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

Final Report

(Province-2)

Energy Consumption and Supply Situation in Federal System of Nepal (Province No. 1 and Province No. 2)

January 2021

Submitted By:

CMS Engineering Consult Private Limited and
126 Green House, Thapagaun, Naya Baneshwor
GPO Box 10872, Kathmandu, Nepal

Center for Energy Studies
Institute of Engineering
Tribhuvan University, Pulchowk, Lalitpur, Nepal

Executive Summary

Global Energy Outlook and Current National Energy Overview

World Energy Outlook emphasizes that energy is of paramount importance to human society and economic activity (IEA, 2018). Providing modern energy services is a necessity for eradicating poverty and reducing the divide between rich and poor. Energy features have prominence in the United Nations Sustainable Development Goals (SDGs), agreed by almost 200 nations in 2015. Nepal, in its roadmap for achieving SDGs by 2030 (NPC, 2016), envisions a middle-income country by 2030. To reach this kind of status, Nepal needs an enormous consumption of energy resources based on renewable energy and energy efficiency for sustainable energy development and energy security in the country.

A recent report by World Wildlife Fund (WWF) in 2019 shows that developing nations must discourage usage of fossils fuels and concentrate on renewable energy and energy efficiency for meeting its rising energy demand. But unfortunately, Nepal is becoming too much dependent on imported fossil fuels - imports of petroleum products against commodity exports of Nepal have jumped from 24% in 2004 to above 200% in 2019 (MoF, 2018/19). Hence, for the development of a "Prosperous Nepal," it has become essential to have proper and dynamic energy planning of the whole energy systems in place at the local and provincial levels which need to be later integrated to the national energy systems planning for sustainable energy development and energy security in the country.

The total energy consumption of Nepal stands at 586 PJ in 2019, which was 400 PJ in 2009, with an annual average growth rate of 4%. The traditional energy consumption decreased from 82% in 2009 to 69% in 2019. Meanwhile, there is an improvement of commercial energy consumption from 12% in 2009 to 29% in 2019, growing at the rate of 13% per annum. The renewable energy consumption increased at the rate of 17% per annum, constituting 2% share of total energy in 2019. In 2009, electricity consumption was 2% of total energy consumed in the country, which has improved to 4% by 2019 with the annual average growth rate of 10%.

Nepal's petroleum imports declined 10% in 2020 and growth in electricity consumption stood at just 2% only compared to those in 2019 due to the impact of COVID -19 pandemic. In the current situation of COVID-19 pandemic still in existence, uncertainties are still prevalent. Two issues are naturally linked - success in bringing the pandemic under control would facilitate a recovery in economic activity, while prolonged outbreaks of Covid-19 would weigh heavily on the prospects for growth. However, it is expected that energy demand rebounds quite rapidly in those parts of the world that had early success in bringing the pandemic under control, returns to growth during 2020, while the negative impacts may persist for longer in many lower income countries (IEA, 2020). The updated assessment by International Energy Agency reports that renewables, especially those in the power sector, are less affected than other fuels by the pandemic and its aftermath. With aid of massive investment in new, more efficient, and cleaner capital stock, the structural transformation in energy sector would be possible. The world energy outlook 2020 also have included the well signified Net Zero Emission by 2050 scenario in this its latest analysis. Achieving this goal would involve a significant further acceleration in the deployment of clean energy technologies together with wide ranging behavioral changes.

Nepal has abundant hydropower resource es and switching to electricity in energy access is a better option from the point of economic efficiency, energy efficiency, sustainability, and energy security. Nepal Electricity Authority (NEA) is responsible for developing, operating, and distributing hydropower in Nepal. Currently, there is a demand for 1,444 MW of electricity in the country, and the 65% of it is supplied by from domestic generation, and the remaining 35% is imported to fulfil the demand (NEA 2019). With the increase in generation of hydropower the imports of power from India are expected to decline soon in near future. There is an installed capacity of 32 MW off grid micro, and pico - hydropower plants located in remote parts of the country (AEPC 2018).

General Overview of Province 2

Province 2 is spread along the south-eastern part of Nepal. It stretches east to west comprising eight districts of Terai regions and covers an area of 9,661 km2. The province encompasses a total of 1 metropolitan city, three sub-metropolitans, 73 municipalities, and 59 rural municipalities. With a population of 5.4 million as per the 2011 Census of Nepal, it was the most densely populated province of Nepal.

According to National Economic census, among the registered institutions in province 2, more than 85% are commercial institutions, around 11% are industries, 1% of institutions involved in agriculture while construction and mining account for less than 1% (CBS, 2019). Meanwhile, in economic terms, the largest share of GDP is from the commercial sector (47.5%) followed by agriculture (40%), construction and mining (6.4%) and industry (7.8%) in 2019 (CBS, 2019).

Methodology of Study

This study followed a combination of quantitative and qualitative methods and data are mainly collected from primary and secondary sources. Primary data were collected from sample survey of all the economic sectors of Province 2.

- Residential Sector
- Industrial Sector
- Commercial Sector
- Transport Sector
- Agricultural Sector and
- Construction and Mining Sector

The projected census population has been used as the population to determine the sample size for the survey (Table 1).

Table 1. District Wise Population and Household Status in Province 2

		2011		2019	
	Districts	Population	Households	Population	Households
Province 2	Bara	687,708	108,635	765,586	131,998
	Parsa	601,017	95,536	669,078	115,358
	Rautahat	686,722	106,668	764,489	131,808
	Sarlahi	769,729	132,844	856,896	147,741
	Mahottari	627,580	111,316	698,649	120,457
	Dhanusa	754,777	138,249	840,250	144,871
	Siraha	769,729	132,844	856,896	147,741
	Saptari	639,284	121,098	711,679	122,703
	Total	5,536,546	947,190	6,163,523	1,062,677

The questionnaire survey has been carried out in this Province, using the survey design. It is focused on identifying occupant and building information, device and occupant behaviors, and their energy consumption based on the geographical and ecological division of Province 2.

The questionnaire for the survey was developed and the survey was carried out for six economic sectors identified as:

- Residential/Domestic sector
- Industrial Sector
- Transport Sector
- Commercial sector
- Agricultural sector
- Construction and Mining sector

Structured questionnaires were prepared for six sectors and these questionnaires were administered in KOBO Toolbox. KOBO Toolbox is a set of open-source applications which allow one to create a questionnaire form in the X form format, fill it out on a mobile phone or table turning the Android operating system, store and view the aggregated information on a central server, and retrieve the aggregated data to one's computer for analysis.

After completing data collection, the final data sets have been transferred into SPSS software for the analysis. The report has been prepared using SPSS, MS-Word, and EXCEL software.

For the energy demand projection and supply analysis, the main energy drivers are the economic and the populations growths. These data for the year 2019 were obtained from the CBS. According to the NPC, there had not been done any studies yet for the projection of GDPs at the provincial level. Hence, for Province 2, a macroeconomic model has been developed with 71 variables consisting of 12 policy variables and other exogenous variables and 59 endogenous variables. The CBS has started to publish the provincial Gross Value Added by industrial division for seven provinces since fiscal year 2018/19 (Table 2). Based on these single year provincial data and three scenarios of national GDP at producer's prices, Gross value added by industrial division for Provinces No. 2 have been projected assuming that the structure of provincial gross value added of these provinces will remain the same for the projected period.

Table 2. Provincial Gross Value Added by Industrial Division in Province No. 2 (MoF, 2019)

(In Million Rs. at 2017/18 prices)	
Industrial Classification	**2018/19**
Agriculture and forestry	154,156
Fishing	8,298
Mining and quarrying	2,637
Manufacturing	25,008
Electricity gas and water	2,955
Construction	23,520
Wholesale and retail trade	53,936
Hotels and restaurants	3,008
Transport, storage and communications	36,375
Financial intermediation	12,511
Real estate, renting and business activities	22,271
Public administration and defense	11,876
Education	35,623
Health and social work	3,463
Other community, social and personal service activities	11,099
Total GVA including FISIM	406,736
Financial Intermediation Services Indirectly Measured (FISIM)	8,309
Gross Domestic Product (GDP) at basic price	39,8427
Taxes less subsidies on products	46,069
Gross Domestic Product (GDP)	444,496

Provincial gross value added by industrial division of Provinces No.2 is forecasted based on the three growth scenarios of national GDP at producer's prices. Thus, the province has three growth scenarios. Additionally, the recent COVID-19 has had a great impact on economic activities. The preliminary economy growth rate as estimated by CBS is around 2.27% (CBS, 2020). The world bank has estimated a growth rate of 1.8% for fiscal year 2019-2020 (World Bank, 2020). Thus, for early year, a growth rate of 1.8% have been taken and it has been assumed that by period of 2025, the economy will bounce back to normal as evident from the case of economic rebound in year 2016/17. Based on these contexts, the compound annual growth rates used for projection are given in Table 3.

Table 3. Economic Growth Rates for Three Scenarios

	2019 - 2020	2020 - 2025	2025 - 2030	2030 - 2035	2035 - 2040	2040 - 2045	2045 - 2050	Average
Low	1.80%	3.54%	5.27%	5.66%	6.00%	6.32%	6.64%	5.57%
Reference	1.80%	3.93%	6.08%	6.52%	6.90%	7.11%	7.28%	6.30%
High	1.80%	4.03%	6.24%	6.81%	7.34%	7.87%	8.15%	6.74%

Scenarios give pictures of potential future demand and supply requirements and other activities however these should not be confused with either predictions or forecasts. It gives one particular image of how the future could unfold under certain circumstances. Scenarios provide a framework for exploring future perspectives, including various combinations of activities, technology options and their implications. Scenarios are useful tools for investigating alternative future developments and their implications, for learning about the behavior of complex systems such as energy and environment systems and for policy-making decisions related to them (Nakicenovic, 2000).

The energy scenario development process requires certain drivers for activities. The rate of activities is dependent on specific variables. In the study, the activities are linked with economic and demographic parameters (Table 4).

Table 4. Assumptions and Sectoral Categorization

Particulars		References
GDP*	Low economic growth	(MoF, 2016; NPC, 2014; NPC, 2017; CBS, 2012; CBS, 2014; ADB, 2015) and other recent documents as published by authorized agencies.
	High economic growth	
	Reference economic growth	
Demography	Population	

Methodological Framework for Energy Planning and Scenario Analysis applied for this study is presented in Figure 1. The energy system analysis will be done from the bottom-up approach, i.e., all possible energy activities will be considered at the end-use level for each sector. The base year will be taken as 2019 for energy demand analysis. From here, energy scenarios have been developed until 2050, and a short term, medium term, and long-term targets have been devised. The initial data collected from survey have been used to develop a base year energy model with inclusion of socio-economic parameters. Based on predicted demographic and economic parameters, the energy scenarios have been developed at the provincial level that include –

- Demand analysis – for each of the economic sectors based on end-use activities and fuels
- Supply analysis – for determination of energy supply required
- Resource analysis – for analysis of feasibility and potential energy supply system

The energy scenario development has been a two-step process. Firstly, in MAED for energy demand projection as it is one of the robust, freely available energy demand analysis softwares. Secondly, TIMES model is used as the MAED is limited or demand projection only, while the TIMES model is capable of analyzing the supply side as well as the emissions of the energy system. Although the details of data required in TIMES is much vast, as MAED provides a rigid framework, the data required for both models can be derived from same sets of information derived from primary survey and secondary sources as depicted Figure 1. The final results in both the energy models were compared, calibrated, and verified for validation of input sets of economic and demographic data and their respective outputs.

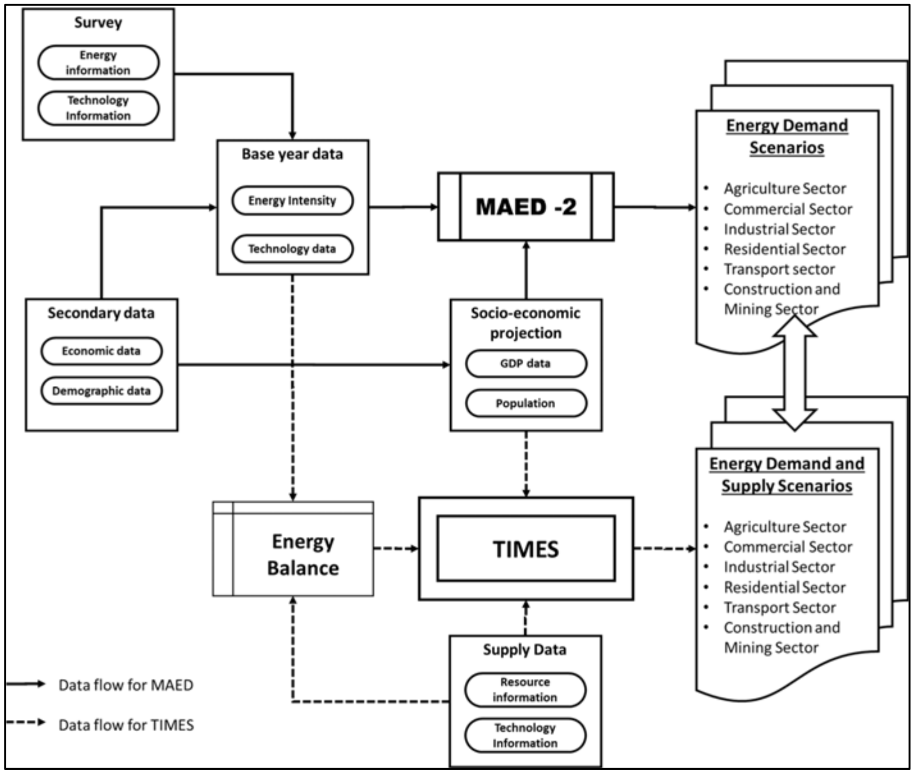


Figure 1. Methodological Framework for Energy Demand and Supply Scenario Development

MAED calculates the energy demand for each end-use category, subsector, and sector, aggregating then the economic sectors into four main "energy consumer" sectors: Industry (including Agriculture, Construction, Mining and Manufacturing), Transportation, Service and Household. At the same time, it provides a systematic accounting framework for evaluating the effect on the energy demand of any change of economic nature or in the standard of living of the population. The TIMES model generator was developed as part of the IEA-ETSAP (International Energy Agency - Energy Technology Systems Analysis Program) to conduct energy and environmental analyses. It is the successor of MARKAL. The model combines two different, but complementary, systematic approaches to modeling energy: a technical engineering approach and an economic approach. TIMES is a technology rich, bottom-up model generator, which uses linear-programming to produce a least-cost energy system, optimized according to several user constraints, over medium to long-term time horizons.

The energy resources can be categorized into renewable and non-renewable energy resources. Renewable energy is divided into conventional renewable and new renewable. Conventional renewable energy is further divided into traditional biomass and modern biomass whereas new renewable category includes the solar energy, wind energy, solar-wind hybrid system, geothermal energy, hydrogen fuel, hydropower etc. The traditional biomass means fuel wood, agricultural residues, and animal dung whereas modern biomass includes both liquid and non-liquid biofuels. Biogas from the animal and human excreta and other waste biomass, ethanol, biodiesels are some of the examples ofthe liquid biofuels whereas non liquid biofuel means bio briquettes, charcoal etc. Non-renewable energy resources primarily include the fossil fuel that covers petroleum fuel, natural gas, coals.

Energy Supply in Province 2

Fuelwood Supply

In past decades, because of the increasing population, the area under agriculture expanded and forest shrunk. The forest area in the Terai is declined by 16,500 ha in the years from 2001 to 2010 and by 32,000 ha in the 19 years from 1991 to

2010. The annual rate of decrease in forest cover was 0.44% during the last nine years from 2001 to 2010 and was 0.40% during the last 19 years from 1991 to 2010/11. The annual rate of deforestation in all 20 Terai districts was 0.06%, excluding protected area (FRA/DFRS, 2014). In Province 2 also the land under cultivation increased at cost of forest land. On the other hand, due to poverty, the demand for fuelwood increased despite the rapid growth in the commercial energy sector in the Terai region, because the fuelwood is practically free if people afford time for collection. Large quantity of fuelwood is being collected from community managed and government managed forest by the local people (Table 5).

Table 5. Forest Area and Actual Fuelwood Produced

	Terai area in ha	Churia area in ha	Total area in ha	Per ha Vol in cubic m with branch	Growing stock in forests in m cum	Fuel wood produced in chatta
Saptari	3,584	30,595	34,179	96.42	1,949,899	85
Siraha)	3,307	2,4400	27,707	37.61	781,364	50
Dhanusa	27,218	380	27,598	29.2	805,861	8,803
Mahottari	12,009	10,050	22,059	37.61	829,639	102
Sarlahi	13,868	15,494	29,736	148	4,400,928	621
Rautahat	22,063	7,337	29,400	112.49	3,307,206	342
Bara	34,426	14,731	49,152	156.27	6,404,739	150
Parsa	77,124	0	77,124	220	2,227,630	383

(DFO Bara, 2074; DFO Dhanusa, 2075; DFO Parsa, 2069; DFO Rauthat, 2074; DFO Saptari, 2075; DFO Siraha, 2075)

Petroleum Products

All the petroleum consumed in the country is imported from India. The only company that deals with import and sales of petroleum products – that include diesel, petrol, kerosene, and LPG is Nepal Oil Corporation Ltd. (NOC). The furnace oils and other oil residues are imported by the industries themselves. Thus, the supply of petroleum products is obtained from regional offices of NOC. District wise sales data for 2075-76 is as shown in Table 6. All the units for petrol or Motor Spirit (MS), Diesel and Super Kerosene Oil (SKO) are in kiloliters except for LPG in metric ton (MT). These sales data represent the sales to depots at each district. However, it is to be noted that neither the sales from these depots are bound within the district only nor the supply in each district is bound by the capacity of depots only – there are inter-boundary trade and transportation of petroleum fuels. Hence, the supply of petroleum products and their consumptions may not tally properly (Table 6).

Table 6. Petroleum Sales in 2075-76 in Province 2

Districts	MS	Diesel	SKO	LPG
	kL	kL	kL	tons
Bara	13,113	93,779	755	482
Dhanusha	15,832	44,541	1,982	152
Mahottari	7,588	19,094	84	
Parsa	14,077	46,702	864	181
Rautahat	9,480	23,829	287	
Saptari	8,654	19,477	567	
Sarlahi	10,644	28,708	239	
Siraha	11,565	26,392	332	
	90,956	302,524	5,114	815

(Source: NOC 2020)

Electricity

There is no sizeable hydropower potential in province 2. All the electricity through national grid must be brought from other provinces. The only indigenous source of electricity could be the decentralized gensets that are used by industries – of which reliable data are not available and all the electricity produced is used within the industry. Thus, the main source of electricity is via national grid distributed by Nepal Electricity Authority (NEA). The district wise electricity supply status as obtained from NEA for province 2 is as shown in Figure 2. It shows Bara and Para has comparatively high consumption of electricity due to mainly the numbers of industries located in the districts.

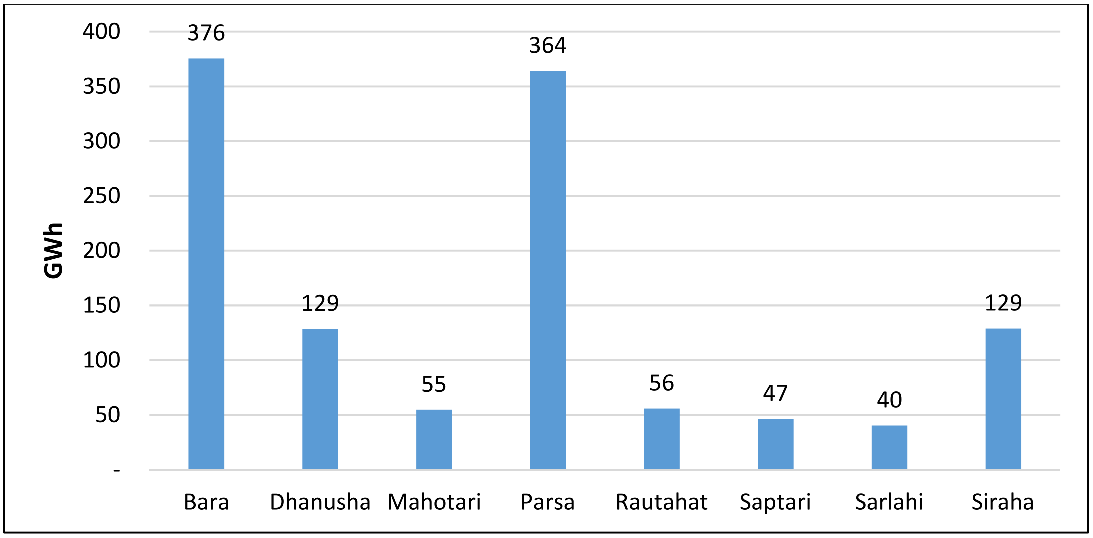


Figure 2. Electricity Consumption in Province 2 in 2075 (NEA, 2019)

A per NEA, 98% of the households lie within minimal amperage capacity of 5 A, and 1% relate to 6-15 A connection. Less than 1% have electricity connection above 16 A. In province 2, 80% of household have access to electricity (NEA, 2019).

Modern Renewable Energy Sources

Modern Renewable energy sources includes wind, biogas, solar, micro hydro, and other renewables. Alternative Energy and Promotion Centre (AEPC) is the leading organization working in the promotion of renewable energy in Nepal. The modern energy access is gradually increasing in Nepal with the current status of electricity access from renewables reaching 18% population. There has been a contribution of 30.6 MW of electricity from mini and micro hydro schemes, 26.5 MW from solar PV system wind energy. 36% of population have been benefited from different renewable energy sources for cooking, lighting and productive end uses (MoF, 2019).According to AEPC, the number of installed plants for solar home system (SHS), small solar home system (SSHS), Mud Improved Cook stoves (MUDICS), domestic biogas and Institutional solar PV system (ISPS) in province 2 is as shown in Table 7: Approximately 190 kWp from SHS, 123 kWp from SSHS and 184 kWp form ISPS have been installed in Province 2. In addition to these, solar photovoltaic pumping system (SPVPS) has gained much popularity amongst farmers. Thera are total of 498 SPVPS units, ranging from capacity of 500 Wp to 3.5 kWp. Most of the biogas plants are sized 4 cubic meter in the province. Due to low land of the region, there is no micro hydro plants installed in province 2 (Table 7).

Table 7. Number of Modern Renewable Technologies Installed in Province 2 (AEPC, 2019)

District	SHS	SSHS	SPVPS	MUD ICS	Domestic biogas	ISPS
Bara	1,057	0	28	0	4,289	7
Dhanusha	147	21	15	9,501	820	30
Mahottari	463	679	6	3,424	1,803	9
Parsa	30	0	63	0	929	1
Rautahat	2,794	778	205	840	1,829	12
Saptari	1,176	187	44	2,008	688	5
Sarlahi	6,878	765	116	183	3,131	27
Siraha	140	44	21	4,556	626	12
Grand Total	12,685	2,474	498	20,512	14,115	103

Energy Consumption in 2019

The total energy consumption in 6 economic sectors in province 2 and its energy mix in 2019 is summed to about 63 PJ. Although the residential sector still dominates the sectoral energy consumption and wood and biomass dominated the energy source type, change in energy mix can be observed as compared to previous studies at national and regional levels (Figure 3 and Figure 4). Nearly 62% of the total energy consumption is in residential sector while about 64% of the energy comes from conventional renewables. The driving factor behind this change in energy pattern is seemingly due to energy transition and energy efficiency improvement, as indicated by IEA (2018) in developing countries.

Fuelwood is still the main source of energy in residential sector, while commercial sector thrives on use of electricity. The transport, industry and agricultural sectors still shows huge dependency on fossil fuels. However, a shift from diesel power water pumping system to solar powered can be seen in agricultural sector.

The energy mix in Province 2 shows dominance of traditional renewable (biomass). However, the share of wood in total biomass seems lower than previous reference results, as the province is very much active in agricultural activities, thus having abundance of agricultural residue and animal wastes. The share of LPG is nearly equal to share of electricity, thus indicating the raise in dependence on imported fuel (Figure 3).

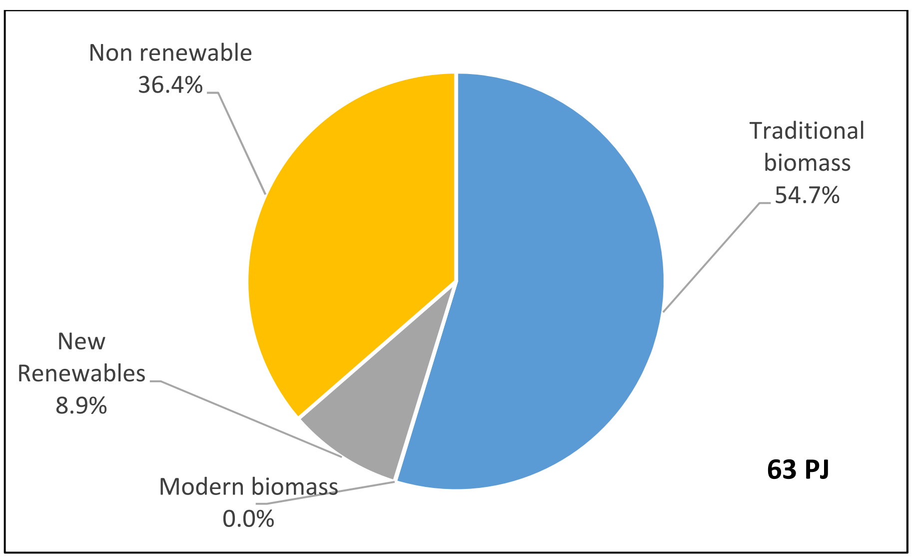


Figure 3. Energy Consumption Share in Province 2 by Fuel Group

Sector wise, the residential sector is still prevalent in terms of energy consumption with nearly 62% consumption out of total final energy. However due to massive industrial and commercial activities in this province, the energy share in residential sector comes to be lower than the share at national average (Figure 4).

