including OWL located in the different districts of Bagmati Province are shown in Table 5.3.

Table 5.3: Forest area in Bagmati Province

District	Forest (km ²)	Other woodland (km ²)	Total Forest land(km ²)	Total area(km ²)
Mountain (Subtotal)	260,715	17,766	278,481	614,020
Rasuwa	49,821	4,935	54,756	150,123
Dolakha	97,091	10,751	107,842	214,871
Sindhupalchowk	113,803	2,080	115,883	249,026
Hill (Subtotal)	643,825	21,081	664,906	1,192,311
Bhaktapur	2,459	15	2,474	12,311
Dhading	86,067	6,676	92,743	190,674
Kathmandu	15,129	150	15,279	41,361
Kavrepalanchowk	72,533	2,775	75,308	139,443
Lalitpur	23,924	536	24,460	39,683
Makwanpur	163,943	2,590	166,533	244,366
Nuwakot	49,423	2,616	52,039	119,317
Ramechap	65,248	4,125	69,373	156,553
Sindhuli	165,099	1,598	166,697	248,603
Terai (Subtotal)	141,668	5,821	147,489	223,970
Chitwan	141,668	5,821	147,489	223,970
Total	1,046,208	44,668	1,090,876	2,030,301

(MoITFE, 2075)

5.3.2 Fuelwood

Fuelwood or solid biomass is one of the most important renewable energy sources especially in developing and under developed country. In case of Nepal, more than 66.5% of the total energy consumption is due to traditional energy i.e. fuelwood, agricultural residue and dung cake (MoF, 2020/21). According to Multi-Tier Framework 2019, 73.5% of the household uses firewood for cooking either as their primary or secondary source. In case of rural areas, the proportion is even greater with 75.8% of the household using firewood for cooking. Similarly, according to the annual household survey 2016/17 conducted by CBS, 52.4% of the households lists firewood as their primary source of cooking while in rural areas 65.8% of the households use firewood as primary source of cooking. In case of Bagmati Province more than 46.14% of the household uses fuelwood as their primary source of cooking (CBS, 2011)

The use of firewood in inefficient manner has the adverse effect on the environment with release of various harmful gases like CO, methane etc. With the aim to improve the use of firewood, Government of Nepal along with various partners have been continuously promoting renewables energy technology like domestic biogas, improved cook stoves, induction stoves etc. for cooking purpose.

5.3.3 Deforestation

The unplanned collection of firewood from the forest along with the nationalization of forest and smuggling of timber has largely caused deforestation in different part of the country. The National Forest Inventory (NFI, 1999) showed that Nepal had a forest area of 5.8 million ha (40% forest

cover) that consisted of 4.2 million ha (29%) of forest and 1.6 million ha (10.6%) of shrub land. These forests are distributed across the three geographical regions of the country. The middle mountains have about 48% of the forest area and the plains (Terai) has about 25%. The remainder is distributed in the high mountains of the Himalayas.

Land Resource Mapping Project (LRMP, 1984) conducted an assessment of the distribution of forest in the country. A comparison of NFI results with LRMP shows that the forest area in the country decreased by 24% over a period of 15 years (1979–1994), at an annual rate of 1.6%, and the area under shrub land increased by 126% during the same period. The high increase in shrub land whilst the overall forest area was decreasing gives clear evidence of high rates of forest degradation over the period, although the total loss of forested area was not substantial. In mountain districts, forest cover declined from 34.2% in 1978-79 to 23.7% in 1992-1996 (a decrease of 2.3% annually).

FAO's Global Forest Resource Assessment (2005) based on national data sources clearly shows the decreasing forest area in Nepal from 4.82 million ha (in 1990) to 3.64 million ha (in 2005). In addition, 400,000 ha were estimated to have been lost through fires in 2000. This area does not include forest degradation caused by grazing and encroachment. LRMP (1984) estimated that forest and shrub cover was 42.7% of the total land area (forest 38% and shrub 4.7%). Analysis made in this study also indicated a historically high rate of forest loss of 0.5% annually (of forest and shrub land combined) since 1978-79 and an annual decrease in forest cover of 1.7%.

5.3.4 Biomass form Forest

According to the Department of Forest Research and Survey (2014), The average stem volume for the forest is 167.42 m³/ha. Similarly, in case of middle mountain (hills) and high mountain the average stem volume is 124.26 m³/ha and 225.24 m³/ha. The above ground air dried biomass in Terai, middle mountain (hills) and high mountains is 190.02 t/ha, 143.26 t/ha and 271.46 t/ha. Similarly, the above ground oven dried biomass in Terai, middle mountain (hills) and high mountains is 172.74 t/ha, 130.24 t/ha and 246.78 t/ha.

Similarly, according to the Energy Sector Synopsis Report published by WECS (2010), the recovery factor for biomass in terai, middle mountain and upper mountain is 90%, 80% and 70% respectively. Depending on these parameters, the biomass production from forest in Bagmati Province is presented in Table 5.4.

Table 5.4: Biomass in Bagmati Province

District	Total forest land	Stem volume (m ³)	Total above ground biomass (MT)		Available above ground biomass (MT)	
			Air dried	Oven dried	Air dried	Oven dried
Mountain (Subtotal)	278,481	62,725,060	75,596	68,724	52,918	48,106
Rasuwa	54,756	12,333,241	14,864	13,513	10,405	9,459
Dolakha	107,842	24,290,332	29,275	26,613	20,492	18,629
Sindhupalchowk	115,883	26,101,487	31,458	28,598	22,020	20,018
Hill (Subtotal)	664,906	82,621,220	95,254	86,597	76,204	69,278
Bhaktapur	2,474	307,419	354	322	284	258

District	Total forest land	Stem volume (m ³)	Total above ground biomass (MT)		Available above ground biomass (MT)	
			Air dried	Oven dried	Air dried	Oven dried
Dhading	92,743	11,524,245	13,286	12,079	10,629	9,663
Kathmandu	15,279	1,898,569	2,189	1,990	1,751	1,592
Kavrepalanchowk	75,308	9,357,772	10,789	9,808	8,631	7,846
Lalitpur	24,460	3,039,400	3,504	3,186	2,803	2,549
Makwanpur	166,533	20,693,391	23,858	21,689	19,086	17,351
Nuwakot	52,039	6,466,366	7,455	6,778	5,964	5,422
Ramechhap	69,373	8,620,289	9,938	9,035	7,951	7,228
Sindhuli	166,697	20,713,769	23,881	21,711	19,105	17,368
Terai (Subtotal)	147,489	24,692,608	28,026	25,477	25,223	22,930
Chitwan	147,489	24,692,608	28,026	25,477	25,223	22,930

5.4 Biogas

5.4.1 Animal Dung Production

Biogas is obtained by the anaerobic digestion of organic waste. Biogas technology is suitable especially in area and household with animal husbandry. Biogas has an added advantage that it has net zero emission. For the estimation of the biogas potential, number of domestic animals play a vital role. The number of animals in Bagmati Province is presented in Table 5.5.

Table 5.5: Number of animals

Districts	Cattle	Buffaloes	Sheep	Goat	Pigs	Fowl	Duck
Mountain (Subtotal)	154,239	136,867	50,195	404,094	18,469	1,089,275	2,006
Rasuwa	14,410	6,800	29,062	40,026	950	110,025	300
Dolakha	77,553	59,928	12,373	168,322	9,101	511,496	836
Sindhupalchowk	62,276	70,139	8,760	195,746	8,418	467,754	870
Hill (Subtotal)	817,196	681,947	40,190	1,701,151	136,950	21,010,724	70,051
Bhaktapur	26,132	8,349	958	39,365	16,068	3,566,970	5,724
Dhading	128,724	96,952	8,465	178,574	17,903	2,850,956	1,853
Kathmandu	46,468	39,254	1,331	50,372	34,372	4,537,730	29,753
Kavre	146,555	146,285	3,659	286,410	12,173	3,246,230	3,613
Lalitpur	21,809	56,102	2,328	72,625	10,934	1,768,097	14,002
Makwanpur	106,610	113,539	2,789	295,210	10,120	2,507,812	5,298
Nuwakot	129,902	106,000	17,095	285,000	11,200	1,005,000	3,298
Ramechhap	75,043	46,290	3,166	208,481	12,028	303,576	1,640
Sindhuli	135,953	69,176	399	285,114	12,152	1,224,353	4,870
Terai (Subtotal)	92,914	76,112	3,254	245,972	16,858	22,741,958	13,053
Chitwan	92,914	76,112	3,254	245,972	16,858	22,741,958	13,053
Total	1,064,349	894,926	93,639	2,351,217	172,277	44,841,957	85,110

(MoALD, 2019/20)

In case of Nepal, only cow dung and buffalo dung are collected due to various sociocultural reasons and difficulty in collection. On average on a day, the dung production from cow and buffalo is 10 kg and 15 kg respectively (WECS, 2010). Hence the daily production of cow dung and buffalo dung in Bagmati Province is 10,643 tonnes and 13,423 tonnes.

Table 5.6: Dung production in Bagmati Province

Districts	Number		Annual dung production in tonnes		
	Cattle	Buffaloes	Cow dung	Buffaloes dung	Total
Mountain (Subtotal)	154,239	136,867	562,972.35	749,347.83	1,312,319.18
Dolakha	77,553	59,928	283,068.45	328,105.80	611,174.25
Rasuwa	14,410	6,800	52,596.50	37,230.00	89,826.50
Sindhupalchowk	62,276	70,139	227,307.40	384,011.03	611,318.43
Hill (Subtotal)	817,196	681,947	2,982,765.40	3,733,660.84	6,716,425.24
Bhaktapur	26,132	8,349	95,381.80	45,710.78	141,092.58
Dhading	128,724	96,952	469,842.60	530,812.20	1,000,654.80
Kathmandu	46,468	39,254	169,608.20	214,915.65	384,523.85
Kavre	146,555	146,285	534,925.75	800,910.38	1,335,836.13
Lalitpur	21,809	56,102	79,602.85	307,158.45	386,761.30
Makwanpur	106,610	113,539	389,126.50	621,626.03	1,010,752.53
Nuwakot	129,902	106,000	474,142.30	580,350.00	1,054,492.30
Ramechhap	75,043	46,290	273,906.95	253,437.75	527,344.70
Sindhuli	135,953	69,176	496,228.45	378,738.60	874,967.05
Terai (Subtotal)	92,914	76,112	339,136.10	416,713.20	755,849.30
Chitwan	92,914	76,112	339,136.10	416,713.20	755,849.30
Total	1,064,349	894,926	3,884,874.85	4,899,720.87	8,784,593.72

5.4.2 Biogas Production Potential

Due to the impact of Covid-19, the number of livestock in Bagmati Province in 2020 will remain same as that of 2019/20. Considering the biogas production factor of 0.036 m³/kg of dung (WECS, 2010) and a calorific value of 20 MJ/ m³, the biogas potential of various district of Bagmati Province is shown in Table 5.7.

Table 5.7: Biogas potential

District	Animal dung (Tonnes)	Biogas (m ³)	Energy (TJ)	Percentage potential	Biogas potential (TJ)
Mountain (subtotal)	1,312,319.18	47,243,490.30	944.88	0.50	472.43
Dolakha	611,174.25	22,002,273.00	440.05	0.5	220.02
Rasuwa	89,826.50	3,233,754.00	64.68	0.5	32.34
Sindhupalchowk	611,318.43	22,007,463.30	440.15	0.5	220.07
Hill (subtotal)	6,716,425.24	241,791,308.10	4,835.83	0.75	3,626.87
Bhaktapur	141,092.58	5,079,332.70	101.59	0.75	76.19
Dhading	1,000,654.80	36,023,572.80	720.47	0.75	540.35

District	Animal dung (Tonnes)	Biogas (m ³)	Energy (TJ)	Percentage potential	Biogas potential (TJ)
Kathmandu	384,523.85	13,842,858.60	276.86	0.75	207.64
Kavre	1,335,836.13	48,090,100.50	961.8	0.75	721.35
Lalitpur	386,761.30	13,923,406.80	278.47	0.75	208.85
Makwanpur	1,010,752.53	36,387,090.90	727.74	0.75	545.81
Nuwakot	1,054,492.30	37,961,722.80	759.23	0.75	569.43
Ramechhap	527,344.70	18,984,409.20	379.69	0.75	284.77
Sindhuli	874,967.05	31,498,813.80	629.98	0.75	472.48
Terai (subtotal)	755,849.30	27,210,574.80	544.21	1	544.21
Chitwan	755,849.30	27,210,574.80	544.21	1	544.21
Total	8,784,593.70	316,245,373.20	6,324.91	0.73	4,643.52

The percentage potential of biogas is considered 1, 0.75 and 0.5 for terai, hill and mountain. In addition to the production of the biogas, this process has an advantage of production of slurry which can be used as fertilizer. Also, the production of biogas from cow dung limits the production of dung cake and hence help the country to achieve net zero emission.

5.5 Agricultural Residue

There is the production of various crops in Bagmati Province that results in production of huge amount of agricultural residue. This agricultural residue if managed properly has a huge energy production potential. The detail of the agricultural residue produced and the energy potential is shown in Table 5.8.

Table 5.8: Energy production from agricultural residue

Crops	Area (hectare)	Residue (tonnes)	Energy (GJ)	Energy (%)
Paddy	129,830	765,997	11,489,955	35.37
Maize	191,268	1,042,411	15,636,159	48.13
Wheat	55,878	188,308.9	2,824,633	8.70
Sugarcane	199	4,776	71,640	0.22
Buckwheat	2,470	3,705	55,575	0.17
Oil seed	35,147	44,988.16	674,822.4	2.08
Millet	59,355	112,774.5	1,691,618	5.21
Barley	1,772	2,658	39,870	0.12
Total	475,919	2,165,618	32,484,272	100

The total energy produced due to the agricultural residue is 32,484,77 GJ. The major contributor in the production of energy from agricultural residue is maize at 48.13% followed by paddy at 35.37%. But energy from the agricultural residue should be used immediately as the it requires huge storage. Also, as the residue produced can be utilized only by the farmers its use is limited

to the residential sector only. If properly managed, the agricultural residue can be employed in the sugarcane industry as cogeneration plant thus reducing the cost of electricity of the plant.

5.6 Petroleum Products

In case of Nepal, all the petroleum product is imported from India. Nepal Oil Corporation is the sole importer of the petroleum products i.e. petrol, diesel, kerosene and LPG while furnace oil, lubricants etc. are imported directly by the industries and organizations themselves. The petroleum products are further supplied by the Nepal Oil corporation to private vendors (petrol pump, LPG suppliers etc.) which is then supplied to the consumers. The detail of the sales of petroleum product is shown in Table 5.9

Table 5.9: Petroleum sales in 2077/78

District	Petrol (kL)	Diesel (kL)	Kerosene (kL)	Aviation Fuel (kL)
Bhaktapur	17,081.05	24,790.51	275	
Chitwan	24,289.22	81,603.03	1,888.00	
Dhading	4,841.95	35,076.40	204	
Dolkha	1,047.00	8,020.81	144	
Kathmandu	106,139.55	96,575.37	2,855.61	54,497.97
Kavrepalanchok	9,319.41	48,897.66	299.94	
Lalitpur	24,815.70	23,328.90	285.15	
Makawanpur	9,696.82	77,634.16	420	
Nuwakot	3,161.83	11,325.18	73.97	
Ramechhap	1,137.00	5,859.00		62.43
Rasuwa	223	3,145.00		
Sindhuli	4,453.58	18,100.64	83.87	
Sindhupalchowk	1,577.00	9,698.43		

(NOC,2021)

5.7 Electricity

According to the NEA 2020/21, Bagmati Province has 60 fully electrified local level, 58 partially electrified local level and 1 not electrified level. There are 37 IPPs hydropower within the Bagmati Province with a total capacity of 252.27 MW distributed over 8 districts. There are 10 hydropower over 10 MW, 20 hydropower between 1 to 10 MW and 6 hydropower below 1 MW. The list of IPPs hydropower is mentioned in Table 5.10.

Table 5.10: List of IPPs hydropower project

S.N.	Hydropower projects	Districts	Capacity (kW)
1.	Khimti Khola	Dolakha	60,000
2.	Upper Bhotekoshi Khola	Sindhupalchok	45,000
3.	Indrawati-Iii	Sindhupalchowk	7,500
4.	Chilime	Rasuwa	22,100

S.N.	Hydropower projects	Districts	Capacity (kW)
5.	Rairang Khola	Dhading	500
6.	Sunkoshi Small	Sindhupalchowk	2,500
7.	Chaku Khola	Sindhupalchowk	3,000
8.	Baramchi Khola	Sindhupalchowk	4,200
9.	Sali Nadi	Kathmandu	250
10.	Upper Hadi Khola	Sindhupalchowk	991
11.	Solar	Lalitpur	680
12.	Sipring Khola	Dolakha	9,658
13.	Middle Chaku	Sindhupalchowk	1,800
14.	Tadi Khola (Thaprek)	Nuwakot	5,000
15.	Ankhu Khola-1	Dhading	8,400
16.	Charanawati Khola	Dolakha	3,520
17.	Lower Chaku Khola	Sindhupalchowk	1,800
18.	Bhairab Kunda	Sindhupalchowk	3,000
19.	Mailung Khola	Rasuwa	5,000
20.	Jiri Khola Small	Dolakha	2,200
21.	Belkhu	Dhading	518
22.	Suspa Bukhari	Dolakha	998
23.	Jhyadi Khola	Sindhupalchowk	2,000
24.	Tungun-Thosne	Lalitpur	4,360
25.	Khani Khola	Lalitpur	2,000
26.	Dhunge-Jiri	Dolakha	600
27.	Chake Khola	Ramechhap	2,830
28.	Syauri Bhumey	Nuwakot	23
29.	Bagmati Khola Small	Makwanpur/Lalitpur	22,000
30.	Hadi Khola, Sunkoshi A	Sindhupalchowk	997
31.	Upper Chaku A	Sindhupalchowk	22,200
32.	Ghatte Khola	Dolakha	5,000
33.	Thoppal Khola	Dhading	1,650

(NEA 2020/21)

In addition to these, 1,882 MW of IPPs hydropower plant is under construction in different phases. The list of hydropower under construction is shown in Table 5.11.

Table 5.11: List of IPPs hydropower under construction

S.N.	Hydropower Project	District	Capacity (kW)
1.	Upper Belkhu	Dhading	750
2.	Ankhu Khola	Dhading	34,000
3.	Super Ankhu Khola	Dhading	23,500
4.	Ummer Tamakoshi	Dolakha	456,000
5.	Khani Khola I	Dolakha	40,000
6.	Khani Khola	Dolakha	30,000
7.	Tinekhu Khola	Dolakha	990
8.	Lower Khare	Dolakha	11,000
9.	Khare Khola	Dolakha	24,100
10.	Singati Khola	Dolakha	25,000
11.	Suri Khola	Dolakha	6,400
12.	Upper Lapche	Dolakha	52,000
13.	Lapche Khola	Dolakha	99,400
14.	Upper Suri	Dolakha	7,000
15.	Khimti 2	Dolakha & Ramechhap	48,800
16.	Chauri Khola	Kavre, Ramechhap, Sindhupalchowk & Dolakha	6,000
17.	Tadi Khola	Nuwakot	5,000
18.	Upper Tadi	Nuwakot	11,000
19.	Salankhu Khola	Nuwakot	2,500
20.	Lower Tadi	Nuwakot	4,993
21.	Chulepu Khola	Ramechhap	8,520
22.	Lower Likhu	Ramechhap	28,100
23.	Likhu 2	Ramechhap, Solukhumbu	33,400
24.	Lihu 1	Ramechhap, Solukhumbu	51,400
25.	Likhu Khola A	Ramechhap, Solukhumbu	24,200
26.	Uppe Khimti	Ramechhap	12,000
27.	Likhu Iv	Ramechhap	52,400
28.	Nupche Likhu	Ramechhap	57,500
29.	Sano Milti	Ramechhap and Dolakha	3,000
30.	Upper Mailung A	Rasuwa	6,420
31.	Upper Mailun	Rasuwa	14,300

S.N.	Hydropower Project	District	Capacity (kW)
32.	Upper Sanjen	Rasuwa	14,800
33.	Rasuwadgadhu	Rasuwa	111,000
34.	Sanjen	Rasuwa	42,500
35.	Phalankhu Khola	Rasuwa	13,700
36.	Upper Khimti Ii	Rasuwa	13,700
37.	Langtang Khola	Rasuwa	20,000
38.	Phalanku Khola	Rasuwa	5,000
39.	Upper Trishuli 1	Rasuwa	216,000
40.	Upper Trishuli 3b	Rasuwa	37,000
41.	Gelun	Sindhupachowk	3,200
42.	Selang Khola	Sindhupachowk	990
43.	Middle Bhotekoshi	Sindhupalchowk	102,000
44.	Balephi A	Sindhupalchowk	22,140
45.	Upper Balephi A	Sindhupalchowk	36,000
46.	Upper Nyasem	Sindhupalchowk	41,400
47.	Liping Khola	Sindhupalchowk	16,260
48.	Yambling Khola	Sindhupalchowk	7,270

(NEA 2020/21)

The total electricity consumption in Bagmati Province is 2249.8 GWh. Looking at the sectoral consumption, the majority of the electricity is consumed in residential sector at 51.78% followed by that in industrial sector at 23.36%. Similarly, the electricity consumption in commercial sector is 11.65%. The detail of the sectoral energy consumption is shown in Figure 5.2.

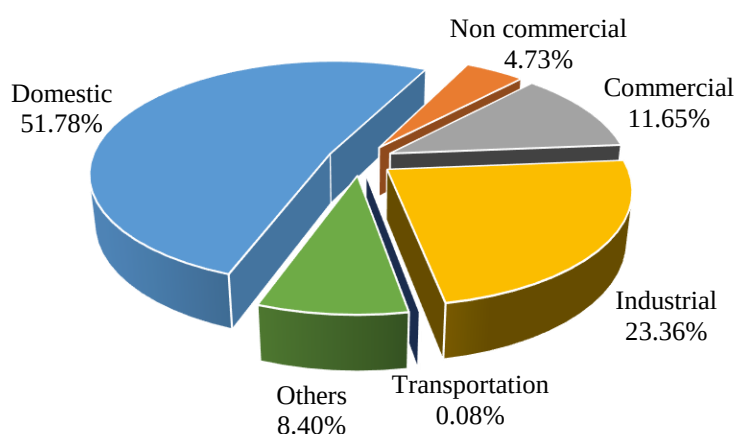


Figure 5.2: Sectoral electricity consumption

5.8 Renewable Energy Sources

Alternative Energy Promotion Center (AEPC) is devoted for the development of a expanded range of Renewable Energy Technologies (RETs) projects using different instruments and establishing high quality performance assurance and monitoring systems. Table 5.12 shows number of Improved Water Mill installed in Bagmati Province. According to user survey conducted by AEPC in 2020, it was found that nearly 95% of IWMs are in well operation condition.

Table 5.12: Number of IWM installed in Bagmati Province

Districts	Large plant	Small plant
Kavreplanchowk	2	10
Lalitpur	-	3
Makawanpur	-	30
Nuwakot	-	17
Sindhuli	9	7
Total	11	67

(CREF 2021, Unpublished)

Table 5.13 represents generation of power from different renewable energy in different districts of Bagmati Province. It seems that 234 kWh power is generated from ISPS. It has been calculated on the basis of Solar Design Guideline of AEPC which explains that solar radiation time for Nepal is normally 5 hours while efficiency of solar equipments is 70%. However, 177 kW power has been generated from IBG. Moreover, MHP and PHP has been generating 860 kW and 40 kW respectively.