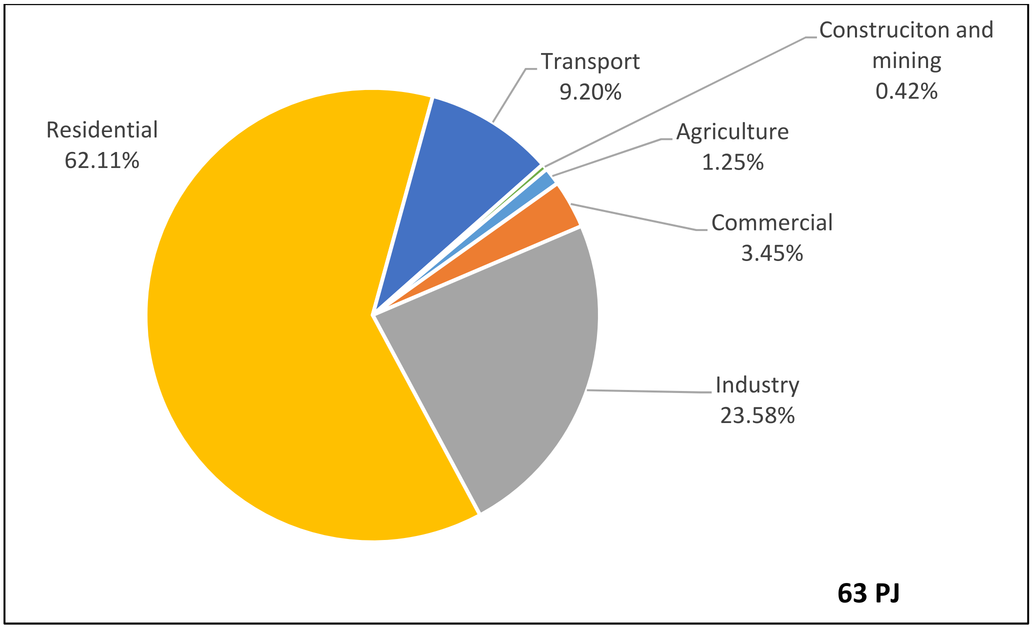


Figure 4. Energy Consumption Share in Province 2 by Sectors

Sankey diagram in Figure 5 graphically represents the energy flow from supply to demand in 2019. The diagram evidently shows that highest portion of supply is from biomass – wood, agricultural and animal wastes and large portion of these goes to residential sector. While in demand side, residential sector tales a large chunk of energy – of which biomass is the largest source, while industry is largely dependent on coal and petroleum products. Meanwhile, agriculture sector seems to be replying on non-machinery power like animals and human.

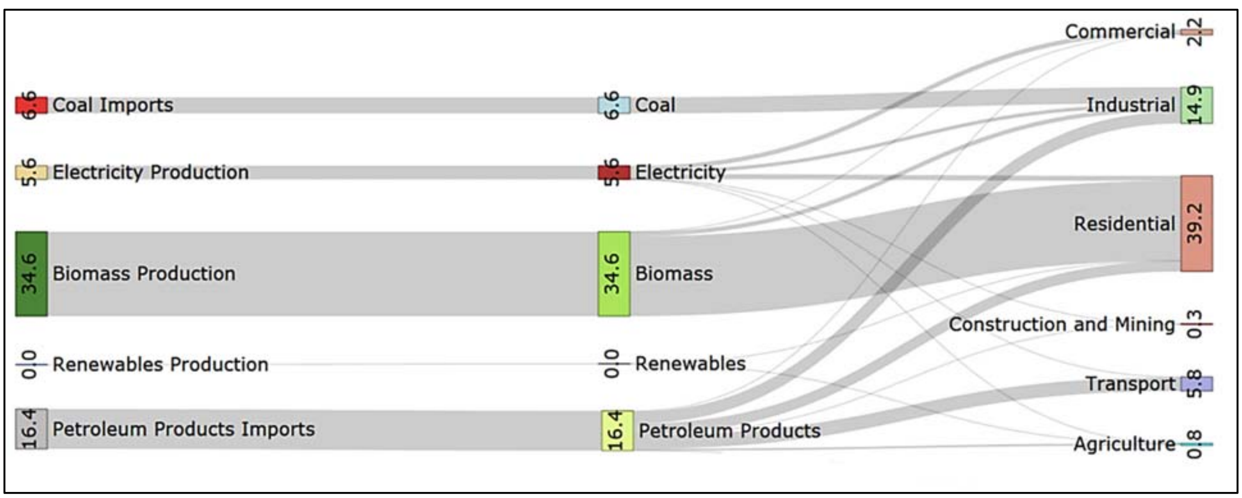


Figure 5. Sankey Diagram for Flow of Energy in Province 2 (PJ)

Table 8 shows the energy consumption indicators which highlight the status of energy consumption in Province 2. The total final energy consumption per capita of 10.4 GJ is lower than previous national average. This can mainly be attributed to the change in energy mix and transition to modern energy types as explained earlier. The electricity consumption per capita also comes to be higher than national average of 225 kWh (NEA, 2019; CBS, 2014). As per NEA, the national average per capita electricity generation is 264 kWh. This is mainly due to higher electricity consumption by commercial and industrial sectors. The residential electricity consumption per household lies in tier-3 of multi-tier framework and is way behind the tier-5 level of 3,000 kWh (World Bank/ESMAP, 2019).

Table 8. Energy Consumption Indicators

Parameter	Value	Unit (per annum)
Energy per capita	10.41	GJ per capita
Energy per GVA	174	GJ per million NRs
Share of conventional renewable energy in total	63.6%	
Share of modern and new renewable energy	8.9%	
Electricity Consumption (Total)	256	kWh per capita
Electricity Consumption (Residential)	629	kWh per HH

Details of analysis of energy consumptions in sub sectorial segments of each economic sectors in each district are given in the main report and its annex.

Scenario development

Based on the energy consumption obtained from primary survey in Province 2 and energy supply situation in the Province from various sources, scenarios were developed for energy demand and supply analysis from 2019 to 2050. In developing the scenarios, three different sets of possible future energy demands have been considered – each of which corresponds to a future economic growth scenario. These are:

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

In addition to these three, an additional scenario has been explored to analyze the impact of strategic interventions in the energy sector. For comparative analysis, reference case of 6.3 % GDP growth rate is taken as the policy intervention scenario called Sustainable Energy Development Scenario (SEDS) and its results will be compared with those of the Reference Economic Growth Scenario. Details of the analysis of other scenarios are subsequently provided in the report.

Reference Economic Growth Scenario

The following are the major assumptions of this scenario:

- Average GDP growth rate of 6.3%
- The shares of each demand technology in the energy supply in future years will be same as in the base year

Table 9 below shows the total energy demand for the reference growth case of various fuel types from base year to year 2050. The total energy demand in Province 2 is expected to grow from current level of 63.2 PJ in 2019 to 83 PJ in 2030 and 189 PJ in year 2050 which accounts for three folds of increase. The average annual growth rate of energy demand is 3.6% for the case. The per capita energy demand is expected to grow from 10 GJ in 2019 to 21 GJ in 2050 in this scenario.

Table 9. Fuel Demand in Reference Economic Growth Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	34.56	35.04	37.73	40.96	44.7	49.14	54.49	61.11
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05
			Bio briquettes	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
			Grid Electricity	5.59	5.68	6.46	7.81	9.68	12.32	16.03	21.31
Non renewable			Petrol	3.01	3.1	3.38	3.7	4.04	4.43	4.85	5.33
			Diesel	4.84	4.92	5.87	7.66	10.25	13.99	19.36	27.11
			Kerosene	0.15	0.15	0.17	0.18	0.19	0.21	0.23	0.25
			Furnace Oil	3.65	3.71	4.5	6.05	8.29	11.57	16.31	23.18
			ATF**	0.06	0.06	0.07	0.08	0.08	0.09	0.1	0.11
			LPG	4.64	4.7	5.09	5.58	6.18	6.92	7.85	9.05
			Coal	6.63	6.75	8.19	11	15.09	21.06	29.68	42.18
Total				63.19	64.17	71.51	83.08	98.58	119.8	149	189.73

*PSF (Primary Solid Fuels) : Fuelwood, Agricultural Residue, Animal Residue

**ATF : Aviation Turbine Fuel

Sustainable Energy Development Scenario (SEDS)

In this scenario all combined policy measures are considered at an average annual GDP growth of 6.3% for various technology Interventions. The major focus is on electrification by renewable energy and energy efficiency in various demand technologies. The assumptions/strategic options are in line with the various published reports and documents of Nepal Governmental agencies, IEA, IRENA, Paris Agreement, UN's SDGs programs, and other international energy and emissions-related programs.

The following are the major assumptions of this scenario.

- GDP growth rate according to reference case i.e., 6.3%.
- The shares of energy technologies vary in line with intervening strategies which are:

Agriculture:

- 50% Electrification in water pumping by 2050
- 50% Solar water pumping by 2050

Commercial sector

- 100% electrification by 2050

Transportation

- Intercity transport
  - 80% intercity passenger vehicle by public bus
  - 50% electric bus by 2050,
  - 10% electric car by 2050
  - 2.5% electric two wheelers by 2050
- Intercity transport
  - 5% electric car by 2050,
  - 5% electric train by 2050
- Freight transport
  - 30% electric train by 2050

Industry:

- Boiler
  - electric boiler in food beverage and tobacco and 100% share by 2050

   - electric boiler in textile and leather and 100% share by 2050
   - electric boiler in chemical rubber and plastic and 100% share by 2050
- Motive power and other
   - 100% electrification by 2050
- Process Heat
   - 70% electrification by 2050

Residential sector:

- Rural cooking: 60% electric, 10% fuelwood and 20% LPG by 2050
- Rural space heating: 100% electrification by 2050
- Rural water heating: 100% electrification by 2050
- Rural Animal Feeding:10% LPG, 10% wood, 50% Electric, 30% Biogas by 2050
- Rural others: 100% electrification by 2050
- Urban cooking: 100% electrification by 2050
- Urban space heating: 100% electrification by 2050
- Urban water heating: 100% electrification by 2050
- Urban Animal Feeding:10% LPG, 50% Electric, 40% Biogas by 2050
- Urban others: 100% electrification by 2050

The final demands of various fuels in the SED scenario have been given in Table 10. The total energy consumption in 2030 and 2050 is expected to be 71 PJ and 144 PJ respectively. Per capita energy demand is expected to be 16 GJ in 2050 in the Sustainable Energy Development Scenario (SEDS), whereas it would be 21 GJ in the Reference Economic Growth Scenario.

Table 10. Fuel Demand in Sustainable Energy Development scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	34.56	33.97	30.87	27.33	23.12	18.09	12.04	4.63
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.03	0.04	0.11	0.19	0.28	0.38	0.49	0.62
			Bio briquettes	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0
	New Renewables		Solar PV	0.01	0.01	0.02	0.04	0.08	0.14	0.23	0.39
			Grid Electricity	5.59	6.23	10.61	17.33	27.38	42.73	66.29	102.72
Non renewable			Petrol	3.01	3.1	2.9	2.65	2.33	1.92	1.42	0.8
			Diesel	4.84	4.86	5.38	6.44	7.76	9.4	11.29	13.35
			Kerosene	0.15	0.15	0.13	0.12	0.1	0.07	0.05	0.02
			Furnace Oil	3.65	3.62	3.85	4.44	5.08	5.69	6.04	5.78
			ATF**	0.06	0.06	0.07	0.08	0.08	0.09	0.1	0.11
			LPG	4.64	4.57	4.23	3.86	3.41	2.87	2.19	1.33
			Coal	6.63	6.61	7.14	8.41	9.92	11.59	13.16	14.19
Total				63.19	63.24	65.33	70.89	79.55	92.98	113.32	143.96

**PSF (Primary Solid Fuels) : Fuelwood, Agricultural Residue, Animal Residue*

***ATF : Aviation Turbine Fuel*

Energy Indicators in the Sustainable Energy Development Scenario (SEDS)

Table 11 highlights the energy indicators for policy scenario i.e. SEDS, and it clearly presents that impacts of strategic interventions in energy sector. Per capita final energy demand is 3/4th of that in the Reference Economic Growth Scenario in 2050, while the electricity – which comes from clean renewable resources – increases by nearly 5 folds to over 3,000 kWh per capita. The impact of energy efficiency is visible in energy demand per capita as well as energy required per millions of GDP as well. In addition to this, the share of fuel imports nearly flattens till period of 2030 and decreases in quantity to by one third in 2030. On other hand, use of national resources increases with increase in use of renewables to 72% in 2050 as compared to only 11% in the Reference Economic Growth Scenario.

Table 11. Energy Indicators in Sustainable Energy Development Scenario (SEDS)

Energy Indicators									
		2019	2020	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	10.42	10.29	9.94	10.08	10.58	11.57	13.18	15.66
Final electricity demand	kWh/capita	256	282	449	686	1,014	1,481	2,149	3,116
Final energy demand	GJ/million NRS	1,791	1,761	1,500	1,212	991	830	718	642
Final Electricity Demand	kWh/million NRS	44,049	48,238	67,798	82,465	95,027	106,298	117,042	127,671
Total Electricity Used/household	kWh/HH	629	689	988	1,288	1,588	1,888	2,187	2,487
share of non-carbon energy in primary supply	per cent	8.85%	9.86%	16.27%	24.50%	34.51%	46.10%	58.70%	71.63%
Share of renewable energy in final total energy demand	per cent	8.93%	9.96%	16.47%	24.79%	34.88%	46.51%	59.14%	72.06%
the ratio of net import to total primary energy supply	per cent	36.37%	36.31%	36.27%	36.65%	36.06%	34.02%	30.23%	24.72%
GHG emission	GHG in Kg/capita	335	330	315	319	324	329	328	312

GHG emissions per capita flattens in the whole study period because of clean and renewable energy interventions and they will decrease by 3 times by 2050. Total electricity consumption per household will triple by 2050 to 2,500 kWh which will be three times that of the Reference Economic Growth Scenario.

Comparative Analysis

Figure 6 shows the Sankey diagram for the energy flow from the primary sources to the final energy demand in the respective economic sectors in 2050 in the Reference Economic Growth Scenario.

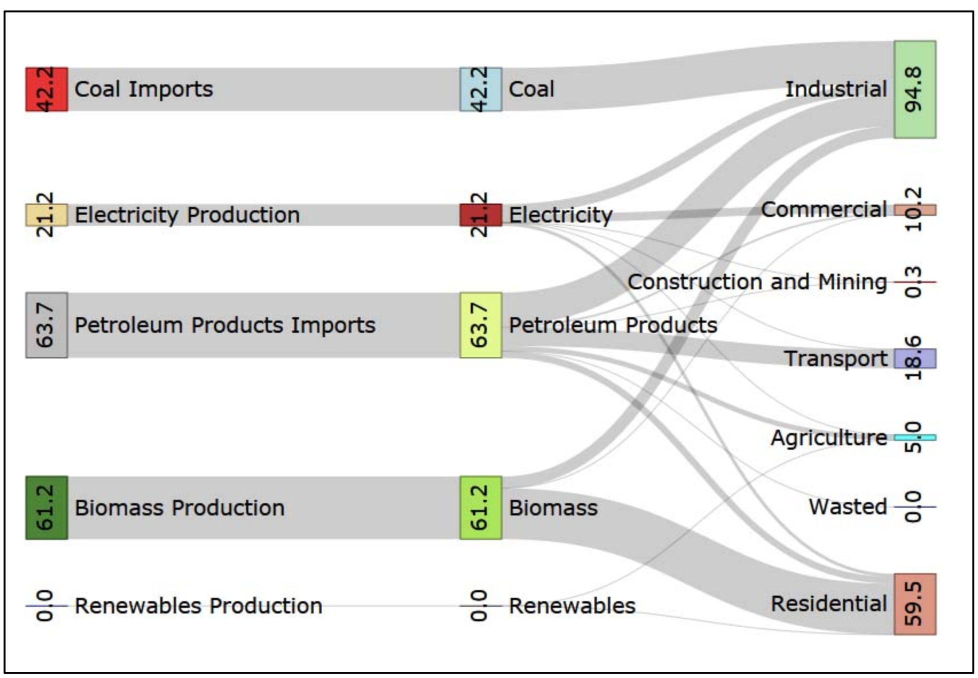


Figure 6. Sankey diagram for flow of energy in Province 2 for the Reference Economic Growth Scenario in 2050 (PJ)

It is evident from Figure 6 that without policy intervention for the clean and renewable energy Province 2 will be still dependent on biomass energy sources and there will be tremendous increase in the demand for fossil fuels by 2050. It is highly doubtful that such kind of demand for biomass energy sources can be sustained by the forest resources in the country and furthermore, one can wonder whether Nepal's economy could sustain imports of such huge quantities in the long run.

Figure 7 shows the Sankey diagram for the energy flow from the primary sources to the final energy demand in the respective economic sectors in 2050 in the SED Scenario.

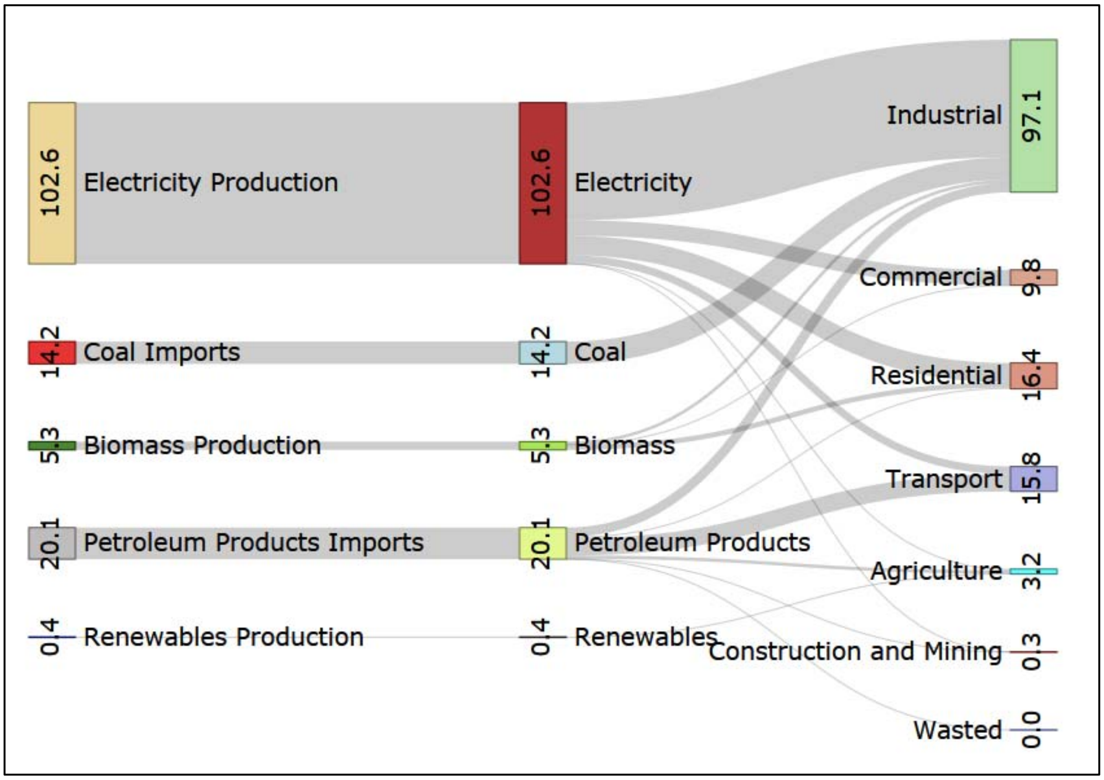


Figure 7. Sankey Diagram for Flow of Energy in Province 2 for the SED Scenario in 2050 (PJ)

Sankey diagram in Figure 7 indicates drastic curtailment of dependence on solid biomass and the imports of fossil fuels on minimum requirement basis as shown in the SED Scenario by 2050. Electricity generation in Nepal is clean and from renewable energy which of course enhances energy security and sustainability in the Province 2.

Figure 8 depicts the electricity demand in compared scenarios which shows that in the SEDS, the household electricity demand of 2,500 kWh/HH comes near to the Tier-5 criteria of 3,000 kWh/HH by the World Bank (WB/ESMAP, 2019). Additionally, the growth in access to electricity means increase in demand for nationally available hydroelectricity production.

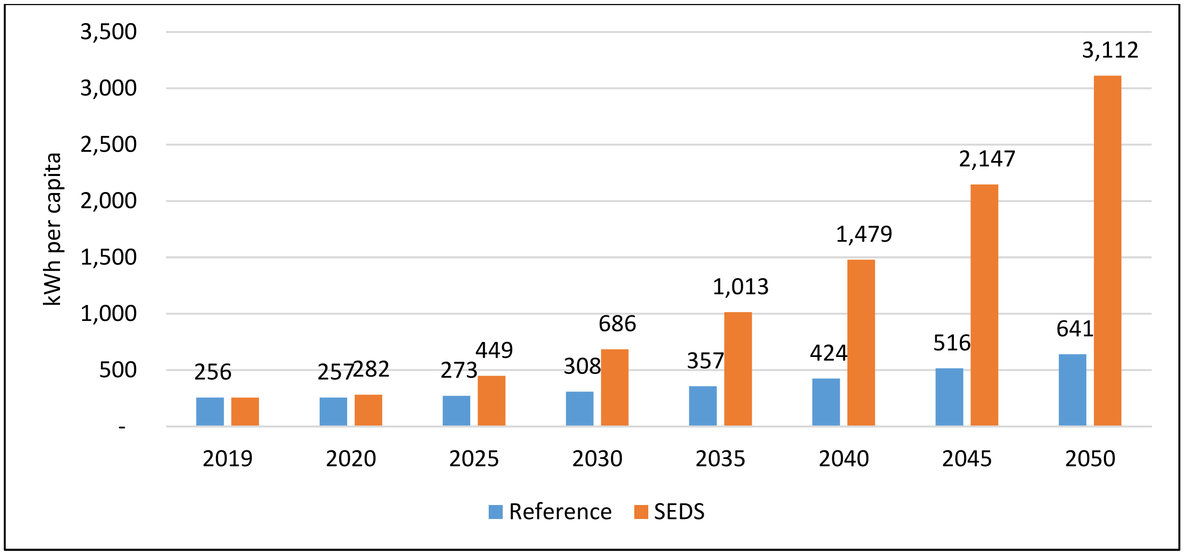


Figure 8. Electricity Demand Per Capita in Province 2

Figure 9 shows the impact in GHG emissions dues to policy interventions of clean and renewable energy. Emissions which will growing at the rate of 22% in the Reference Economic Growth Scenario will increase at the rate of only 1% resulting in the GHG emission reduction of 25% in year 2030 and up to 69% in year 2050. This reduction in GHG emissions is not only beneficial for climatic reasons, but also for (a) health perspective – since use of carbon-based fuels emit other local pollutants that directly affect health of local population and users, and (b) economic co-benefits - by monetizing the emission reduction by carbon trading.

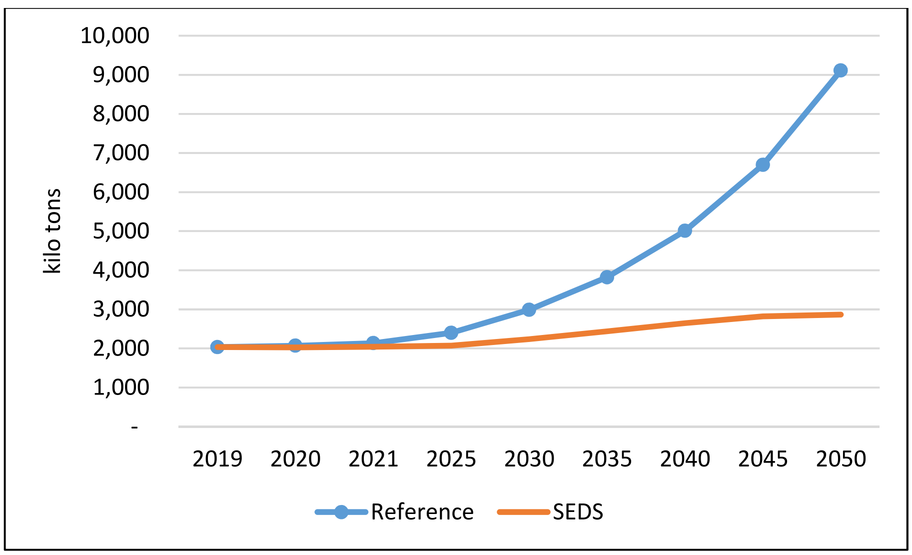


Figure 9. GHG Emission in Province 2

To meet large share of the energy requirements in the SEDS and achieve the goals described above paragraphs, the development of hydropower plant is essential. With respect to reference case, the hydro power plant installed capacity in policy scenario in 2030 and 2050 would be 2.4 times and 5 times respectively than those in the Reference Economic Growth (REF) Scenario as shown in Figure 10.

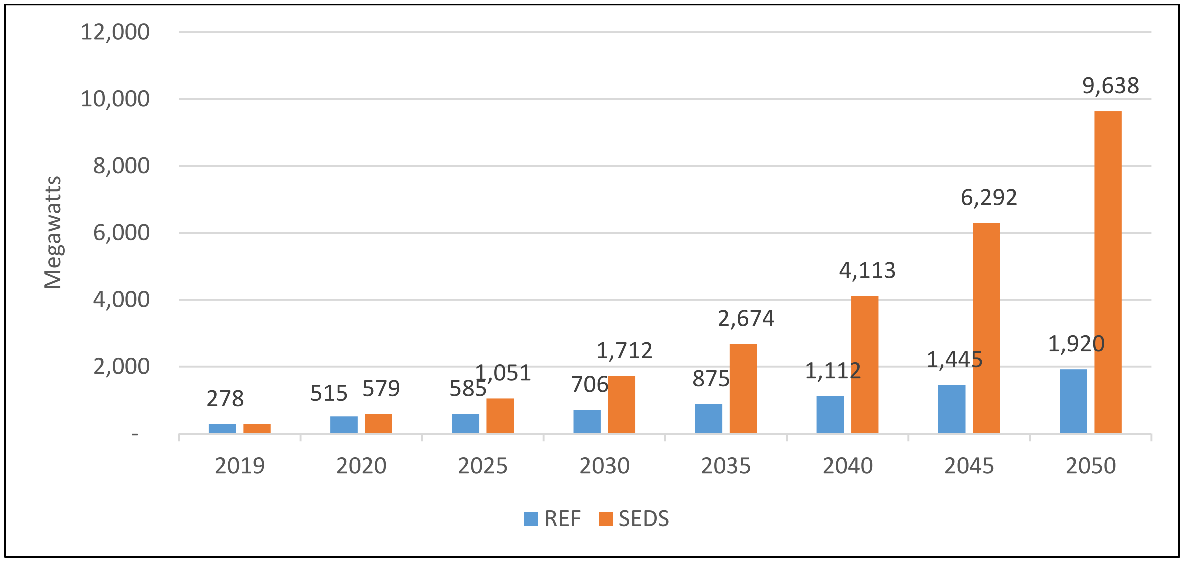


Figure 10. Power Plant Requirement in Province 2

In the REF scenario, the gross investment share in supply technologies is around 4 % of GDP on average. In the SED scenario, new and efficient technology interventions are done. To achieve the sustainable developments goals, the capital investment should increase form current 3.5% of GDP to 8.5% by 2030 and 12.6% by 2050 respectively. The high investment in the SED scenario is mainly due to the investments required in developing hydropower and other renewable energy plants to meet the growing electricity demand because of electrification in all major end uses in all economic sectors (Table 12).

In case of the Province 2, which have extremely limited resources and feasibility for development of hydropower plants, the province basically needs to bring in the electricity from other provinces. Thus, the capital investment as given in Table 12, is not the actual investments needed to be put upon by the province 2 itself and the province does not need to bear all the capital costs of the hydropower development. However, the grid capacity development has to be done within the province for improvement to meet larger electricity demand. In addition to this, the province can build up solar power plants within the region for daytime supply at peak solar insolation hours of the day, but still needs to reply on national grid for major part of power supply. In the SED Scenario, it is planned that 320 MW and 800 MW will be developed in 2030 and 2050 respectively.

Table 12. Total Technology Cost for Different Scenarios

	2020	2025	2030	2035	2040	2045	2050
REF	12.91	23.13	35.46	48.37	63.18	82.11	108.66
Capital Investment as % of GDP	3.12%	4.61%	5.26%	5.23%	4.89%	4.51%	4.20%
SEDS	14.65	31.76	57.30	91.25	139.76	212.39	325.02
Capital Investment as % of GDP	3.54%	6.32%	8.49%	9.86%	10.82%	11.67%	12.56%

The high capital costs required in electricity production in years 2030 onwards are huge and looks beyond its capacity for the Provincial Government. As development of large hydropower plants are under the purview of the Federal Government, the capital investments for electricity production will be within the range of 6% of the GDP as envisaged by a policy research working paper of the World Bank (WB, 2015) in the South Asia Region

It is seen that the saving in fuel imports is substantial under the SEDS scenario counting over 19 billion NRs in 2030 and 289 billion NRs in 2050 respectively from that of the REF scenario. All the cost incurred are at constant price of 2018. This cost benefits can be invested in development of the electricity generation and distribution system for quality supply of the energy. Comparing the savings to the investment required for power plant development, the savings can account for more than 30% investment required in 2030 for clean power plant development, while in 2050 the saving can contribute nearly 90% of the investment required. This indicates significant reduction in dependency on imported fuels. Policy intervention in promoting modern and efficient indigenous energy sources will hence improve energy security of the nation. These highlights need of proper energy policy in the future. Furthermore, detailed analysis for the strategic actions plans for investment from cost savings needs to be carried out for proper implementation and achievement of the clean and energy efficient targets.

In addition to savings from imports of fuel and the value addition to national economy by trading of electricity produces within the nation's boundary, additional economic benefits can also be caught. The significant abatement of GHG emissions in the SEDS compared to the REF scenario can be traded. At the current international carbon pricing of $10, the benefits from carbon trading will be NR 3 billion and NR 36 billion in 2030 and 2050 respectively.

In the decade from 2020-2030, incremental supply costs are higher than the savings from fuel imports and carbon trading if the Province 2 makes investments in hydropower development in other Provinces. Otherwise, if it purchases electricity from the national grid for meeting its demands and it does not have to invest in the other power development apart from the solar power plants, there are benefits higher than the investment costs in the Province 2 even in the decade 2020-2030. After 2040, there are huge benefits of NR 157 billion and NR 289 billion in 2045 and 2050, respectively. Overall, if the Province takes a pathway of sustainable energy development, Province 2 will be hugely benefited in the long run.

Conclusion and the Policy Implications

In year 2018/2019, it is seen that the total final energy consumption of the Province 2 was 63,200 TJ which accounts for 10.4 GJ per capita. The residential sector is still the most energy consuming sector. However, different from the previous national average, the share of residential sector is about 62% while that of industrial sector consumption is 23% and commercial 3%. This is primarily because Province 2 is an economic hub for industry and trade. Thus, it is obvious that the consumption for economic sectors would be higher. As for energy consumption by fuel types, the used of biomass is still prevalent at above 50%. Yet, there is also difference in energy mix as per to national mix due to reasons like – the region having high potential for forest and agricultural resources, the access to modern energy is easier and the region being industrially and commercially active. Therefore, there is higher usage of commercial energy sources such as fossil fuels and electricity. In residential sector there is seemingly transition from traditional to modern fuels while the agricultural sector has taken a leap forward towards the renewable energy by intervention of solar water pumps. Commercial sector is a huge electricity user with highest chances of intervention of solar PV system while industry is a largest consumption sector for electricity which would require dedicated large hydropower capacities.

Similarly, in the Reference Economic Growth Scenario, the total final energy demand attains 83,000 TJ in 2030 and it reaches to 189,000 TJ in 2050. In the context of High Economic Growth case, the final energy demand is expected to reach 83,000 TJ and reaching 205,000 TJ in 2050. If the current trend of fossil fuels continues in the long run, they may surpass the demand for solid biomass in 2050.

In the SEDS, the final energy is projected to be 71,000 TJ in 2030 and 144,000 TJ in 2050 respectively. In the SEDS, demands for other energy carriers will be flattened or will be decreasing whereas electricity generated by renewable energy 24% of the total energy demand in 2030 and it will reach 72% in 2050 respectively. The power plant requirements reach 1,699 MW in 2030 and will be attaining 9,649 MW in 2050. In the SEDS, per capita electricity demand will reach 3,100 kWh in 2050 and the electricity demand per household reaches 2,500 kWh which is near to the tier 5- electricity consumption of household as per the World Bank/EMAP. The electricity demand in the industrial sector is expected to be remarkably high.

Comparative analysis of the SEDS with the Reference Scenario shows that energy demand is reduced by 15% in 2030 and the reduction reaches 24% in 2050. In the SEDS, net fuel import ratio comes down to 24% compared to the

Reference case of 56% in 2050 which no doubt indicates positive impact in the balance of payment condition and enhances energy security in the Province 2 and in the country. GHG emissions are reduced by 25% in 2030 – a reduction 750 ktons of CO2 equivalent from the Reference Scenario. The reduction attains 69% in 2050 compared to the Reference case value of 9,100 ktons of CO2 equivalent. Furthermore, energy intensity in the SEDS improves to 635 GJ/NRS millions of GDP in 2050, which is 65% less than in the base year value of 1,791 GJ/NRS million GDP.

Overall, the energy consumption analysis in the base year 2019 and the policy measures taken in the SEDS indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development. This study also indicates that with the core focus on energy security, reliability, and sustainability, energy development both in the Province 2 and in Nepal should be geared towards 5 development aspects – (a) Sustainable Energy Development Policy, (b) Hydropower/renewable Energy Development, (c) Infrastructure Development, (d) Creation of Domestic Power Demand and Exploration of Power Markets in the South Asia, and (e) Reduction in Demands for Fossil Fuels.

Table of Contents

List of tables

List of figures

Abbreviations

AEPC	Alternative Energy Promotion Center
ATF	Aviation Turbine Fuel
CBS	Central Bureau of Statistics
CF	Community Forests
CO2	Carbon Dioxide
CPI	Consumer Price Index
cu m	cubic meter
EIA	Environmental Impact Assessment
ESMAP	Energy Sector Management Assistance Program
FY	fiscal year
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GPS	Global Positioning System
GTF	Global Tracking Framework
GVA	Gross value added
GW	Gigawatt
GWh	Gigawatt-hour
ha	hectare
HECS	Household Energy Consumption Survey
HH	Households
HSD	High Speed Diesel
ICS	Improved Cooking Stove
IEA	International Energy Agency
IEE	Initial Environmental Examination
ISPS	Institutional Solar PV System
Kg	Kilogram
kW	kilowatt
kWh	kilowatt-hour
kWp	kilowatt peak
LCEDS	Low Carbon Economic Development Strategies
LPG	Liquefied Petroleum Gas
m	meter
MICS	Metallic Improved Cooking Stove
MJ	mega joule
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MoF	Ministry of Finance
MoPE	Ministry of Population and Environment
MoPIT	Ministry of Physical Infrastructure and Transport
MS	Motor Spirit (petrol)
MT	Metric Ton
MTF	Multi-Tier Framework
Mtoe	Million tons of oil equivalent
MW	Megawatt

MWp	Megawatt peak
NEA	Nepal Electricity Authority
NGO	Non-Governmental Organizations
NOC	Nepal Oil Corporation
NPC	National Planning Commission
NRB	Nepal Rastra Bank
NREP	National Rural Energy Programme
NRs	Nepalese Rupees
NSIC	Nepal Standard Industrial Classification
PJ	Peta Joule
PV	Photo Voltaic
RCC	Reinforced Cement Concrete
RE	Renewable Energy
RET	Renewable Energy Technology
Rs	Rupees
SASEC	South Asia Sub Regional Economic Cooperation
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy for all
SEDS	Sustainable Energy Development Scenario
SHS	Solar Home System
SKO	Superior Kerosene Oil
SPSS	Statistical Package for the Social Sciences (software)
SPVPS	Solar Photovoltaic Pumping System
SSHS	Small Solar Home System
TJ	Terajoule
Toe	Tons of oil equivalent
ToF	Trees outside forest
TOR	Terms of reference
USD	US dollar
WECS	Water and Energy Commission Secretariat
Wp	Watt peak
WWF	World Wildlife Fund

1 Introduction

1.1 Background

Energy consumption, specifically electricity consumption per capita, is one of the significant indicators of the development status of the country. It indicates the current situation of economic activities as well as how well a country is progressing towards development. Data and information regarding energy can provide crucial insights for developing provincial targets and integrating them to reach the national target. Thus, a well-organized energy database is a basis for policy formulation and sustainable energy planning.

Water and Energy Commission Secretariat (WECS) has been the national government authority to collect, compiles, and publish energy database. The institution has been collecting national, regional, and sector-wise energy data ever since its initiation. WECS completed Sectorial Energy Supply/Demand Profiles at the regional level and Residential Energy Supply/Demand Profiles at the district level during 1990-1995. Such regional and district level sectoral energy supply-demand profiles were updated and compiled in 1995/96 at the national level. Industrial Sector Energy Consumption Survey was completed in 1997/98 covering both traditional and modern energy sub-sectors.

Furthermore, WECS conducted the Commercial Sector Energy Consumption Survey in 1998/99 and Transport Sector Energy Consumption in the year 1999/2000. Agricultural Sector Energy consumption survey was also completed in 2000/01. Based on these primary surveys of energy demand-supply situation, WECS published Energy Sector synopsis report regularly. Energy Consumption and Supply Situation of Nepal, 2011/12 was the latest survey carried out by WECS.

1.2 Global Outlook

It seems that there is a mismatch between what has been promised as Energy to all with the fact that about 1 billion people are deprived of access to electricity. Similarly, the gap between the latest scientific evidence highlighting the need for evermore rapid cuts in global greenhouse gas emissions and the data showing that energy-related emissions is very high in 2018. People are still rigid regarding dependence on fossil fuels that create a huge gap between expectations of fast, renewables-driven energy transition and the reality of today's energy systems (IEA, 2019).

As per the International Energy Agency's (IEA) findings, there has been increase in global energy demand by 2.3%, the quickest in a decade that causes 1.7% of growth in energy-related CO_2 emissions in 2018. It appears that the rates of improvement are lower than required to meet the objectives of the Paris Agreement on climate change in matters of the increment of share of renewable energy sources in meeting new energy demand and energy efficiency(IEA, 2018).

World Energy Outlook emphasizes that energy is of paramount importance to human society and economic activity(IEA, 2018). Providing modern energy services is a necessity for eradicating poverty and reducing the divide between rich and poor. Energy features have prominence in the United Nations Sustainable Development Goals (SDGs), agreed by almost 200 nations in 2015. Nepal, in its roadmap for achieving SDGs by 2030 (NPC, 2016), envisions a middle-income country by 2030. To reach this kind of status, Nepal needs an enormous consumption of energy resources based on renewable energy and energy efficiency for sustainable energy development and energy security in the country.

The updated assessment by International Energy Agency reports that there would be expected fall of global energy demand by 5% in 2020 due to global pandemic (IEA, 2020). In addition to that, it is expected that there will be reduction of 7% in energy related CO2 emissions and 18% in energy investment. Oil consumption is anticipated to decline by 8% in 2020 and coal use by 7%. Renewables, especially those in the power sector, are less affected than other fuels by the pandemic and its aftermath. With aid of massive investment in new, more efficient, and cleaner capital stock, the structural transformation in energy sector would be possible. The world energy outlook 2020 also have included the well signified Net Zero Emission by 2050 scenario in this its latest analysis. Achieving this goal would involve a significant further acceleration in the deployment of clean energy technologies together with wide ranging behavioral changes.

A recent report by World Wildlife Fund (WWF) in 2019(Lambrides, 2019) shows that nations need to focus their attention on low- carbon, low -cost and low- impact energy. Thus, developing nations must discourage usage of fossils fuels and concentrate on renewable energy and energy efficiency for meeting its rising energy demand. But unfortunately, Nepal is becoming too much dependent on imported fossil fuels - imports of petroleum products against commodity exports of Nepal have jumped from 24% in 2004 to above 200% in 2019(MoF, 2018/19). Hence, for the development of a "Prosperous Nepal," it has become essential to have proper and dynamic energy planning of the whole energy systems in place at the local and provincial levels which need to be later integrated to the national energy systems planning for sustainable energy development and energy security in the country.

World trilemma index – which indicates the overall energy development situation of a country. It aims at helping 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. In 2020, the overall scores top ten ranks remain dominated by OECD countries, which illustrates the benefit of longstanding active energy policies. The path followed by the greatest improvers since 2000 have denoted the importance of diversifying energy systems and increasing access. The top three countries improving their overall Trilemma performance are Cambodia, Myanmar, and Kenya. These countries have low overall ranks but have made significant and sustained efforts to improve their energy systems. Meanwhile, Nepal ranks 7th amongst top improvers with 425% score improvement. Yet Nepal stands at 102nd rank among 108 and with the least rankers among the Asian countries with trailing trend towards the bottom of the index (WEC, 2020).

Within the SAARC region, Afghanistan and Pakistan seems to have stuck in poorest conditions as for energy development. With only 35% of the country electrified, Afghanistan has high consumption of biomass as well as dependent on kerosene, candles for lighting. Meanwhile Pakistan is stuck with circular debt in the power sector, poor financial position of energy companies, high fossil fuel imports and decline in domestic gas production. With increase in industrial and commercial growth, the imports can be expected to grow further in coming years. In terms of energy development, India seems to be far ahead. Going forward, usage of renewable energy is expected to improve strongly on the back of conducive government policies and higher private sector participation. Nepal is also dependent on imported fuels, yet highly dependent on biomass. However, with growth in residential as well as commercial and industrial consumption, the energy demand for commercial form of energy can be expected to grow further (SAARC Energy Centre, 2018).

Meanwhile, in the current situation of pandemic still in existence, rises the uncertainties. The two issues are naturally linked; success in bringing the pandemic under control would facilitate a recovery in economic activity, while prolonged outbreaks of Covid-19 would weigh heavily on the prospects for growth. However, it is expected that energy demand rebounds quite rapidly in those parts of the world that had early success in bringing the pandemic under control, returns to growth during2020, while the negative impacts may persist for longer in many lower income countries(IEA, 2020).

1.3 National Energy Scenario

The overall energy consumption of Nepal is largely dominated by usage of non-commercial forms of energy, such as fuelwood, agricultural residue, and animal waste. Economic survey 2015/16 indicates that the total energy consumption increased to 11 million tons of oil equivalent (Mtoe) in 2015/2016 (MOF 2016) with an annual growth rate of 3%. WECS completed the National Survey of Energy Consumption and Supply situation of Nepal in the year 2011/12 to determine energy consumption patterns 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. According to the survey, residential sector accounts for the significant share of energy consumption (80.4%) followed by industrial (7.9%), transport (7.1%), commercial (3.4%) and agriculture (1.2%) in 2011/12.

The primary source of energy in the residential sector is fuelwood, agriculture residue, animal waste, biogas, and other biomass energy resources. Electricity by hydropower and solar energy substitute traditional energy in urban residential area, mainly for cooking and lighting. The industrial sector consumes coal, fuelwood, diesel, and electricity as major sources of energy with a 63% share of non-renewable energy consumption. Transport sector consumes 99% of gasoline and 87% of diesel imported in the country (Malla 2014). Diesel, petrol, and Aviation Turbine Fuel (ATF) are major fuel sources in the transport sector with minimal contribution from electricity. The National Survey of Energy Consumption and Supply Situation in Nepal, 2013 shows fuelwood, LPG, coal, and grid electricity as major energy sources in the commercial sector with 34% share of non-renewable energy consumption. Agriculture sector mainly uses fuel for water pumping and farm machinery that consume diesel as major fuel source.

The total energy consumption of Nepal stands at 586 PJ in 2019, which was 400 PJ in 2009, with an annual average growth rate of 4% (WECS, 2010; MoF, 2020). The traditional energy consumption decreased from 82% in 2009 to 69% in 2019. Meanwhile, there is an improvement of commercial energy consumption from 12% in 2009 to 29% in 2019, growing at the rate of 13% per annum. The renewable energy consumption increased at the rate of 17% per annum, constituting 2% share of total energy in 2019. In 2009, electricity consumption was 2% of total energy consumed in the country, which has improved to 4% by 2019 with the annual average growth rate of 10%.

1.4 Energy Policies in National Context

Energy policy of Nepal has a clear policy of maximizing hydropower utilization to meet domestic demand for electricity and to accelerate the renewable energy service in the country. To provide access to energy and energy efficient technologies, various subsidy mechanisms are in effect. National Rural Energy Programme (NREP) provided a framework for the implementation in local communities across the country. 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.

The UN's Sustainable Development Goals (SDG7) and Sustainable Energy for all (SE4ALL) program target to achieve universal access to affordable, reliable, and modern energy services, doubling the global rate of improvement in energy efficiency and increasing the share of renewable energy in the global energy mix by 2030 (UNDP, 2012; NPC, 2018). Currently, 75% of households (HHs) use solid fuels as a primary source of energy for cooking and 18% use LPG. The access to electricity extends to 78% of HHs(NEA, 2019). In 2019, Energy Sector Management Assistance Program (ESMAP) of World Bank group reported that 72% of households have electricity from the national grid, whereas 23% are connected to off -grid sources. However, the actual supply of reliable and resilient electricity is inadequate. Rural areas have access to 10% of off-grid electricity that is used mainly for lighting and for small electrical appliances. There is still above 12% of the population without electrification in Nepal (Adhikari, 2019; NEA, 2019). Solar home system is taking its strong foothold in Nepal with the reduction of its global price per unit as well as readily available technology. However, the scope of solar energy is still limited to lighting. SDG7 targets 99% HHs access to electricity, shifting the use of fuelwoods, and limiting the use of LPG by 2030 (NPC, 2016). To elevate the current energy status of the country to that of developing countries, the first requirement is to develop a rigid and updated database of the energy demand, the supply, and resources potential. Based on those, appropriate energy plans are to be formulated to achieve sustainable development.

Development of energy vision 2050 encompassed development of different energy development scenarios based on the main energy drivers (a) economic growth rate of the country (GDP growth rates), and (b) demographic growth rate. For three GDP growth rates namely, low economic growth scenario, medium economic growth scenario and high economic growth scenario, scenarios were developed. It is necessary to observe these scenarios without any technology and new policy intervention. Based on the UN's Sustainable energy for all (SE4ALL) program and the aspirations as expressed by the participants in the stakeholders' workshops at different regional development centers, there was a need of scenario analysis being conducted for medium economic growth scenario with the technological policy intervention(WECS, 2013).

In order to address the specifics of energy-access needs outlined in the Sustainable Development Goals (SDGs) of the United Nations, there has been an origin of Multi-Tier Framework (MTF). Its main function is to check a variety of energy-service issues and solutions that include but go beyond access alone. For example, under the role of MTF, in addition to considering the viability of decentralized off grid solutions (such as mini-grid and solar home systems), it considers on-grid solutions also as the main sources of electricity.

Global Tracking Framework (GTF) has been brought to existence by The Energy Sector Management Assistance Program (ESMAP) in the World Bank, in consultation with multiple development partners. Its main role is to measure and monitor energy access using the MTF in terms of attributes and tiers. Energy access has been defined as one that is “adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive enterprises, and community institutions” by the MTF. Nepal is one of the 17 countries enlisted under detailed data collection activities of ESMAP that aims to find out access via the MTF as part of the stock-taking exercise. A small country of 29million people in South Asia, Nepal has always been committed to achieving the Sustainable Development Goal on Energy Access (SDG 7.1)(World Bank/ESMAP, 2019).

2 The Status Quo

2.1 Energy Consumption and Supply Situation of Nepal

Biomass is the primary source of energy, particularly in rural Nepal. Firewood from forest and tree resources, charcoal mainly from firewood biomass, residues from different crops and animal dung are the primary biomass-based energy resources. Coal, petroleum products, and electricity are the commercial sources of energy that are utilized in Nepal. The overall energy consumption of Nepal is mostly dominated using non-commercial forms of energy, such as firewood, agricultural residue, and animal waste. However, the country spends a considerable amount of its foreign exchange reserves for the import of petroleum products. According to economic survey 2015/16, total energy consumption increased from 373 PJ in 2006/07 to 494 PJ in 2015/2016 at an annual growth rate of 3%. The most recent economic survey reported that the total energy consumption in 2018/19 was 586 PJ and had reached 390 PJ by second trimester of 2019/20 (MoF, 2020).Traditional energy sources met about 69% of total energy consumption, commercial energy about 29%, and the rest by renewable energy sources. Approximately 80% of total energy is consumed in the residential sector followed by industrial (8%), transport (7%), commercial (3%) and agriculture (1%) in 2012 in Nepal (WECS 2013). The share of commercial energy has increased from about 12% in 2006/07 to about 20% in 2015/16 at an annual growth rate of 9%.

Similarly, there is a growing trend in renewable energy consumption. The share of renewable energy increases from 0.6% in 2007 to 2.5% in 2016.Commercial fuels such as petroleum products, coal, and electricity comprise 16% of total energy consumption in 2017 (CBS 2019).Approximately 64% of commercial energy comes from petroleum products, followed by coal 20% and the rest of the electricity (15%) in 2017. Commercial fuel consumption is increasing at the rate of 8% per annum and whereas electricity demand is at the rate of 12% per annum. Traditional fuel consumption is increasing at an annual rate of 2%. It depicts the shift in fuel consumption pattern from traditional to commercial and renewable energy sources over time.

In the context of Nepal, Firewood has been a major source of fuel for cooking as more than half (52.4 %) are using it as main fuel source. By quantile groups firewood is highly used for cooking by first, second and third quantile whose dependency proportion is 67.2 %, 71.7 % and 69.3 % respectively. Firewood is used by 65.8 % rural and 35.4 % urban households. Use of LPG gas is the second most used cooking source in Nepal (33.1 %). In urban 54.1 % and in rural 16.5 % households are using LPG gas. It is also found that 8.5 % use cow dung, 2.7 % leaves, 3.1 % biogas, and 0.2 % other source for cooking (CBS, 2016/17).

Electricity has become the prime source of lighting for Nepalese households as 85.2 % of the households reported electricity as the main source of lighting. The percentage of households using electricity as main source of lighting are 91.3 % in urban and 80.4 % in rural. Solar energy is also gaining some popularity as in 2015/16 only 13.4 % were using it which is now used by 9.6 %. However, solar power is observed more popular in lower quintiles and rural households which should be due to the governmental subsidies to this cohort. Solar is used by 13.1 % rural and 5.2 %urban and is used by 13.1 % of the poorest quintile. Kerosene and other lightening sources are still used by about 3.3 % household mostly of the poorest quintiles and of the rural. It has been observed that the use of Kerosene is more than 11.2 % poorest quintile households. Similarly, Biogas is used by 0.1 % and other sources by 1.8 % household for lightening(CBS, 2016/17).

Nepal has abundant hydropower resources and switching to electricity in energy access is a better option from the point of economic efficiency, energy efficiency, sustainability, and energy security. Nepal Electricity Authority (NEA) is responsible for developing, operating, and distributing hydropower in Nepal. Currently, there is a demand for 1,444 MW of electricity in the country, and the 65% of it is supplied by from domestic generation, and the remaining 35% is imported to fulfil the demand (NEA 2019). By mid-March of FY 2018/19, 30.6 MW electricity generated by micro and small scale hydroelectricity projects, and 26.5 MW of renewable energy generated by solar and wind power have been utilized as an alternative energy (MoF, 2019).