Table 5.13: Generation of power from renewable energy in Bagmati Province

Districts	ISPS(kWh)	MHP(kW)	IBG(kW)	PHP(kW)
Bhaktapur	-	-	5.2	-
Chitwan	17.5	-	5.3	9.0
Dolakha	77	26.2	-	-
Dhading	-	464.5	2.7	-
Kathmandu	7	-	133.2	-
Kavrepalanchowk	42	20.0	5.1	-
Lalitpur	-	-	14.7	-
Makawanpur	24.5	16.5	11.2	-
Ramechhap	7	258.5	-	23.0
Sindhuli	59.5	75.0	-	8.5
Total	234.5	860.7	177.4	40.5

(CREF 2021, Unpublished)

According to User survey conducted by AEPC in fiscal year 2018/19, it was found that more than 90% of ISPS and IBGs are in operation condition. The users are fully satisfied by the uses of such renewable energy.

CHAPTER SIX : ENERGY CONSUMPTION

The energy consumed in Bagmati Province is 83.53 Petajoule (PJ). The highest proportion of the fuel used is due to fuelwood at 32.73% as in rural residential and industrial sector, the consumption of fuelwood is more. Likewise, consumption of commercial traded fuels (diesel, gasoline, kerosene, LPG, coal, furnace oil, electricity and ATF) is 52.11%. The higher share of commercially traded fuels is due to its accessibility and availability. As in industrial and transport sector, diesel is used most so, the share of diesel is more as compare to other commercially traded fuels while LPG is preferred for cooking in residential sector. Beside the use of electricity is also increasing in every sectors as Nepal Government is planning to replace the fossil fuel with electricity. On the other hand, although the use of solar energy is low, its demand is increasing.

Consumption of aviation fuel is also more in this province because the international airport (TIA) lies within it. Although Bagmati Province being developed, the consumption of traditional renewables is more due to its highest consumption in rural residential and industrial sector. Also, the consumption of non-renewable energy is also more and these consumptions are slowly being replaced by new renewables such as electricity and solar energy. However, the users still prefer to use easily accessible fuel and the users from rural sectors feel comfortable to use the traditional fuels rather than modern and new renewable fuels.

The consumption of fuelwood in Bagmati Province is less when compared with national consumption (60.58%) this signifies that most of the areas of Bagmati Province has been urbanized with access to commercially traded fuels. Energy consumption by fuel used in Bagmati Province presented in Figure 6.1.

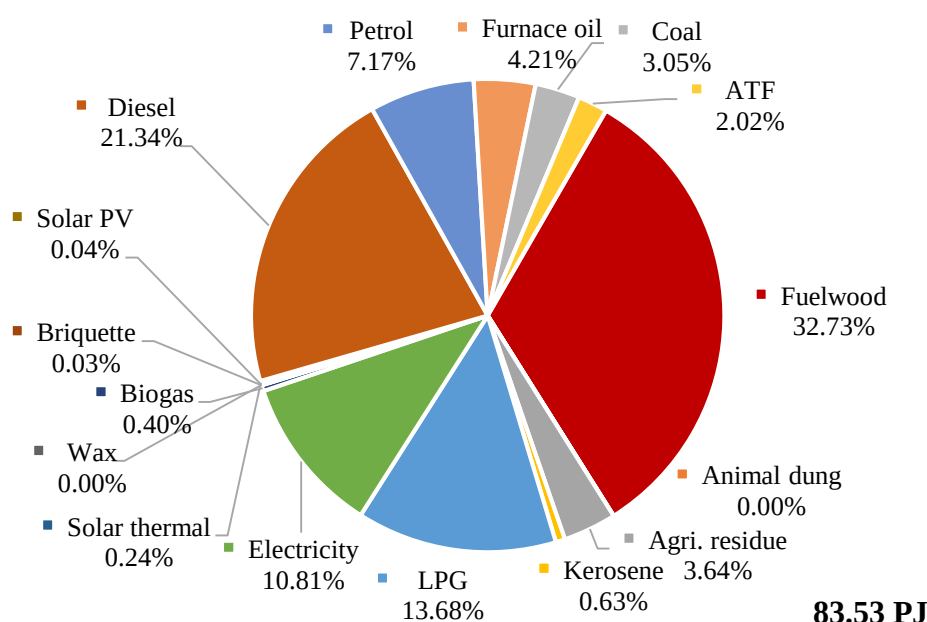


Figure 6.1: Energy mix in six economical sector in Bagmati Province

Energy consumption in six different economic sectors is shown in Figure 6.2. It has been found that energy consumption in residential sector is higher which contribute 42.26% share of total energy consumption in Bagmati Province. The main reason behind this is Bagmati Province being

densely populated. Similarly, industrial sector consumes 33.34% of total energy which is followed by transport sector and commercial sectors. In agricultural and construction & mining sectors, energy consumption is comparatively lower. It implies that energy consumption in construction and mining sector is low while in agricultural sector, traditional agricultural tools are still being used.

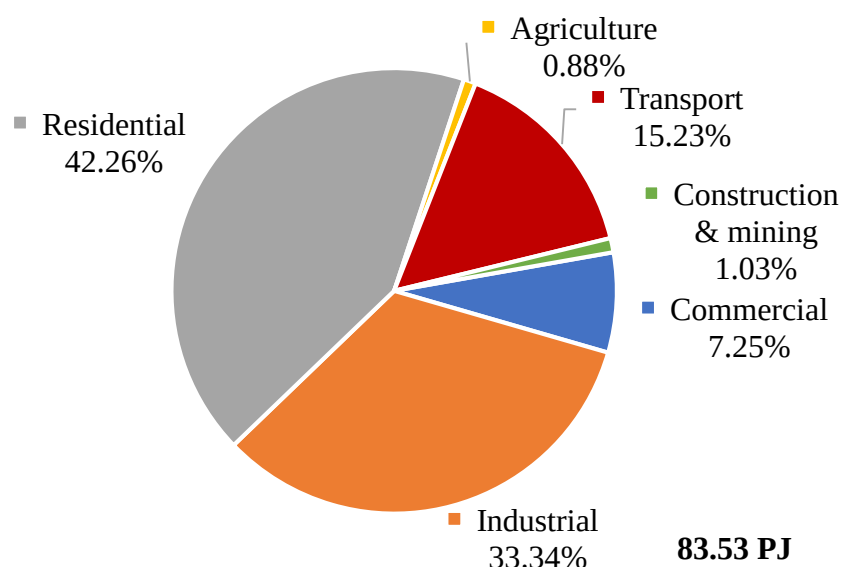


Figure 6.2: Energy consumption in six different economic sector

The energy consumption in Bagmati Province by physiographical region is shown in Figure 6.3. It portrays Hilly region as the highest energy consuming physiographic region at 80.53%. This is because the proportion of land and population in Bagmati Province is more in Hilly region than Mountain and Terai region. Energy consumption in transport sector and construction and mining sectors are not included as their data are taken provincial.

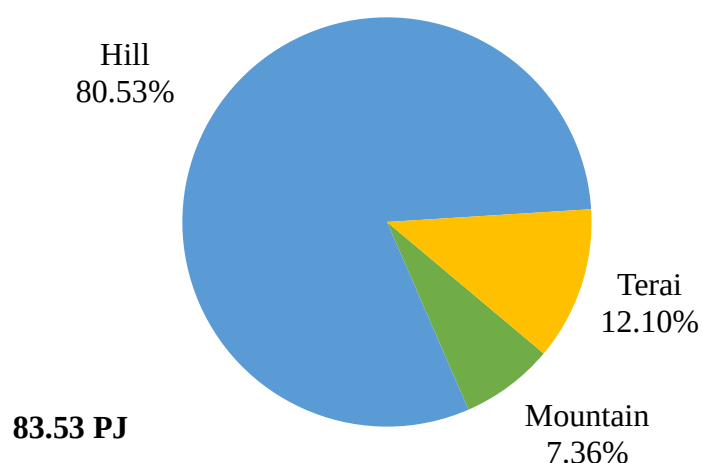


Figure 6.3: Energy consumption in Bagmati Province by physiographical region

Table 6.1 shows energy consumption in different economic sector by fuel types. It implies that economic sectors in Bagmati Province depend upon 48% of non-renewable energy and 52%

renewable energy. Residential and commercial sector are highly dependent on conventional renewable energy as well as new renewable energy. While industrial, transportation and construction and mining sector are dependent on nonrenewable energy i.e. the consumption of diesel is more in these sectors. The highest consumption of fuelwood is in rural residential sector as households are still using fuelwood for cooking. The consumption of diesel and petrol is more in transportation and construction and mining sector.

Table 6.1: Energy consumption in economic sectors by fuel types in 2021 (TJ)

Fuel type	Agriculture	Commercial	Industrial	Residential	Transportation	Construction and mining	Total
Traditional fuels (Renewable)							
Fuelwood	-	114	6,912	20,302	-	11	27,340
Animal Residue	-	-		3	-	-	3
Agriculture Residue	-	-	1,039	2,005	-	-	3,043
Modern fuels (Renewable)							
Biogas	-	-	-	335	-	-	335
Briquette	-	15	0	7	-	-	22
New Renewables							
Electricity	55	2,179	2,139	4,635	14	12	9,033
Solar PV	6	-	-	25	-	-	31
Solar Thermal	-	10	-	189	-	-	199
Non-Renewables							
Coal	-	286	2,261	0	-	-	2,547
Kerosene	-	-	529	0.4	-	0	529
LPG	-	3,455	93	7,799	15	64	11,427
Diesel	677	-	10,257	-	6,217	676	17,827
Gasoline	1	-	1,110	-	4,791	89	5,990
Furnace oil	-	-	3,508	-	-	9	3,518
Aviation Fuel	-	-	-	-	1,689	-	1,689
Total	739	6,059	27,848	35,300	12,726	861	83,535

The consumption of energy by ecological regions and sectors of Bagmati Province is illustrated in Table 6.2. The consumption of energy is low in mountain region while in the consumption is highest in hilly region. The consumption of energy is more in residential sector of hilly region as in this region the population than in other region. The consumption of energy in Mountain region is 5,149 TJ, hilly region is 56,331 TJ and terai region is 8,467 TJ. The total consumption of fuelwood and diesel is highest which 27,340 TJ and 17,827 TJ respectively. The total consumption of energy in transport and construction and mining sector of Bagmati Province is 12,726 TJ and 861 TJ respectively. The total consumption of energy in Bagmati Province is 83,535 TJ.

Table 6.2: Energy consumption by ecological regions and sectors of Bagmati Province (TJ)

	Fuelwood	Animal Residue	Agri. Residue	Biogas	Briquette	Electricity	Solar PV	Solar Thermal	Coal	Kerosene	LPG	Diesel	Gasoline	Furnace oil	Aviation fuel	Total
Mountain	4,072	0	283	158	0	165	1	3	0	0	407	62	-	-	-	5,149
Residential	4,022	0	283	158	-	83	1	0		0	320					4,867
Industrial	23		0		-	4			-	-	2	12	-	-		41
Commercial	26			-	0	77		3	0	-	85					191
Agricultural						1	0					49	-			50
Hill	20,912	3	1,229	85	21	7,968	25	196	1,870	529	9,921	8,975	1,087	3,508	-	56,331
Residential	14,796	3	696	85	6	4,136	19	189		0	6,710					26,640
Industrial	6,053		533		-	2,102			1,586	529	87	8,383	1,087	3,508		23,868
Commercial	63			-	15	1,677		7	284	-	3,124					5,171
Agricultural						54	6					592	-			651
Terai	2,345	-	1,532	91	1	875	5	-	677	-	1,020	1,898	23	-	-	8,467
Residential	1,484	-	1,026	91	1	416	5	-		-	769					3,793
Industrial	837		505		0	33			675	-	5	1,862	22	-		3,940
Commercial	24			-	-	425		-	2	-	246					697
Agricultural						0	0					37	1			37
Province																
Transport						14					15	6,217	4,791		1,689	12,726
Construction and mining	11					12				-	64	676	89	9		861
Total	27,340	3	3,043	335	22	9,033	31	199	2,547	529	11,427	17,827	5,990	3,518	1,689	83,535

Sankey chart signifies the energy flow of various energy resource, their conversion into various economic sector. The Sankey diagram for the Bagmati Province is shown in Figure 6.4. This shows the proportion of various energy resource in the total final energy consumption of Bagmati Province. Similarly, the majority energy consumption is due to wood product followed by diesel and LPF import and Hydropower production. The share of renewable energy technologies in the total energy consumption in Bagmati Province is minimal. It also shows the energy flow from various energy resources into different economic sectors. Based on economic sector, the highest share of energy consumption is in residential sector followed by industrial sector, transport sector, commercial sector, agricultural sector and construction & mining sector.

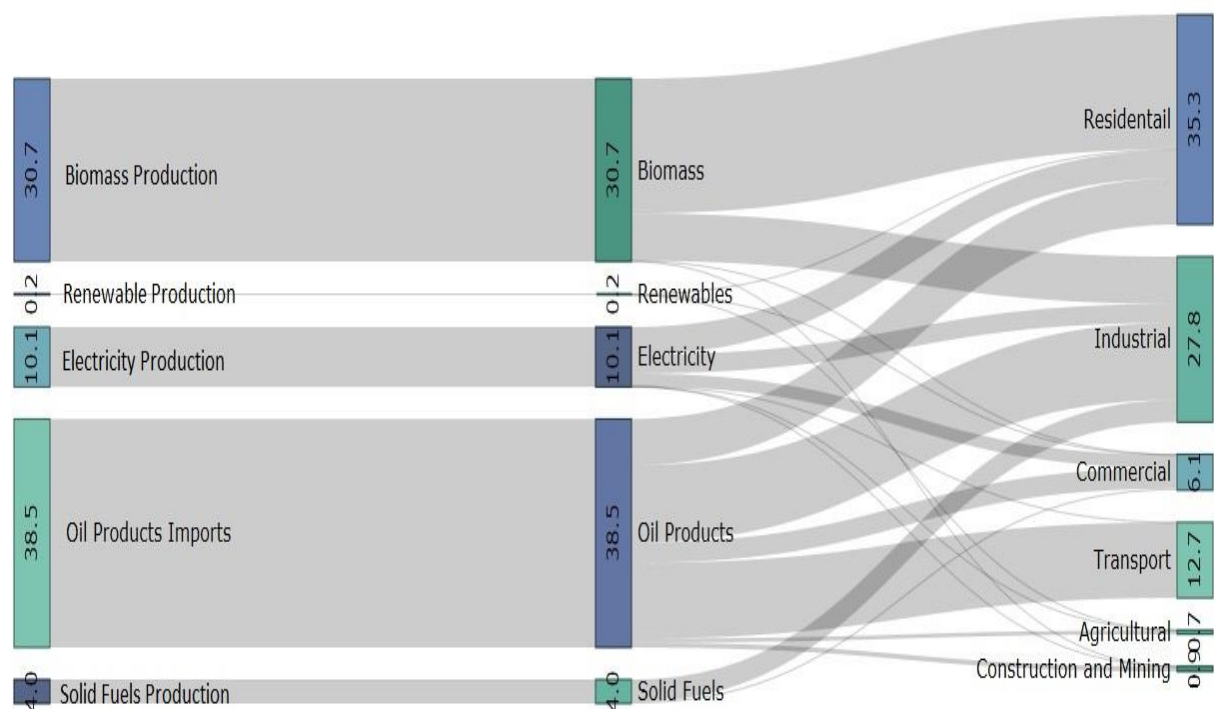


Figure 6.4: Sector-wise Sankey diagram for energy demand in Bagmati Province

6.1.1 Residential Sector

In residential sector of Bagmati Province, the total consumption of energy is about 35.3 PJ. Energy consumption in end use of residential sector is shown in Figure 6.5. It shows that energy consumption is mainly for cooking which constitutes about 64.54% followed by electrical appliances and animal feed preparation which contributes 8.42% and 11.71% respectively. This shows that the consumption of energy for thermal heating is more i.e. 85.02% which consists of cooking, animal feed preparation, water boiling, food and agro processing and space heating.

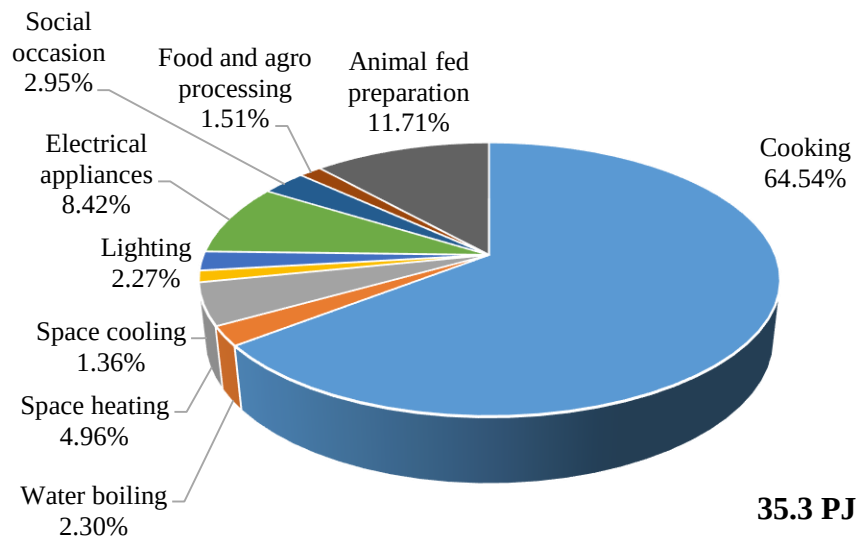


Figure 6.5: Share of final energy demand in residential sector by end-uses

Energy mix in residential sector is represented in Figure 6.6. As Nepal is still a developing country and people living here are dependent on cheaper source of energy. Hence, fuelwood constitutes 57.51% of total consumption and is used as the major source of energy since it can be collected from the local forest and farm easily and also the cost of fuelwood is cheaper than other sources of energy. Similarly, LPG and electricity constitute 22.09% and 13.13% share of total energy respectively while remaining percentage of energy share is covered by other energy sources. The consumption of solar thermal and solar PV is lower as compared to other energy resource as more than 90% of local levels are facilitated by electricity and so the consumers are using electricity instead of solar energy.

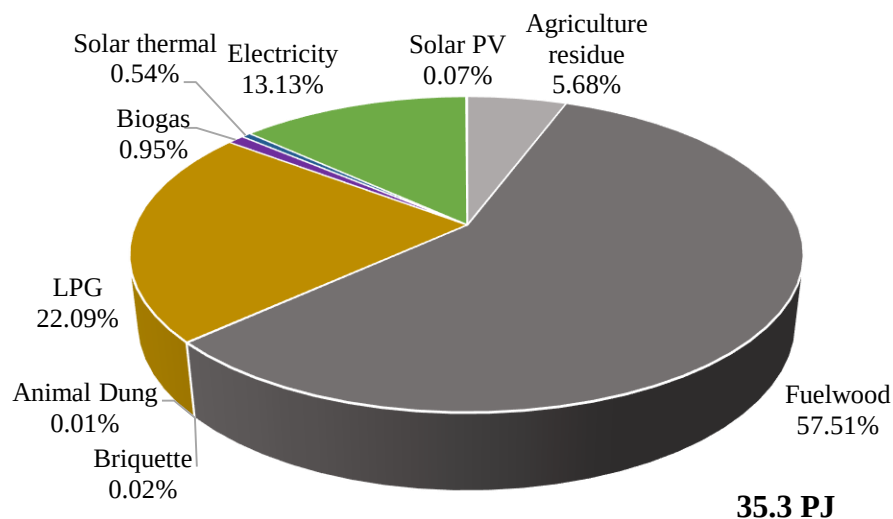


Figure 6.6: Energy mix in residential sector

In Bagmati Province, final energy demand in residential sector is 35,300 TJ as shown in Table 6.3. It is found that dependency on fuelwood is still high as it is the cheaper source of energy and can be easily available. The high consumption of fuelwood is for cooking and animal feed preparation. However, consumption of LPG for cooking purpose is increasing as it is easily

accessible. For water heating, solar thermal and LPG is use more, for space heating, fuelwood is the major source of energy while for space cooling only electricity is use as energy source. As more than 90% of local levels are facilitated by electricity, the major source of energy for lighting is electricity while for electrical appliances only electricity is use.

Table 6.3: Energy consumption in residential sector (TJ)

Energy sources	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliance	Social occasion	Food & agro processing	Animal feed	Total
Fuelwood	13,930.0	154.9	1,592.3	-	-	-	402.4	261.4	3,961.3	20,302.3
Animal dung	-	-	-	-	-	-	0.2	3.2	0.0	3.4
Agriculture residue	1,842.3	-	-	-	-	-	-	11.2	151.1	2,004.6
Kerosene	-	-	-	-	0.4	-	-	-	-	0.4
LPG	6,728.9	392.8	-	-	-	-	452.0	225.2	0.1	7,799.0
Electricity	182.2	74.6	152.8	479.8	774.3	2,970.9	0.0	0.0	-	4,634.5
Biogas	97.6	-	-	-	-	-	185.3	30.8	21.1	334.7
Briquette	1.2	-	5.7	-	-	-	0.0	-	-	6.9
Wax	-	-	-	-	0.1	-	-	-	-	0.1
Solar PV	-	-	-	-	25.0	-	-	-	-	25.0
Solar thermal	-	189.1	-	-	-	-	-	-	-	189.1
Total	22,782.2	811.3	1,750.8	479.8	799.9	2,970.9	1,039.9	531.6	4,133.6	35,300.0

Figure 6.7 represents energy consumption in residential sectors by physiographical region. Energy consumption in hilly region is highest contributing 74.71% which is followed by mountain 14.06% and the remaining is consumed by terai region. Comparatively, economical activities are performed lower in mountain part due to which energy utilization is lesser share of energy consumption. Also, the energy consumed in mountain region is inefficient i.e. traditional energy is used mostly in mountain region so the consumption of energy is more than in terai region while terai region consists of only one district so the consumption of energy is also lower this region.

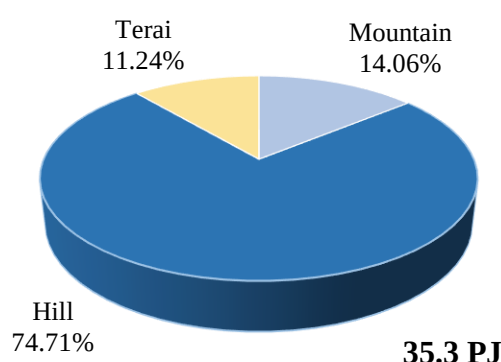


Figure 6.7: Energy consumption in residential sector by physiographical region

Residential sector is broadly divided into two sub-categories namely rural and urban area. Table 6.4 shows energy consumption in rural residential sector is 15610.0 TJ. Fuelwood is major energy source in rural residential sector which is followed by agriculture residue as fuelwood and

agricultural residue is easily available and cheaper source of energy. Since most of the rural areas of Bagmati Province are still developing, cooking activity seems to consume more energy than other activities. Also, in rural areas, fuelwood is the major energy source for space heating and animal feed preparation. Some of the rural sector of this province, have no electrification so in those areas solar PV is the key source of energy for lighting.

Table 6.4: Energy consumption in rural-residential sector in TJ.