The trends for primary supply of petroleum products in Nepal areas shown in Figure 2.1, along with its different product consumptions. The figure highlights the sharp increase in the consumption of petroleum from the year 2008/09 onward. The consumption rate was increasing at the rate of 17% and 18% for petrol and diesel respectively per annum over the last decade. The drop in 2015/16 was due to blockade in Nepal that also affected fuel imports. However, the imports soared exceptionally since 2016. The high consumption of diesel was due to the increasing use of diesel to produce electricity from captive genets for over the years. However, the significant increase in diesel consumption in last two years was attributed to import of many vehicles, the high fuel consumption of freight vehicles, construction equipment and machinery, high diesel consumption in industries, and infrastructural development.

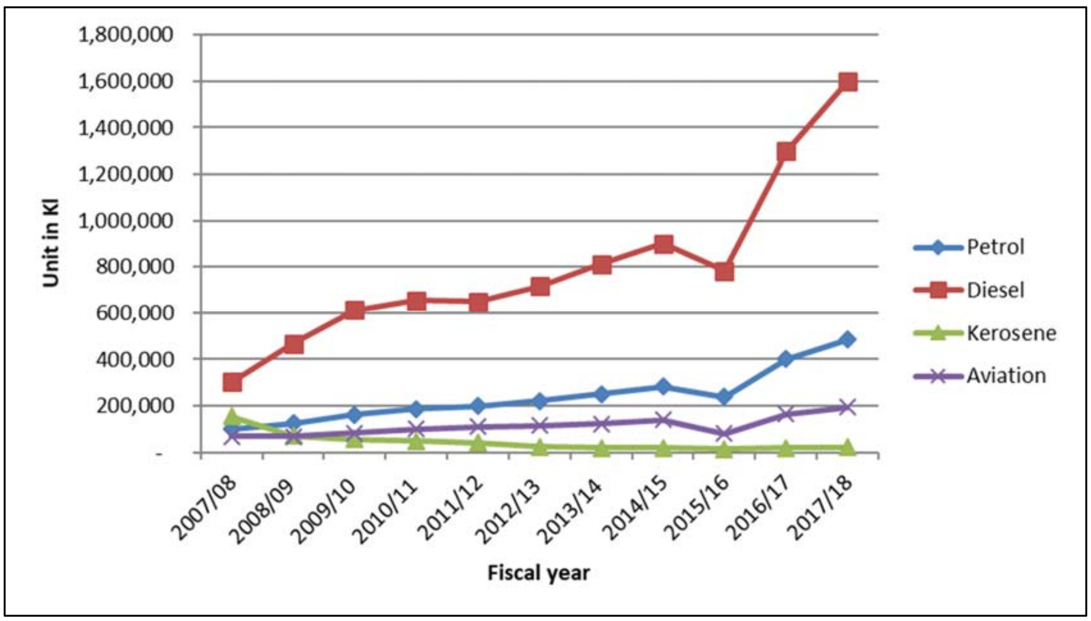


Figure 2.1: Primary Supply of Petroleum Products (Nepal oil corporation)

NEA(2019) showed that 6,350 GWh of electric energy was sold in FY 2018/19, There has been a gradual increase in the number of electricity consumers of NEA. Data suggest that during the year 2018/19, an increase of 9.38 % from 3.57 million to 3.91 million in total number of consumers has been observed. As usual, with 3.66 million consumers, the domestic consumer category topped the chart the largest category with over 90% share of the entire electricity consumers. The contribution to the gross electricity sales revenue was found to be 38% of domestic consumer category and 40% of Industrial consumer category. Remaining percentage of the gross sales revenue was collected from the rest of the other consumer category.

Figure 2.2 gives the picture of province wise electrification in Nepal. Bagmati Province (Province 3) has the highest electrification rate of 90% of the total population, whereas Karnali province has the lowest with 27%. Province 2 has around 80% of its population electrified (NEA, 2019).

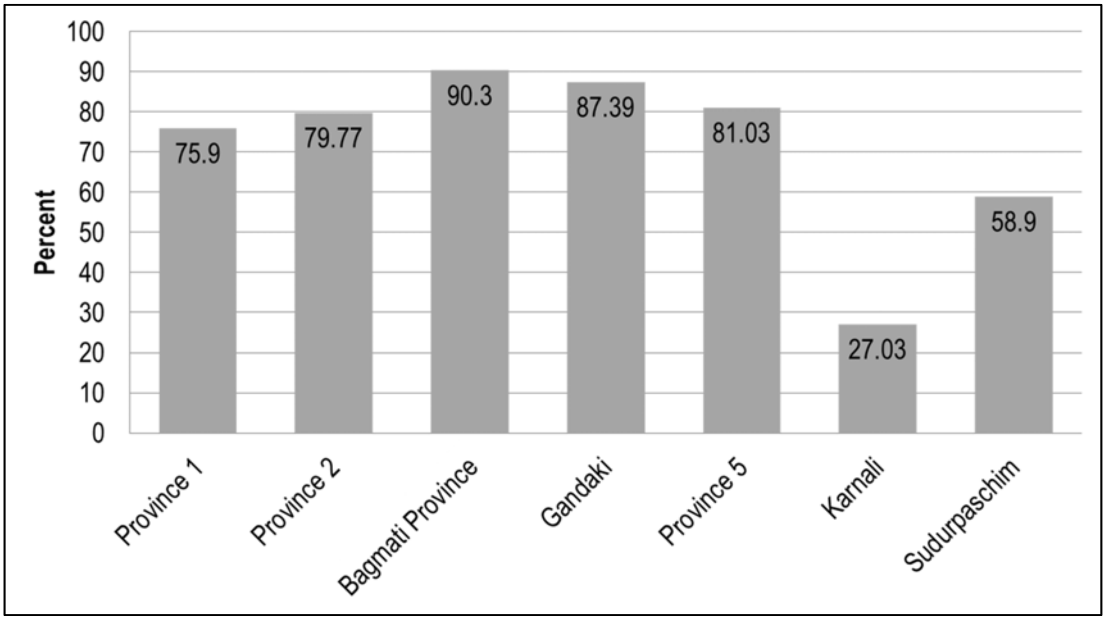


Figure 2.2: Province Wise Electrification by Households(NEA, 2019)

There is a huge potential for solar energy resources in Nepal. The estimated commercial potential of solar energy is 2,100 MW(UNEP/GEF, 2008). The use of solar energy is growing lately. It is mostly used for lighting, pumping, and water heating. The small solar home system, institutional solar home system, and photovoltaic pumping system are used both in an urban and rural area to harness solar energy in Nepal. The total installed capacity of solar energy is estimated to be 36.7 MW (AEPC 2018). Another source of renewable energy in Nepal is wind. There is an estimated potential of 448 MW of wind power in Nepal(UNEP/GEF, 2008; AEPC, 2018). However, only 160 kW of wind power has been harnessed so far in Nepal. As per data from AEPC (2018) and CBS (2019), total mud type ICS reached to 1.281 million units, and metallic type is 153,517 units. In the meantime, 281 units of IICS have been installed in different parts of the country.

2.1.1 Province 2

Province 2 is spread along the south-eastern part of Nepal. It stretches east to west comprising eight districts of Terai regions and covers an area of 9,661 km^2. The province encompasses a total of 1 metropolitan city, three sub-metropolitans, 73 municipalities, and 59 rural municipalities. With a population of 5.4 million as per the 2011 Census of Nepal, it was the most densely populated province of Nepal. The location and administrative boundaries of province 2 are, as shown in Figure 2.3.

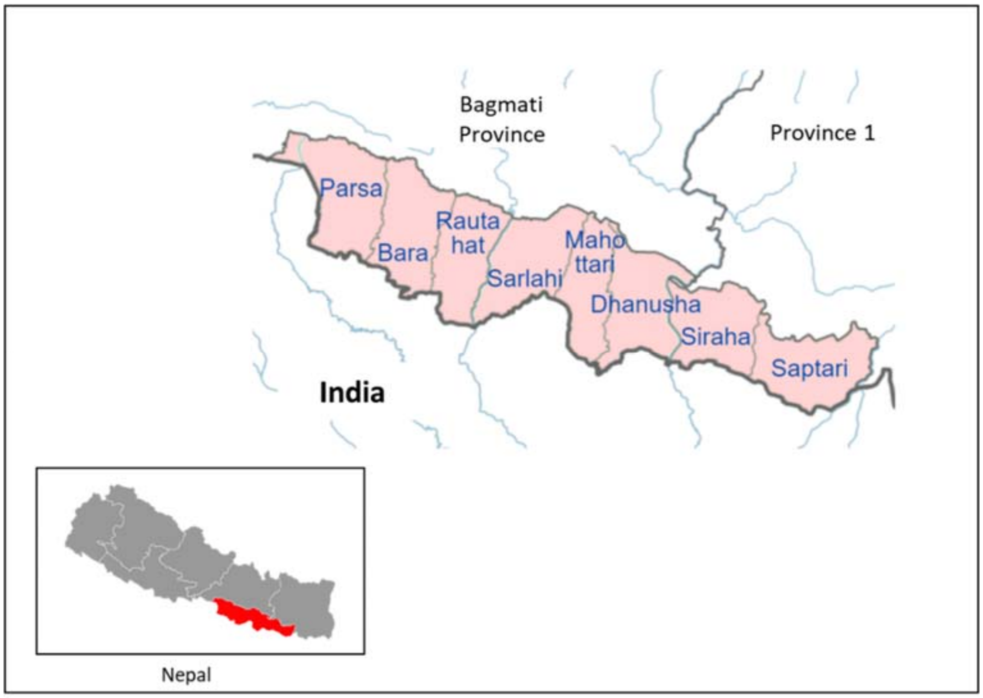


Figure 2.3:Province 2 –Location and Administrative Boundaries

Trade, industries, and agriculture dominate economic activity in province 2. In terms of GDP, this province comes at the 3rd place with a share of 16.2% in the national GDP. However, due to the high population and other socio-economic characteristics, the province still lags in development. The energy demand of the province also shows that the residential sector uses a huge quantity of traditional fuel resources. The primary consumers of commercial energy are industries and commercial sectors. The transport activity is also predominantly high due to access to road networks and being the main corridor for international trade. In terms of energy potential, traditional resources are abundant, but in a degrading pattern. Due to lower altitude differences, there is no significant potential for hydro energy, yet there are still chances for solar energy generation.

According to National Economic census, among the registered institutions in province 2, more than 85% are commercial institutions, around 11% are industries, 1% of institutions involved in agriculture while construction and mining account for less than 1%(CBS, 2019). Meanwhile, in economic terms, the largest share of GDP is from the commercial sector (47.5%) followed by agriculture (40%), construction and mining (6.4%) and industry (7.8%) in 2019(CBS, 2019).

2.2 Review Related to Plans, Policies, Regulations, and Guidelines Related to Energy

2.2.1 Policy and Strategy Overview

2.2.1.1 Energy Policy

Energy policy of Nepal has a clear policy of maximizing hydropower utilization to meet domestic demand for electricity and to accelerate the renewable energy service in the country. To provide access to energy and energy efficient technologies, various subsidy mechanisms are in effect. National Rural Energy Programme (NREP) provided a framework for the implementation in local communities across the country. 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.

2.2.1.2 Ministry of Energy, Water Resources, and Irrigation (MoEWRI) White Paper 2075

Ministry of Energy, Water Resources, and Irrigation (MoEWRI) had released white paper 2075 in July 2018 with the objectives to elevate hydropower and renewable energy generation in the coming decade to take the country towards the path of sustainable development. It has set the target to improve per capita electricity consumption from current 700kWh to 1,500 kWh in the coming ten years. It requires the penetration of electricity in all the sectors, including electrification in residential, commercial, transport, industry, and agriculture. It plans to generate 3,000 MW of hydropower by 2021 and upgrade the generation capacity by 5,000 MW in the coming five years and by 15,000 MW in 10 years. It also envisages that domestic demand will increase to 10,000 MW in the coming ten years. Government plans to generate 200 MW of solar power from province 2, where the hydropower potential is minimal. The white paper focuses on optimum generation and utilization of clean energy resources, including efficiency improvement in the country.

2.2.1.3 Low Carbon Economic Development Strategy

Ministry of Population and Environment (MOPE) has prepared a Low Carbon Economic Development Strategy (LCEDS), with the vision of the strategy for enabling Nepal to become a developing nation through low carbon green economic development. It promotes the use of renewable energy in all economic sectors with the approach to reduce national GHG emissions. The strategy provides a framework for achieving sustainable development, prioritizing the sector-specific implementation plans for low GHG emission. The strategic sectors included in the report are energy, agriculture and livestock, industry, transportation, and commercial sectors.

2.2.1.4 Environment-Friendly Local Government Framework

The framework aims to initiate sustainable development activities at the local level as households and communities. The framework prioritizes the promotion of renewable and clean energy and efficient energy technology and as well as implementations of rural renewable energy programs to make local governance system environment friendly.

2.2.1.5 Nepal's Intended Nationally Determined Contribution (INDC)

The Government of Nepal - Ministry of Population and Environment has, in February 2016, communicated its INDC to the UNFCCC as a national pledge to contribute its parts to the promotion of renewable energy services across the nation. Most of the mitigations strategies and targets included in the INDC report adheres to the existing policies and plans. One of the key strategies includes the formulation of Low-Carbon Economic Development Strategy (LCEDS) that provides the framework for the promotion of renewable energy across the country in all economic sectors.

2.2.1.6 Nepal: Sustainable Development Goals Status and Roadmaps 2016-2030

The National Planning Commission prepared the status and roadmaps to achieve sustainable development goals by 2030. It envisions Nepal to graduate from the list of Least Developed Countries which requires the rapid economic growth of at least 7% over the decades. It highlights significant issues and challenges along the route to meet SDGs. It emphasizes thee sectors mainly clean energy, agriculture, and tourism for the sustainable prosperity of the nation.

2.2.1.7 Nepal Electricity Regulatory Commission Act 2074

Nepal Electricity Regulator Commission Bill was endorsed in 2017 to form a regulatory body for facilitating electricity production, transmission, distribution, trading, and management transparently. Its other objectives are to balance supply and demand, to set electricity tariff, to develop competition in the electricity market and to protect consumer rights. With the establishment of this regulatory body, the electricity market is expected to develop in a competitive environment where stakeholders' rights are protected, and electricity is made accessible, affordable and acceptable

2.2.1.8 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%.

2.2.1.9 Nepal's 20 Year Renewable Energy Perspective Plan 2000-2020

The renewable energy perspective plan was formulated to accelerate the development of renewable energy to meet Nepal's increasing energy needs. It attempts to quantify the contribution of renewable energy in the overall energy consumption in the country. The installed renewable capacity was 35 MW in 2015, and it targets to increase the installed capacity to 894MW by 2030. The share of renewable energy in total energy consumption was 2% in 2015 and the plan targets to increase the share to 15% by 2030. The contribution of small/micro hydropower was 1.7%, and 0.1% each from wind, solar and biomass in 2015. The 20-year perspective plan targets to increase the share of small/micro hydropower to 9% and each of wind, solar, and biomass to 2% in 2030. The target for domestic biogas plant installation is 1.5 million plants from 0.3 million in 2015. Similarly, the target for improved cook stove is 2 million by 2030 from 0.6 million in 2015. The plan documents the institutional framework, policy & regulatory environment, capacity building, research & development, implementation mechanism, and prioritization of tasks to achieve this objective.

2.2.1.10 National Energy Strategy of Nepal, 2013

The National Energy Strategy of Nepal is a clear and comprehensive policy on the energy strategy developed by the Water and Energy Commission Secretariat (WECS), with inputs from key stakeholders, and has adopted a set of objectives and policy principles that provide the framework for strategy formulation. Also, several mitigating issues related to the energy sector such as; poverty, access to electricity, clean and modern energy access, generating hydropower, conserving the environment and reducing health impact due to indoor air pollution are identified. However, the topmost priority of the strategy is on the development and management of Integrated energy planning in the existing sub-sectoral energy planning process under the guiding principles of socio-economic development and environmental sustainability.

2.2.1.11 National Energy Efficiency Strategy, 2075

Owing to the lack of a separate strategy related to promotion energy efficiency, National Energy Efficiency Strategy, 2075 was formulated with the vision to assist in energy security by increasing the energy access through efficient use of available energy. Its specific target is to double the average improvement rate of energy efficiency in Nepal from 0.84% per year, which existed during the period of 2000 -2015 AD to 1.68% per year in 2030 AD. It aims to do so by massive inclusion of stakeholders – from consumers to policy makers and establish all required frameworks for resources management, resources mobilization, infrastructure development and human resources development required for energy efficiency. Additionally, it also ought to develop national standard regarding energy efficiency as well as develop equipment's and means for measuring energy efficiency.

2.2.1.12 Climate Change Policy (2011, 2019)

The climate change policy formulated in 2011 was revised in 2019 with the objective to reduce GHG emissions by promoting the use of clean energy; enhancing the climate adaptation and resilience capacity of local communities for optimum utilization of natural resources and their efficient management; and adopting a low-carbon development path. It emphasizes on promoting low carbon economic development by encouraging investment on renewable energy and energy efficient technologies (MOFE, 2019).

Other supporting plans, policies, and programs are:

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 hand over any part of National Forest to a user's group in the form of a community forest for developing, managing, and utilization of the forest.
Motor Vehicle and Transport Management Act (1993)	• Legal provision for vehicles to pass the roadworthiness test for registration and operation - the test includes pollution test and age of vehicles. • Provision of penalties for violating the regulations and on the spot check and fine for vehicles that are not roadworthy • Clear roles and responsibilities, and institutional setup of Department and Transport Management Committee • Appointment of transport inspector.
Forest Sector Policy (2000)	• Promotion of community forestry by entrusting forest protection and management to user's groups. • Development and promotion of alternative energy sources and adoption of energy efficient ICS
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)	• Supporting policies and programs that address emission reductions 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 exempt custom duty and tax on non-polluting vehicles • Formation of Road Transport Authority for road transport management • Formation of National Transport Board to coordinate authorities relating to transport, including civil aviation
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 Center
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)	• A legal provision is providing responsibility to the Local Body for solid waste management. • Partnership with the private sector, community and non-governmental organizations, and local body • Instruction 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. • Legal provision to form Solid Waste Management Council • Provision to establish a Solid Waste Management Technical Support Center
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

Key Plans, Policies, programs	Features
	• Ordinance for auditing and reporting of energy intensity of industries • Provision to build the capacity of the Department to monitor and control pollution.
Environment-friendly Vehicle and Transport Policy (2014)	• Promotion, development, and expansion of environment-friendly and electric vehicles and transportation. • Provision to allow conversion of technically feasible motor vehicles into electric vehicles. • Target to achieve more than 20% of vehicle fleets to be environment-friendly vehicles by 2020. • Development of cycle tracks and charging stations for electric vehicles. • Preparation of LCEDS inclusive of environment-friendly vehicles and transport modes • Tax exemption and the provision of loans for private consumers to purchase environment-friendly vehicles • Establishment of separate division or section under the MOPIT, or its departments to oversee the registration, regulation, and monitoring of environment-friendly vehicles
National Urban Development Strategy (2015) National Urban Policy (2012)	• Prioritize compact settlements over scattered areas and integration of land use and transportation planning. • Creation of infrastructure for smart cities • Development of institutional mechanism and coordination capacity to address issues related to urban transport and land use, and • Preparation 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.
Subsidy Policy for Renewable Energy (2015) Urban Solar Energy System Subsidy and Loan Guidelines (2015)	• Explicit subsidies and financial arrangement/guidelines • Provision of net metering policy for urban solar energy. • Provision for tax exemption for importing solar energy systems, net metering equipment, and LED lights
14th three-year plan 2073 - 76	• Establishment of pollution monitoring systems in major urban areas • Revision of the standards for lifespan and emission level for vehicles • Sustainable management of waste • Establishment of waste processing centers in each municipality • Promote and develop clean, renewable energy • Priority for hydropower development including storage power plants, rural electrification, and smart grid and smart metering. • Generation of 2,300 MW hydropower, 11 MW mini, and micro-hydro, 16 MW solar, 1 MW wind • Study and development of railway including metro • Establishment of 7 Vehicle fitness testing center and old vehicle management
15th Plan Approach paper 2076/77-2080/81	• 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 • 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	• Accelerate the transition from subsidy centered model to credit-focused model along with a smart subsidy mechanism • Improve access to renewable energy

2.3 Energy Pathway

From the review of literature on the energy status of Nepal, it is evident that Nepal, as well as provinces need to head towards decreasing dependence on petroleum fuels while utilizing the indigenous renewable energy resources at its maximum potential. Almost all plans and polices related to energy aid the production of renewable energy and sets targets for development in energy sector, mainly in hydropower, solar and clean energy. It is imminent that demand for commercial energy would grow nationally as well as in provinces as well. Therefore, in this context, in accordance with the current policies and targets set by government, the study team will look upon for clean accessible energy for all. The future energy supply plan will be based on current energy consumption as analyzed by the study itself, taking consideration of supply potential of each province first and national potential to supply energy as well as the cost effectiveness.

3 Methodology

This study followed a combination of quantitative and qualitative methods and data are mainly collected from primary and secondary sources.

3.1 Primary Data

Primary data were collected from sample survey of all the economic sectors of Province 2.

a) Residential Sector
b) Industrial Sector
c) Commercial Sector
d) Transport Sector
e) Agricultural Sector and
f) Construction and Mining Sector

3.2 Data Collection Methodology

Population and Households in each province for 2011 are based on census 2011. Population and Households for 2019 are estimated based on population growth rate and household size of each province. In province 2, the population growth rate of 1.75% per annum, and household size of 5.8 is used(MoPE, 2017). The district wise population and households in each province for 2011 and 2019 is as shown in Table 3.1. The projected census population has been used as the population to determine the sample size for the survey.

Table 3.1: District Wise Population and Household Status in Province 2

		2011		2019	
	Districts	Population	Households	Population	Households
Province 2	Bara	687,708	108,635	765,586	131,998
	Parsa	601,017	95,536	669,078	115,358
	Rautahat	686,722	106,668	764,489	131,808
	Sarlahi	769,729	132,844	856,896	147,741
	Mahottari	627,580	111,316	698,649	120,457
	Dhanusa	754,777	138,249	840,250	144,871
	Siraha	769,729	132,844	856,896	147,741
	Saptari	639,284	121,098	711,679	122,703
	Total	5,536,546	947,190	6,163,523	1,062,677

The projected urban and rural population in 2019 in Province 2 is as shown in Table 3.2.

Table 3.2: District Wise Urban and Rural Population in Province 2

	2019	
	Rural	Urban
Bara	258,158	507,428
Dhanusa	161,180	679,070
Mahottari	184,167	514,482
Parsa	274,990	394,088
Rautahat	51,908	712,581
Saptari	266,118	445,561
Sarlahi	268,072	588,824
Siraha	263,816	593,080
Total	1,728,409	4,435,114

3.2.1 Survey Design

The questionnaire survey has been carried out in each province using the survey design, as shown in Figure. It is focused on identifying occupant and building information, device and occupant behaviors, and their energy consumption based on the geographical and ecological division of Province 2. The questionnaire for the survey is attached in the Annex II. The survey is carried out for six economic sectors identified as:

- Residential/Domestic sector
- Industrial Sector
- Transport Sector
- Commercial sector
- Agricultural sector
- Construction and Mining sector

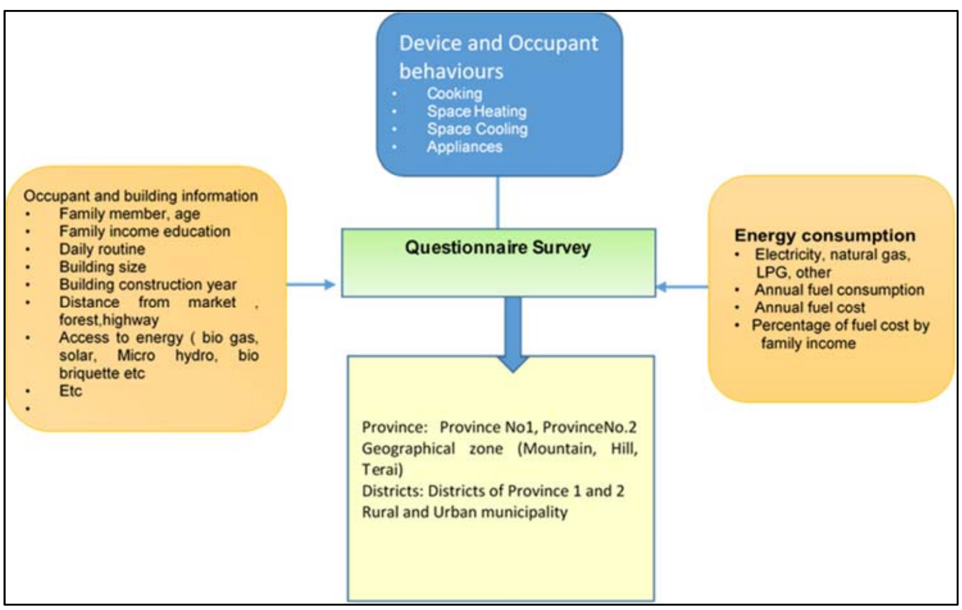


Figure 3.1:Questionnaire Survey Design

3.2.2 Data Collection Method

Six structure questionnaires were prepared for six sectors and these questionnaires were administered in KOBOToolbox. KOBO Toolbox is a set of open-source applications which allow one to create a questionnaire form in the X form format, fill it out on a mobile phone or table turning the Android operating system, store and view the aggregated information on a central server, and retrieve the aggregated data to one's computer for analysis. Data capture includes GPS coordinates for real-time mapping of responses in Google Maps, or near-real time once the surveyor has an Internet connection to send the collected forms back to the server. It is supported by Harvard Humanitarian Initiative, Kweyo, Brigham and women's hospital UNOCHA, UNHCR, UNDP, WFP and many more.

3.3 Sample Size

In this research sample size is calculated using given formula in Equation 3.1

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

Equation 3.1

Where,

p = Probability of success = 0.5

q= 1 - p

z^2 =Z square for the specified confidence level (95%) = 3.841

N = Population size

E = Assumed Marginal error =0.05

n= Required sample size of at least378

3.3.1 Residential/Domestic Sector

This study adopts a combination of quantitative and qualitative research methods. Data has been collected mainly from primary sources (households survey) while some information have also been gathered from the secondary sources (available reports/documents) of National and International report on energy sectors. The dwellings survey methodology is as described below:

- Research Population and Primary Sample Unit (PSU)

The Population of the household energy consumption survey (HECS) consists of dwellings occupied as the primary residence of and province-2 of Nepal. For the sampling frame of (HECS) a number of dwellings of province -2 during census 2011are considered as population size. Primary sample unit (PSU) considers dwellings of province -2. Each district of province 2 considered as subpopulation. And each population was divided into Rural and Urban (Table 3.3). Rural municipality was considered as rural area and Urban, sub-metropolitan, Metropolitan were considered as urban area, from each district 383 samples were collected from rural and urban areas. Within rural and urban areas households were subdivided into building roof type: thatch/straw, Galvanized iron sheet, Tile/ slate, RCC and Wood/plank/mud/others. Detail is shown in Annex III.

Table 3.3:Residential Sector

District	Total HH	Sample
Saptari	121,064	383
Siraha	117,929	383
Dhanusa	138,225	383
Mahottari	111,298	383
Sarlahi	132,803	383
Rautahat	106,652	383
Bara	108,600	383
Parsa	95,516	383
Total	932,087	3064

Energy demand was calculated from bottom-up approach. The energy data are collected with the information of what energy is used for specific end-uses. Such energy uses were summed up to get the total energy at each upper level – from per capita to per sub-sector to sector to district, subsequently giving the total energy of the province. The general formula for approximation of energy in residential sector is

$$E_{d,s} = \sum_{x} \left[\sum_{u} \sum_{f} \left(\frac{E_{f,u}}{H} \times hv_f \right) \times P_x \right]$$

Equation 3.2

Where,

$E_{d,s}$ = energy demand of district d of sector s [in TJ]

$E_{f,u}$ = energy demand of fuel f for end use u [in local unit]

H = household size [person per household]

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

P =Population of sub sector x

d = district

s = sector

x = sub-sector

u = end use

f = fuel types

The total energy consumption in the province is the summation of energy demands in all districts.

3.3.2 Industrial Sector

The industrial sector is the sector of those manufacturing institutions which process raw materials and give specific products. This sector has been classified into 24 categories by type of products and economic output by Nepal Standard Industrial Classification (NSIC). These categories represent very specific outputs. Thus, for simplification of energy analysis, the industries have been grouped into 8 categories based on type of output and energy activity they utilize. Table 3.4 shows the categorization for each of the industry type .

Table 3.4: 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 n .e .c
	Manufacture of motor vehicles, trailers and semi -trailers
	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

The populations of the industry taken for sampling are based on National Census of Manufacturing Establishments-2011/12 by Central bureau of statistics. The census has provided the classification of manufacturing industries for each district for each category. In addition to that, the census has also published the directory of the industries listed. There is no such updated information complied thereafter. Thus, the consultant has proposed to use the data from former data. The sample size is calculated taking provincial level population of industries. The total sample size is distributed into each district proportionately. It is to be noted that, in some districts there were more industry types than the allocated proportions. In such case, additional samples are taken to comprise each type of industry in that respective district. The sample distribution is given in the ANNEX lll.

Energy consumption for industry sector was also calculated from bottom-up approach. The energy data are collected with the information of what energy is used for what purpose. Such energy us summed up to get the total energy at each upper level – from per value added to per sub-sector to sector to district, subsequently giving the total energy of the province. The general formula for approximation of energy in industry sector is

$$E_{d,s} = \sum_{x}\left[\sum_{u}\sum_{f}\left(\frac{E_{f,u} \times hv_f}{va_{x,d}}\right) \times VA_{x,d}\right]$$

Equation 3.3

Where,

$E_{d,s}$ = energy demand of district d of sector s [in TJ]

$E_{f,u}$ = energy demand of fuel f for end use u [in local unit]

$va_{x,d}$ = value addition of industry x in district d

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

VA_x = Total Value addition of sub sector x

d = district

s = sector

x = subsector

u = end use

f = fuel types

The total energy consumption in the province is then the summation of industrial energy demands in all districts.

3.3.3 Transport Sector

The transport sector has one of the vast definitions if the type of vehicle, the ownership and usage all are accounted for, thus for simplicity, two stage classification has been adopted with reference to Energy vision 2050 and LCEDS. In the first level, the vehicles are classified into three groups by purpose –

a. Intercity – passenger, long distance transport
b. Intercity – passenger, short distance transport within local area
c. Freight – transportation of goods and materials

In second level, the vehicles are classified according to their types into the respective groups. The total population of vehicles in each province is taken from total number of registered vehicles in the province as per list published by Department of Transport Management. For distribution of samples amongst the district, the total sample size has been proportionately divided to districts by the number of households in each district with an assumption that more the population, more transportation service is required or is available. However, to make sure that sufficient number of each kind of vehicle is sampled in each district, a minimum threshold of three vehicles is taken as lower limit. The sample distribution is provided in Annex III.

One of the methodologies followed to collect data regarding the transport sector is to combine the transport questionnaire with residential, commercial as well as industrial along with other independent sample survey.

Energy consumption for transport sector was also calculated from bottom-up approach. The energy data are collected with the information of what energy is used for what purpose. Such energy us summed up to get the total energy at each upper level – from per value added to per sub-sector to sector to district, subsequently giving the total energy of the province. The general formula for approximation of energy in transport sector is

$$E_p = \sum_s \left[\sum_u \sum_f \left(\frac{FE_{u,f} \times M_u \times hv_f}{H_{h,d}} \times V_u \right) \right]$$

Equation 3.4

Where,

E_p = energy demand of province p [in TJ]

$FE_{f,u}$ = fuel economy of fuel f for vehicle type u [per km]

M_u = total distance travelled by vehicle u per year

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

V_u = Total number of vehicle u in province

s = use of vehicle (passenger, freight)

u = type of vehicle

f = fuel types

3.3.4 Commercial Sector

The commercial sectors are representing service providing institutions ether in form of goods or other services. The NSIC also classifies the commercial sector into different groups by the type of goods or service provided. Since the energy pattern in commercial sector are not as varying and highly intensive as industry and residential, the commercial sector has also been grouped into five main categories as shown in Table 3.5.

Table 3.5: Commercial Sector Categorization

Category	Inclusions/description
Trade and retails	Wholesale and retail trade and repair of motor vehicles and motorcycles
	Wholesale trade - of manufacturing productions
	Retail sales of products/second hand products in stores, via stalls and market, via internet or mail order
Accommodation and food	Short term accommodation
	restaurants and food service, food delivery, catering, other food, beverage servicing activities
Financial services	Financial, insurance
	Real estate agencies
Social Services	Education
	Human health, social work
Other services	Information and communication
	Professional, scientific, technical
	Administrative, support service
	Arts, entertainment, recreation
	Other service activities

The population for sample calculation of commercial sector has been taken from National Economic Census 2018 by Central Bureau of Statistics. The database however takes account of the institutions that are not registered as well, which can affect the approximation as their output and value added are not accounted for. The sample size is calculated taking province level population of commercial institutions. The total sample size is distributed into each district proportionately. It is to be noted that, in some districts there were more institution types than the allocated proportions. In such case, additional samples are taken to comprise each type of institution in that respective district. The sample distribution is given in Annex III.

Energy consumption for commercial sector was also calculated from bottom-up approach. The energy data are collected with the information of what energy is used for what purpose. Such energy us summed up to get the total energy at each upper level – from per value added to per sub-sector to sector to district, subsequently giving the total energy of the province. The general formula for approximation of energy in commercial sector is

$$E_{d,s} = \sum\nolimits_x \left[\sum_u \sum_f \left(\frac{E_{f,u} \times hv_f}{va_{x,d}} \right) \times VA_{x,d} \right]$$

Equation 3.5

Where,

$E_{d,s}$ = energy demand of district d of sector s [in TJ]

$E_{f,u}$ = energy demand of fuel f for end use u [in local unit]

$va_{x,d}$ = value addition of the institution x in district d

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

VA_x = Total Value addition of sub sector x

d = district

s = sector

x = subsector

u = end use

f = fuel types

The total energy consumption in the province is then the summation of energy demand in all districts.

3.3.5 Agricultural Sector

This sector, although in broad sense signify any crop, fruit, animal husbandry or fishery, for the scope of this study, the most energy intensive crop farming is being considered. The major energy using activities taken in this sector are irrigation, land tilling and crop threshing. Drought animal power in this sector are ignored in this survey as per TOR as it requires separate and specific survey for accurate estimation. For population of agriculture sector, holding as defined by CBS has been taken. The holdings are the separated into three groups as per National Sample Census of Agriculture 2011/12 (Schedule 1 – questionnaire). The general criteria given by document and the categorization adopt is given in Table 3.6.

Table 3.6: Categorization of Farm Size

Category		Terai		Hills		For study purpose
		Bigha	Ha	Ropani	Ha	Ha
Small	Less than	1	0.68	10	0.51	0.5
Medium	Between	1 to 3	0.68 to 2.03	10 to 30	0.51 to 1.53	0.5 to 2
Large	More than	3	2.03	30	1.53	2*

*1.53 is more suitable for hills but as CBS categorizes in interval of 1ha to 2 ha, 2 ha has been taken as interval point.

For time being, the total holdings of farmland have been taken as population. However, a specific end-uses wise population is being sought for – such as number of holdings using irrigation by solar pump, holdings using tractors, thresher and so on. The sample size is calculated taking province level population of agricultural holdings. The total sample size is distributed into each district proportionately. The sample distribution is given in Annex III.

Energy consumption for agriculture sector was also calculated from bottom-up approach. The energy data are collected with the information of what energy is used for what purpose. Such energy us summed up to get the total energy at each upper level – from per value added to per sub-sector to sector to district, subsequently giving the total energy of the province. The general formula for approximation of energy in agriculture sector is

$$E_{d,s} = \sum\nolimits_h \left[\sum_u \sum_f \left(\frac{E_{f,u} \times hv_f}{H_{h,d}} \times A_{u,h,d} \right) \right]$$

Equation 3.6

Where,

$E_{d,s}$ = energy demand of district d of sector s [in TJ]

$E_{f,u}$ = energy demand of fuel f for end use u [in local unit]

$H_{h,d}$ = area of holding h in district d

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

$A_{u,h,d,}$ = Total area of holding H in district d using technology u

d = district

s = sector

h = holding (small, medium, large)

u = end use

f = fuel types

The total energy consumption in the province is then the summation of energy demand in all districts.

3.3.6 Construction and Mining Sector

This sector has been under mining sector in previous studies. With growing development works at large scale and in fast pace, this sector is deemed to be using huge quantity of energy as well. This sector includes all major construction works such as water supply, irrigation, hydropower, crushers, high rise building construction, road construction, bridge construction projects and mining industries (Limestone, Coal etc.). Since the consultant tried its best but could not acquire specific list of all construction projects in province 2, for optimal sample size determination, the number provided by National Economic census 2018 is taken as population. Besides, the construction projects are mostly using freight transport and hence, the energy consumption in this subsector may have possibility of double counting. The population being very small, 10% lump sum is taken as sampling criteria along with the condition that at least one of sample represents each district. The total sample is distributed proportionately amongst each district. sample size has been attached in Annex III.

The database of heavy equipment used in construction and mining sector are also registered in transportation office. However, the types of vehicles in this sector are not categorized by the recorded system. In addition to this, the construction and mining sector is primarily dependent upon how many of these industries are running as the construction equipment can come from any region, when required. Thus, the population of industries were used to calculate the total energy demand of the construction and mining industry in Province 2 using formula

$$E_p = \sum\nolimits_i \left[\sum_f \left(\frac{AF_{u,f} \times hv_f}{n_i} \times N_i \right) \right]$$

Equation 3.7

Where,

E_p = energy demand of province p [in TJ]

$AF_{f,u}$ = Average fuel demand of fuel f per year per industry

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

N_i = Total number of construction and mining industry in province

n_i = number of surveyed industries

i = type of industry

f = fuel types

3.4 Data Collection Tool

Data have been collected using semi-structured questionnaire. The questionnaires and checklists prepared in English have been finalized after approval from WECS. Their suggestions have duly been incorporated. Thereby, the questionnaires and checklists have been translated into Nepali to ease the task for enumerators and respondents. The finalized tools have been pre-tested at project sites district. Having received feedback of pre-testing, adjustments have been made on the tools before field mobilization.

3.4.1 Data Collection Process

The survey consists of an online questionnaire that could be accessed through Android based personal smart devices such as cell phones and tablets.

- The semi-structured questionnaire is coded in Open Data Kit (ODK) platform through KOBO Toolbox in Nepali and English languages which has been deployed in Enumerator's Android mobile and the Tablets.
- The list of the sample HHs has been provided with the address to the Enumerators in advance. GPS coordinates have tracked the enumerators during the household survey through online data survey system.
- Two days' data collection training have been conducted, including a mockery and a pre-test for enumerators to make them familiar with data collection tools as well as to the digital data collection procedures.
- Enumerators have been informed to transfer collected data daily to the "Server" using their Android mobile/tabs.
- Data collections at the field have been continuously monitored by the core team for quality assurance.

3.4.2 Data Quality Assurance

Following measures have been applied to assure data quality.

- Questionnaires finalization using the expertise of the study team as well as the suggestions from the WECS officials;
- Training of enumerators on questionnaire and data collection mockery as well as pre-testing of the tool
- Data collection through online system track enumerators using GPS coordinate in KOBO Toolbox.
- The core team of the researchers supervise & monitor the data collection in the field during the survey;
- Day to day feedback to the enumerators by the statistician helps to assure data quality.
- Data collected in less than 15 minutes and more than 3 hours will not be included for analysis.

3.4.3 Data Analysis

After completing data collection, the final data sets have been transferred into SPSS software for the analysis. The report has been prepared using SPSS, MS-Word, and EXCEL software.

3.4.4 Workflow of Data Collection

The workflow of data collection has been followed, as shown in Figure 3.2. The template is designed at first. The final questionnaire is uploaded to the cloud server. Enumerators have downloaded the template using the server. The survey has been carried out in the mobile using the application developed for the survey. After completing the survey, the enumerators have uploaded the data into the cloud survey to be received by the statistician for the analysis.

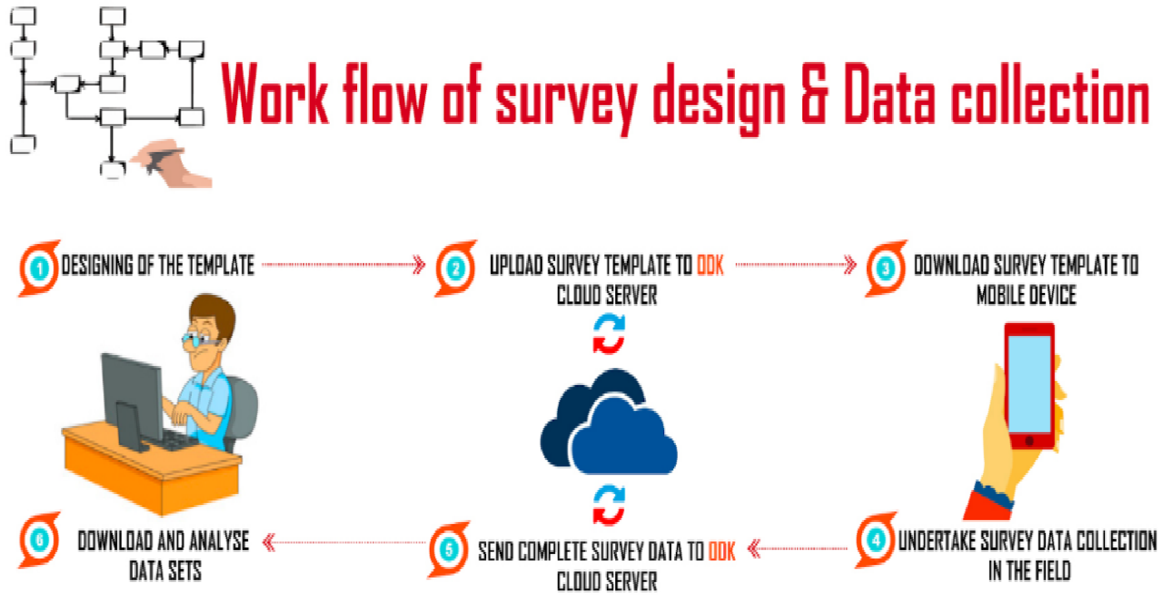


Figure 3.2:Workflow of Survey Design

4 Macroeconomic Analysis

4.1 Introduction

In consultation with the officials at the Economic Management Division, NPC, it was informed that there had not been done any studies yet for the projection of GDPs at the provincial level. Hence, for Province 2, a macroeconomic model has been developed with 71 variables consisting of 12 policy variables and other exogenous variables and 59 endogenous variables. The model has been built with 26 behavior equations and 33 identities. The model has been simulated based on the historical reference period from 1974/75 to 2017/18. The model simulation starts with the insertion of the projected values of policy variables and other exogenous variables and the model processes through different blocks, namely, real sector, government sector, external sector, monetary and price sectors, and employment. Lastly it ends with the projection of major macroeconomic indicators / variables.

4.2 Provincial Gross Value Added for year 2018/19

The CBS has started to publish the provincial Gross Value Added by industrial division for seven provinces since fiscal year 2018/19 (Table 4.1). Based on these single year provincial data and three scenarios of national GDP at producer's prices, Gross value added by industrial division for Provinces No. 2 have been projected assuming that the structure of provincial gross value added of these provinces will remain the same for the projected period although this assumption cannot be taken as realistic. Compilation of provincial data is just at the very initial stage and better data on it can be expected in future.

Table 4.1: Provincial Gross Value Added by Industrial Division in Province No. 2(MoF, 2019)

(In Million Rs. at 2017/18 prices)	
Industrial Classification	**2018/19**
Agriculture and forestry	154,156
Fishing	8,298
Mining and quarrying	2,637
Manufacturing	25,008
Electricity gas and water	2,955
Construction	23,520
Wholesale and retail trade	53,936
Hotels and restaurants	3,008
Transport, storage and communications	36,375
Financial intermediation	12,511
Real estate, renting and business activities	22,271
Public administration and defense	11,876
Education	35,623
Health and social work	3,463
Other community, social and personal service activities	11,099
Total GVA including FISIM	406,736
Financial Intermediation Services Indirectly Measured (FISIM)	8,309
Gross Domestic Product (GDP) at basic price	39,8427
Taxes less subsidies on products	46,069
Gross Domestic Product (GDP)	444,496

4.3 Economic Growth

As discussed earlier, the economy has been classified into three major sectors namely, agriculture, industry, and services. After the restoration of democracy in 1990 in the country, liberalized economic policy under the globalization was followed and private sector was encouraged to involve in economic activities reducing the government involvements. Privatization policy was followed to privatize the public enterprises. Consequently, economic activities were expanded and thus, relatively higher economic growth rate was achieved during the last decade of the twentieth century.

More than 6 %annual growth rate of GDP at factor cost was achieved in last two fiscal years 2016/2017 and 2017/18 due to political stability, improvement in electricity supply, and favorable climate for agriculture. The abovementioned problems are not being so serious at present as before and better future is expected till the political stability. A shortage of agricultural labor force has yet been felt due to the continuation of outflow of Nepalese youths for foreign employment. Both Nepal Labor Force Survey 2017/18 and National Economic Survey 2018 have shown drastic declining trends of labor supply in agriculture sector. Consequently, mechanization has been initiated in this sector and it has made the farmers happy due to the cost effective and time saving practice.

Since 1st quarter of 2020 the world is marred by the unprecedented COVID-19 pandemic bringing out health, humanitarian, and economic crises all over the countries. South Asia is expected to face its worst economic crisis in the past several decades and Nepal's GDP will decline to 1.8% (WB 2020) compared to 8.5% envisaged in the Nepal Government's budget in 2019/20.Even recent CBS's GDP projection stands at 2.27% for the fiscal year 2019/20 (CBS 2020). The budget 2020/21 of Nepal Government has a projection of GDP growth rate of 7% if there will be quick recovery post COVID -19 pandemic (MOF 2020). Due to crises, economic growths may be affected in some particular year but for mid -term and long- term energy projections these slump downs in economy are taken as outliers/aberrations and economic growth rates in normal years are usually considered for future economic projections.

4.4 Variables

The lists of policy variables and other exogenous variables as well as of endogenous variables, used in the model, are presented in the Table 4.2and Table 4.3.

Table 4.2: List of Policy Variables and Other Exogenous Variables

1. ACMFERT1	Chemical Fertilizers
2. ATCA1	Total Cultivated Land Areas
3. CDIAG1	Cumulative gross fixed capital formation in agriculture sector
4. CDIIND1	Cumulative gross fixed capital formation in Industry sector
5. CDISERV	Cumulative gross fixed capital formation in Service sector
6. EXGRATE1	Foreign exchange rate in terms of US Dollar
7. FXGS	Export of goods and services in external sector
8. GFGRANT1	Foreign grants to government sector
9. GFI_N1	Government net financial investment
10. IMPFUEL1	Imports of petroleum products
11. INDCPI1	Indian consumer price index
12. POP1	Population in million

Table 4.3: List of Endogenous Variables

1. CPI	Consumer Price Index
2. DCG	Government Consumption Expenditures
3. DCP	Private Consumption Expenditures
4. DCST	Change In Stocks
5. DCTOT	Total Consumption Expenditures
6. DGFCF	Gross Fixed Capital Formation
7. DGFCFG	Government Gross Fixed Capital Formation
8. DGFCFP	Private Gross Fixed Capital Formation
9. DMGS	Imports Of Goods And Services In Real Sector
10. DTINV	Gross Capital Formation
11. DXGS	Exports Of Goods And Services In Real Sector
12. FCAB	Current Account Balance
13. FGSB	Balance On Goods And Services
14. FKFAB	Capital And Financial Account Balance
15. FMGS	Imports Of Goods And Services In External Sector
16. FOB	Overall Balance In External Sector
17. FTRB	Current Transfers Net
18. FYB	Primary Income Net
19. GCASHBAL	Budgetary Cash Balance
20. GDBOR	Domestic Borrowing
21. GDTX	Direct Taxes
22. GFAID	Foreign Aids
23. GFISCBAL	Budgetary Fiscal Balance
24. GFLOAN	Foreign Loans
25. GGEXP	Total Government Expenditure
26. GGOVRECI	Total Government Receipts
27. GGREV	Government Revenue
28. GINDTX	Indirect Taxes
29. GKEXP	Government Capital Expenditures
30. GNTXREV	Non-Tax Revenue
31. GOVSAV	Government Saving
32. GPR	Principal And Interest Repayment
33. GREXP	Government Regular Expenditures
34. GTRAF	Government Transfers (Government Subsidies)
35. GTXREV	Tax Revenue
36. LAG	Employment In Agriculture Sector
37. LIND	Employment In Industry Sector
38. LSERV	Employment In Service Sector
39. LTOT	Total National Employment
40. MM2	Broad Money Supply (M2)
41. PSAV	Private Savings
42. PY	Implicit GDP Deflator
43. RGAP	Resource Gap
44. Y	Gross National Income
45. YAG	Value Added In Agriculture Sector
46. YBP	Gross Domestic Product At Basic Prices
47. YDI	Gross National Disposable Income
48. YDIP	Per Capita Gross National Disposable Income
49. YDIP$	Per Capita Gross National Disposable Income In US Dollar
50. YDSAV	Gross Domestic Saving
51. YFC	Gross Domestic Product At Factor Cost (Including FISIM)
52. YFISIM	Financial Intermediation Services Indirectly Measured (FISIM)
53. YIND	Value Added In Industry Sector
54. YINDTXN	Indirect Tax (Net) (Tax Less Subsidies On Products)
55. YNSAV	Gross National Saving
56. YP	Per Capita Gross National Income
57. YP$	Per Capita Gross National Income In US Dollar
58. YPP	Gross Domestic Product At Producers' Prices
59. YSERV	Value Added In Services Sector

4.5 Model Simulation

The macro econometric model has been simulated based on the historical data of period 1974/75 to 2017/18. This model has projected required macroeconomic variables for coming 31 years of period (2018/19 to 2049/50) for study on "Energy Consumption and Supply Situation in Federal System of Nepal (Province 2)" using the ordinary least square estimates.

4.5.1 Sources of Data and Use of Software

Sources and Processing of Data

An economy consists of five different sectors namely, production, government, external, monetary and price, and private sectors. They are usually presented into different blocks in macro modeling exercise. The data required for the modeling exercise is of the secondary type and can be obtained from different government authorities especially, MOF, CBS, NRB, and NPC and other organizations.

The publications of Central Bureau of Statistics (CBS) have been used to collect the data relating to population and national account statistics such as: production, investment, and consumption and GDP deflator. The data relating to the national account statistics, government finance, foreign loans and grants, have been collected from the Economic Survey published in different years by the Ministry of Finance. Similarly, data relating to the monetary, prices and interest rates as well as the data relating to the balance of payment are collected from the publications of Ministry of Finance and the Nepal Rastra Bank (NRB).