Energy sources	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliance	Social occasion	Food & agro processing	Animal feed	Total
Fuelwood	9,299.6	98.7	519.4	-	-	-	134.0	167.0	3,512.7	13,731.4
Animal dung	-	-	-	-	-	-	0.2	-	0.0	0.2
Agriculture residue	813.5	-	-	-	-	-	-	11.0	151.1	975.6
Kerosene	-	-	-	-	0.1	-	-	-	-	0.1
LPG	387.7	14.4	-	-	-	-	19.8	3.5	0.0	425.3
Electricity	3.2	3.3	3.8	32.0	61.2	140.3	0.0	-	-	243.6
Biogas	64.9	-	-	-	-	-	163.4	-	-	228.3
Briquette	-	-	-	-	-	-	0.0	-	-	0.0
Wax	-	-	-	-	0.1	-	-	-	-	0.1
Solar PV	-	-	-	-	4.3	-	-	-	-	4.3
Solar thermal	-	1.0	-	-	-	-	-	-	-	1.0
Total	10,568.9	117.4	523.2	32.0	65.7	140.3	317.4	181.4	3,663.9	15,610.0

The energy consumption in rural sector is dominated by fuelwood at 87.97% followed by agriculture residue at 6.25% as these fuels are cheaper and easily available. Similarly, in terms of the end use, cooking has the highest proportion of energy consumption at 64.38% followed by animal feed preparation at 21.80%. The main reason behind the consumption of energy in animal feed preparation comparatively higher is that the people are dependent on animal husbandry for income generation activities. The energy consumption in rural residential is shown in Figure 6.8 and Figure 6.9 respectively.

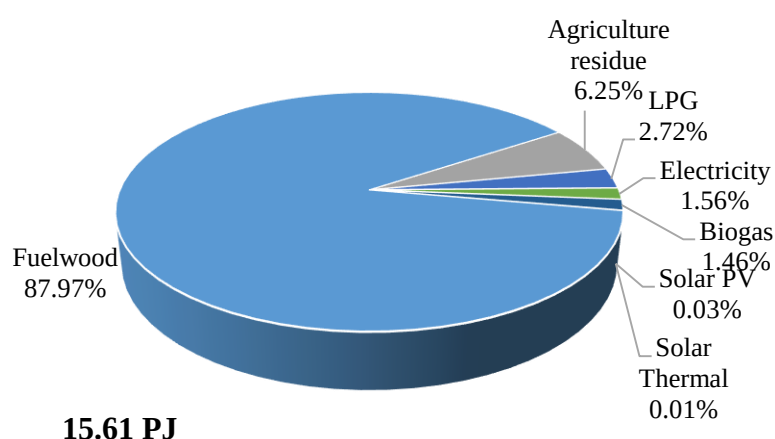
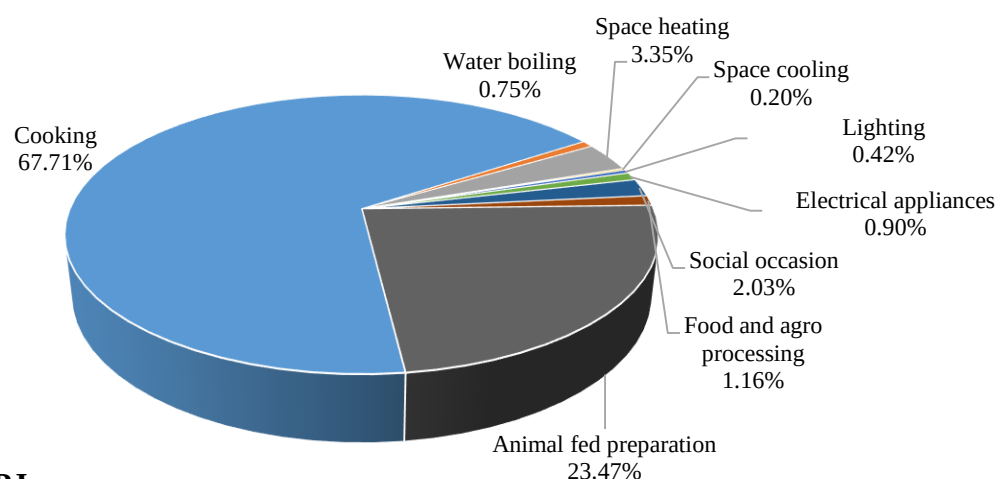


Figure 6.8: Share of final energy demand in rural-residential sector by fuel type



15.61 PJ

Figure 6.9: Share of final energy demand in rural-residential sector by end-uses

The total energy consumption in urban residential sector is 19,690 TJ. The energy consumption is dominated by LPG at 7,373.7 TJ as it is most accessible source of energy for cooking. However, now a days electricity for cooking i.e. use of induction and hot plates is increasing. Also, the consumption of electricity is higher due to its use in electrical appliances and lighting. Although the use of fuelwood has been decreased, the households still prefer it occasionally for cooking and for space heating use of fuelwood is still higher. The fuelwood consumption is determined to be more because of its less efficiency as more quantity of fuelwood is required to cook same amount of food than that of other fuels such as LPG and electricity. The details of the energy consumption in urban residential sector is shown in Table 6.5.

Table 6.5: Energy consumption in urban-residential sector (TJ)

Energy sources	Cooking	Water boiling	Space heating	Space cooling	Lighting	Electrical appliance	Social occasion	Food & agro processing	Animal feed	Total
Fuelwood	4,630.4	56.1	1,073.0	-	-	-	268.4	94.4	448.6	6,570.9
Animal dung	-	-	-	-	-	-	-	3.2	-	3.2
Agriculture residue	1,028.8	-	-	-	-	-	-	0.2	-	1,029.0
Kerosene	-	-	-	-	0.4	-	-	-	-	0.4
LPG	6,341.2	378.5	-	-	-	-	432.3	221.7	0.1	7,373.7
Electricity	179.0	71.3	149.0	447.8	713.2	2,830.6	0.0	0.0	-	4,390.9
Biogas	32.7	-	-	-	-	-	21.9	30.8	21.1	106.4
Briquette	1.2	-	5.7	-	-	-	-	-	-	6.9
Wax	-	-	-	-	-	-	-	-	-	-
Solar PV	-	-	-	-	20.7	-	-	-	-	20.7
Solar thermal	-	188.1	-	-	-	-	-	-	-	188.1
Total	12,213	693.9	1,227.6	447.8	734.2	2,830.6	722.6	350.2	469.7	19,690.0

In urban residential, the largest proportion of energy consumption is due to LPG at 37.45%. Similarly, the share of electricity and fuelwood in final energy demand is 22.30% and 33.37%

respectively. On the basis of end use, cooking (62.03%) leads the consumption followed by electrical appliances (14.38%).

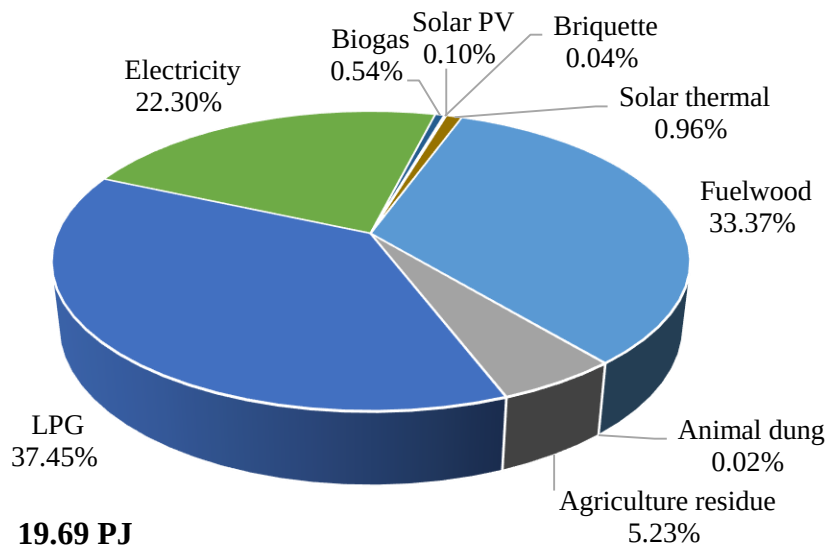


Figure 6.10: Share of final energy demand in urban-residential sector by fuel type

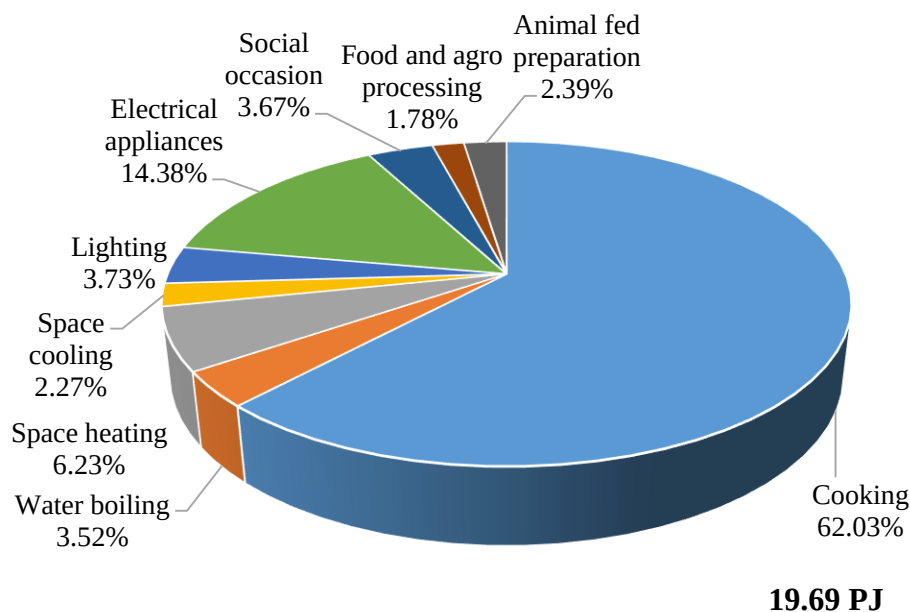


Figure 6.11: Share of final energy demand in urban-residential sector by end-uses

This shows that the energy consumption in the urban-residential sector is less than the rural-residential sector although the population of urban sector is more. The cause for this is urban households consumes LPG and electricity more as compare to rural sector and the efficiency of these fuel is more than biomass. While in rural sector, fire wood, agricultural residues are used as the major fuel type in which the efficiency is very less.

6.1.2 Transport Sector

Transport sector is divided into two sectors on the basis of end-use i.e. passenger and freight type. Also, the passenger type transport is divided into Intercity and Intracity categories in which Intercity is the transports that are travelling between cities and Intracity is travelling within the city. Here, we considered long distance transport as Intercity and short distance as Intracity. The transport available in this province are also divided according to the fuel type such as diesel, petrol, LPG and electric. Table 6.5, indicates vehicle categories on the basis of fuel type.

Table 6.6: Vehicle Categories on the basis of fuel type

Transport Fuel	Devices	End-use
Diesel	Truck, Pick up, Tractor, Car, Bus, Mini bus, Micro bus, Van, Jeep	Passenger/Freight
Petrol	Car, Tempo, Motorcycle, Van, Jeep	Passenger
Electricity	Tempo, E rickshaw, Rope way	Passenger
LPG	Tempo	Passenger
Jet fuel	Air plane	Passenger

The total energy consumed by transport sector is 12.73 PJ. The share of energy consumption in transport sector by vehicle types is shown in Figure 6.12. It has been found that major share of energy is consumed by truck (17.17%) which is followed by aviation fuel (13.27%). As the consumption of fuel by aviation is more the share of fuel consumption by buses and motorcycle is found to be low though the number of buses and motorcycles are more. Freight vehicle (truck, mini truck, tractor and pickup) consumed 26.42% of total energy consumed in this sector while private car/jeep/van together consumed 21.16% of the energy. Similarly, public passenger vehicles consume about 49.67% of total energy.

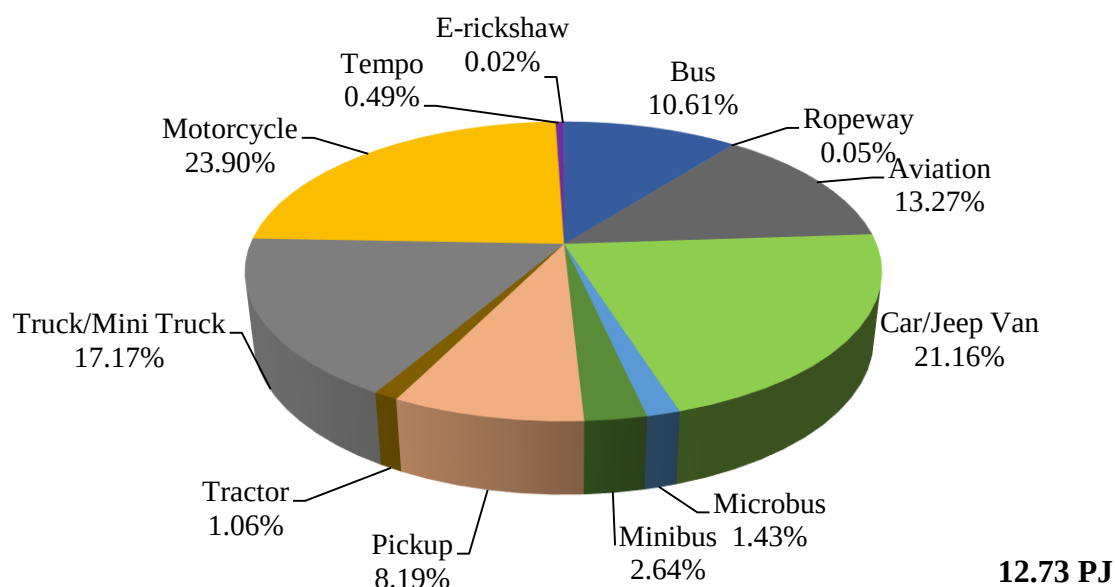


Figure 6.12: Share of energy consumption by vehicle types

Truck is major energy consumption mode of transportation sector which is followed by aviation fuel. However, according to the passenger mode of transport, motorcycle consumes more fuel as

people prefer to use motorcycle to travel. Table 6.7 represents the fuel consumption capacity of different types of vehicles and the average distance travelled annually by various mode of transport.

Table 6.7: Energy consumption in transport sector by fuel types

Transport	Annual distance travelled(km)	Vehicle mileage		Fuel		Energy consumed (TJ)
		Quantity	Unit	Quantity	Unit	
Diesel consumption						
Bus	29,416.62	4.06	km/liter	37,421,948.91	Liter	1,350.18
Car/Jeep/Van	17,671.09	13.77	km/liter	27,319,173.32	Liter	985.68
Microbus	24,466.04	9.27	km/liter	5,048,151.83	Liter	182.14
Minibus	14,789.23	5.51	km/liter	9,324,408.33	Liter	336.42
Pickup	21,843.88	10.41	km/liter	28,897,608.56	Liter	1,042.63
Tractor	14,967.11	3.98	km/liter	3,745,648.88	Liter	135.14
Truck	18,726.50	3.66	km/liter	60,551,179.72	Liter	2,184.69
Subtotal				172,308,119.54	Liter	6,217
Petrol consumption						
Car/Jeep/Van	16,411.43	14.68	km/liter	50,591,129.27	Liter	1,707.45
Motorcycle	8,761.78	41.68	km/liter	90,118,460.66	Liter	3,041.50
Tempo	23132.06449	18.54	km/liter	1,247,256.74	Liter	42.09
Subtotal				141,956,846.67	Liter	4,791
Electricity consumption						
E-rickshaw	10,004.02	18.26	km/kWh	708,225.65	kWh	2.55
Tempo	547,500.00	12.22	km/kWh	1,702,800.00	kWh	6.13
Ropeway	28,425.00		km/kWh	1,546,878.40	kWh	5.57
Subtotal				4,190,913.71	kWh	14.25
Aviation Fuel						
Aviation	-	-	-	54,497,970	Liter	1,689.43
Subtotal				54,497,970	Liter	1,689.43
LPG						
Tempo	33,171	10.22	km/liter	335,109	Liter	15.31
Subtotal				761,004.99	Liter	15.31
Grand Total						12,726

Overall energy consumption in transport sector indicates, petroleum product is still predominating source of energy. However, consumers are interested to shift towards electric vehicle.

The total number of the vehicle registered in Bagmati is obtained from Provincial Ministry of Transport, Hetauda (unpublished data). Out of total vehicles registered in Nepal, 45% is registered in Bagmati Province. Although the total number of transport is high, all of the transport are not in operating condition. So, adjustment of the data is done for modeling considering operational factor for each type of vehicle. Table 6.8 shows the total number of registered vehicles in Bagmati till 2077/78.

Table 6.8: Total number of vehicles registered in Nepal

	Large size vehicles	Small size vehicles	Tempo and Rickshaw	Motorcycle	Tractor	others	Total
2075/76	68,375	224,611	5,382	1,125,140	1,759	3,702	1,428,969
2076/77	2,911	14,081	1,225	75,180	30	150	93,577
2077/78	3,405	14,472	1,615	104,440	287	86	124,305
Total	74,691	253,164	8,222	1,304,760	2,076	3,938	1,646,851

On the other hand, the data related to aircraft are obtained from Civil Aviation Authority of Nepal (CAAN). In Bagmati Province, there are all together six airports in which three airports, Meghauli Airport, Jiri Airport and Langtang Airport are not in operation. So, the movements are only present in Bharatpur Airport, Ramechhap Airport and Tribhuvan International Airport. Table 6.9 shows the aviation activities in different Airports situated in Bagmati Province.

Table 6.9: Aviation sector activity in Bagmati Province

Airport	Aircraft Movement	Passenger Movement	Cargo Movement (in kg)
Bharatpur	6,050	170,734	131,023
Ramechhap	6,958	33,424	1,327,010
TIA Domestic	91,816	3,188,479	3,112,950
TIA International	32,439	4,138,563	7,547,822
Total	137,263	7,531,200	12,118,805

(CAAN, 2020)

6.1.3 Agricultural Sector

As represented in Figure 6.13, the final energy consumption in agricultural sector is 739 TJ. It seems that, 91.65% of total energy in agriculture sector is consumed by diesel which is followed by 7.43 % of electricity. Generally, agricultural sector which is dependent upon diesel source of energy because agriculture sector is heavily dependent upon diesel engine technologies like tractor, power tiller, diesel pump, and thresher. Nowadays, use of solar energy are increasing for irrigation system.

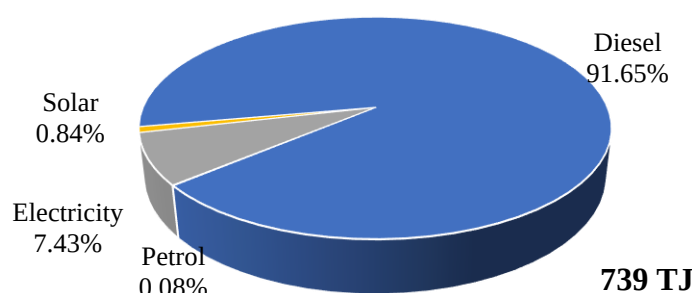


Figure 6.13: Final energy demand in agricultural sector by fuel type

Irrigation, tillage, planting and threshing are the major energy consuming process involved in agriculture sector. Among these processes, tillage is highest energy consuming, agricultural processes constituting 75% share of total energy consumption followed by irrigation (14%) and threshing (11%) consecutively as shown in Table 6.10. Diesel has been consumed for tillage and

threshing process while electricity and solar has been used only for irrigation. In small size farm area, total energy consumption is 381.99 TJ. Diesel fuel is the major energy source used for tillage while there is few consumptions of electricity and solar energy. In medium size farm area, energy consumption is 221.47 TJ. Also, energy consumption pattern is similar in small size farm area. In large size farm area, energy consumption is 135.53 TJ. The consumption of energy in small size farm is more than medium and large as most of people living in Bagmati Province are farming in small size rather than large size.

Table 6.10: Energy consumption in agriculture sector (TJ)

Fuel	Tillage (TJ)	Irrigation (TJ)	Threshing (TJ)	Total (TJ)
Small size				
Diesel	270.64	25.11	36.51	332.26
Petrol	-	0.14	-	0.14
Electricity	-	43.91	-	43.91
Solar	-	0.34	-	5.68
Subtotal	270.64	74.84	36.51	381.99
Medium size				
Diesel	175.23	6.18	28.12	209.53
Petrol	-	0.42	-	0.42
Electricity	-	11.01	-	11.01
Solar	-	0.51	-	0.51
Subtotal	175.23	18.12	28.12	221.47
Large size				
Diesel	111.55	8.66	15.33	135.53
Petrol	-	-	-	-
Electricity	-	-	-	-
Solar	-	-	-	-
Subtotal	111.55	8.66	15.33	135.53
Total	557.37	101.62	79.96	739.00

The overall energy consumption in different physiographic region and each district on the basis of fuel type is represented in Table 6.11. In Chitwan District, agriculture activities are carried out commonly using machineries as a consequence, energy consumption is highest among all districts. Meanwhile, it is found that energy consumption in Rasuwa and Ramechhap district is insignificant because agricultural activities are generally performed by using traditional technologies (Drought animal power, rain water, and canal water).

Table 6.11: Energy consumption in different physiographical regions by end-use

District	Tillage	Irrigation	Threshing	Total
Himalayan	49.27	0.89	-	50.16
Rasuwa	0.24	-	-	0.24
Dolakha	32.12	0.00	-	32.12
Sindhupalchok	16.91	0.89	-	17.80
Hill	323.52	47.68	50.41	421.61

District	Tillage	Irrigation	Threshing	Total
Bhaktapur	14.33	19.76	3.38	37.47
Dhading	83.14	3.13	-	86.27
Kathmandu	31.89	-	-	31.89
Kavrepalanchok	45.68	-	-	45.68
Lalitpur	39.03	1.86	1.80	42.69
Makwanpur	26.10	15.32	12.67	54.09
Nuwakot	56.54	0.41	8.82	65.77
Ramechhap	0.04	5.18	-	5.22
Sindhuli	26.77	2.02	23.74	52.53
Terai	184.63	53.05	29.54	267.22
Chitwan	184.63	53.05	29.54	267.22
Total	557.42	101.62	79.95	739.00

Table 6.12 shows energy consumptions in different physiographical region by fuel type which indicates agricultural activities is highly dependent on fossil fuel. Also, still now agriculture sector uses traditional technologies which is inefficient and consumes more time. So, although the main source of income of people living in Bagmati Province is agriculture the consumption of energy in this sector is lower than that of other sectors.

Table 6.12: Energy consumption in different physiographical regions by fuel types

District	Diesel	Petrol	Electricity	Solar	Total
Himalayan	49.27	-	0.89	0.00	50.16
Rasuwa	0.24	-	-	-	0.24
Sindhupalchok	16.91	-	0.89	-	17.80
Dolakha	32.12	-	-	0.00	32.12
Hill	401.62	0.56	13.67	5.78	421.63
Dhading	83.14	-	3.13	-	86.27
Bhaktapur	36.50	0.56	0.35	0.05	37.47
Kathmandu	31.89	-	-	-	31.89
Kavrepalanchok	45.68	-	-	-	45.68
Lalitpur	42.69	-	-	-	42.69
Makwanpur	40.62	-	7.99	5.49	54.09
Nuwakot	65.36	-	0.17	0.24	65.77
Ramechhap	5.22	-	-	-	5.22
Sindhuli	50.51	-	2.02	-	52.53
Terai	226.44	-	40.37	0.41	267.22
Chitwan	226.44	-	40.37	0.41	267.22
Total	677.33	0.56	54.92	6.19	739.00

Energy consumption for agriculture in mountain, hill and terai region of Bagmati Province is 8%, 62% and 30% respectively as shown in Figure 6.14. Moreover, energy consumption in Mountain and hilly part is mostly for tillage while in terai part both tillage and irrigation has similar pattern.

Despite, the area covered by terai is lower, the agricultural activities conducted in this region is more than hilly and mountain.

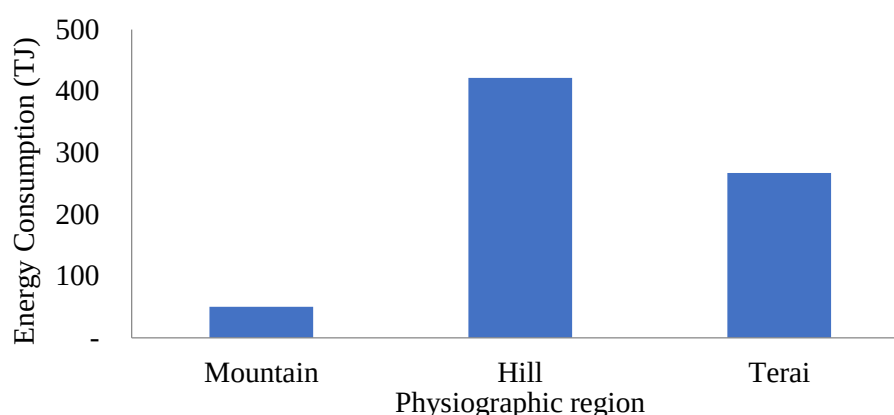


Figure 6.14: Energy consumption in agricultural sector by physiographical region

6.1.4 Industrial Sector

The energy consumption in industrial sector of Bagmati Province is 27.85 PJ. Figure 6.15 shows energy mix in industrial sector. About 75% of energy has been contributed by fossil fuel so it can be concluded that industrial sector is still depends heavily on the non-renewable energy sources. Major fuel consumption is diesel contributing 36.83% which is followed by fuelwood 24.82% and furnace oil 12.6%.

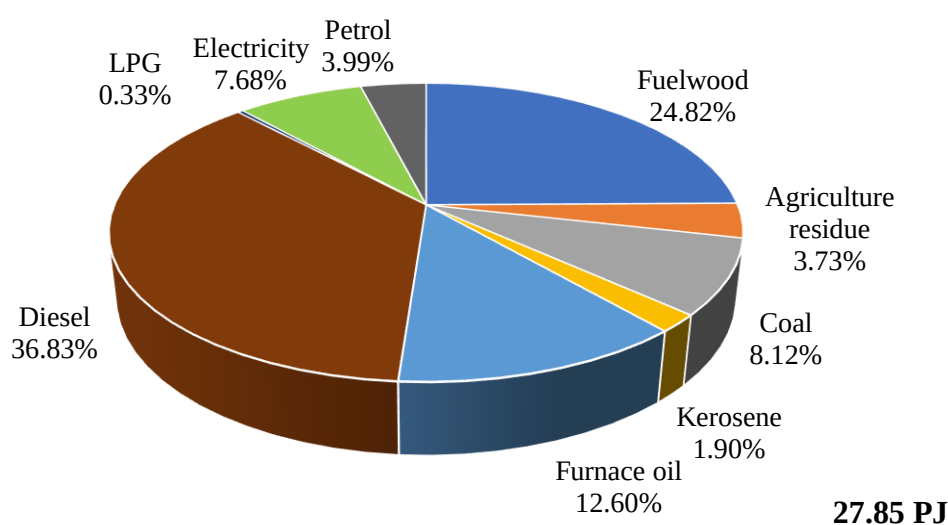


Figure 6.15: Energy consumption in industrial sector by fuel types

Table 6.13 shows energy consumption in different sub sector of industries in Bagmati Province by fuel types. It indicates that diesel is main energy source usages in food, beverage and tobacco industries. Similarly, Electricity has highest consumption in chemical product, rubber, glass and plastic product. Also, food, beverage and tobacco consumes the highest energy i.e. about 55% of total energy. The consumption of coal is more in Bagmati Province because of its consumption in cement, bricks, concrete and clay industry and chemical products, rubber, glass & plastic industry. While diesel is consumed in every type of industry and consumption of electricity is increasing.

Table 6.13: Energy consumption in industrial sub-sector in Bagmati Province by fuel type (TJ)

Sub category	Fuelwood	Agriculture residue	Coal	Kerosene	Furnace oil	Diesel	LPG	Electricity	Petrol	Briquette	Total
Cement, bricks, concrete & clay products	1,915	70	1,604	-	-	1,382	0.05	183	17	-	5,171
Chemical products, rubber, glass & plastics	551	37	628	-	16	1,706	18	898	961	-	4,816
Electrical & electronic products	0.07	-	-	-	-	26	-	22	-	-	48
Food, beverage & tobacco	3,857	910	21	449	3,389	6,054	41	634	0.08	-	15,356
Mechanical engineering, iron, steel, machineries, & other metal	2	-	8	42	102	308	12	81	101	-	657
Paper, publication & printing, furniture & fixtures	5	0.06	-	-	1	54	5	44	28	-	136
Textiles, readymade garment & leather products	580	13	-	-	-	583	14	211	4	-	1,404
Miscellaneous	3	8	-	38	-	144	3	66	-	0.01	261
Grand Total	6,912	1,039	2,261	529	3,508	10,257	93	2,139	1,110	0.01	27,848

In industrial sector, process heat is the major energy consuming end user which is followed by motive power and boiler. About 54% of total energy is consumed by process heat while the remaining energy is consumed by other end uses. Furthermore, the consumption of energy in process heat is highest in food, beverage & tobacco industry. Energy consumption in different sub-sector of industries in Bagmati Province by end-uses is shown in Table 6.14.

Table 6.14: Energy consumption in industrial sub-sector in Bagmati Province by end-use (TJ)

Sub category	Lighting	Space heating	Space cooling	Boiler	Process heat	Motive power	Ingeneration	Total
Cement, bricks, concrete & clay products	8	1.3	0.7	0	3,591	1,325	245	5,171
Chemical products, rubber, Glass & plastics	14	2	4	309	2,044	2,323	118	4,816
Electrical & electronic products	2	4	0.7	0	8	6	26	48
Food, beverage & tobacco	19	11	5	5,796	6,761	1,739	1,026	15,356
Mechanical engineering, iron, steel, machineries, & other metal	4	0.9	2	0	200	230	220	657
Paper, publication & printing, furniture & fixtures	4	2	0.3	10	12	63	45	136
Textiles, readymade garment & leather products	29	3	0.1	682	42	374	273	1,404
Miscellaneous	1.4	2	1.2	11	41	66	139	261
Grand Total	81	27	14	6,809	12,700	6,127	2,091	27,848

Table 6.15 shows district wise energy consumption in industrial sector by fuel types. Kathmandu district uses highest energy share in industrial sector due to more number of operating industries. While Rasuwa and Ramechhap are the districts consuming the least energy in industrial sector. Industries are highly dependent upon diesel and electricity.

Table 6.15: District wise energy consumption in industrial sector by fuel types in (TJ)

Districts	Fuelwood	Agriculture residue	Coal	Kerosene	Furnace oil	Diesel	LPG	Electricity	Petrol	Briquette	Total
Mountain	23	0.10	-	-	-	12	2	4	-	-	41
Rasuwa	0.02	-	-	-	-	-	-	0.15	-	-	0.17
Dolakha	23	0.10	-	-	-	3	-	2	-	-	28
Sindhupalchowk	-	-	-	-	-	10	2	2	-	-	13
Hill	6,053	533	1,586	529	3,508	8,383	87	2,102	1,087	-	23,868
Bhaktapur	203	132	264	-	-	129	4	181	8	-	920
Dhading	659	57	668	-	-	67	9	123	1	-	1,584
Kathmandu	4,076	325	8	334	3,459	4,535	45	928	973	-	14,682
Kavreplanchowk	465	5	-	-	-	2	5	126	-	-	604
Lalitpur	620	13	-	45	33	2,201	4	271	105	-	3,292
Makwanpur	11	2	645	150	16	1,448	12	461	-	-	2,744
Nuwakot	0.02	0.05	2	-	-	1	8	6	-	-	19
Ramechhap	-	-	-	-	-	0.19	-	0.01	0.17	-	0.5
Sindhuli	18	-	-	-	-	-	-	5	-	-	23
Terai	837	505	675	-	-	1,862	5	33	22	0.01	3,940
Chitwan	837	505	675	-	-	1,862	5	33	22	0.01	3,940
Total	6,912	1,039	2,261	529	3,508	10,257	93	2,139	1,110	0.01	27,848

Table 6.16 shows district wise energy consumption in industrial sector by end use. Among different manufacturing process, process heat consumes highest energy which is followed by boiler and motive power. Here, hilly region consumes the highest energy i.e. about 86% energy while mountain region consumes the least energy (0.15%) and the remaining percentage of energy is consumed by terai region.

Table 6.16: District wise energy consumption in industrial sector by end use(TJ)

Districts	Lighting	Space heating	Space cooling	Boiler	Process heat	Motive power	Ingeneration	Total
Mountain	0.21	0.15	0.14	17.62	16.69	3.16	2.71	40.68
Rasuwa	0.05	0.01	-	0.00	-	0.11	-	0.17
Dolakha	0.10	0.14	0.13	17.62	5.53	1.37	2.61	27.50
Sindhupalchowk	0.06	-	0.01	-	11.16	1.69	0.09	13.01
Hill	72.11	21.96	13.14	5,939.15	11,497.83	5,209.41	1,114.55	23,868.15
Bhaktapur	12.69	0.15	0.92	248.76	501.11	155.86	0.02	919.51
Dhading	3.44	2.26	1.10	4.42	1,451.74	119.88	1.45	1,584.28
Kathmandu	28.58	13.35	5.57	3,682.59	6,963.08	3,874.71	114.52	14,682.38
Kavreplanchowk	5.72	0.15	-	151.79	375.72	70.20	0.15	603.73
Lalitpur	15.71	0.46	1.03	575.48	1,285.61	485.68	927.89	3,291.86
Makwanpur	5.85	5.58	4.51	1,267.64	895.57	494.03	70.52	2,743.70
Nuwakot	0.07	0.00	0.02	8.47	2.41	7.80	-	18.76
Ramechhap	0.00	0.00	0.00	-	0.01	0.48	0.01	0.50
Sindhuli	0.05	-	-	-	22.59	0.78	-	23.42
Terai	9.06	4.63	0.47	852.19	1,184.99	914.40	973.90	3,939.63
Chitwan	9.06	4.63	0.47	852.19	1,184.99	914.40	973.90	3,939.63
Total	81.38	26.73	13.75	6,808.97	12,699.51	6,126.97	2,091.15	27,848

6.1.5 Commercial Sector

The energy consumption in commercial sector of Bagmati Province is 6,059 TJ as shown in Figure 6.16. The major fuel consumption in commercial sector is petroleum products, electricity and fuelwood. Uses of LPG appears highest contributing 57.02% share of total energy consumption which is followed by electricity of 35.97%. As the number of accommodation and food service is highest, and in this sector, cooking is done the most which consumes LPG. So the consumption of LPG is maximum in commercial sector. While, electricity is consumed more in retail shops as the number of these shops is higher and the most used energy in retailer is electricity for using electrical appliances.

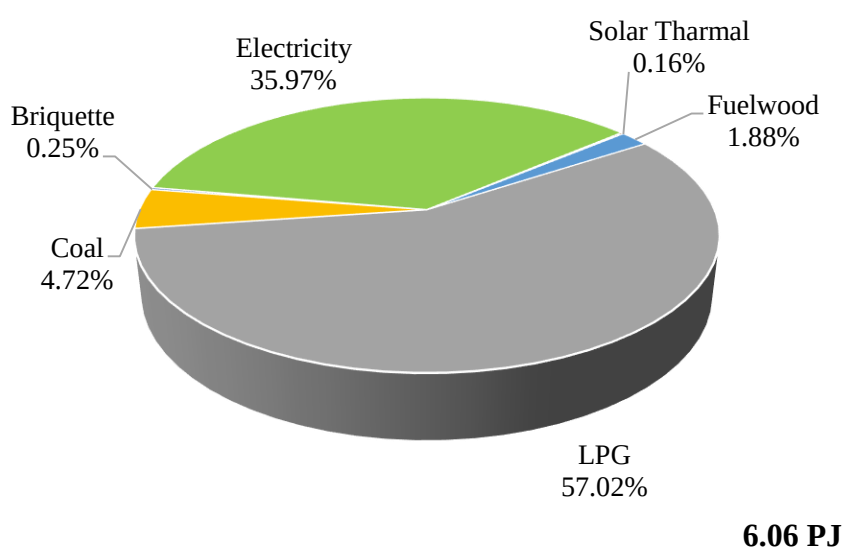


Figure 6.16: Energy consumption in commercial sector by fuel types

Table 6.17 represents the consumption of energy by end use in commercial sector. Major energy is consumed for cooking purpose and electrical appliances constituting nearly 63.67% and 26.24% respectively. The consumption pattern illustrates traditional fuelwood is shifting toward clean energy.

Table 6.17: Energy consumption in commercial sector by end-use (TJ)

Energy resource	Cooking	Water heating	Lighting	Space heating	Space cooling	Social event	Electrical appliances	Total
Fuelwood	102	3	-	8	-	1	-	114
Kerosene	-	-	-	-	-	-	-	-
LPG	3,439	7	-	-	-	9	-	3,455
Char coal	286	-	-	-	-	0.03	-	286
Briquette	15	-	-	0.01	-	0.00	-	15
Biogas	-	-	-	-	-	0.00	-	0.00
Electricity	16	51	1	54	416	52	1,590	2,179
Solar thermal	-	10	-	-	-	-	-	10
Total	3,858	71	1	62	416	61	1,590	6,060

Table 6.18 represents consumption of energy in different sub sector of commercial sector by end uses. It indicates that major energy are consumed for cooking purpose in accommodation and food

services sub-sector which is followed by electrical appliances in other services. While cooking consumes the highest energy along with electrical appliances.

Table 6.18: Energy consumption in sub-sector of commercial sector by end-use in (TJ)

Sub category	Cooking	Water heating	Lighting	Space heating	Space cooling	Social event	Electrical appliances	Total
Accommodation and Food service	3,191	14	0.13	9	53	61	386	3,714
Education	459	9	0.10	3	60	-	136	667
Finance service	43	3	0.02	2	13	-	88	150
Health & Social service	37	12	0.23	23	146	0.05	194	413
Trade & retail	84	29	0.40	5	113	-	582	1,590
Other service	45	3	0.08	19	31	-	204	302
Total	3,858	71	1	62	416	61	1,590	6,060

Figure 6.17 shows energy consumption in commercial sector in different physiographical region. The consumption of energy in hilly is more in commercial sector than in other two regions with 85.25% while terai and mountain consumes 11.75% and 3% respectively. As the major cities of Nepal lies in hilly region of Bagmati Province, the energy consumption in commercial sectors such as accommodation and food service, health and social service and trade and retail is more which signifies that hilly region of Bagmati Province consumes more energy.

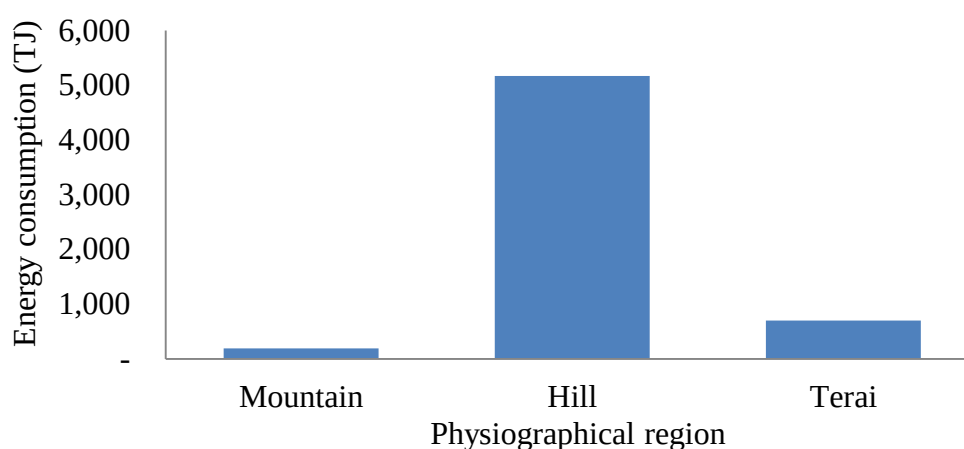


Figure 6.17: Energy consumption in commercial sector by different physicographical regions

Table 6.19 shows district-wise energy consumption in commercial sector in Bagmati Province. Kathmandu district has highest energy consumption due to high economical activities where major energy is consumed for cooking and electrical appliances. However, energy consumption is lesser in Mountain region due to its lower economic activities.

Table 6.19: District wise energy consumption in commercial sector by end-use (TJ)

District	Cooking	Water heating	Lighting	Space heating	Space cooling	Social event	Electrical appliances	Total
Himalayan	103	10	0	16	2	0	61	191
Dolakha	34	3	0	8	1	-	41	86

District	Cooking	Water heating	Lighting	Space heating	Space cooling	Social event	Electrical appliances	Total
Rasuwa	32	7	0	1	0	0	4	44
Sindhupalchok	37	0	0	7	1	0	16	61
Hill	3,483	61	1	46	206	61	1,313	5,171
Bhaktapur	280	20	0	19	37	9	321	686
Dhading	33	10	0	6	8	-	33	90
Kathmandu	2,672	29	0	2	112	52	588	3,455
Kavrepalanchok	16	0	0	0	-	0	25	41
Lalitpur	258	1	0	3	10	-	146	418
Makwanpur	43	0	0	2	28	-	114	188
Nuwakot	94	1	0	4	10	0	42	152
Ramechhap	32	0	0	2	0	-	1	36
Sindhuli	55	1	0	8	-	-	43	107
Terai	272	-	0	1	209	-	216	697
Chitwan	272	-	0	1	209	-	216	697
Total	3,858	71	1	62	416	61	1,590	6,060

Table 6.20 represents district wise energy consumption in commercial sector by fuel types. It indicates that consumption of LPG and electricity is higher in Kathmandu district due to its easy accessibility. The consumption of solar thermal energy to heat water seems increasing. Also, the consumption of electricity is also high in this sector.

Table 6.20: District wise energy consumption in commercial sector by fuel types (TJ)

District	Fuelwood	LPG	Coal	Briquette	Biogas	Electricity	Solar thermal	Total
Himalayan	26	85	0	0	-	77	3	191
Dolakha	11	23	-	-	-	52	0	86
Rasuwa	9	26	0	0	-	6	2	44
Sindhupalchok	6	36	0	0	-	19	-	61
Hill	63	3,124	284	15	-	1,677	7	5,171
Bhaktapur	1	288	-	-	-	397	0	686
Dhading	27	6	-	-	-	56	1	90
Kathmandu	-	2,407	242	15	-	786	5	3,455
Kavrepalanchok	-	15	-	-	-	25	-	41
Lalitpur	-	217	41	-	-	159	1	418
Makwanpur	3	40	0	-	-	144	-	188
Nuwakot	18	76	0	0	-	57	1	152
Ramechhap	6	28	-	-	-	2	-	36
Sindhuli	8	46	-	-	-	52	-	107
Terai	24	246	2	-	-	425	-	697
Chitwan	24	246	2	-	-	425	-	697
Total	114	3,455	286	15	-	2,179	10	6,060

Overall energy consumption in commercial sector indicates dependency of traditional fuelwood is shifting toward LPG and electricity.

6.1.6 Construction and Mining Sector

In construction and mining sector, diesel energy (78.49%) is found as the major source of energy consumption because this sector is mainly depending upon heavy equipment with diesel engine. Furnace oil (1.07%) is used during construction of highway. Electricity (1.36 %) is used for the operation of electrical machines and lighting purpose. Overall, energy consumption in construction and mining sector is 860.81 TJ as shown in Figure 6.18.

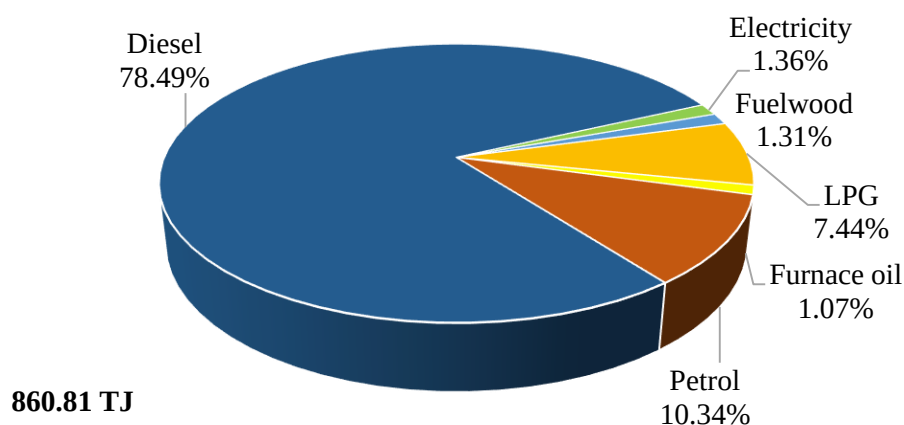


Figure 6.18: Share of energy consumption in construction and mining sector

Table 6.21 shows the energy consumed in each construction and mining sites where major fuel consumed is diesel. Motive powers used in the construction and mining industry are crane, dozer, concrete mixture, excavator etc. which consumes diesel fuel on excessively huge amount. The machineries used in construction and mining sector are usually operated by diesel engines, petrol and only some by electricity.

Table 6.21: Energy consumption in construction and mining sector (TJ)

Fuel type	Energy consumption
Diesel	675.63
Petrol	88.97
Grid electricity	11.66
Fuel wood	11.26
LPG	64.02
Coal	0.00
Kerosene	0.02
Furnace oil	9.25
Total	860.81

CHAPTER SEVEN : SOCIO-ECONOMIC ANALYSIS

7.1 Socio-economic Status

One of the important aspects of socio-economic behavior is Average Income and sources of income. The- major source of income of the respondents is agriculture contributing 45 % of the total income generated followed by business and salary/wages. Income from Job/Service and Foreign employment is also substantial whereas only insignificant proportion of people. as shown in Figure 7.1.

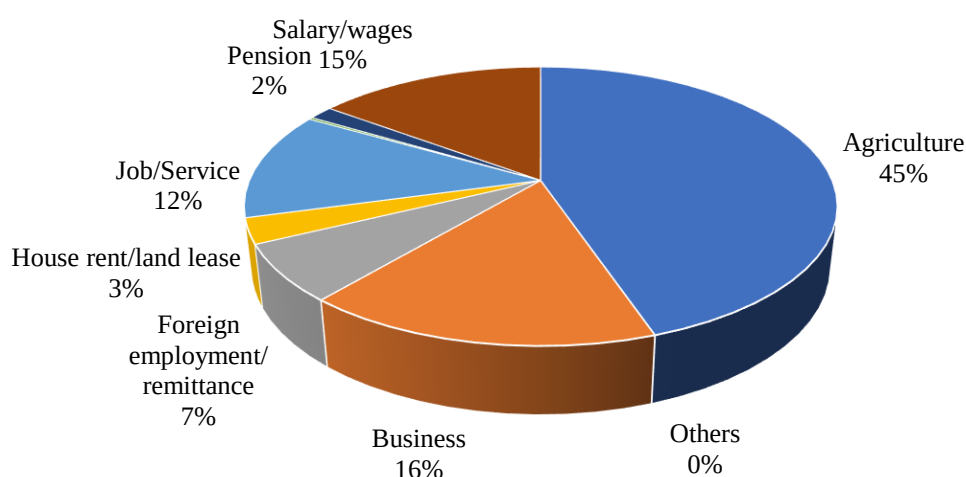


Figure 7.1: Source of income in Bagmati Province

The average monthly family income level ranges from as low as 8,000 per month to highest of 30,000 (at average). This comes to an average of NRs 250,000 annual income per household.