The System of National Accounts (SNA) 1993 has been used in the country since the fiscal year 2000/01. Therefore, the structure of national accounts has been changed since the fiscal year 2000/01. The economy has been classified into 15 sectors against the traditional classifications of 9 sectors. For this modeling exercise, these classifications have been rearranged into three broad sectors. Similarly, GDP by expenditure category has been restructured since the date. Consumption expenditure has been classified into government consumption, private consumption and non-profit institutions. In the same way the structure of the government finance has also been changed since the fiscal year 2001/02. The government expenditure has been classified into recurrent, capital and principle payment instead of conventional classification into regular and development expenditure. The regular and development expenditures before the fiscal year 2001/02 have been transformed into recurrent and capital expenditures and principal payment with required adjustments. Since then net internal loan and net investment have been added in the financing the fiscal balance. The balance of payment data has also been changed since the fiscal year 1999/2000. Both export and import of goods are classified into two: oil and others. Income has been separated from the service trade. The financial account has been treated as a separate sub heading and has presented in detailed structures from the capital account (capital transfers). Thus, the structures of national account statistics, government finance and balance of payment statistics have been improved since the starting of the twenty first century. These improvements have been considered and have made necessary adjustments for making the data before and after the structure changes of the data consistent.

The Central Bureau of Statistics (CBS) publishes only the government and private gross fixed capital formation. Sectoral gross fixed capital formation is not published. Sectoral gross fixed capital formations for period of 1974/75 to 2017/18 have been estimated based on its annual control totals published by the CBS. Sectoral and national ICOR used in the Fifteenth Plan have also been used as basis for estimation of sectoral gross fixed capital formation for last few years. That's why; data on sectoral gross fixed capital formation is also weak. Population is calculated using figures from the decennial census of CBS. For the intermediate years' interpolation method with compound growth rate has been used. Similarly, Indian CPI has been taken from the website of the Reserve Bank of India.

Employment database is very weak because the employment data in different sources are widely different and inconsistent. So, the sectoral employment has been estimated using the interpolation and extrapolation of the sectoral employment growth rates based on the economically active population published in Population Census Reports of 1971, 1981, 1991, 2001, and 2011 since the employment data published in Nepal Labor Force Surveys Reports and in National Economic Census Reports are in unexpectedly low side especially for last decade. No doubt, employment was low due to the increasing foreign employment and political instability during last decade, but it is difficult to expect to that extent. In fact, this method of interpolation and extrapolation based on inter censuses gives us linear growth rate of the employment of respective sectors, which can hardly be realistic but, it is bound to accept it since there is no other option.

Software Used

E-views computer software has been used for macroeconomic modeling exercises since; it is comparatively appropriate and user-friendly software for estimating the behavior equations with statistical tests and running the model.

4.5.2 Assumptions

Since the data on sectoral as well as national capital stocks are not available, cumulative figures of these sectors have been used as the proxy of their capital stocks in this model and these cumulative figures of sectoral gross fixed capital formation are determined exogenously using the linear trend method in the baseline scenario. They are considered as the policy variables in the model for other alternative scenarios. That's why; they are exogenously assumed in these alternative scenarios to achieve the expected economic growth rates. In addition to them, some other exogenous variables such as: exchange rate, Indian consumer price index, foreign grants, import of fuels, chemical fertilizers, Total cultivated area, exports of goods and services in external sector, population, and government net financial investment, have been projected using trend method for baseline scenario and exogenously fixed for alternative scenarios.

4.5.2.1 Baseline Scenario

Policy variables:

This model consists of two types of variables namely: independent (exogenous) variables including policy variables and other exogenous variables; and dependent (endogenous) variables. For the baseline scenario most of these policy variables have been projected using the trend method and rest of policy variables have been exogenously fixed with some economically valid assumptions. The projected annual growth rates of above mentioned policy / exogenous variables are presented below:

Table 4.4:Projected Annual Growth Rates of Policy/Exogenous Variables in Baseline Scenario

In Percent

Indicators	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050
ACMFERT1	119.1	41.2	7.6	6.1	5.3
ATCA1	1.5	0.1	1.1	0.8	0.8
CDIAG1	5.9	5.7	5.7	5.7	5.8
CDIIND1	5.8	5.9	5.6	5.4	5.2
CDISERV	6.3	7.8	9.1	9.1	9.1

In the above table, trend projections of average annual percentage growth rate of cumulative gross fixed capital formation in industry is at declining trend whereas that in services sector has a faster rising trend. Use of chemical fertilizers usually based on its availability not on demand as its supplying public corporations such as: Agriculture Inputs Corporation and Salt Trading Corporation could not meet the farmers' demand in time.

Other Exogenous Variables:

In the baseline scenario it is assumed that all other exogenous variables (including EXGRATE1, POP1, ATCA1 and INDCPI1) continue business as usual. That's why; these variables have been projected based on the trend method. ACMFERT1, GFGRANT1, GFI_N1, and IMPFUEL1 have also been projected using same trend method. The annual growth rate of FXGS, has been projected using researcher's personal judgment considering economic reasoning and past trends. Here in this model, the researcher has assumed that recently achieved political stability will resume and will increase the export of goods and services gradually. That's why; the annual growth rate of FXGS has been assumed gradual increasing. The projected average annual growth rates of other exogenous variables are presented in the following tables.

Table 4.5: Projected Average Annual Growth Rates of Other Exogenous Variables in Baseline Scenario

In Percent

Indicators	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050
EXGRATE1	1.0	4.0	2.2	1.8	1.5
GFGRANT1	15.7	(4.3)	4.0	3.9	4.4
GFI_N1		16.0	9.8	8.0	7.1
IMPFUEL1	14.0	10.3	0.8	2.1	1.7
INDCPI1	6.4	5.7	2.7	2.2	1.8
POP1	1.4	1.4	1.3	1.1	1.0
FXGS	(2.9)	4.2	5.1	5.6	6.0

4.5.2.2 Medium Growth Rate Scenario

It is assumed that the country's economic situation will gradually be improved in future. After successful completion of a decade long Maoist conflicts and a decade long political instability, the political stability has been achieved with the formation of two-third majority government of Nepal Communist Party (NCP) under the new regime of federal democratic republic political system. Most of the political parties have thought that the political issue has been solved for a while and economic transformation is, now, the important task. So, the government has concentrated solely on the economic prosperity of the country and has fixed a slogan "Prosperous Nepal and Happy Nepali".

The government has decided to develop agriculture sector encouraging and mobilizing the returnees from overseas employment by providing them economic incentives and skill trainings to be self-employed in agriculture sector. Some of them have returned with skills and technical knowhow too. They have invested and operating their agriculture farms. Load shedding problem has also been almost completely solved. NEA has started to replace other types of energies with electricity by linking the electricity of completed hydroelectricity projects to national grids. That's why; investments on agriculture (vegetables farming, livestock, horticulture, poultry and fish farming and agro processing industries) and industry (electricity, mining, manufacturing and construction) are expected to go up and will increase the productions and will generate sufficient employment opportunities to solve the rising unemployment problem.

In order to reduce the faster increasing foreign trade deficit, the government is trying to implement the export promotion and import substitution policies for increasing exports of goods and services on the one hand and on the other hand for gradual reduction of the imports. For both purposes, major way outs are the increases in outputs of agriculture and industries have to be increased. The widening economic activities also demand the production and productivity of services sector too in consistent way. Investment has to be increased for higher growths to achieve the abovementioned goals. Sustainable development goals have also to be achieved. That's why; the investments for these broad economic sectors are projected exogenously. ATCA1 and ACMFERT1 are expected to be increased and similarly the FXGS too. The projected annual growth rates of other policy/exogenous variables are taken the same as those in the baseline scenario. These projected average annual growth rates of these policy/exogenous variables are presented as below:

Table 4.6: Projected Average Annual Growth Rates of Policy/Exogenous Variables for Scenario 1

In percent

Indicators	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050
ACMFERT1_1	119.1	41.2	7.6	6.1	5.3
ATCA1_1	1.5	0.1	1.2	1.1	1.0
CDIAG1_1	5.9	6.2	8.7	9.1	9.1
CDIIND1_1	5.8	6.1	10.7	11.3	11.4
CDISERV_1	6.3	8.1	9.9	10.0	9.7
FXGS_1	(2.9)	4.3	5.9	6.4	6.1

4.5.2.3 Higher Growth Rate Scenario

It is assumed in the Scenario 3 that all policy /exogenous variables namely, CDIAG1, CDIIND1, and CDISERV1 are exogenously projected with further higher increment in order to achieve higher growth rates of sectoral as well as national GDP growth rates. Agriculture sector has been increased slightly only as the productivity of capital in this sector is relatively low whereas, that of services sector is relatively high and moderate in industry sector. That's why; CDISERV1 has increased in higher trend. As the country has recently achieved political stability after facing a longer period of economic recession due to nearly two decades long political turmoil and political transition, the country will need higher economic growth to compensate the economic losses to resume its normal growth in future. That's why; it is targeted to have 7.0 percent average annual growth rate of GDP at producers' prices for coming 31 years and accordingly, average annual growth rates of these policy/exogenous variables CDIAG1, CDIIND1, and CDISERV1 have been projected at the higher side in order to achieve the targeted growth rate. Other exogenous variables have been projected using the trend method as in baseline scenario. The projected average annual growth rates of these policy/exogenous variables are presented in the table below.

Table 4.7: Projected Annual Growth Rates of Policy/Exogenous Variables for Scenario 2

In percent

Indicators	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050
ACMFERT1_2	119.1	41.8	7.6	6.1	5.3
ATCA1_2	1.5	0.6	1.2	1.1	1.0
CDIAG1_2	5.9	5.7	8.7	9.1	9.1
CDIIND1_2	5.8	5.6	10.7	11.3	11.4
CDISERV_2	6.3	8.4	10.2	10.6	10.9
FXGS_2	(2.9)	4.3	5.9	6.4	6.1

4.6 Projection of Provincial Gross Value Added by Industrial Division

The CBS has started to publish the provincial Gross Value Added by industrial division for seven provinces since fiscal year 2018/19. Based on these single year provincial data and three scenarios of national GDP at producer's prices, Gross value added by industrial division for Provinces No. 2 have been projected assuming that the structure of provincial gross value added of these provinces will remain the same for the projected period although this assumption cannot be taken as realistic. Compilation of provincial data is just at the very initial stage and better data on it can be expected in future. Provincial gross value added by industrial division of Provinces No.2 is forecasted based on the three growth scenarios of national GDP at producer's prices. Thus, the province has three growth scenarios. Additionally, the recent COVID-19 has had a great impact on economic activities. The preliminary economy growth rate as estimated by CBS is around 2.27% (CBS, 2020). The world bank has estimated a growth rate of 1.8% for fiscal year 2019-2020 (World Bank, 2020). Thus, for early year, a growth rate of 1.8% have been taken and it has been assumed that by period of 2025, the economy will bounce back to normal as evident from the case of economic rebound in year 2016/17. Based on these contexts, the compound annual growth rates used for projection are given in Table 4.8. The projected GDP/GVA are given in ANNEX VII.

Table 4.8: Economic Growth Rates for Three Scenarios

	2019 - 2020	2020 - 2025	2025 - 2030	2030 - 2035	2035 - 2040	2040 - 2045	2045 - 2050	Average
Low	1.80%	3.54%	5.27%	5.66%	6.00%	6.32%	6.64%	5.57%
Reference	1.80%	3.93%	6.08%	6.52%	6.90%	7.11%	7.28%	6.30%
High	1.80%	4.03%	6.24%	6.81%	7.34%	7.87%	8.15%	6.74%

5 Energy Scenario Development

5.1 Introduction on Scenario-Based Approach

Scenario based planning was first introduced in the 1970s as a planning technique that replaced traditional forecasting tools(Wulf, et al., 2010). Scenario planning is a method for developing and thinking through possible future states based on different scenarios(Schoemaker, 1995). The future development is highly uncertain, and thus must be based on assumptions which can vary upon perceptual biases, giving multiple possibilities. The scenario based approach helps, not to accurately predict the future, but rather to develop better strategies by overcoming such biases and coming up into multiple options (Porter, 1985; Wack, 1985; Schoemaker, 1995; Wulf, et al., 2010). Thus, scenarios help to open the future as a space of possibilities.

Scenarios give pictures of potential future demand and supply requirements and other activities however these should not be confused with either predictions or forecasts. It gives one particular image of how the future could unfold under certain circumstance. Scenarios provide a framework for exploring future perspectives, including various combinations of activities, technology options and their implications. Scenarios are useful tools for investigating alternative future developments and their implications, for learning about the behavior of complex systems such as energy and environment systems and for policy-making decisions related to them(Nakicenovic, 2000).

5.2 Major Assumptions/Options for Demand (Supply) Analysis

5.2.1 Economy and Population Growth

The scenario development process requires certain drivers for activities. The rate of activities is dependent on specific variables. In the study, the activities are linked with economic and demographic parameters. The agricultural, commercial, and industrial activities are assumed to be dependent on respective gross value added (GVA) in each sector respectively. Meanwhile, the residential sector, waste outputs are assumed to be dependent on population. The transport sector, in other hand is dependent of both economic and demographic parameters for freight and passenger transportation respectively. Thus, the scenario development is based on provincial and sectoral GVA and population growth rates as shown in

Table 5.1. The GDP growth rate is one of the uncertain parameters which can be affected by many factors such as national development activities, political influence, international trade as well as even natural calamities. Thus, GDP growth rates are taken from the targets set for national economy in government documents or will be calculated based on the macro-economic activities in the provinces as detailed in Chapter 4. The population growth rate for each province has been taken from census data by Central Bureau of Statistics (CBS, 2012; Worldbank, 2013; CBS, 2014). Another major assumption undertaken in the model is that the economic activities go hand in hand with GDP growth to reach the target set, thus indicating growing sectoral GDP or GVA also require increase in activity such as production in respective sector and vice versa.

Table 5.1:Assumptions and Sectoral Categorization

Particulars		References
GDP*	Low economic growth High economic growth	(MoF, 2016; NPC, 2014; NPC, 2017; CBS, 2012; CBS, 2014; ADB, 2015) and other recent documents as published by authorized agencies.
	Reference economic growth	
Demography	Population	

*Details are given in Chapter 4

5.2.2 Energy Sector Parameters

The energy sector refers to the consumption of energy by combustion of biomass and fossil fuels for energy extraction purpose. The major drivers of energy sectors are assumed to be dependent on economic and demographic parameters. Table 5.2 shows the basic assumptions taken for scenario development of each of the energy sectors.

Table 5.2: Energy Sector Dependent Variables

Sector/Activities	Driving factors
Residential	Population
Transport	GDP and population
Industrial	Industrial GVA
Construction and mining	Construction and mining GVA
Commercial	Commercial GVA
Agricultural	Agricultural GVA

In the residential sector, which is a non-economic sector – in a viewpoint that there is no measurable economic output, the consumer behavior is major affecting parameter i.e. the population is the driving factor. Meanwhile in transport sector, which is responsible for transport of person as well as goods, it is affected both by population as well as economic outputs – i.e. GDP. For the rest of the economically active sectors, their respective economic outputs are the driving factors in energy demand.

5.3 Use of Energy Modelling Tools

For modeling future demand scenarios of the energy systems of Nepal at provincial level from the current base year to 2050, various planning tools are available. The energy planning process includes database generation for a base year, including energy consumption, supply, and resource assessment. The next step is to project demand under various circumstances. It is in best practice that along with demand projection, the supply chain is also analyzed side by side. This will aid in developing strategic action plans and measures for improving energy performance to attain sustainable development with regards to energy consumption and production. One of the key steps for sustainable energy planning is evidence-based scenario analysis. A scenario provides a picture of likely future energy demand and supply requirements before-hand under specific conditions. Energy scenarios provide a framework for exploring future energy perspectives, including various combinations of technology options and their implications, and as a consequence, they provide a pathway for energy development for the policymakers at the national and the provincial levels.

Methodological Framework for Energy Planning and Scenario Analysis applied for this study is presented in Figure 5.1. The energy system analysis will be done from the bottom-up approach, i.e., all possible energy activities will be considered at the end-use level for each sector. The base year will be taken as 2019 for energy demand analysis. From here, energy scenarios have been developed until 2050[1], and a short term, medium term, and long-term targets have been devised. The initial data collected from survey have been used to develop a base year energy model with inclusion

[1] Though the TOR mentions the study end year as 2040, the projections are done till 2050 because many international energy/environmental programs have taken 2050 as one of the milestone years.

of socio-economic parameters. Based on predicted demographic and economic parameters, the energy scenarios have been developed at the provincial level that include –

- Demand analysis – for each of the economic sectors based on end-use activities and fuels
- Supply analysis – for determination of energy supply required
- Resource analysis – for analysis of feasibility and potential energy supply system

The energy scenario development has been a two-step process. Firstly, in MAED for energy demand projection as it is one of the robust, freely available energy demand analysis softwares. Secondly, TIMES model is used as the MAED is limited or demand projection only, while the TIMES model is capable of analyzing the supply side as well as the emissions of the energy system. Although the details of data required in TIMES is much vast, as MAED provides a rigid framework, the data required for both models can be derived from same sets of information derived from primary survey and secondary sources as depicted in Figure 5.1. The final results in both the energy models are compared, calibrated, and verified for validation of input sets of economic and demographic data and their respective outputs.

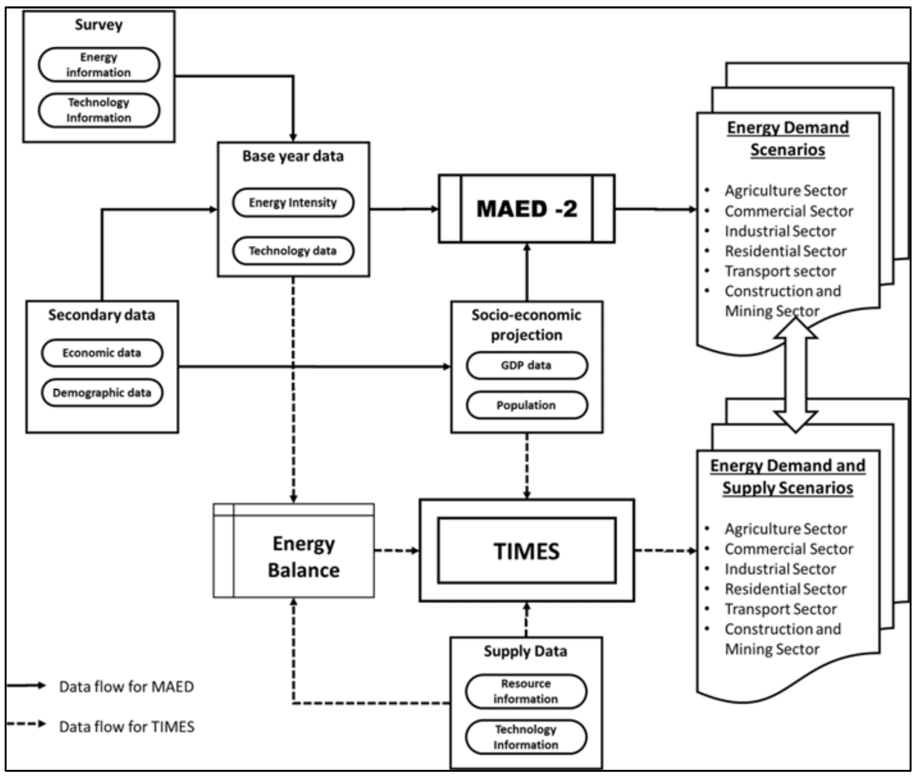


Figure 5.1: Methodological Framework of Projection in MAED and TIMES

5.3.1 Choice of the Modelling Tool

The MAED model is a robust model for demand projection. However, the model is limited by its rigid structural framework for detailed energy demand analysis only and lacks supply side database and analysis for the base year as well as in future projections. Furthermore, it lacks a least-cost optimization for economic resources mobilization.

Amongst the energy models presented above, TIMES model is the advanced successor of MARKAL – one of the most widely accepted and robust energy models. Nevertheless, other energy modeling tools given are also particularly good ones. International Energy Agency – Energy Technology Systems Analysis (IEA-ETSAP), the developer of the MARKAL model, has now advanced the state-of-the-art in energy system modelling with TIMES (The Integrated

MARKAL-EFOM System), the evolutionary successor to MARKAL. The ETSAP executive committee has decided to promote TIMES for new users since 2008. The trend in energy modeling tools shows that TIMES is the most widely used least-cost energy system optimization model for dynamic energy planning and policy development, both in the developed and in the developing countries. The model will facilitate harmonization and coordination of policy formulation at the provincial and central level to facilitate better communication among policy makers with the goal of fostering sustainable energy development and energy security in the country.

TIMES model have been used for developing least-cost optimization scenarios. However, the energy demand projections will be carried on the MAED framework. The results and scenarios developed using such kind of modeling framework will have much more valid acceptance from the development partners and multilateral financial institutions.

5.4 Energy Demand Projection

The energy demand is calculated by the model MAED_D as a function of a scenario of possible development. This scenario covers two types of scenario elements (see Figure 5.2):

- One is related to the socio-economic system and describes the fundamental characteristics of the social and economic evolution of the country or province.
- The second is related to the technological factors, which should be considered in the calculation of energy demand, for example the efficiency of each alternative energy demand technology and its penetration into its potential markets.

5.4.1 Model for Analysis of Energy Demand (MAED)

MAED is an energy modeling tool developed by IAEA. It evaluates future energy demand based on medium- to long-term scenarios of socio-economic, technological, and demographic developments. Energy demand is disaggregated into many end-use categories corresponding to different goods and services. The influences of social, economic, and technological driving factors are estimated and combined in each different category to present an overall picture of future energy demand growth under the assumptions of that scenario. For energy demand analysis and projections in MAED, the end-use categories are (1) residential (2) industrial, (3) commercial, (4) transport, (5) agricultural, and (6) construction, and mining. Based on the intensities of energy use, the end-use categories are re-organized into subcategories.

MAED model used survey data for constructing base year energy consumption. It calls for compiling and reconciling necessary data from different sources, deriving, and calculating various input parameters and adjusting them to establish a base year final energy balance. It helps to calibrate the model to the country's specific situation. Scenarios of future energy demand are developed from the base year until 2050 under different economic growth rates (socio-economic, demographic, and technology) and scenarios. The socio-economic system describes the fundamental characteristics of the social and economic evolution of the province and the technological factors such as efficiency and market penetration potential of each alternative energy demand technology affects energy demand. The model output is exclusively energy demand, particularly demand for specific energy services. The end-use category energy demand is calculated in the form of useful energy demand and then converted to final energy demand considering efficiency and market penetration of the energy sources. Moreover, the 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.

MAED_D calculates the energy demand for each end-use category, subsector and sector, aggregating then the economic sectors into four main "energy consumer" sectors: Industry (including Agriculture, Construction, Mining and Manufacturing), Transportation, Service and Household. At the same time, it provides a systematic accounting framework for evaluating the effect on the energy demand of any change of economic nature or in the standard of living of the population.

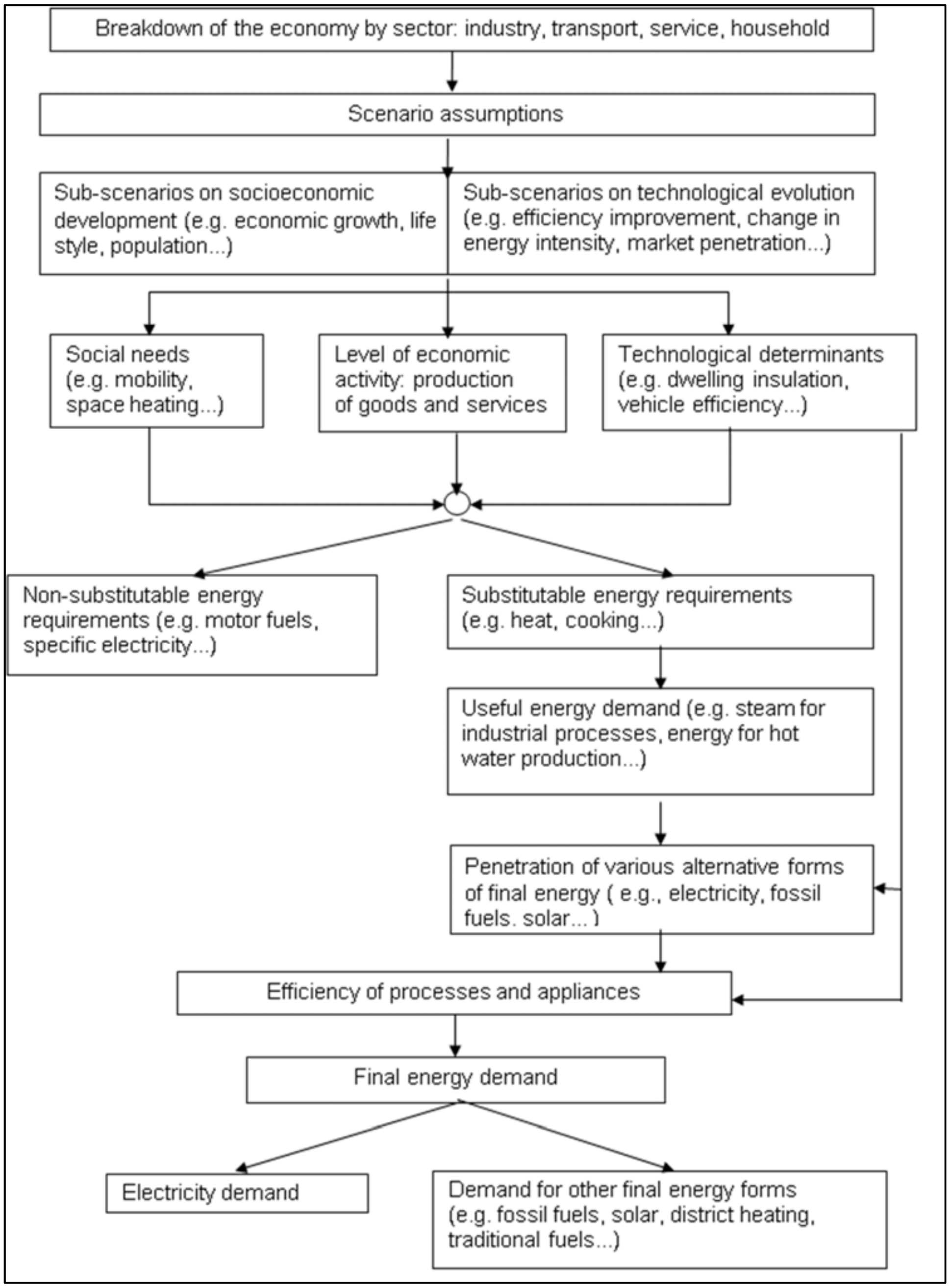


Figure 5.2: Scheme Used to Project Useful and Final Energy Demand in Module 1 of MAED

5.5 Energy Supply Analysis

With limitation of MAED only being able to project the energy on demand basis only. TIMES model has been used to analyze the overall supply-demand system in the province. VEDA-TIMES have been used for the purpose of the analysis of complete energy system.