The income level is higher in average in urban areas than the rural. This is mostly due to higher economic activity in urban areas due to easy access to economic centers and better opportunities. However, there is a huge variance from mean level of income in most of the cases which is evident from Figure 7.2.

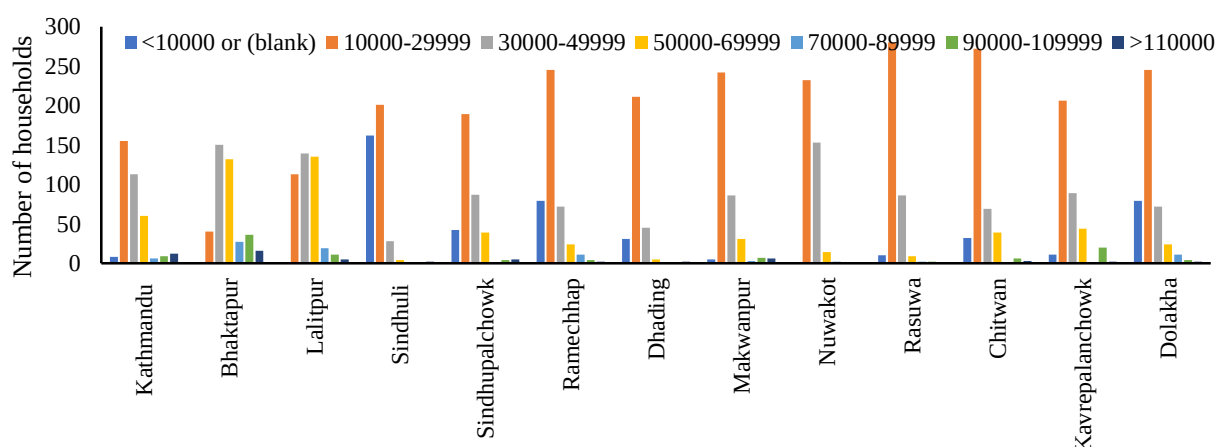


Figure 7.2: Average income in household

7.2 Education Status of Household Head

Education plays an important role in shaping, molding, sharpening and directing an individual, the society and the nation towards achieving the desired goals. Thus, looking at the education level of household heads it was seen that significant number of household heads have no formal education followed by partially educated. Nearly 25% of household's heads do not have formal education Figure 7.3. whereas more than 60% of the population are partially educated. Substantial numbers of household heads from urban area have higher education.

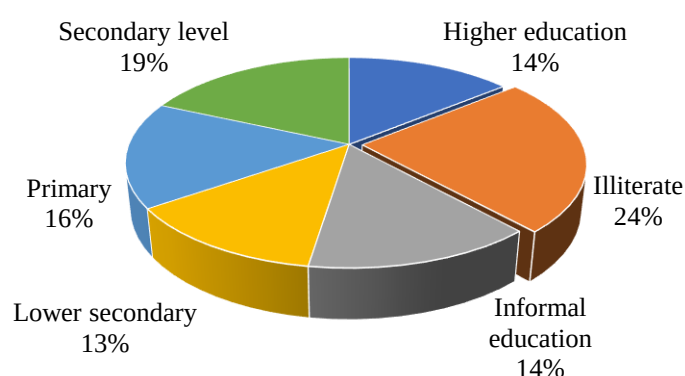


Figure 7.3: Education status of household head

And the impact can be seen in the energy mix–firewood still being predominant in the energy mix which is followed by LPG and electricity. Use of LPG for cooking seems to be escalating in Rural Areas whereas Urban population are opting to electricity for cooking and other household energy demands.

7.3 Types of Household Building

In this Survey more than 48% of the surveyed households found are made of RCC frame structure followed by Mud or Mortar with bricks and cement mortar which is 38% whereas the remaining are from zinc sheet or prefab and bamboo or wood respectively. However, the share of RCC frame with cement mortar is seen to be in increasing current, especially after earthquake back in 2015. Meanwhile, for roof structure, majority of household still used galvanized iron sheet or tile or slate followed by RCC and then wood or plank in older houses.

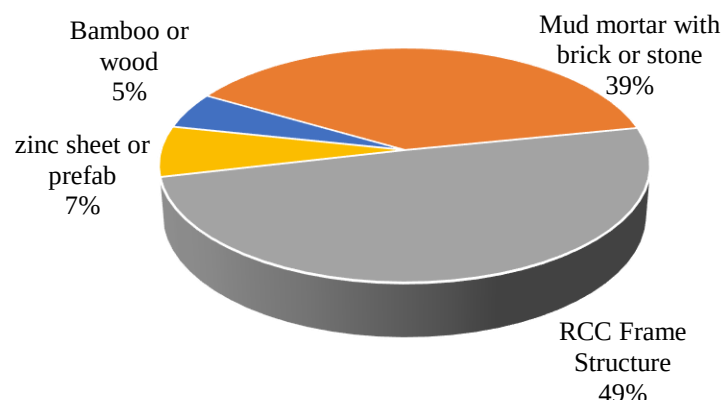


Figure 7.4: Types of household building

7.4 Average Cost of Commercially Traded Fuel

Figure 7.5 shows how much people paid for the commercially traded energy sources. At current times, even firewood is being traded at an average rate of NRs. 432 per bhari (around 40 kg) on average. Meanwhile the LPG costs at around NR 1,540 per cylinder, with transportation cost. It is observed that LPG is available at marked prices in roadway accessible area, however due to transportation costs; it is much higher in cost in hilly and mountain regions.

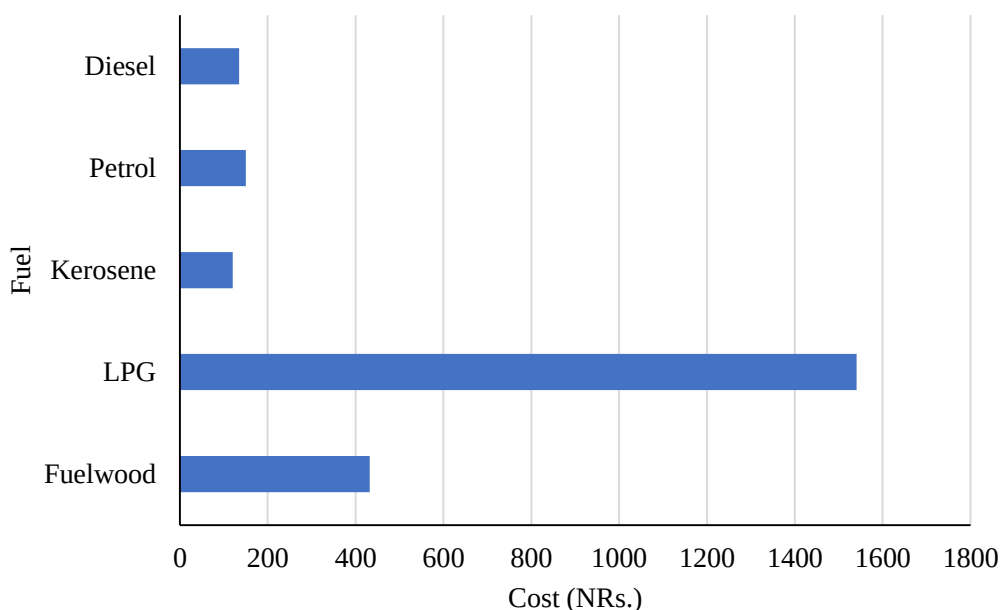


Figure 7.5: Average cost of commercially traded fuel

7.5 Types of Fuse Rating in Household

Figure 7.6 shows the proportion of electricity connection as per ampere capacity of households. It was observed in survey that over 65% of the households lies within minimal amperage capacity of 5A. This is sufficient for basic electrical appliances except cooking and use of heavy appliances. Over 30% of the population have electricity connection of 15A capacity followed by substantial

portion of people with 30A capacity connection. These 15A and 30A connection are capable for the use of heavy electrical appliances and for the purpose of cooking.

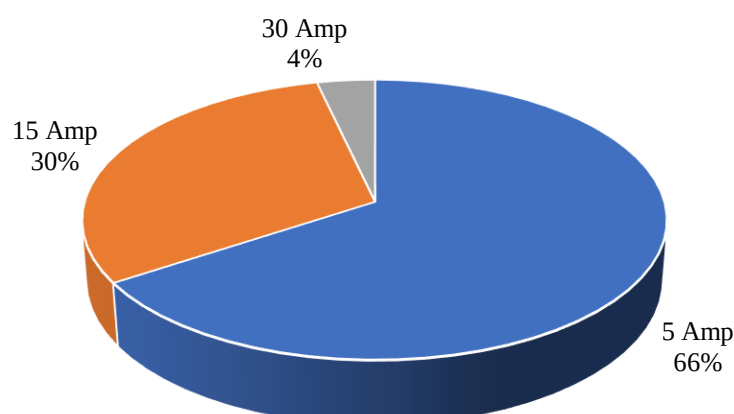


Figure 7.6: Type of fuse rating in households

7.6 Gender and Social Inclusion

Energy is a driver of economic development, underpinning all forms of economic activity. It is also a significant aspect of everyday life through its domestic uses and its role in modern communications, transport and technology. Energy plays an essential role in both women's and men's lives. However, it has been recently acknowledged that energy policy is not gender neutral. Achieving gender equality in the field of energy can be linked with human rights and social, environmental and economic development.

From a gender and human rights perspective, women and men have different energy needs. Women spend more time than men in unpaid household work. This means that women spend more time at home and are therefore more dependent than men on heating and indoor air quality. In addition, women are more dependent on energy consumption in household. Poor housing conditions (such as poorly insulated environments) and pollutant electronic devices and fuels may have a negative impact on women's health. Thus increasing women's involvement in the field of energy has the potential to stimulate sustainable economic growth. Gender parity would consolidate women's right to equality and represent a significant social achievement.

Several social factors constrain households' access to energy, including limited access of energy services to poor and marginalized ethnic groups and limited capacity of households to pay for services. Language and culture is not given due recognition, especially of the more disadvantaged Janajati groups. Remoteness, geographical isolation and discrimination due to different culture, traditions, and practices are the factors contributing in less involvement of Janajati group in energy conversion areas. In case of Madhesi groups language and culture barriers, differences across various Madhesi groups are some of the factors that hinders to active involvement of energy consumption.

CHAPTER EIGHT : ENERGY SCENARIO ANALYSIS

8.1 Scenario Development

Different sets of possible future energy demands have been considered in scenario development which are listed below:

- Reference Economic Growth Scenario
- Low Economic Growth Scenario
- High Economic Growth Scenario

8.1.1 Reference Economic Growth Scenario

In this scenario, the share of each demand technology in the energy supply in future will become similar as in the base year. Here, the population growth rate was found to be 1.012%, 0.852%, 0.895%, 0.938%, 0.980% and 1.022% for year 2025, 2030, 2035, 2040, 2045 and 2050 respectively. The GDP growth rate was determined to be 7% per annum for this model and the respective share for all the sectors that consumes energy are determined. Different sectors considered for this scenario are Agriculture, Construction and Mining, Manufacturing, Transport, Residential and Service sector. The inputs were provided to MAED and the final forecasted value is provided by it. The main input parameters for MAED were energy penetration which was calculated using the energy demand in present scenario and the efficiency of different fuels used. The efficiency was determined by doing literature review of different national and international articles.

Here, the penetration of energy carried for useful thermal energy demand in manufacturing sector is divided into three sub sectors i.e. steam generation, furnace/direct heating and space/water heating. The penetration for steam generation was determined to be 1.35% electricity, 73.99% traditional fuels and the remaining was fossil fuels, for furnace/direct heat the penetration was 18.07% electricity, 18.93% traditional fuels and remaining was fossil fuel, whereas for space/water heating, 69.52% of penetration was electricity, 30.47% was traditional fuels, 0.019% was modern biomass and the remaining was fossil fuels.

For transport sector, the division was done as freight, intracity and intercity. Freight consists of vehicles which carry goods such as Truck, pickup, tractor etc. while intracity mode consists of vehicles running within small distance such as mini-bus, micro-bus, tempo, motorcycle, e-rickshaw and ropeway and intercity consists of vehicles running long distance like bus, car and airplane. The model split, energy intensity and load factors were provided as input parameters for transport sector according to which the final energy demand was determined by MAED.

Household sector was divided into urban and rural sector which was again divided into space heating, water heating, cooking, air conditioning and electrical appliances. For these parameters, penetration and efficiencies for traditional fuel, modern biomass and electricity was provided as input in MAED. Similarly, for commercial sector, penetration of different energy forms and efficiencies were provided as input. The scenario was developed taking the penetration of energy forms same as the base year.

Table 8.1 illustrates the energy demand in different year according to fuel type. In 2021, 83.53 PJ energy was consumed which was increased to 143.50 PJ in year 2030 and in year 2050, total

energy demand was 308.75 PJ. Here, the primary solid fuel has the highest rate on the basis of energy while the bio-briquette has the lowest rate.

Table 8.1: Energy demand in different year determined by using MAED (PJ)

				2021	2025	2030	2035	2040	2045	2050
Renewable	Conventional Renewable	Traditional	Primary Solid fuel	30.39	33.54	37.60	43.67	52.28	64.31	81.12
		Modern Biomass	Biogas	0.33	0.34	0.34	0.34	0.34	0.35	0.35
			Bio briquette	0.02	0.03	0.04	0.05	0.06	0.09	0.12
	New Renewables		Solar	0.23	0.24	0.27	0.29	0.32	0.36	0.41
			Grid Electricity	9.03	10.46	12.83	16.03	20.42	26.48	34.86
Non Renewable			Petrol	5.99	6.56	7.41	8.54	10.04	12.07	14.84
			Diesel	17.83	21.85	28.36	37.38	49.88	67.28	91.52
			Kerosene	0.53	0.69	0.97	1.36	1.91	2.68	3.77
			Furnace oil	3.51	4.61	6.47	9.07	12.72	17.84	25.02
			Aviation Fuel	1.69	1.56	1.63	1.71	1.79	1.88	1.97
			LPG	11.43	12.89	15.30	18.49	22.79	28.63	36.64
			Coal	2.55	3.34	4.68	6.57	9.21	12.92	18.13
Total				83.53	96.12	115.91	143.50	181.78	234.90	308.75

Figure 8.1 illustrates the energy projection trend line for different year. This shows that the consumption of petroleum product is more and is growing every year at the rate of 4.9% per annum. The consumption of solid fuel is also high and is growing at the rate of 3.5% per annum. Similarly, the demand of electricity would grow at the rate of 5.1% per annum whereas the demand of coal would grow at the rate of 7.0% per annum. The demand of other forms of energy were also growing as it depends on the population and GDP growth rate.

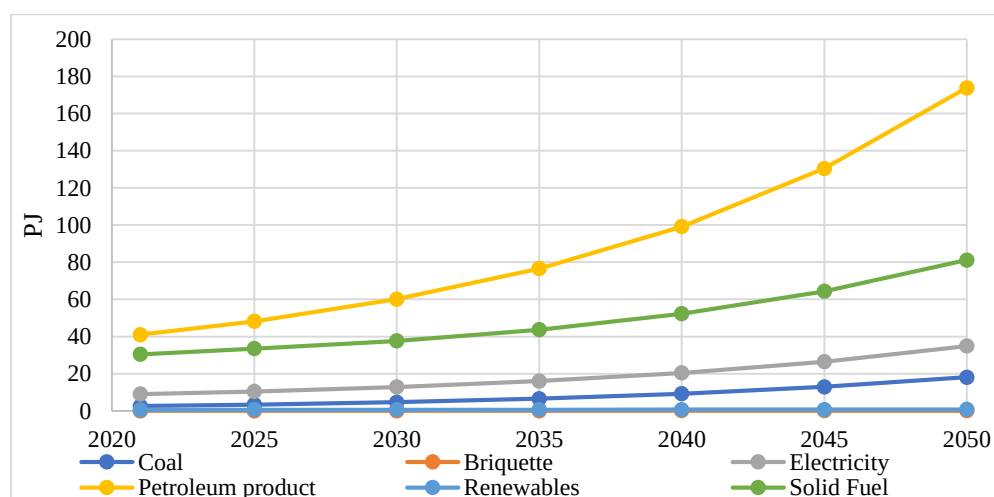


Figure 8.1: Energy projection trend at reference economic growth scenario

Figure 8.2 shows the percentage share of different sectors for year 2030. Here, the total consumption of energy is 115.91 PJ in year 2030 in which the share of primary solid fuel is 32.44%, diesel is 24.47% and grid electricity is 11.07%. While, Figure 8.3 represents the share of energy demand in year 2050. In this year, the total demand of energy was determined to be 308.75

PJ. In 2050, the demand of primary solid fuels would decrease to 26.27% and the demand of electricity would increase to 11.29%.

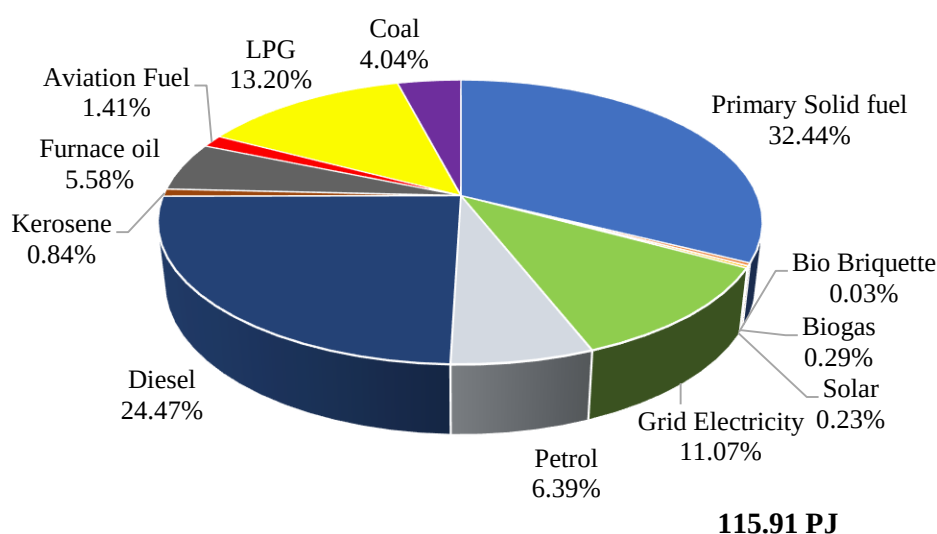


Figure 8.2: Share of energy demand in year 2030

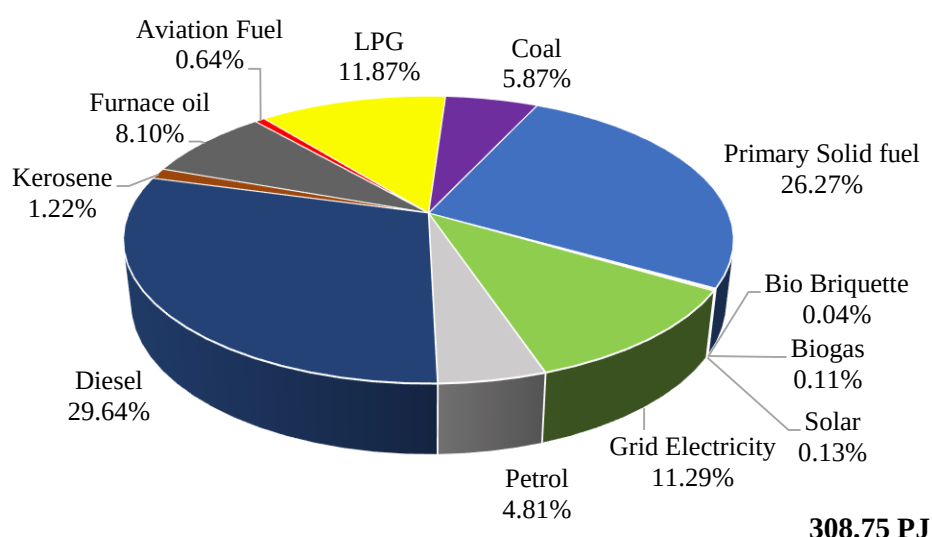


Figure 8.3: Share of energy demand in year 2050

Table 8.2 represents sectoral energy demand at reference economic growth rate scenario. This shows that the demand of energy is high in residential sector followed by industrial sector in base year and is in increasing rate. The energy demand by industrial sector will increase significantly and reach 44.2% in 2030 and 64.2% in 2050. While, the energy demand growth rate of agricultural and construction and mining will be the highest with 7.0% each.

Table 8.2: Sectoral demand at reference economic growth rate (PJ)

	2021	2025	2030	2035	2040	2045	2050
Agriculture	0.74	0.97	1.36	1.91	2.67	3.75	5.26
Commercial	6.06	7.78	10.73	14.85	20.62	28.71	40.04
Construction and mining	0.86	1.13	1.58	2.22	3.11	4.37	6.12
Industry	27.85	36.53	51.24	71.87	100.80	141.37	198.29
Residential	35.30	36.51	37.13	38.07	39.20	40.46	41.87
Transport	12.73	13.20	13.86	14.59	15.38	16.24	17.17
Total	83.53	96.12	115.91	143.50	181.78	234.90	308.75

Figure 8.4 represents the power plant capacity requirement for reference economic growth scenario. As the demand of electrical energy increases every year to fulfil the particular demand, the power plant capacity should also increase. In the base year, 2021 the power plant capacity requirement was 560 MW which would increase to 786 MW in year 2030 and 2282 MW in year 2050.

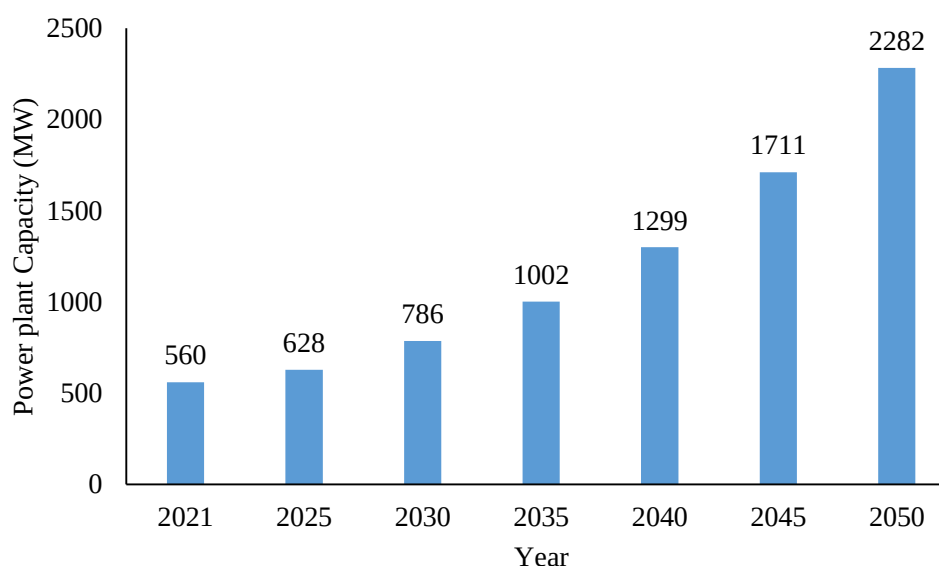


Figure 8.4: Installed power plant capacity requirement for reference economic growth scenario

Figure 8.5 shows the GHG emission for reference economic growth rate scenario. In the base year, the emission was only 3248.6 thousand metric tons which would increase to 3921 thousand metric tons in year 2030 and again would increase to 8029 thousand metric tons in year 2050. The main reason for GHG emission is use of fuelwood, biomass and fossil fuels. So, to reduce the emission of GHG use of energy should switched to clean source of energy such as electricity and renewable energy.