5.5.1 The Integrated MARKAL-EFOM System (TIMES)

The TIMES model generator was developed as part of the IEA-ETSAP (International Energy Agency - Energy Technology Systems Analysis Program) to conduct energy and environmental analyses. It is the successor of

MARKAL. The model combines two different, but complementary, systematic approaches to modeling energy: a technical engineering approach and an economic approach. TIMES is a technology rich, bottom-up model generator, which uses linear-programming to produce a least-cost energy system, optimized according to several user constraints, over medium to long-term time horizons.

TIMES models include all the points of energy flow from primary resources to end-use consumers, including the processes of transformation, transportation, distribution, and conversion of energy into the supply of energy services. On the energy supply-side (producers), it comprises fuel mining, primary and secondary production, and exogenous import and export. Through various energy carriers, energy is delivered to the demand-side (consumers), which is structured into sectors. The mathematical, economic, and engineering relationships between these energy "producers" and "consumers" are the basis of underpinning TIMES models. Once all the inputs, constraints and scenarios have been put in place, the model will attempt to solve and determine the energy system that meets the energy service demands over the entire time horizon at the least cost. The results will be the optimal mix of technologies and fuels at each period, together with the associated emissions to meet the demand Figure 5.4.

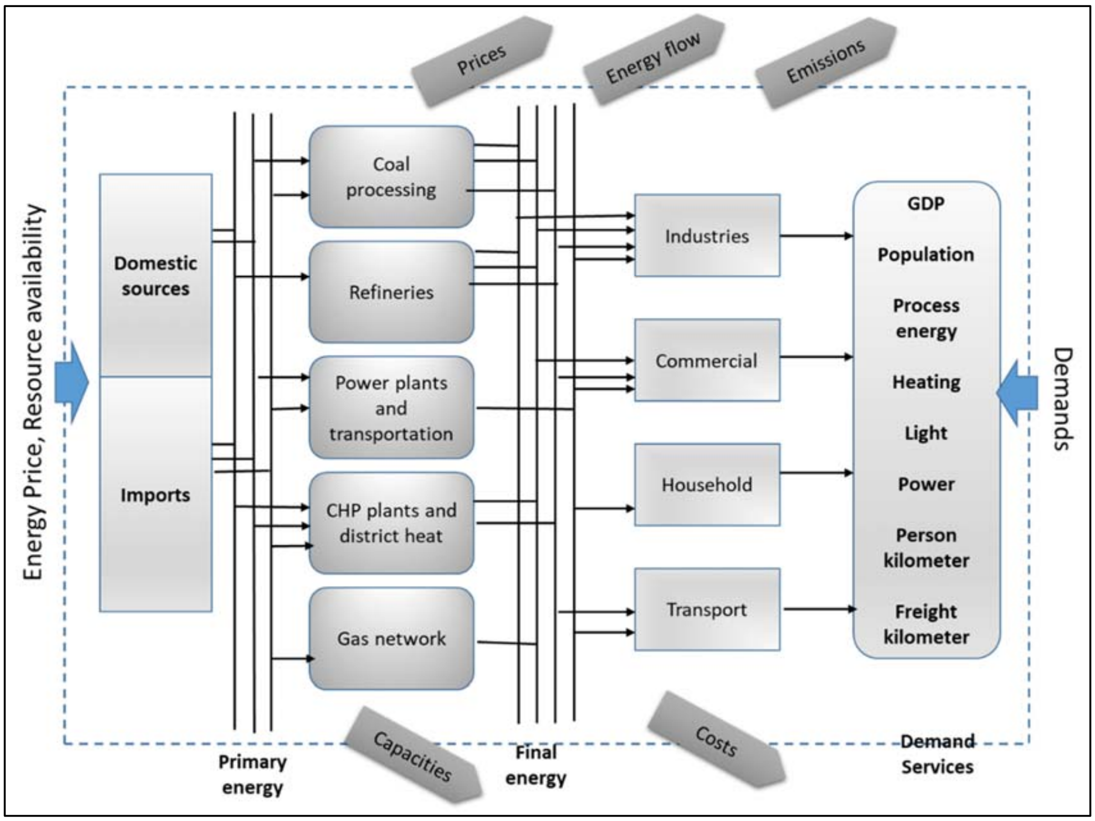


Figure 5.4: Structure of TIMES Framework

The elements of a TIMES energy system can be grouped as follows.

- *Energy carriers* encompass all the energy forms in the energy system, such as petroleum, electricity or fuelwood.
- *Demands* are the end-use demands of energy services, such as residential lighting or intercity freight transport demands.
- *Resource technologies* are the means by which energy enters or leaves the system, other than by end use consumption.
- *Process technologies* convert one energy carrier into another, excluding load-dependent ones such as electricity.

- *Conversion technologies* convert an energy carrier into electricity and/or district-heat.
- *Demand technologies* consume an energy carrier to meet end-use demands.
- *Emissions* encompass the environmental impacts of the energy system.

In TIMES, the energy system as a whole is graphically represented in the RES (Reference Energy System) that provides a convenient outline for the user to map the flow of each energy carrier. Components are represented as blocks and lines in the RES showing the flow of energy resources from source to end-use. In the RES, commodities like energy carriers, demands and emissions are represented as lines while all technologies are represented as blocks.

TIMES Model Run and Solutions

As in other optimization models, TIMES also solves a model run by minimizing the objective function within the constraints given. It uses LP methods to optimize the system. The present value of the total energy system costs throughout the planning horizon is the objective function, which is subject to specific constraints. The discount rate should be provided by the user. TIMES assumes perfect foresight in making the decisions, i.e. decisions are made with full knowledge of future events.

The objective function consists of present values of the following individual costs.

- Investment costs of technologies
- Fixed and variable O&M costs of technologies
- Transportation, distribution and transmission costs of commodities
- Resource extraction costs
- Import costs of commodities
- Export revenue of commodities
- Costs incurred due to losses
- Costs associated with environmental emissions

A typical model consists of thousands of decision variables. They represent the choices made by the model. The following are the various kinds of decision variables in a TIMES model.

- New capacity addition for technologies
- Installed capacity of technologies
- Activity level of technologies
- Quantity of resources extracted
- Quantity of import/export of commodities
- End-use demands
- Environmental emissions

In the simplest form, the TIMES modelling framework can be represented by the following linear programming objective function

$$\text{Min } c.X$$

$$\text{s.t. } \sum_{k} CAP_{k,i}(t) \geq DM_{i}(t) \qquad i = 1,2, \ldots, I;\ t = 1,2,\ldots, T$$

$$\text{and, } B.X \geq b$$

Equation 5.1

Where, X = vector of all decision variables

I = number of demand categories

CAP = capacities of end-use technologies

DM = exogenous demands to be satisfied

B = coefficient of other constraints

In our modelling framework, there are almost 300 plusvariables for technology sets alone, both for the end-use and conversion technologies. Apart from this, the resources sets and other parameters such as emissions and costs multiply the extent of variables accordingly.

In the conversion technologies especially in the electricity generation, although various technologies such as diesel and nuclear plants were considered for supply analysis but they were not preferred compared to hydropower plants because of the cost and availability factors. But their options for supply of electricity may not be ruled out in future.

6 Energy Supply Situation

The energy resources can be categorized into renewable and non-renewable energy resources. Renewable energy is divided into conventional renewable and new renewable. Conventional renewable energy is further divided into traditional biomass and modern biomass whereas new renewable category includes the solar energy, wind energy, solar-wind hybrid system, geothermal energy, hydrogen fuel, hydropower etc. The traditional biomass means fuel wood, agricultural residues and animal dung whereas modern biomass includes both liquid and non-liquid biofuels. Biogas from the animal and human excreta and other waste biomass, ethanol, biodiesels are some of the examples of the liquid biofuels whereas non liquid biofuel means bio briquettes, charcoal etc. Non-renewable energy resources primarily include the fossil fuel that covers petroleum fuel, natural gas, coals. The categorization of energy resources is given in Figure 6.1.

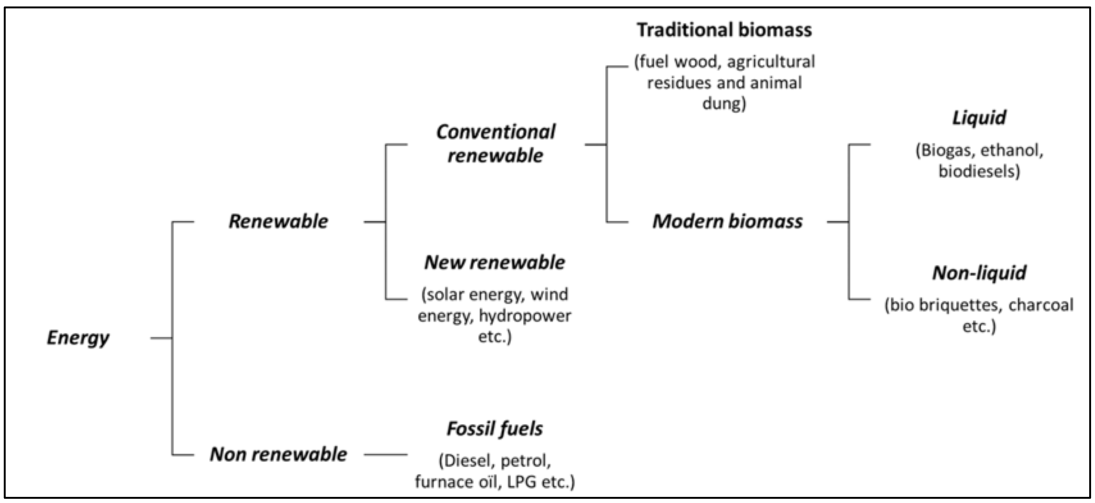


Figure 6.1: Energy Classification for Nepal[2]

For simplicity, the description of each category of energy resources are presented at their respective bottom level.

6.1 Solid Biomass

Province 2 Nepal is blessed by nature with good sunlight, enough water and alluvial soil. Therefore, there used to be very good forests in the province. But urbanization and agriculture have impacted good forests, and some of good forests are changed into non forests. Similarly, human pressure for fuelwood in the past changed the good forests into degraded one. But, due to the better conditions for plant growth, Province 2 still has good potential for forest management and production. Therefore, from perspective of energy these forests have very high potentials. On the other hand, most of the people in the province are poor, therefore they still depend upon bioenergy and is very important for them.

6.1.1 Physical Environment of the Terai

Province2 lies in the Terai Physio-graphic Region of Nepal. In terms of morphology, the forests in Province 2 consists of gently sloping, recent and post- Pleistocene alluvial deposits which form a predominant plain south of the Himalayan. It is bordered by the Indian Gangetic plain in the south and middle mountain districts in the north. Province 2 mostly consists of flat lands or Terai, its elevation varies from 63 m to 330 m above mean sea level, and it is

[2] As per Terms of Reference

sloped gently at 2-10 m per kilometer (LRMP, 1986). The Terai physio graphic zone is divided into three sub zones: The Bhabar, the Terai and the Southern Terai (Jackson, 1994). Out of seven districts in Province 2, only Sarlahi has the Bhabar sub zone and it is a narrow stretch of recent alluvial and colluvial fan deposits at the foot of the Churia Hills, which consists of thick deposits of gravel, pebbles and boulders, mixed with sand and silt. The alluvial and colluvial fans in the Bhabar coalesce into predominant slopes and merge with the main Terai in the south, which is formed by sediment deposited by braided rivers. The Terai is the area, where the water drained in Bhabar will reappear again at the surface. Whereas the Southern Terai is an extension of the Gangetic Plains.

6.1.2 Forest in the Province

Province 2 consists of two Eco-regions, Chure and Terai, which harbor tropical forest of Nepal in both Chure and Terai regions. These places are comparatively warmer than hill districts. Plant species which grow in Province 2, generally need hot temperature and high moisture in soil. Therefore, the forests in Province 2 is tropical. It predominantly composed of Sal (*Shorea robusta*), followed by *Terminalia-Anogeissus* and *Acacia catechu*and*Dalbergia sissoo* forest along stream banks and river beds. The other species generally grown there are h*aldu, harro, barro, simal, kadam, jamun, kusum,* etc. In State 2 or Terai region, growth rate of these species is higher in comparison to mountainous species. Species like *sal, asna, kadam* etc are good construction timber. *Sisoo* is very good for furniture and *khayar* fletches high cost due to kattha content in wood, which is main ingredient of *panparag*. Most of above tree species are also good as firewood. Stems and big branches of these species are used as timber. Small branches below size of timber are used as firewood. Volume or weight of these tree biomass are estimated as potential firewood production of Province 2. Total forest area outside protected area is 202179 ha which accounts 21.1%. Highest forest area lies in Bara district.

Forest resources are significant for ecosystem balance and people's livelihood of Nepal. Reliable and up-to-date information on forest resources is essential for supporting policy formulation, strategic planning, and sustainable forest management. Such information can ultimately guide in wise decision-making aiming at supporting in livelihoods, sustainable development and poverty reduction as stipulated in major policy documents(GoN, 2014; GoN, 2015; NPC, 2013). Further, reliable forest statistics are essential for several international reporting obligations and initiatives such as the Global Forest Resource Assessment, Sustainable Development Goals, the Millennium Development Goals, United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD), Convention on Biological Diversity (CBD), and United Nations Forum on Forests (UNFF).

6.1.3 Forest Management in Province 2

Parsa National Park is the only protected area in the province, which is managed for biodiversity conservation. All remaining forests are managed for production which include timber, fuelwood and non-timber forest products. Most prominent forest management type in Province 2 current are Collaborative Forest Management, block forest management and community forest management.

Area of forests in Province 2 under community forest management is given in Table 5-1. The table shows that 77,640 ha area is handed over to 512 forest user groups (UG)(DoF, 2019). This figure is very low as compared to community forests area handed over in hill districts. In addition, trees outside forests are also very important for Terai, especially for southern villages, which are from forests.

Table 6.1: Community Forests and Areas in Province 2

SN	Districts	No of UG	Area Managed ha
1	Saptari	132	17,940
2	Siraha	102	14,662
3	Dhanusa	40	8,856
4	Mahotari	74	7,557
5	Sarlahi	77	13,260
6	Rauthat	43	7,256
7	Bara	40	8,102
8	Parsa	4	7.5
		512	**77,640**

6.1.4 Wood as Fuel

Biomass, the total of non-fossil organic material derived from biological sources, is the most important source of renewable energy in the world(Lauri, et al., 2014). It accounts for 35 % of primary energy consumption in developing countries and 14 % of the final energy consumption, globally(Parikka, 2004; Demirbas, et al., 2009; Panwar, et al., 2011). Fuel wood is the main source of energy in rural Nepal. Fuelwood accounted for 70% and biomass for 92% of Nepal's total energy consumption. The main use of Nepal’s forests is to provide biomass to satisfy the needs of domestic fuel. Fuelwood is used for several purposes like cooking, heating, lighting etc. Historically, Nepal’s rural populations have been meeting the energy needs from the traditional sources liked fuel-wood and other bio-mass resources(AEPC, 2000). Most of the fuel wood has been reported to be derived from forests with some tree outside forest and tree growing on homeland and agricultural areas. Forests provide about 81 % of the total fuel requirements of Nepal. However, the average annual production of fuelwood constitutes only 31 % of demand. Agricultural residues contribute about 51 % and cattle dung account for the rest (18 %)(WECS, 1997). Following its national policy, Nepal gives emphasis to alternative and other renewable energy sources that aim at reducing dependence on forest products and animal dung(FAO, 2019). The demand for fuelwood in the country has rapidly increased due to population growth and has resulted tremendous pressure on existing forests. Local community bring hundreds of cycles loaded of fuel wood to their villages from forests in Terai districts. The demand for fuel wood will continue to increase significantly due to population increase in Terai.

6.1.5 Effect of Fuelwood Collection to Forest

In past decades, because of the increasing population, the area under agriculture expanded and forest shrunk. The forest area in the Terai is declined by 16,500 ha in the years from 2001 to 2010 and by 32,000 ha in the 19 years from 1991 to 2010. The annual rate of decrease in forest cover was 0.44% during the last nine years from 2001 to 2010 and was 0.40% during the last 19 years from 1991 to 2010/11. The annual rate of deforestation in all 20 Terai districts was 0.06%, excluding protected area(FRA/DFRS, 2014). In Province 2 also the land under cultivation increased at cost of forest land. On the other hand, due to poverty, the demand for fuelwood increased in spite of the rapid growth in the commercial energy sector in the Terai region, because the fuelwood is practically free if people afford time for collection. Large quantity of fuelwood is being collected from community managed and government managed forest by the local people.

In present context, forests and forest conditions in different districts of Province 2 are as given in Table 5-2.

Table 6.2: Forest Area and Actual Fuelwood Produced

	Terai area inha	Churia area inha	Total area inha	Per ha Vol in cubic m with branch	Growing stock in forests in m cum	Fuel wood produced in chatta
Saptari	3,584	30,595	34,179	96.42	1,949,899	85
Siraha)	3,307	2,4400	27,707	37.61	781,364	50
Dhanusa	27,218	380	27,598	29.2	805,861	8,803
Mahottari	12,009	10,050	22,059	37.61	829,639	102
Sarlahi	13,868	15,494	29,736	148	4,400,928	621
Rautahat	22,063	7,337	29,400	112.49	3,307,206	342
Bara	34,426	14,731	49,152	156.27	6,404,739	150
Parsa	77,124	0	77,124	220	2,227,630	383

(DFO Bara, 2074; DFO Dhanusa, 2075; DFO Parsa, 2069; DFO Rauthat, 2074; DFO Saptari, 2075; DFO Siraha, 2075)

Note: A chatta is length 20 ft, height 5 ft, width 5 ft.

6.1.6 National Demand and Supply Situation

Assessing true state of fuelwood resources in Nepal is a difficult task because forest use is diverse and an integral part of the subsistence economy(Thompson & Warburton, 1985). The government of Nepal is the predominant supplier of wood products in Nepal. The supply of fuel wood was estimated at 2.58 million tons, 5.44 million tons and 0.94 million tons for Terai, hills and mountains respectively in 2011.The supply would increase to 3.72 million tons, 6.96 million tons and 1.13 million tons in 2020 and 5.07 million tons, 9.60 million tons and 1.51 million tons in 2030 for Terai, hills and mountains respectively. Mathematically fuelwood demand is function of households, their fuelwood uses and per capita consumption.:

Fuel Demand=f (No. of HH, % using fuel wood, per capita consumption)(MFSC, 2013)

6.1.6.1 Fuelwood from Community Based Forests

Most of the forest product in Province 2 come either from community forests or collaborative forests or private forests. There government forests are mostly over matured and degraded. Therefore, these forests have small growing stock ranging from 37.6 cu m /ha in Siraha to 220 cu m /ha in Collaborative forests of Parsa. In the pasts, although forest management plans are made, forests are not managed on sustained basis. Felling of trees in government forests are often limited to the clearing of site for different projects like road, resettlement of villagers, transmission lines, irrigation channels, industrial states etc. Lately, managements are initiated in community forests and collaborative forests as pilot programmes. Results of these forest management are highly positive, therefore, in future managed forest area will be increased and this will produce more forests products like timber and fuelwood.

For example, community Forests in Siraha, there are 102 Cfs, which comprise 15001 ha. Out of this area, production forests are 8251 ha, which has growing stock 37.61 cu m per ha and total of CF is 310320 cu m. Similarly, in Saptari, community forests are main source of fuelwood for the communities in north of East west high way, whereas communities in south of the high way depend more on scattered trees in private lands. Major amount of firewood is expected to come from private forests, because, they go on cutting followed by planting. As firewood is cheap source of Energy, there is high demand from people. But, in absence of firewood, where there are no forests, poor people are compelled to use LPG and Kerosene.

As clearing of forests depends upon sites to be converted for non-forestry purposes, annual data on firewood production in different districts do not match with forests area and these figures stand in its own (Table 6.3).

Table 6.3: Forest Area and Potential Fuelwood Production

	Area, ha	Production Forest Area, ha	Fuelwood Production/year inm^3	Fuelwood Production/year in kilo ton
Parsa	140,648	17,224	57,597	40.98
Bara	127,261	46,132	51,317	109.78
Rautahat	103,655	26,078	76,464	62.05
Sarlahi	126,463	25,562	62,792	60.83
Mahottari	100,136	22,059	72,763	52.49
Dhanusa	118,965	26,862	74,232	63.92
Siraha	114,957	18,028	131,316	42.90
Saptari	128,649	20,234	49,029	48.15
Total			575,511	481.127

Thus, annual firewood increment from whole Province 2 is 575,511 m^3(This is harvestable quantity). This volume accounts for 11 categories, 10 defined species and 1 other (miscellaneous). And to classify timber production as per each species, proportion of stem volume of each species is multiplied to the 575,511 m^3. Thus, obtained value is converted to the kilogram and or tone using wood density (average 1 m^3 =836 kg) and totaled to final wood to 481127 tons or 481.12 kilo tons.

6.1.7 Fuel wood from Tress Outside Forests

Like in other parts of Nepal, trees outside forests (ToF) are also important source of firewood in Province 2, because most of the farmer plant trees to fulfill their demand of forage and fuelwood. As production of food is major objective and the trees are scattered, growing stock of trees are low as compared to that of forests. A study is done in Nawalparasi district which shows the stem volume of 3.3 cubic meter per hectare. Assuming that same volume of tree bio mass exists in the districts of Province 2, when multiplied by agriculture area in the district, one can estimate of stem volume in ToF in Province 2. As rotation of trees in agriculture land will be less and assuming 10-year rotation or harvesting 10 % of stem volume, Table 6.4 provides estimates of fuel wood from ToF in Province 2.

Table 6.4: Estimation of Fuelwood from ToF

	Agri area in ha	Stem volume inm^3	Annual yield inm^3	Ann yield or firewood in "000" tons
Saptari	94,397	311,510	31,151	26.04
Siraha	94,268	311,084	31,108	26
Dhanusa	83,617	275,936	27,593	23.06
Mahottari	70,897	233,960	23,396	19.55
Sarlahi	100,624	332,059	33,205	27.76
Rautahat	78,805	260,056	26,005	21.74
Bara	78,480	258,984	25,898	21.65
Parsa	63,342	209,028	20,902	17.47
Total	**664,430**	**2,192,619**	**21,926**	**183.30**

(Source: Open Nepal: Odp Geography: District wise Land use pattern.(opennepal, 2001)

Output from trees outside forests could be increased, but as production of agriculture products are main target there, here production of same amount of fuelwood is taken in future also. Therefore, when figures in Table 3 and 4 above are added they show potential production at present or base year is 684.42 kilo ton (183.3+481.12). If sustainable forest management is practiced it will increase to 815 kilo ton (632+183) in Year 2032 and 949 kilo ton (766 +183) in Year 2040.

6.2 Biogas in Province 2

Animal in the province

From perspectives of emission of greenhouse gases (GHG), biogas production from animal dung is very important. First it will stop methane to go to atmosphere as GHG. Second it will save use of other fuel which could have been used in absence of biogas. The gas is produced from animal dung.

In this context, number of animals in different districts of Province 2 can be gathered in Table 6.5.

Table 6.5: Numbers of Animals in Province2

	Cattle	Buffaloes	Sheep	Goat	Pigs	Fowl	Duck
Saptari	232,100	183,943	2,715	197,086	21,898	1,049,998	23,000
Siraha	89,567	92,340	1,132	125,334	5,567	849,878	9,876
Dhanusa	139,854	65,884	652	225,187	5,998	578,052	8,867
Mahotari	124,234	71,508	645	200,939	13,306	337,067	6,075
Sarlahi	185,965	85,564	1,192	222,518	8,765	243,157	9,000
Rauthat	118,437	80,334	920	180,885	8,567	232,998	7,834
Bara	132,878	150,567	335	285,349	21,176	367,009	10,443
Parsa	77,865	49,907	145	116,142	10,050	645,691	78,767
Total	**1,100,900**	**780,047**	**7,736**	**1,553,440**	**95,327**	**4,303,850**	**82,962**

Source:(MoAL, 2019)(MoAL, 2018)(PDCCD, 2019)

In socio-cultural context of Nepal, dung of sheep, goat and pigs are not collected for energy. The reason could be that these animals are not put in shade but grazed in forests and other communal lands. These results spread of dung in bigger geographic area and makes its collection very difficult. Production of dung is 10 kg/day from cattle and 15 kg per day from buffalo(WECS, 2010).

Table 6.6: Dung Production in Province 2

	Cattle	Buffaloes	Dung produced from cattle kg/ year	Dung produced from buffalo kg/ year	Total dung production kg/Year
Saptari	232,100	183,943	847,165,000	1,007,087,925	1,854,252,925
Siraha	89,567	92,340	326,919,550	505,5s61,500	832,481,050
Dhanusa	139,854	65,884	510,467,100	360,714,900	871,182,000
Mahotari	124,234	71,508	453,454,100	391,506,300	844,960,400
Sarlahi	185,965	85,564	678,772,250	468,462,900	1,147,235,150
Rauthat	118,437	80,334	432,295,050	439,828,685	872,123,735
Bara	132,878	150,567	485,004,700	824,354,325	1,309,359,025
Parsa	77,865	49,907	284,207,250	273,240,825	557,448,075
Total	**1,100,900**	**780,047**	**4,018,285,000**	**4,270,757,360**	**8,289,042,360**

6.2.1 Potential of Biogas Production Per Year

In order to estimate potential biogas in Province 2, lets us growth rate of cattle and buffalo in the district of province. Table 6.7 below provides number of livestock in past years.