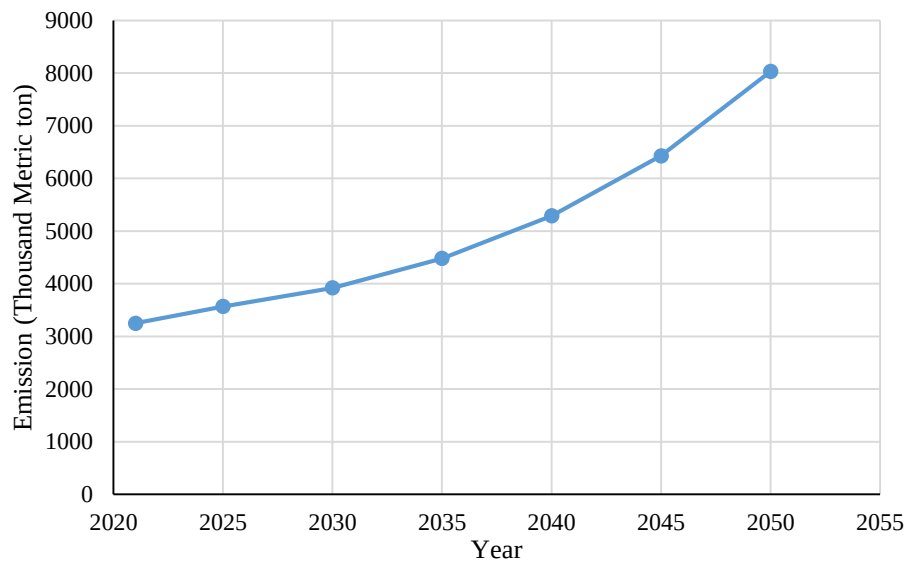


Figure 8.5: GHG emission for reference economic growth scenario

The energy indicators for reference economic growth scenario is shown in Table 8.3. this shows that the per capita energy demand and electricity demand is increasing. The final energy demand per capita in 2021 is 13.73 GJ/capita which would increase to 38.60 GJ/capita. In this scenario the total electricity consumption per household will not get more change also the share of renewable energy and ratio of net import to total energy supply would increase. The GHG emission is 533.95 kg/capita in base year which would increase to 1003.83 kg/capita in year 2050.

Table 8.3: Energy indicators in reference economic growth

	2021	2025	2030	2035	2040	2045	2050
Final energy demand/capita (GJ/capita)	13.73	15.18	17.54	20.77	25.11	30.90	38.60
Final electricity demand (kWh/capita)	412.28	458.72	539.28	644.41	783.45	967.58	1,210.65
Final energy demand (GJ/million NRs)	60.67	53.26	45.79	40.42	36.51	33.63	31.52
Final electricity demand (kWh/million NRs)	1,821.84	1,609.97	1,407.97	1,254.25	1,139.16	1,053.25	988.60
Total electricity used/household (kWh/HH)	821.70	821.76	832.46	839.56	845.25	850.61	855.61
Share of renewable energy	11.51%	11.52%	11.62%	11.64%	11.64%	11.61%	11.58%
Ratio of net import to total energy supply	52.11%	53.58%	55.94%	57.92%	59.60%	61.01%	62.15%
GHG emission (kg/capita)	533.95	563.48	593.32	648.30	730.36	845.46	1,003.83

8.1.2 Low Economic Growth Scenario

In this scenario, the average GDP growth rate is assumed to be 4.8% and the share of each demand technology in future is assumed to be same as in the base year. Table 8.4 illustrates the energy demand in different year for low economic growth scenario in PJ. This shows that the total energy demand is expected to grow from 83.53 PJ in year 2021 to 108.83 PJ in year 2030, and finally to 196.90 PJ in year 2050. The average annual growth rate of total energy demand for this scenario is 3% per annum.

Table 8.4: Energy demand in low economic growth scenario (PJ)

				2021	2025	2030	2035	2040	2045	2050
Renewable	Conventional Renewable	Traditional	Primary Solid fuel	30.39	32.90	35.36	38.84	43.35	49.05	56.25
		Modern Biomass	Biogas	0.33	0.34	0.34	0.34	0.34	0.35	0.35
			Bio Briquette	0.02	0.03	0.03	0.04	0.05	0.06	0.07
	New Renewables	Solar	0.23	0.22	0.24	0.26	0.28	0.31	0.34	
		Grid Electricity	9.03	11.21	13.07	15.35	18.19	21.72	26.14	
Non Renewable			Petrol	5.99	5.82	6.26	6.78	7.39	8.13	9.01
			Diesel	17.83	19.86	21.39	24.53	26.44	29.33	35.46
			Kerosene	0.53	1.05	1.32	1.68	2.13	2.69	3.41
			Furnace oil	3.51	6.94	8.80	11.15	14.12	17.90	22.68
			Aviation Fuel	1.69	1.56	1.63	1.71	1.79	1.88	1.97
			LPG	11.43	12.59	14.29	16.31	18.76	21.77	25.48
			Coal	2.55	4.81	6.10	7.73	9.80	12.41	15.73
Total			83.53	97.33	108.83	124.72	142.64	165.60	196.90	

Figure 8.6 represents the Energy projection trend in different year at low economic growth scenario. The demand of petroleum product is higher and is expected to grow every year at the rate of 3.3% per annum. The demand of all the other energy were also expected to grow every year. The demand of electricity is growing at the rate of 3.3% per annum and the demand of primary solid fuels is growing at the rate of 2.15% per annum.

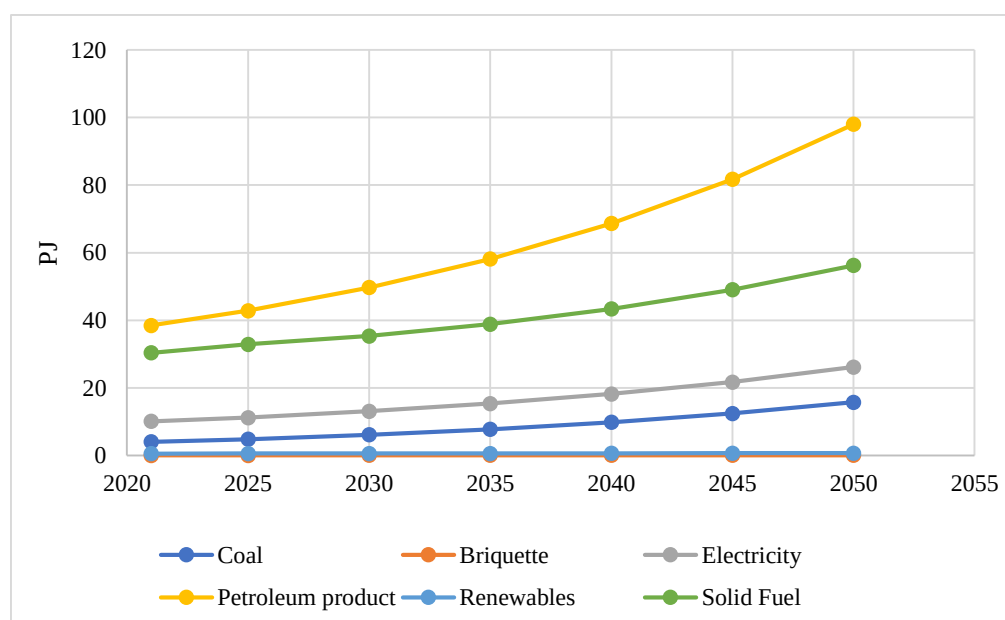


Figure 8.6: Energy projection trend at low economic growth scenario

Figure 8.7, represents the share of energy demand in year 2030. The consumption of primary solid fuel in this case is 33.73% which is the highest followed by diesel (16.59%). Similarly, Figure 8.8 represents the share of energy demand in year 2050. In this year also, the share of primary solid

fuel demand is highest but the percentage share is less as compare to base year i.e. 28.57%. The share of grid electricity is increased to 12.47% in 2030 and 13.27% in 2050.

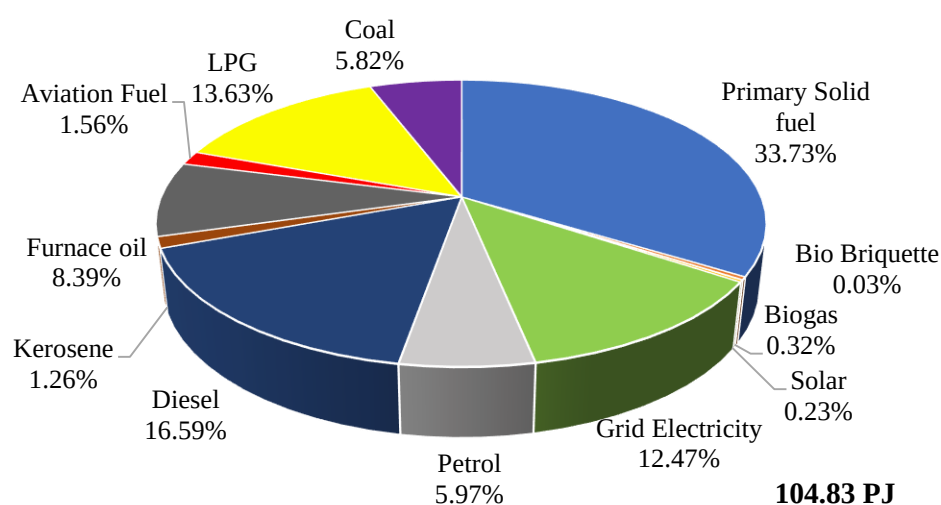


Figure 8.7: Share of energy demand in year 2030 for low economic growth

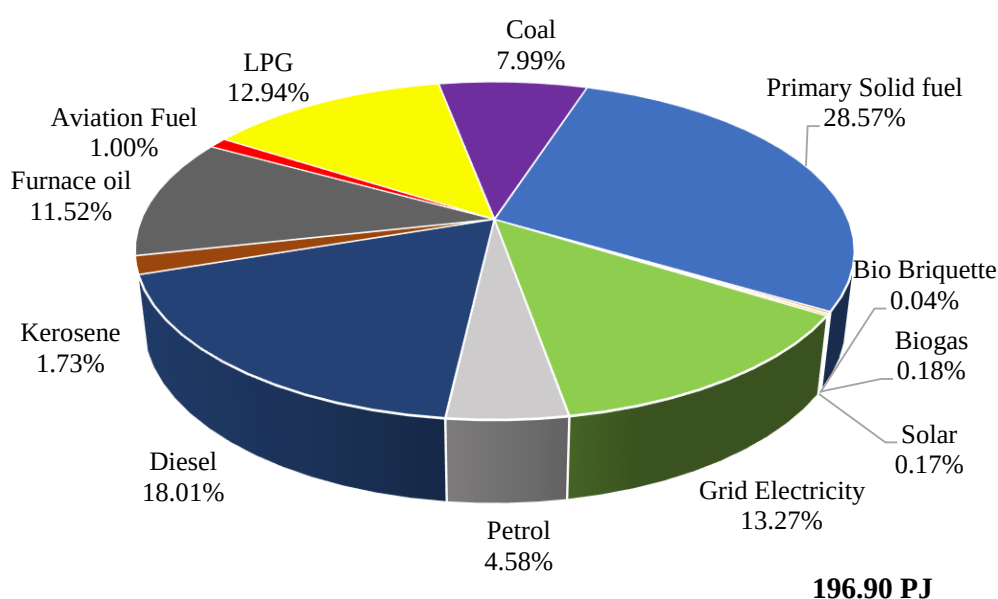


Figure 8.8: Share of energy demand in year 2050 for low economic growth

Table 8.5 shows the sectoral demand for low economic growth rate scenario. The demand of energy would be more in industrial sector in year 2030 (42.69 PJ) followed by residential sector while in 2050 the demand of industrial sector would increase to 110.06 PJ and residential sector would be 41.87 PJ. The average energy demand growth rate of industrial sector is 4.9% per annum while the energy demand growth rate of residential sector is only 0.6% per annum while the total average energy demand growth rate is 3% per annum.

Table 8.5: Sectoral demand for low economic growth rate scenario (PJ)

Economic sector	2021	2025	2030	2035	2040	2045	2050
Agricultural	0.74	0.89	1.13	1.43	1.82	2.30	2.92
Commercial	6.06	7.07	8.85	11.09	13.93	17.52	22.06
Construction and mining	0.86	1.04	1.32	1.67	2.12	2.68	3.40
Industry	27.85	33.68	42.69	54.09	68.54	86.86	110.06
Residential	35.30	36.51	37.13	38.07	39.20	40.46	41.87
Transport	12.73	13.12	13.71	14.35	15.04	15.78	16.59
Total	83.53	97.33	108.83	124.72	142.64	165.60	196.90

Figure 8.9 shows the power plant capacity requirement at low economic growth scenario. The demand of electricity increases every year so the power plant capacity must also increase. The power plant capacity was 560 MW in year 2021 and the requirement would increase to 700 MW in year 2030 and 1419 MW in 2050.

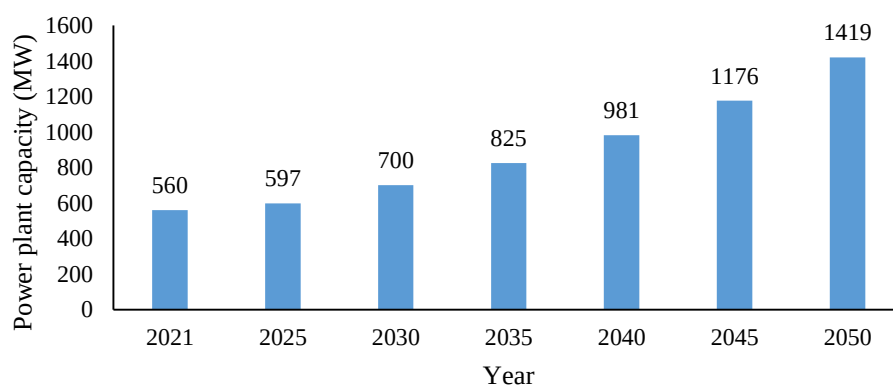


Figure 8.9: Installed power plant capacity requirement at low economic growth rate scenario

Figure 8.10 shows the GHG emission for low economic growth rate scenario. GHG emission was 3248.6 thousand metric tons and would increase to 3681 thousand metric tons in 2030 and again this would increase to 5553.8 thousand metric tons in 2050.

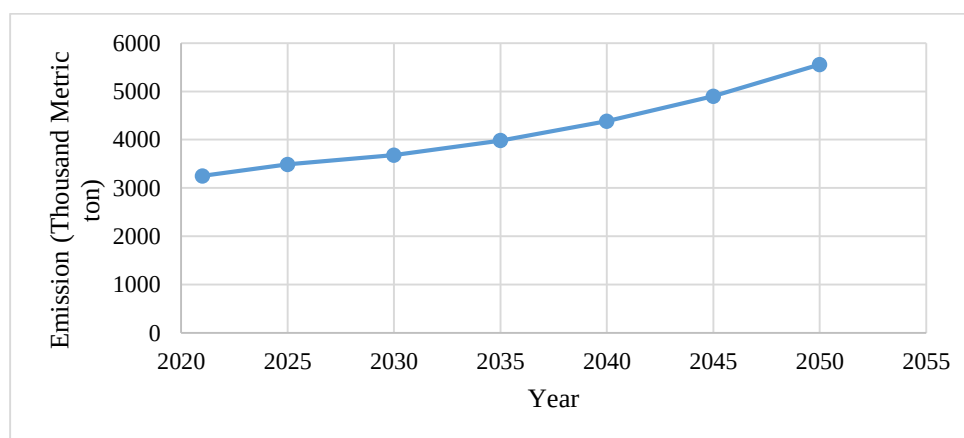


Figure 8.10: GHG emission for low economic growth rate scenario

8.1.3 High Economic Growth Scenario

For high growth rate scenario, the GDP growth rate was assumed to be 10.8% and the other parameters were assumed to be same as in the base year. Table 8.6 illustrates the energy demand in high economic growth rate scenario in PJ. The total energy demand in year 2030 was determined to be 139.64 PJ which will have grown to 743.75 PJ in year 2050. The average annual growth rate of total energy demand for this scenario is 7.8%.

Table 8.6: Energy demand for high economic growth scenario (PJ)

				2021	2025	2030	2035	2040	2045	2050
Renewable	Conventional Renewable	Traditional	Primary Solid fuel	30.39	35.35	43.44	57.38	80.72	119.58	184.32
		Modern Biomass	Biogas	0.33	0.34	0.34	0.34	0.34	0.35	0.35
			Bio Briquette	0.02	0.03	0.05	0.07	0.12	0.19	0.30
	New Renewables		Solar	0.23	0.23	0.25	0.29	0.35	0.44	0.59
			Grid Electricity	9.03	12.03	17.84	26.30	40.25	63.36	101.75
Non Renewable			Petrol	5.99	6.02	5.99	8.33	10.53	14.05	19.76
			Diesel	17.83	19.12	23.83	36.79	56.82	89.90	144.73
			Kerosene	0.53	1.30	2.53	3.63	6.07	10.14	16.93
			Furnace oil	3.51	8.66	12.51	24.14	40.31	67.32	112.42
			Aviation Fuel	1.69	1.71	1.79	1.82	1.88	1.91	1.97
			LPG	11.43	13.68	19.43	24.59	35.45	53.27	82.66
			Coal	2.55	6.00	11.55	16.74	27.96	46.68	77.96
Total				83.53	104.95	139.64	200.33	300.72	467.15	743.75

Figure 8.11, represents the energy projection trend at high economic growth rate scenario. This shows that the consumption of petroleum product is more and is growing every year. The petroleum product is more as there is more demand of petroleum product in manufacturing and transport sectors. In this scenario, petroleum product which is consumed more is increased by four times in year 2050 as compare to low economic growth rate while, solid fuels were increased by 3 times approximately than in low economic growth rate scenario. The average annual growth rate of primary solid fuel in this scenario is 6.4% and grid electricity is 8.29%.

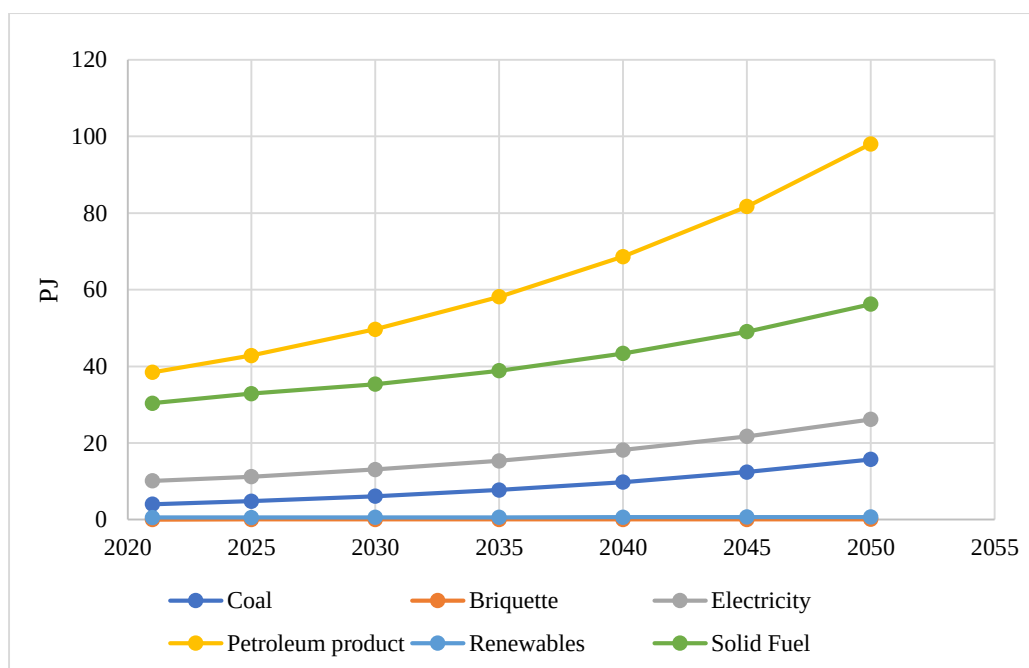


Figure 8.11: Energy projection trend at high economic growth scenario

Figure 8.12 represents the share of Energy Demand in year 2030 for high economic growth rate scenario while, Figure 8.13 represents the share of energy demand in year 2050. In year 2030, the energy demand is 139.64 PJ and in year 2050, the energy demand is 743.75 PJ which is greater than low economic growth rate and reference scenario. The demand of electricity is in increasing trend in every year and the demand of primary solid fuel is 33.73% in year 2030 which is increased to 36.38% in year 2050.

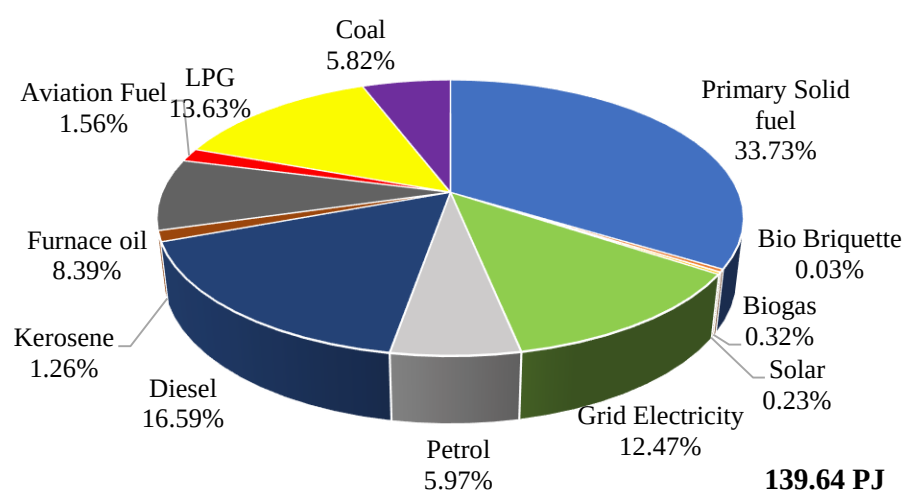


Figure 8.12: Share of energy demand in year 2030 for high economic growth

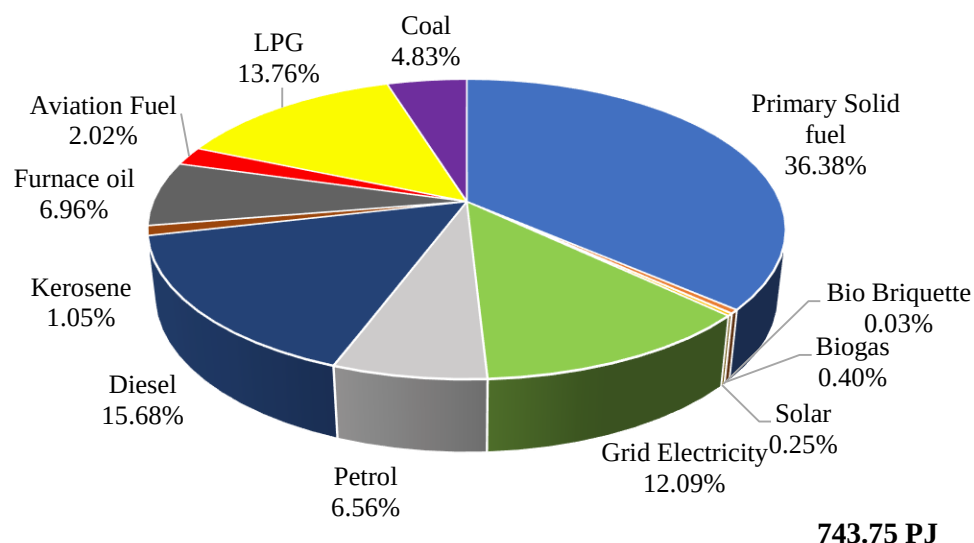


Figure 8.13: Share of energy demand in year 2050 for high economic growth

Table 8.7 illustrates the sectorial demand for high economic growth rate scenario. The demand of energy increases every year in this scenario. The demand in industrial sector would increase to 545.52 PJ in year 2050 which would be the highest demand of energy in that year followed by commercial sector. The average annual growth rate of total energy demand for agricultural, industrial and residential and transport sector are 10.8%, 10.8%, 0.59% and 1.27% respectively.

Table 8.7: Sectorial demand for high economic growth rate scenario (PJ)

Economic sector	2021	2025	2030	2035	2040	2045	2050
Agricultural	0.74	1.11	1.86	3.11	5.19	8.66	14.46
Commercial	6.06	8.69	14.18	23.34	38.62	64.13	106.69
Construction and mining	0.86	1.30	2.17	3.62	6.04	10.09	16.85
Industry	27.85	42.01	70.15	117.14	195.62	326.67	545.52
Residential	35.30	36.51	37.13	38.07	39.20	40.46	41.87
Transport	12.73	13.32	14.14	15.04	16.04	17.13	18.34
Total	83.53	102.95	139.64	200.33	300.72	467.15	743.75

Figure 8.14 shows the power plant capacity requirement for high economic growth rate scenario. It represents that the power plant capacity in year 2021 was 560 MW which would increase to 951 MW in 2030 and would increase drastically throughout the year to reach 5480 MW in year 2050.

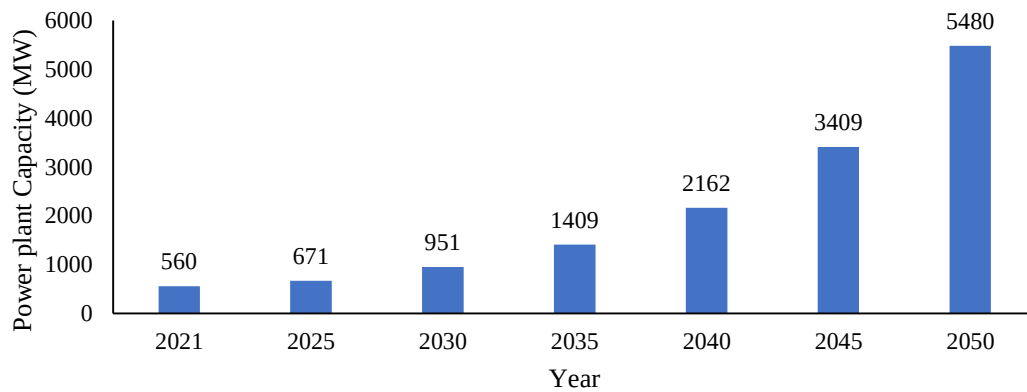


Figure 8.14: Power plant capacity requirement for high economic growth rate

Figure 8.15 represents the GHG emission for high economic growth rate scenario. GHG emission was 3248.6 thousand metric tons in year 2021 and would increase to 4451.5 thousand metric tons in 2030 and as the demand of energy is growing every year the emission would also grow and would reach to 17771.9 thousand metric tons in year 2050.

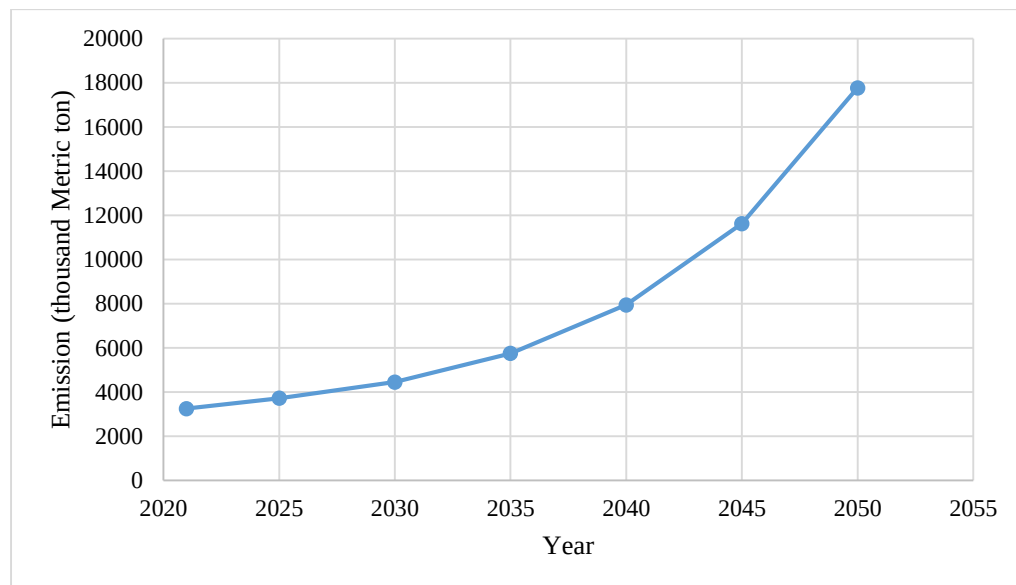


Figure 8.15: GHG emission for high economic growth rate

8.2 Sustainable Energy Development Scenario (SEDS):

For this scenario, the penetration of the energy is calculated on the basis of SDG (Sustainable Development Goals) and Second National Determined Contribution (SNDC). To fulfil these goals, the penetration is changed accordingly and the rate of penetration is calculated in the same rate up to year 2050. The major assumptions for this scenario are as follow:

Agricultural sector:

- 45% electrification in water pumping by 2050
- 45% solar water pumping by 2050

Commercial sector:

- 90% electrification by 2050

Transportation:

Intercity transport

- 60% electric car by 2050 (for new car sales)
- 75% electric bus and train by 2050 (for new sales only)

Intracity transport

- 30% electric mini bus by 2050
- 30% electric micro bus by 2050
- 55% electric motorcycle by 2050 (for new motorcycle sales)

Industrial sector:

- 90% electrification in Boiler by 2050
- 90% electrification in Motive power by 2050
- 90% electrification in Process heat by 2050

Residential sector:

- Urban space heating: 90% electrification by 2050
- Urban water heating: 90% electrification including solar by 2050
- Urban cooking: 90% electrification by 2050
- Rural space heating: 50% electrification by 2050
- Rural water heating: 80% electrification including solar by 2050
- Rural cooking: 60% electrification by 2050

To fulfil the sustainable energy goal, the demand of non-renewable energy and traditional energy is reduced and the demand of renewable energy and modern biomass is increased. In this scenario, the demand of energy is shown in Table 8.8. This shows that in year 2021, the demand of electricity is only 10.10 PJ which would increase to 25.99 PJ in 2030 and this would increase to 123.90 PJ in year 2050. The total energy demand was 83.53 PJ in year 2021 which would increase to 97.65 PJ in 2030 and 214.47 PJ in 2050. The average annual growth rate of total energy demand in this scenario is 3.3%.

Table 8.8: Energy demand in sustainable energy development scenario (PJ)

Particular				2021	2025	2030	2035	2040	2045	2050
Renewable	Conventional Renewable	Traditional	Primary Solid fuel	30.39	31.47	27.80	25.65	23.12	19.23	12.61
		Modern Biomass	Biogas	0.33	0.51	0.54	0.57	0.61	0.65	0.69
			Bio Briquette	0.02	0.05	0.06	0.08	0.10	0.12	0.15
	New Renewables		Solar	0.23	0.37	0.48	0.65	0.89	1.24	1.77
			Grid Electricity	9.03	16.86	25.87	38.04	56.19	83.30	123.79
	Non Renewable			Petrol	5.99	6.01	6.46	6.86	7.27	7.65
Diesel				17.83	17.04	21.12	25.40	30.61	36.60	43.54
Kerosene				0.53	0.48	0.65	0.83	1.04	1.29	1.56
Furnace oil				3.51	3.19	4.34	5.50	6.90	8.54	10.38

Particular		2021	2025	2030	2035	2040	2045	2050
	Aviation Fuel	1.69	1.76	1.83	1.92	2.01	2.11	2.22
	LPG	11.43	10.99	9.65	9.24	8.32	6.49	3.08
	Coal	2.55	2.43	3.32	4.28	5.47	6.94	8.71
Total		83.53	91.16	102.13	119.01	142.52	174.16	216.50

Figure 8.16 represents the energy demand trend at sustainable energy development scenario. In this scenario, the demand of electricity would increase and as the demand of electricity increases the demand of fossil fuels and traditional fuel would decrease. Also, the demand of modern biomass and solar is also expected to increase. The average annual growth rate of electricity, solar and bio gas is 9.03%, 7.71% and 3.29% respectively.

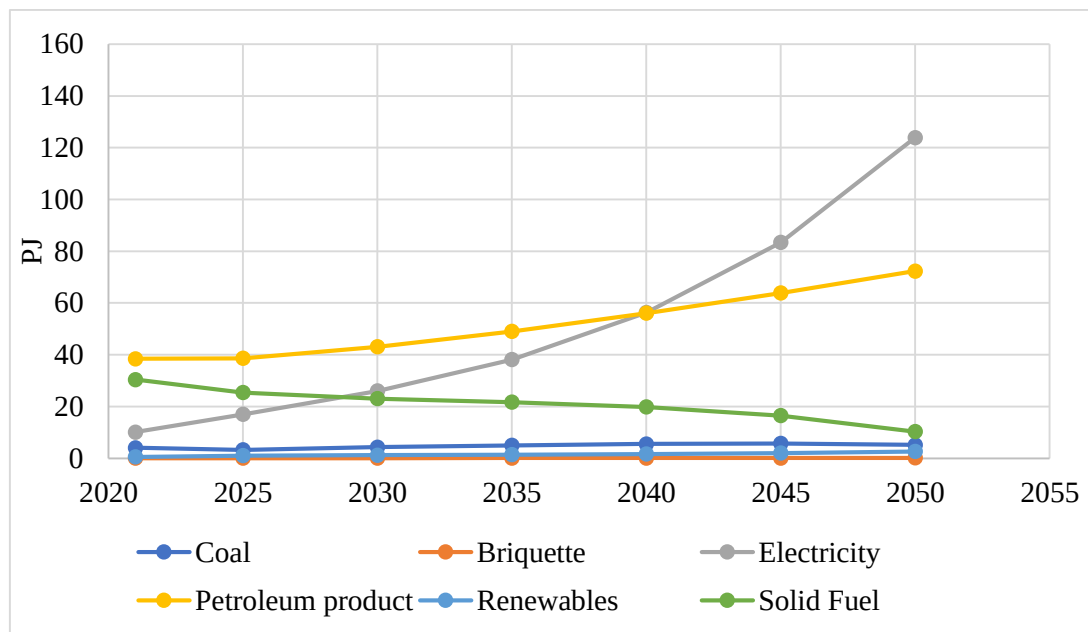


Figure 8.16: Energy demand trend at sustainable energy development scenario

Figure 8.17 represents the share of energy demand in year 2030 for sustainable energy development scenario. The energy demand in this year is 102.13 PJ of which 25.53% share is of grid electricity and 27.22% share is of primary solid fuel. Figure 8.18 illustrates the share of energy demand in year 2050 for sustainable energy development scenario. In this scenario, the demand of electricity is expected to grow to reach 57.18% of total share which means the demand of electricity would increase in this year if sustainable energy development scenario is followed. While the demand of primary solid fuel is expected to decrease to 5.82% of total energy. While the demand of petroleum product is decreased to 43.14% in 2030 and to 30.35% in 2050.

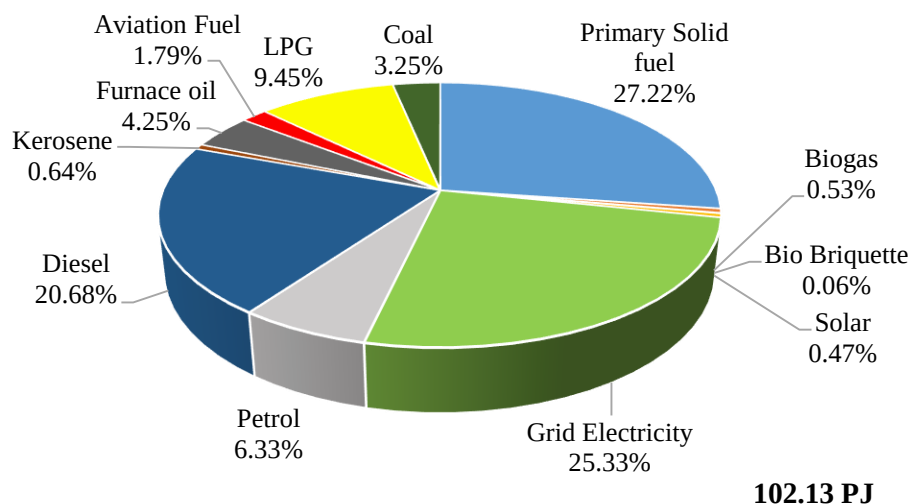


Figure 8.17: Share of energy demand in year 2030 for sustainable energy development scenario

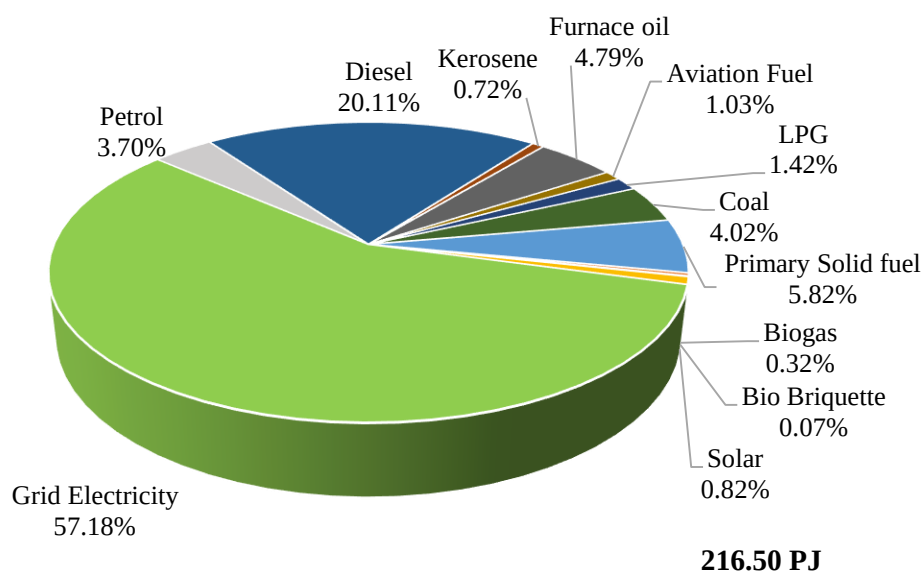


Figure 8.18: Share of energy demand in year 2050 for sustainable energy development scenario

Table 8.9 shows the sectorial demand for sustainable energy development scenario. The demand of energy is more at residential sector in base year while the in 2050 the demand of energy decreases while the demand of energy would increase in industrial and commercial sector. The total energy consumption in year 2030 would be 97.65 PJ and 214.47 PJ in 2050. In 2050, the share of energy demand in agricultural and construction and mining sectors would be the lowest i.e. 2.45% and 2.21% respectively. The share of commercial, industrial, residential and transport sectors are 13.38%, 63.97%, 10.26% and 7.73% respectively.

Table 8.9: Sectorial demand for sustainable energy development scenario (PJ)

	2021	2025	2030	2035	2040	2045	2050
Agricultural	0.74	0.97	1.36	1.91	2.67	3.75	5.26
Commercial	6.06	7.49	9.81	12.85	16.83	22.01	28.70
Construction and mining	0.86	0.88	1.24	1.73	2.49	3.39	4.73
Industry	27.85	32.72	43.80	58.49	77.93	103.55	137.19
Residential	35.30	36.78	32.00	29.46	27.36	25.56	24.04
Transport	12.73	13.31	13.93	14.57	15.23	15.90	16.57
Total	83.53	92.17	102.13	119.01	142.52	174.16	216.50

Figure 8.19 illustrates the power plant capacity requirement for sustainable energy development scenario. This shows that the demand of electricity is only 560 MW in 2021 which would increase to 1964 MW in year 2030 and 9124 MW in 2050. As in this scenario, the assumption was made to replace the demand of traditional and fossil fuels with electricity so the demand of electricity is high in this scenario which spontaneously increased the power plant capacity requirement.

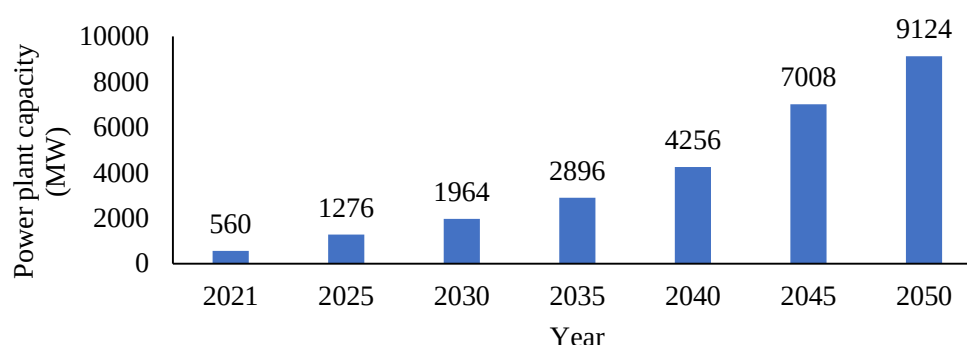


Figure 8.19: Power plant capacity requirement for sustainable energy development scenario

Figure 8.20 shows the GHG emission for sustainable energy development scenario. In this scenario, as the demand of energy is replaced by clean source of energy, the GHG emission would reduce significantly. The emission was 3248.6 thousand metric tons in year 2021 which would decrease to 2685.9 thousand metric tons in year 2030 while this would have expected to reduce to 1208.5 thousand metric tons in 2050.

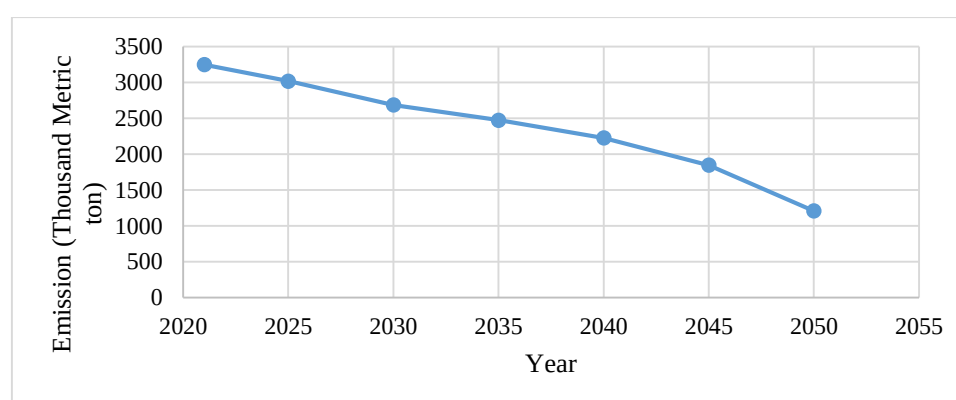


Figure 8.20: GHG emission for sustainable energy development scenario

Table 8.10 shows the energy indicators in sustainable energy development scenario. In this scenario, the non-renewable and traditional energy are replaced by the renewable clean energy so,

the demand of electricity and share of renewable energy is more than in reference scenario. The share of renewable energy would increase to 58.39% in 2050 from 11.51% in base year. The total electricity consumed per household would also increase to 1,869.54 kWh/HH in year 2050 while the demand of imported fossil fuels is in decreasing order. The ratio of net import to total energy supply is 52.11% in base year which would decrease to 35.79% in year 2050.

Table 8.10: Energy indicators in sustainable energy development scenario

Particular	2021	2025	2030	2035	2040	2045	2050
Final energy demand/capita (GJ/capita)	13.73	14.39	15.45	17.22	19.68	22.91	27.07
Final electricity demand (kWh/capita)	412.28	739.39	1,087.39	1,529.23	2,155.82	3,043.79	4,299.10
Final energy demand (GJ/million NRs)	60.67	50.51	40.35	33.52	28.62	24.94	22.10
Final electricity demand (kWh/million NRs)	1,821.84	2,595.04	2,839.00	2,976.39	3,134.65	3,313.27	3,510.57
Total electricity used/household (kWh/HH)	821.68	1,059.64	1,347.24	1,490.79	1,624.25	1,750.08	1,869.54
Share of renewable energy	11.51%	19.52%	26.39%	33.05%	40.54%	48.99%	58.39%
Ratio of net import to total energy supply	52.11%	45.96%	46.39%	45.39%	43.24%	39.97%	35.79%
GHG emission (kg/capita)	533.95	476.70	406.43	358.11	307.47	243.13	151.09

8.3 Comparative Analysis

Figure 8.21 shows the energy demand in reference and sustainable energy demand scenario. This shows that the demand of energy decreases in sustainable energy demand scenario than in reference scenario as the use of more efficient energy is done in sustainable energy demand scenario. The total energy demand in year 2030 would be 115.91 PJ and 102.13 PJ for reference scenario and SEDS respectively while the demand in year 2050 would be 308.75 PJ and 216.50 PJ respectively for reference and SEDS scenarios respectively.

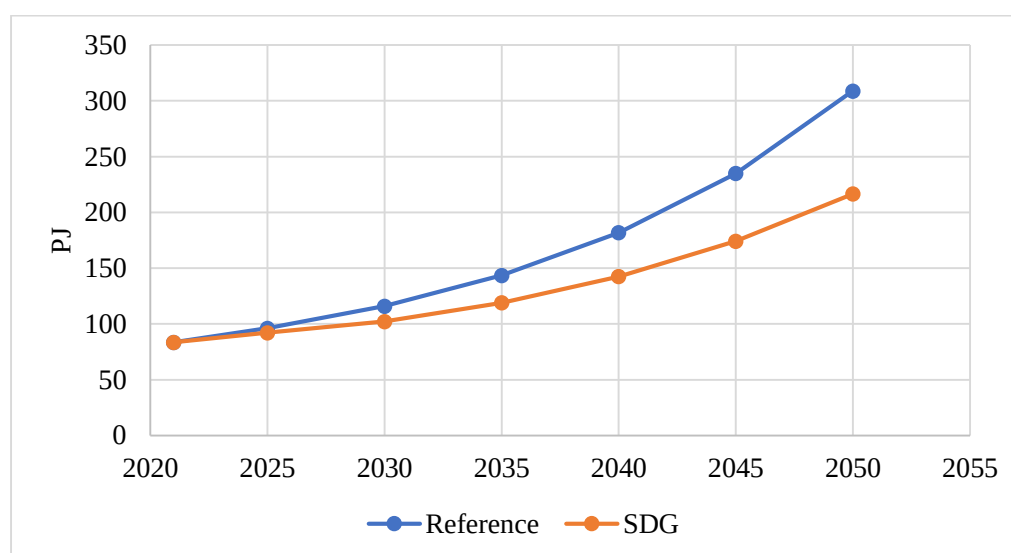


Figure 8.21: Total final energy demand in Bagmati Province

Figure 8.22 shows the renewable energy to total energy demand ratio in Bagmati Province for reference and sustainable energy demand scenarios. The demand of renewable energy in SEDS

scenario would increase drastically. In year 2030, reference scenario would use only 11.09% of total energy as renewable energy while in SEDS scenario, the share of renewable energy is 25.80%. Similarly, the share of renewable energy would increase in SEDS scenario and would reaches to 58.00% in 2050.

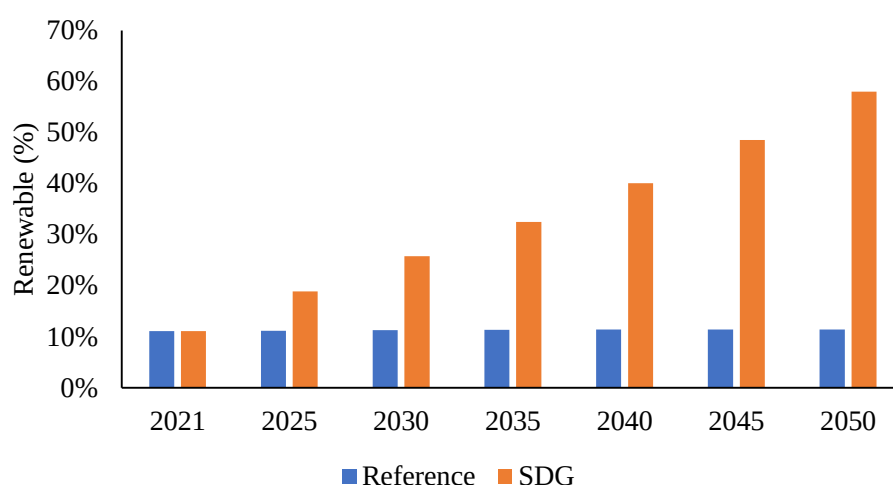


Figure 8.22: Renewable energy to total energy demand ratio in Bagmati province

Figure 8.23 shows the petroleum import to total energy ratio in Bagmati Province. As in sustainable energy demand scenario the use of fossil fuels were replaced by renewable energy so net import of petroleum product is in decreasing order. In base year, the net import of petroleum product to total energy ratio is 46.03% which would be in increasing order in reference scenario and decreasing order in SEDS scenario as shown in the figure below.

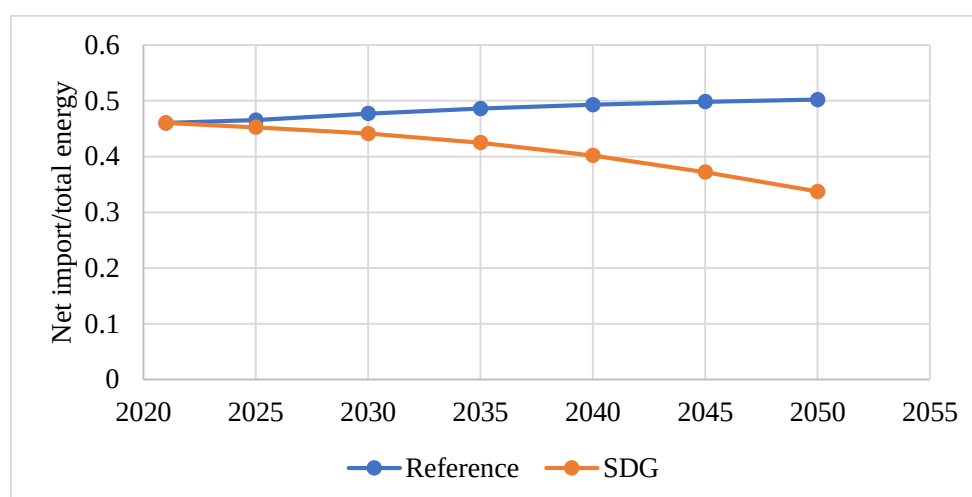


Figure 8.23: Petroleum import to total energy ratio in Bagmati Province

Figure 8.24 shows the GHG emission in Bagmati Province for reference and sustainable energy development scenario. The production of GHG gas would be in decreasing order in SEDS scenario as the use of fossil fuels and traditional biomass is replaced by clean energy.

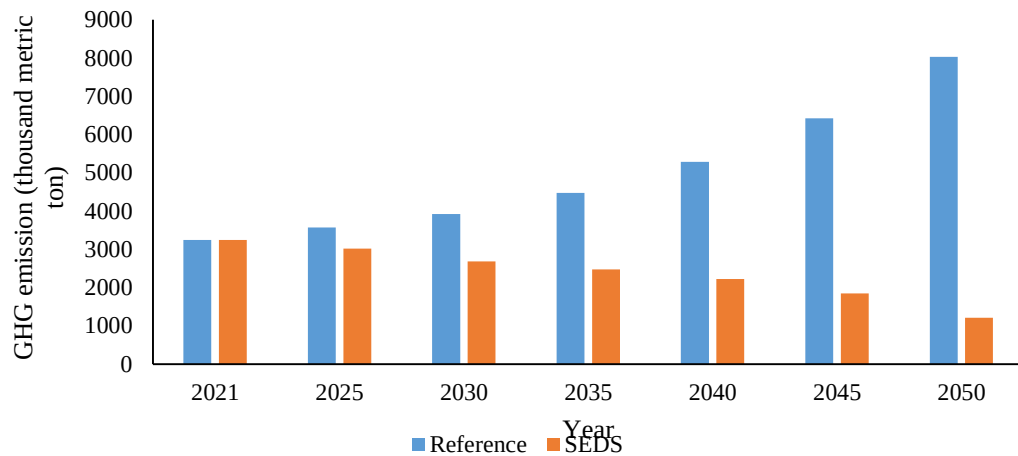


Figure 8.24: GHG emission in Bagmati Province

Figure 8.25 shows the hydro power plant capacity requirement in Bagmati Province. The hydro power plant capacity requirement in SEDS scenario would increase significantly as the use of electricity would be more in SEDS scenario than in reference scenario. The annual growth rate of hydropower plant in reference scenario is 4.96% and in SED scenario the growth rate is 10.1% per annum.

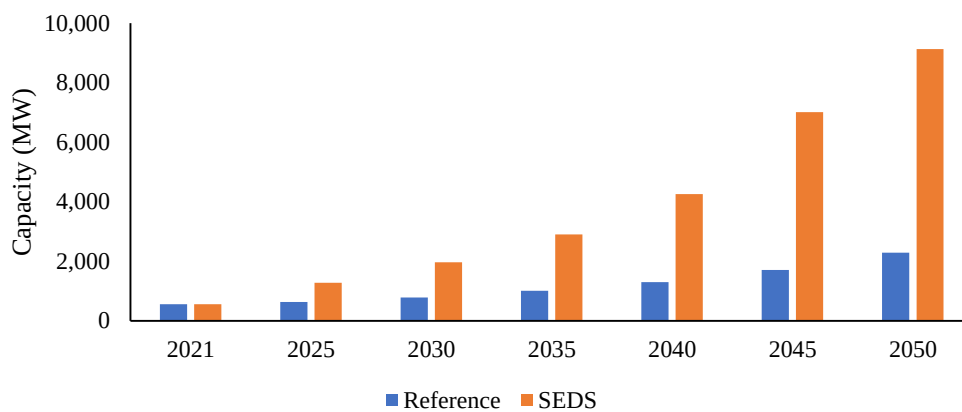


Figure 8.25: Hydro power plant capacity requirement in Bagmati Province

CHAPTER NINE : FINANCIAL ANALYSIS

9.1 Capital Investment

When comparing the sustainable energy development scenario with the reference scenario, the penetration of electricity is high. In case of Nepal, the additional electricity can be produced by utilizing the hydroelectricity potential. For the development of hydro power plant, certain investment is required. The capital investment cost for hydro power plant for reference and sustainable energy development scenario is shown in Table 9.1. not only the development of hydropower, but also solar power plant development within the province can also help in fulfilling the energy demand.

Table 9.1: Capital investment cost for hydro power plant

Particular	2025	2030	2035	2040	2045	2050
Reference	3.42	5.76	7.74	10.62	14.76	20.52
% of GDP	0.23%	0.39%	0.53%	0.72%	1.00%	1.39%
SEDS	14.4	16.92	23.04	33.48	49.68	74.16
% of GDP	0.98%	1.15%	1.56%	2.27%	3.37%	5.03%

9.2 Marginal Abatement Cost

The cost required to reduce each ton of GHG emissions is marginal abatement cost (MAC). In SEDS the use of fossil fuels and traditional fuels which emits more GHG gas would be replaced by clean source of energy such as electricity and solar energy. For this certain initial investment is required which is marginal abatement cost.

In base year, the emission was 3248.6 metric ton which would increase every year in reference scenario by average growth rate of 3.25% while in SEDS scenario, the use of clean energy would have carried out so the emission would reduce each year.

Table 9.2: Incremental investment cost

Particular	2025	2030	2035	2040	2045	2050
Incremental Investment	11	11.1	15.3	22.9	34.9	53.7
GHG Abated	549.7	1235.1	2005.1	3061.8	4578.9	6820.6
MAC ('000 NPR/ton of CO ₂ eq)	-20.01	-8.99	-7.63	-7.48	-7.62	-7.87

9.3 Net Fuel Import Cost

The penetration of electricity for end use in different economic sector reduces the use of imported fuels within the Bagmati Province. The average cost of imported fuels per unit of energy consumed in the FY 2078/79 was around NPR. 2.1 Million/PJ. Based on this cost, the net saving due to reduction in imported fuel consumption is around NPR. 2.1 Billion.

Table 9.3: Fuel import cost (TJ)

Particular	2021	2025	2030	2035	2040	2045	2050
Reference	34.17	40.44	50.85	65.11	84.75	111.95	149.70
SEDS	34.17	33.82	37.83	43.23	50.20	58.27	67.25
Decrease in import	0.00	6.62	13.02	21.88	34.55	53.67	82.45

9.4 Carbon Trading

Carbon trading is the process of buying and selling permits and credits that allow the permit holder to emit carbon dioxide. Carbon trading is one of the pillar to slow climate change. As per the agreement ERPA (Emission Reduction Payment Agreement), Nepal will receive \$5 for each tonne of carbon-dioxide emission reduction.

Table 9.4: Cumulative carbon trading benefits

Particular	2025	2030	2035	2040	2045	2050
GHG Reduction (thousand tonne)	2,748.50	8,924.00	18,949.50	34,258.50	57,153.00	91,256.00
Benefits in \$	13,742.50	44,620.00	94,747.50	171,292.50	285,765.00	456,280.00

CHAPTER TEN : RESULT VALIDATIONS

Energy consumption in Province 1, Madhesh Province and Bagmati Province are 73 PJ, 63 PJ and 83.53 PJ respectively. The comparison shows energy consumption is higher in Bagmati Province due to higher population number as well as performance of higher economical activities.

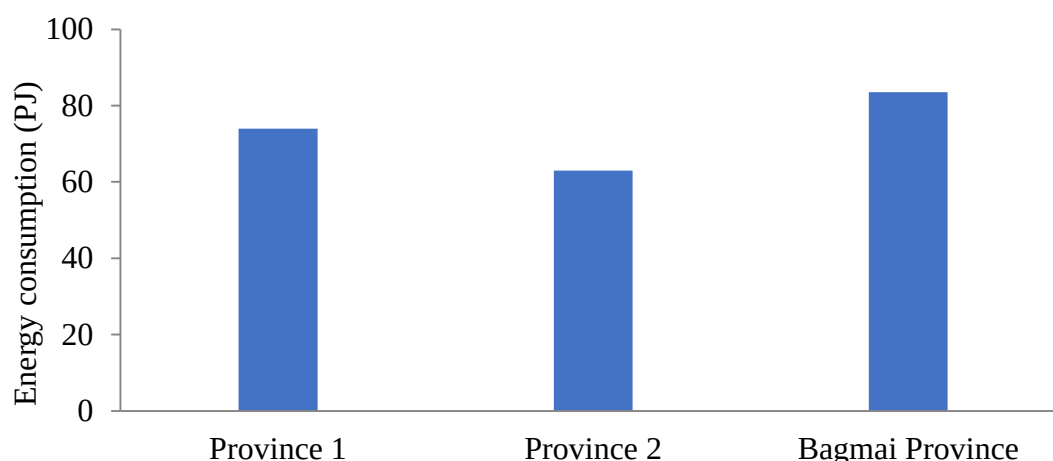


Figure 10.1: Comparison of energy consumption in Province1, Madhesh Pradesh and Bagmati Province

Table 10.1 shows comparison of energy consumption in six different economic sectors in Province 1, Madhesh Province and Bagmati Province. In Madhesh Province, low efficient fuels are consumed in immense quantity which results greater energy consumption among all provinces. Meanwhile, energy consumption in industrial sector is higher in Province 1 due to higher number of iron and steel manufacturing industries which consumes huge coal, fuelwood and agriculture residue, However, economic activities is greater in Bagmati Province due to which energy consumption in commercial, transportation, construction and mining sector is higher among others.

Table 10.1: Comparison of sectotal energy consumption among different Provinces

Economic Sector	Province 1 (TJ)	Madhesh Province (TJ)	Bagmati Province (TJ)	Remarks
Agriculture	534	790	739	Bagmati Province consumes high energy than province 1 due to extensive uses of modern agricultural equipments. However, energy consumption is lower than Madhesh Province due to lower production yield as well as uses of inefficient agriculture tool.
Commercial	2,144	2,178	6,060	Energy consumption in Bagmati Province is higher due to performance of higher economical activities.

Economic Sector	Province 1 (TJ)	Madhesh Province (TJ)	Bagmati Province (TJ)	Remarks
Industrial	32,961	14,900	27,848	Province 1 consumes higher energy due to higher number of metal manufacturing industries.
Residential	30,163	39,248	35,300	Madhesh Province has higher energy consumption due to uses of traditional and inefficient technology for cooking and other domestic purpose.
Transport	7,448	5,812	12,726	Bagmati Province has higher energy consumption due large number of active vehicles.
Construction & mining	585	267	862	Energy consumption in Bagmati Province is higher due to performance of extensive construction activities.
Total	73,835	63,195	83,535	

Comparison of energy consumption per GVA among Province 1, Madhesh Province and Bagmati Province is represented in Table 10.2. It shows that all sector uses energy efficient equipment except agriculture sector among other provinces. Similarly, energy consumption per capita in residential sector is higher in Madhesh Province whereas energy consumption per capita in transport sector is higher in province 1 and Bagmati Province.

Table 10.2: Comparison of energy consumption per GVA/per capita among different Provinces

Economic sector	Energy consumed per provincial gross value addition (kJ/GVA)		
	Province 1	Madhesh Province	Bagmati Province
Agriculture	2.74	4.39	4.85
Commercial	7.78	9.18	7.23
Industrial	871.98	602.51	444.40
Construction & mining	14.50	11.30	14.59
Economic sector	Energy consumed per capita (GJ per capita)		
	Province 1	Madhesh Province	Bagmati Province
Residential	5.97	6.37	5.03
Transport	1.48	0.94	1.44

Table 10.3 shows comparison of energy consumption in Province1, Madhesh Province and Bagmati Province by fuel type. It confirms that consumption of traditional energy is higher in Madhesh Province whereas consumption of petroleum product as well as electricity is higher in Bagmati Province.

Table 10.3: Comparison of energy consumption by fuel types

Fuel source	Province 1 (TJ)	Madhesh Province (TJ)	Bagmati Province (TJ)
Fuelwood	21,859	27,458	27,340
Agricultural Residue	5,925	6,957	3,043

Fuel source	Province 1 (TJ)	Madhesh Province (TJ)	Bagmati Province (TJ)
Animal dung	6,777	826	3
Biogas	28	60	335
Bio briquettes			22
Solar PV	8	10	31
Grid electricity	5,588	5,245	9,033
Petrol	3,009	1,874	5,990
Diesel	4,842	10,150	17,827
Kerosene	155	129	530
Furnace oil	3,645	1,162	3,518
Aviation Fuel	62	563	1,689
LPG	4,638	3,776	11,427
Coal	6,638	15,624	2,547
Solar Thermal			199

Table 10.4 represents the energy balance of electricity consumption and supply by Nepal Electricity Authority (NEA). The consumption of electricity seems higher in commercial sector and transport sector than its supply.

Table 10.4: Sectoral electricity consumption and supply balance

Economic sector	NEA sales (MWh)	Survey (MWh)	Remarks
Residential	1,269,306	1,287,368	
Commercial	496,522	605,397	Electricity supply for commercial sector is also from domestic consumer which is the reason to seem significantly higher consumption of electricity.
Agricultural	16,487	15,256	
Transport	1,829	3,957	Electricity used for the operation of ropeway has been added in transportation sector so the consumption seems extremely higher.
Industrial	545,306	594,047	

CHAPTER ELEVEN : CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

In this study, agricultural, commercial, industrial, residential, construction and mining and transport sectors has been considered as the six economic sectors. The consumption of biomass is found to be the highest in the province. About 53.73% of the total area is covered by forest, national parks and conservation areas in the Bagmati Province. However, deforestation has been the major problem in this province. The petroleum products are imported from India in this province. There are altogether 37 IPPs based hydropower electricity generation with total capacity of 252.27 MW and additional 1882 MW of IPPs based hydropower plant is under construction phase. The total electricity consumption in Bagmati Province is 2249.8 GWh and the majority of electricity is consumed in the residential sector (i.e., 51.78%).

Overall, energy consumption in Bagmati Province is 83.53 PJ in base year of which residential sector, has the maximum share. The energy consumption in the residential sector contribute to about 42.26% share in the total energy consumption of the Bagmati Province. Fuelwood consumption is the dominant source of energy in the residential sector. Meanwhile, consumption of LPG seems increasing for cooking purpose while electricity is used for electrical appliances. The total consumption of energy in residential sector was determined to be 35.3 PJ in which rural sector consumption is 15.61 PJ and urban sector consumption is 19.69 PJ. In this sector most of the energy share is consumed in cooking. Transport sector consumed 12.73 PJ energy in which diesel consumption is highest with 6.22 PJ and 23.90% of total share is consumed by motorcycle. In agricultural sector the total energy consumption is 739 TJ where diesel is major energy source while electricity consumption seems increasing. In this sector, the consumption is divided into three sub sectors tillage, irrigation and threshing. Energy consumption in tillage is found to be 557.37 TJ while irrigation consumed 101.62 TJ and the remaining is consumed by threshing. It is found in commercial sector, the total consumption is 6.06 PJ in which, consumption of traditional fuelwood is shifting towards LPG and Electricity. The LPG consumption is 3.46 PJ and electricity consumption is determined to be 2.18 PJ, on the other hand, the consumption of energy is determined to be higher in accommodation and food service with 3.91 PJ. In industrial sector, the total energy consumption is 27.85 PJ and the energy consumption is maximum for process heat and motive power where diesel and electricity are dominant fuels. It seems contributions of LPG is also significant. The diesel consumption in industrial sector is 10.25 PJ whereas the 15.32 PJ of energy is consumed in food beverage and tobacco sector. The total energy consumption in construction and mining sector is 860.81 TJ in which the diesel consumption is highest with 78.49% i.e. 675.63 TJ.

In scenario development different scenarios were observed i.e. reference, low, high and sustainable energy development scenarios using MAED. In 2030, energy demand in reference scenario would be 115.91 PJ which would increase to 308.75 PJ in 2050. In low economic growth scenario, the demand of energy would reach to 108.83 PJ in 2030 and finally to 196.90 PJ in 2050. Similarly, in high economic growth scenario, the consumption would be 139.64 PJ in 2030 which would grow to 743.75 PJ in 2050. In SEDS, the energy demand would increase to 102.13 PJ in 2030 from 83.53 PJ in 2021 and again this energy would increase to 216.50 PJ in 2050. In this

scenario, the demand of electricity would be highest with 25.87 PJ demand in 2030 and 123.79 PJ demand in 2050.

In reference economic growth rate scenario, the power plant capacity requirement in 2030 would be 786 MW which would increase to 2282 MW in 2050 while in SEDS the power plant capacity requirement would increase to 1343 PJ in 2030 and 6347 PJ in 2050. The GHE emission in reference economic growth rate scenario would be 3921 metric tons in 2030 which would increase to 8029 metric tons in 2050. In case of SEDS, GHG emission would be in decreasing order as it uses clean source of energy. the GHG emission in SEDS would decrease to 2685.9 metric tons in 2030 and 1208.5 metric tons in 2050.

As in SEDS, the clean energy source is preferred i.e. hydro and solar, the capital investment would increase than in reference scenario. The capital investment cost in SEDS would be \$74.2 billion in 2050 while it would be only \$20.5 billion in reference scenario. Also, the benefits could be gain in SEDS scenario from carbon trading. The cumulative carbon trading benefit would be \$456,280 in 2050 which could be used for the development of the county.

11.2 Recommendations

On the basis of this study following recommendations are provided:

- According to the SNDC, 25% of households use electricity as primary source of cooking by 2030. But in Bagmati Province, 66% of households are still using 5A fuse so, fuse rating should be upgraded to at least 16 A. Along with this, transformer and distribution system should be upgraded so that the interruption of power supply may be minimized.
- The current hydropower potential is 252.27 MW but in sustainable development scenario the requirement of electricity exceeds this generation capacity. To meet the SDG7 goals, the projected power plant capacity should be increased to 1,343 MW by 2030.
- The energy consumption in the residential sector is highest i.e. 36.7 TJ and the other sectors, industrial, transportation, commercial, construction and mining and agriculture consumes 27.85 TJ, 9.15 TJ, 6.85 TJ, 0.86 TJ and 0.74 TJ respectively. As in Bagmati Province, 45% of total source of income is dependent on agriculture however the energy consumption in this sector is the lowest. So, the agricultural sector should be modernized by using the modern techniques in tillage, irrigation and threshing.
- In case of transport sector, the goal of SNDC is to increase the sale of private passenger vehicles using electricity by 25% in 2025. But the construction of charging stations is still ongoing and should be constructed on every fuel refilling stations. On the other hand, for charging electric vehicle, three phase supply should be provided to household sector but still 66% of households are using 5 A fuse. So, the supply system should be upgraded as per the requirement of consumers.
- The consumption of fuelwood, diesel and LPG in Bagmati Province is 37.62%, 18.87% and 13.77% respectively. The emission by using these energy resources is very high so the replacement of these energy should be done by renewable energies such as solar, hydro and wind energy.
- GHG emission reduction based on the SNDC can be internationally traded for benefit of \$441,070.7 which can help to achieve the net zero emission target. Hence appropriate measures should be considered to achieve the SNDC target.

- Capital investment required for construction of hydropower for the SED scenario will reach up to 5.03% (NRs.74.16 billion) of the GDP in 2050. So, government should allocate separate budget for the construction and development of hydropower.
- The surplus electricity which is unused during the off-peak period is being wasted. Such surplus electricity can be utilized in the transport and agricultural sectors. The charging of electric vehicles and demand in agricultural sector can be conducted during the off-peak period rather than in the peak demand period which could balance the demand of electricity.
- The possibility of generation of electricity based on solar energy is high in the Bagmati Province. As such, the generation of electricity using solar should be done with its proper utilization. Also, grid connection of the produced electricity with appropriate allowance can motivate the producers.
- Biogas production should be done from degradable wastage produced from the household or any other organization so that the degradable wastage gets managed within the house and also fertilizer produced from this can be used in the agricultural sector or roof top farming.
- The unused biomass can be used to prepare charcoal and bio-briquette. It can also be used in the production of biogas. So, the government should focus on using the biomass more efficient rather than using it for only open burning which creates more air pollution. So its utilization can be done by converting it into bio-briquette and charcoal.

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