Table 6.7:Livestock Numbers in Past Years

Year	Cattle	Buffalo	Total
2008/09	7,175,198	4,680,486	11,855,684
2009/10	7,199,260	4,836,984	12,036,244
2010/11	7,226,050	4,993,650	12,219,700
2011/12	7,244,944	5,133,139	12,378,083
2012/13	7,274,020	5,241,873	12,515,893
2013/14	7,243,916	5,178,612	12,422,528
2014/15	7,241,743	5,167,737	12,409,480
2015/16	7,302,808	5,168,809	12,471,617
2016/17	7,347,487	5,177,998	12,525,485
2017/18	7,376,306	5,277,819	12,654,125

Above table shows average annual rate of increase of livestock is about 0.35 %.

Considering bio gas production factor as 0.036 cubic meter per kg of dung(WECS, 2010), its district wise production potential in cubic meter for the year 2017/2018 is shown in Table 6-8. Per cubic meter of biogas is further converted into calorific value of 20 MJ per cubic meter(Vaid & Garg, 2013).

Table 6.8: Potential of Biogas

	Total dung production kg/Year	Biogas in cubic meter	Energy production in MJ/ Year	Energy in "000" Gj per year
Saptari	1,854,252,925	66,753,105	1,335,062,106	1,335
Siraha	832,481,050	29,969,318	599,386,356	599
Dhanusa	871,182,000	31,362,552	627,251,040	627
Mahottari	844,960,400	30,418,574	608,371,488	608
Sarlahi	1,147,235,150	41,300,465	826,009,308	826
Rautahat	872,123,735	31,396,455	627,929,089	628
Bara	1,309,359,025	47,136,925	942,738,498	943
Parsa	557,448,075	20,068,131	401,362,614	401
Total	**8,289,042,360**	**298,405,525**	**5,968,110,499**	**5,968**

Above figure is maximum potentials of producing energy from dung from biogas plants. Beauty of the biogas is even after producing energy or the gas, slurry left can be used as fertilizer.

On other hand, dung from cow and buffalo is also used as dung cake or dung sticks in terai. When we consider making fuel from dung by local communities, potential of biogas production will decrease. For poor people, who cannot afford to buy LPG or electricity or kerosene, use of either dung or agri- waste or fuelwood will be still means to cook food in many villages of province 2.

6.3 Energy from Agriculture Residues

Agriculture waste is also main source of fuel, because it is already available at home during harvest of agriculture crops. Total source of agriculture residue and energy produced by these wastes are shown in Table 6.9. Total potential energy produced from such waste is 67,208 TJ. More than half of this energy come from paddy straw and about 28 % come from sugar cane.

Table 6.9:Energy from Agriculture Waste

Crop type	Area in ha	Total residue in ton	Energy in GJ	Percentage
Paddy	382,137	2,254,608	33,819,124	50.32
Maize	52,026	283,542	4,253,125	6.33
Wheat	171,863	579,178	8,687,675	13
Sugarcane	53,123	1,277,608	19,164,122	28.51
Oil seed	44,403	56,836	852,538	1.27
Millet	1,711	3,251	48,763	0.07
Jute	7,607	25,331	379,970	0.56
Barley	150	225	3,375	05
Total	**713,020**	**4,480,579**	**67,208,692**	**100**

6.4 Petroleum Products

There is no source of feasible petroleum products anywhere in Nepal. All the petroleum consumed in the country is imported from India. The only company that deals with import and sales of petroleum products – that include diesel, petrol, kerosene and LPG. The furnace oils and other oil residues are imported by the industries themselves. Thus, the supply of petroleum products is obtained from regional offices of Nepal Oil Corporation. District wise sales data for 2075-76is as shown in

Table 6.10. All the units for MS, Diesel and SKO are in liters except for LPG in metric ton (MT). These sales data represent the sales to depots at each district. However, it is to be noted that neither the sales from these depots are bound within the district only nor the supply in each district is bound by the capacity of depots only – there are inter-boundary trade and transportation of petroleum fuels. Hence, the supply of petroleum products and their consumptions may not tally properly.

Table 6.10: Petroleum Sales in 2075-76 in Province 2

Districts	MS	Diesel	SKO	LPG
	kL	kL	kL	tons
Bara	13,113	93,779	755	482
Dhanusha	15,832	44,541	1,982	152
Mahottari	7,588	19,094	84	
Parsa	14,077	46,702	864	181
Rautahat	9,480	23,829	287	
Saptari	8,654	19,477	567	
Sarlahi	10,644	28,708	239	
Siraha	11,565	26,392	332	
	90,956	302,524	5,114	815

(Source: NOC 2020)

6.5 Electricity

There is no sizeable hydropower potential in province 2. All the electricity through national grid must be brought from other provinces. The only indigenous source of electricity could be the decentralized genets that are used by industries – of which reliable data re not available and all of the electricity produced is used within the industry. Thus, the main source of electricity is via national grid distributed by Nepal Electricity Authority. The district wise electricity supply status as obtained from Nepal Electricity Authority for province 2 is as shown in figure. It shows Bara and Para has comparatively high consumption of electricity due mainly to the numbers of industries located in the districts.

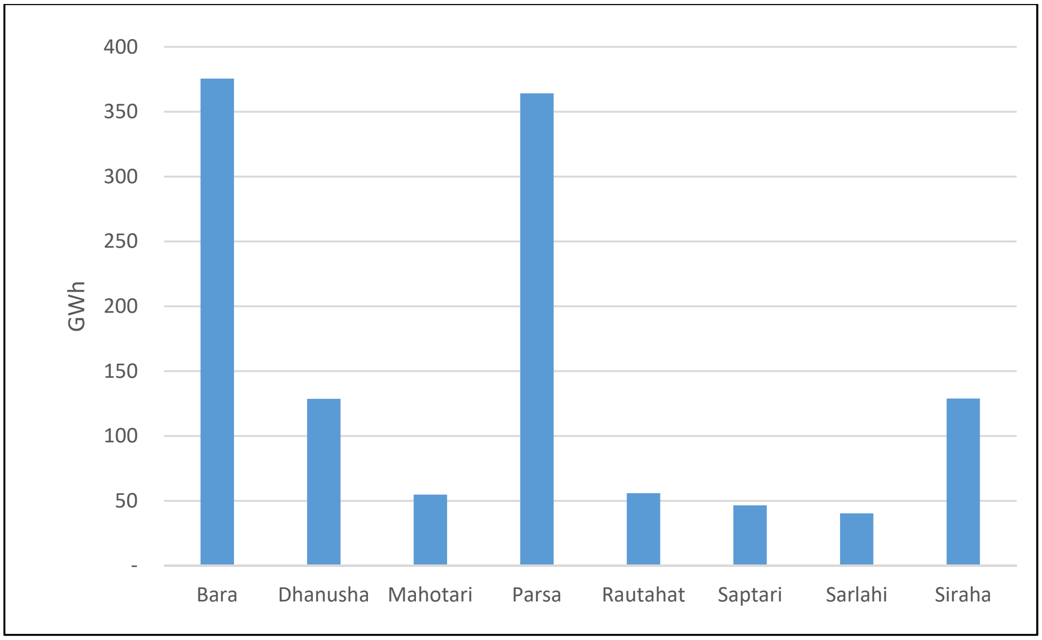


Figure 6.2: Electricity Consumption in Province 2(NEA, 2019)

As per NEA domestic consumption data, the electricity connection as per ampere capacity of households who have electricity is as shown in Figure 6.3. It shows that over 98% of the households lies within minimal amperage capacity of 5A, 1% are connected with 6-15A connection. Less than 1% have electricity connection above 16A. In province 2, 80% of household have access to electricity (NEA, 2019).

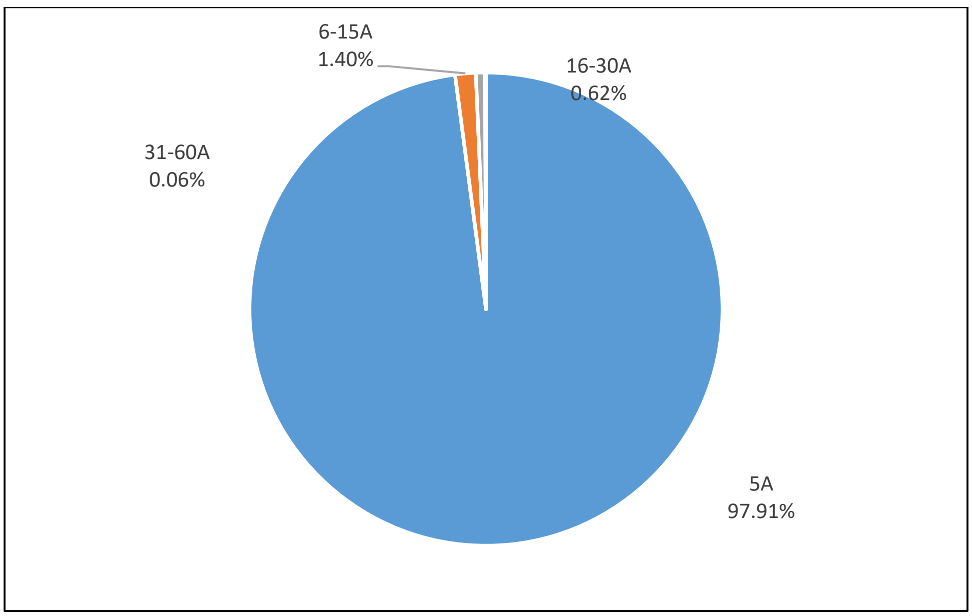


Figure 6.3:Mix of Ampere Capacity of Households with Electricity Access (NEA, 2075)

6.6 Modern Renewable Energy Sources- Solar & Other Renewables

Modern Renewable energy sources includes wind, biogas, solar, micro hydro and other renewables. Alternative Energy and Promotion Centre (AEPC) is the leading organization working in the promotion of renewable energy in Nepal. The modern energy access is gradually increasing in Nepal with the current status of electricity access from renewables reaching 25% population. There has been a contribution of 32MW of electricity from mini and micro hydro schemes, 15 MWp from solar PV system and around 20 kW from wind energy. More than 1.5 million households have been benefited from different renewable energy sources for cooking, lighting and productive end uses(MoPE, 2016).

According to AEPC, the number of installed plants for solar home system (SHS), small solar home system (SSHS), Mud Improved Cook stoves (MUDICS), domestic biogas and Institutional solar PV system (ISPS) in province 2 is as shown in Table 6.11: Approximately 190 kWp from SHS, 123 kWp from SSHS and 184 kWp form ISPS have been installed in Province 2. In addition to these, solar photovoltaic pumping system (SPVPS) has gained much popularity amongst farmers. Thera are total of 498 SPVPS units, ranging from capacity of 500 Wp to 3.5 kWp. Most of the biogas plants are sized 4 cubic meter in the province. Due to low land of the region, there is no micro hydro plants installed in province 2.

Table 6.11: Number of Modern Renewable Technologies Installed in Province 2 (AEPC, 2019)

District	SHS	SSHS	SPVPS	MUD ICS	Domestic biogas	ISPS
Bara	1,057	0	28	0	4,289	7
Dhanusha	147	21	15	9,501	820	30
Mahottari	463	679	6	3,424	1,803	9
Parsa	30	0	63	0	929	1
Rautahat	2,794	778	205	840	1,829	12
Saptari	1,176	187	44	2,008	688	5
Sarlahi	6,878	765	116	183	3,131	27
Siraha	140	44	21	4,556	626	12
Grand Total	12,685	2,474	498	20,512	14,115	103

6.7 Energy Production at Household Level

In residential sector, the households also have their own primary energy sources such as that from own tree farm, agricultural activities and livestock and animal husbandry. Table 6.12 depicts the average energy production at household level based on the only samples which have the respective sources of energy. This indicates that, in province 2, residential sector is majorly dependent on external sources for wood, while use of animal waste is higher in residential sector itself for internal use as discussed in section 7.4.

Table 6.12 Energy Production at Household Level

	tons per annum
Fuelwood	2.12
Animal Waste	13.79
Agricultural Waste	6.68

(From survey, 2019)

7 Energy Consumption in 2019

The total energy consumption in 6 economic sectors in province 2 in 2019 is summed to about 63 PJ (Table 6-1). Although the residential sector still dominates the sectoral energy consumption and wood and biomass dominated the energy source type, change in energy mix can be observed as compared to previous studies at national and regional levels (Figure 7.1 and Figure 7.3). Nearly 62% of the total energy consumption is in residential sector while about 64% of the energy comes from conventional renewables. The driving factor behind this change in energy pattern is seemingly due to energy transition and energy efficiency improvement, as indicated by IEA (2018) in developing countries.

Fuelwood is still the main source of energy in residential sector, while commercial sector thrives on use of electricity. The transport, industry and agricultural sectors still shows huge dependency on fossil fuels. However, a shift from diesel power water pumping system to solar powered can be seen in agricultural sector.

The energy mix in province two shows dominance of traditional renewable (biomass) (Figure 7.1). However, the share of wood in total biomass seems lower than previous reference results, as the province is very much active in agricultural activities, thus having abundance of agricultural residue and animal wastes. The share of LPG is nearly equal to share of electricity, thus indicating the raise in dependence on imported fuel.

Comparing this result to the national level fuel wise share of year 2011/12, we see that the share of fuelwood consumption in almost half in Province 2, while that of petroleum is as twice as in 2011/12 at national level. In addition to that, the share of coal is also very high at 10.5% - more than 2 times than that of national share, and that of electricity is nearly thrice as much at 8.9%. The main reason behind this is the huge economic activities in industries and commercial sector in this province.

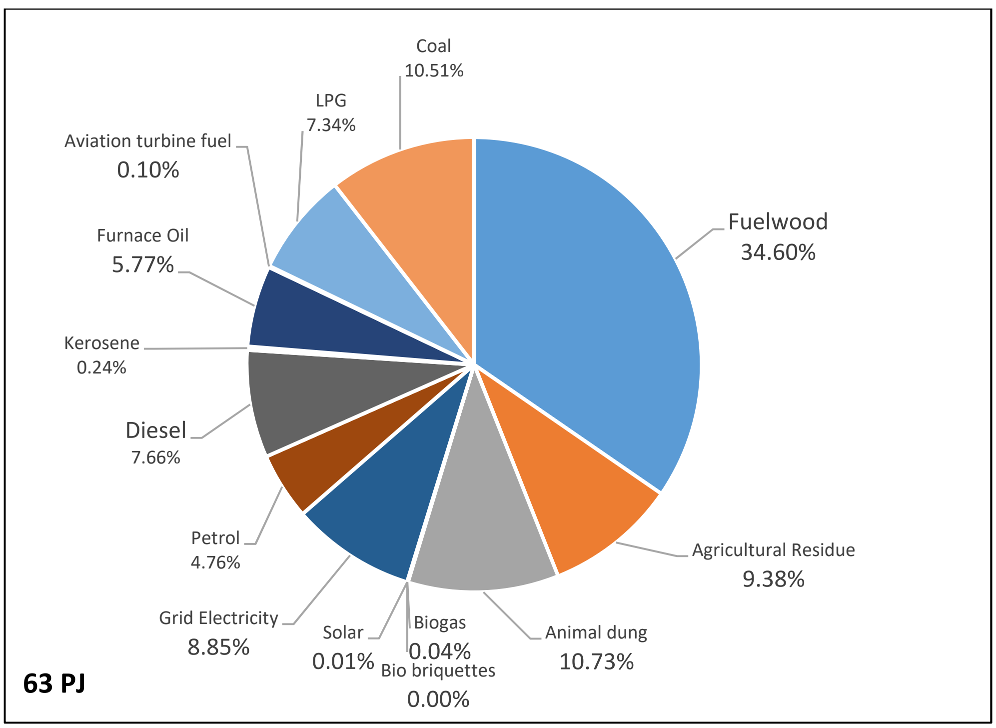


Figure 7.1: Energy Consumption Share in Province 2 by Energy Types

The energy consumption by its energy types is further grouped into traditional biomass, modern biomass, new renewables, and non-renewables as shown in Figure 7.2. It shows that consumption of traditional biomass (fuel wood, animal dung and animal waste) and non-renewables (petrol, diesel, kerosene, aviation, furnace oil and coal) is high in Province 2 contributing 55% and 36% each respectively. The contribution of new renewables which is mostly electricity and few solar is 9% in the province. The share of modern biomass (biogas and bio-briquettes) is less than 0.1%.

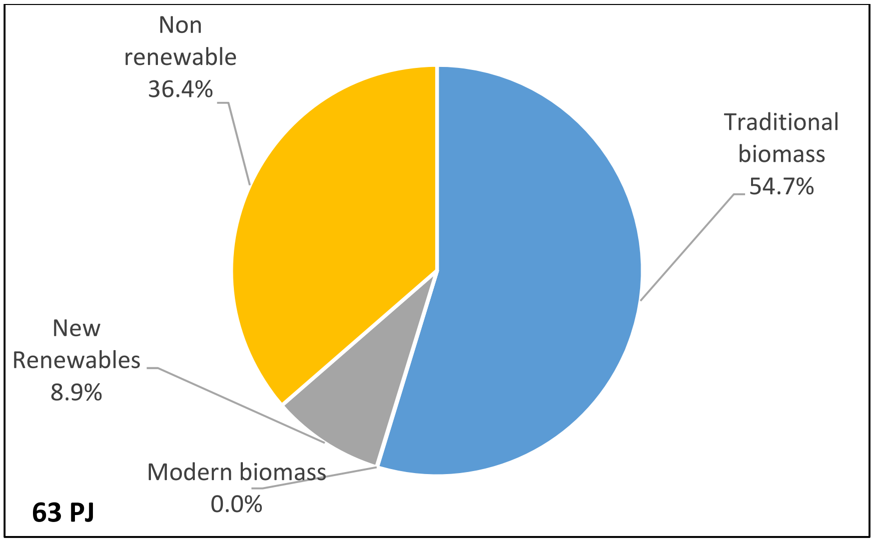


Figure 7.2: Energy Consumption Share in Province 2 by Fuel Group

Sector wise, the residential sector is still prevalent in terms of energy consumption with nearly 62% consumption out of total final energy. However due to massive industrial and commercial activities in this province, the energy share in residential sector comes to be lower than the share at national average. Comparing this result to the national level sectoral share of year 2011/12, we see that the share of residential energy consumption is lower by 20% Province 2, while that for industry is nearly 3 times as much. The main reason behind this is the presence of large number of industries in this province. The impact of economic activity is also seen in transport sector with share taking 9.2% in provincial level as compared to 7% in national level.

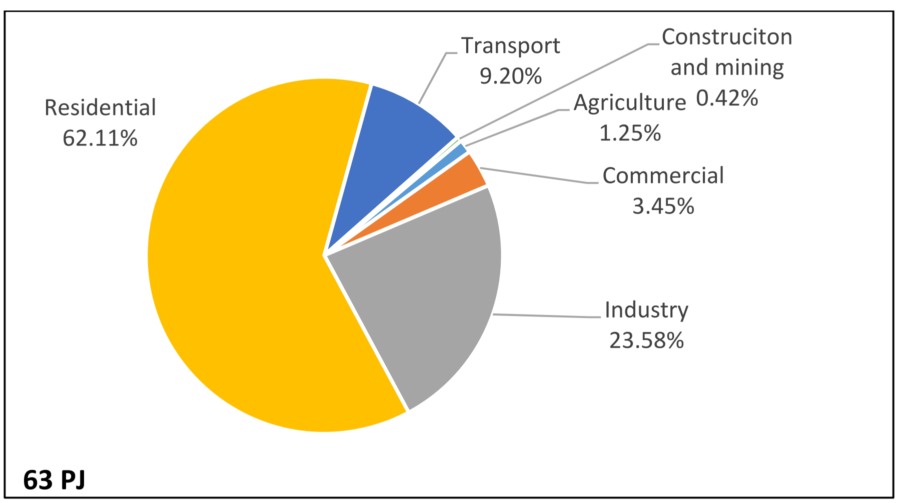


Figure 7.3: Energy Consumption Share in Province 2 by Sectors

The district level average energy consumptions in 2019 are given in the following tables in the main text body whereas other statistical pieces of information are provided in the Annex IV.

Table 7.1: Energy Consumption in Province 2 by Sector and Fuel Type (TJ)

	Renewables							Nonrenewable							Total
	Conventional renewable					New Renewables									
	Traditional biomass			Modern biomass											
	Fuelwood	Agricultural Residue	Animal dung	Biogas	Bio briquettes	Solar PV	Grid Electricity	Petrol	Diesel	Kerosene	Furnace Oil	Aviation turbine fuel	LPG	Coal	
Agriculture	-	-	-	-		0.30	0.16	26	764	-	-	-	-	-	790
Commercial	3.59	-	-	0.22		-	1,869	-	-	-	-	-	305	-	2,178
Industry	975	824	-	-		-	1,511	-	1,254	-	3,645	-	59	6,632	14,900
Residential	20,880	5,101	6,777	27.99	20.84	7.45	2,057	-	-	151	-	-	4,220	5.56	39,248
Transport	-	-	-	-		-	129	2,984	2,638	-	-	62	-	-	5,812
Construction and mining	-	-	-	-		-	23	-	187	4	-	-	54	-	267
Total	21,859	5,925	6,777	28		8	5,588	3,009	4,842	155	3,645	62	4,638	6,638	63,174

Figure 7.4 graphically represents the energy flow from supply to demand. The diagram evidently shows that highest portion of supply is from biomass – wood, agricultural and animal wastes and large portion of these goes to residential sector. While in demand side, residential sector tales a large chunk of energy – of which biomass is the largest source, while industry is largely dependent on coal and petroleum products. Meanwhile, agriculture sector seems to be replying on non-machinery power like animals and human.

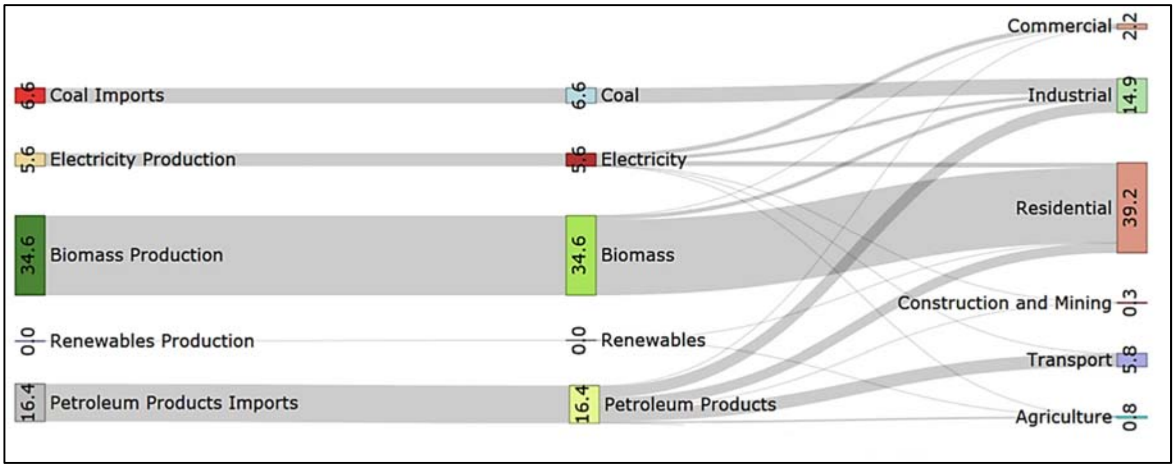


Figure 7.4: Sankey Diagram for Flow of Energy in Province 2 (PJ)

Table 7.2 shows the energy consumption indicators which highlight the status of energy consumption in Province 2. The total final energy consumption per capita of 10.4 GJ is lower than previous national average. This can mainly be attributed to the change in energy mix and transition to modern energy types as explained earlier. The electricity consumption per capita also comes to be higher than national average of 225 kWh (NEA, 2019; CBS, 2014). As per NEA, the national average per capita electricity generation is 264 KWh. This is mainly due to higher electricity consumption by commercial and industrial sectors. The residential electricity consumption per household lies in tier-3 of multi-tier framework and is way behind the tier-5 level of 3,000 kWh (World Bank/ESMAP, 2019).

Table 7.2: Energy Consumption Indicators

Parameter	Value	Unit (per annum)
Energy per capita	10.41	GJ per capita
Energy per GVA	174	GJ per million NRs
Share of conventional renewable energy in total	63.6%	
Share of modern and new renewable energy	8.9%	
Electricity Consumption (Total)	256	kWh per capita
Electricity Consumption (Residential)	629	kWh per HH

7.1 Agriculture Sector

The agriculture sector in Province 2 consumed 790 TJ energy for agriculture activity(Table 7.3). The energy consumption pattern shows highest amount of diesel used in machineries, primarily for water pumping. However, with accessibility of solar pumping technology, the use of solar pumping system has also boosted. The other farm machineries still prevail in use of diesel in 2019. 97% of the total energy is form diesel, followed by 3% by petrol. Meanwhile, 45% of energy is used for water pumping solely followed by farm machineries.

Table 7.3: Energy Consumption in Agriculture Sector in Province 2 (TJ)

	Water pumping	Tilling	Threshing	
Petrol	26	-	-	26
Diesel	326	301	136	764
Electricity	0.05	0.00	0.11	0.16
Solar PV[3]	0.30	-	-	0.30
	651	**301**	**137**	**790**

Energy mix in agriculture sector is as shown in **Figure 7.5.** It shows that diesel is the most dominating source of fuel in agriculture sector. Diesel operated water pumps for irrigation and tilling machines contributed huge consumption of diesel in the sector. Electricity and solar PV are consumed in less than 0.1% in the sector.

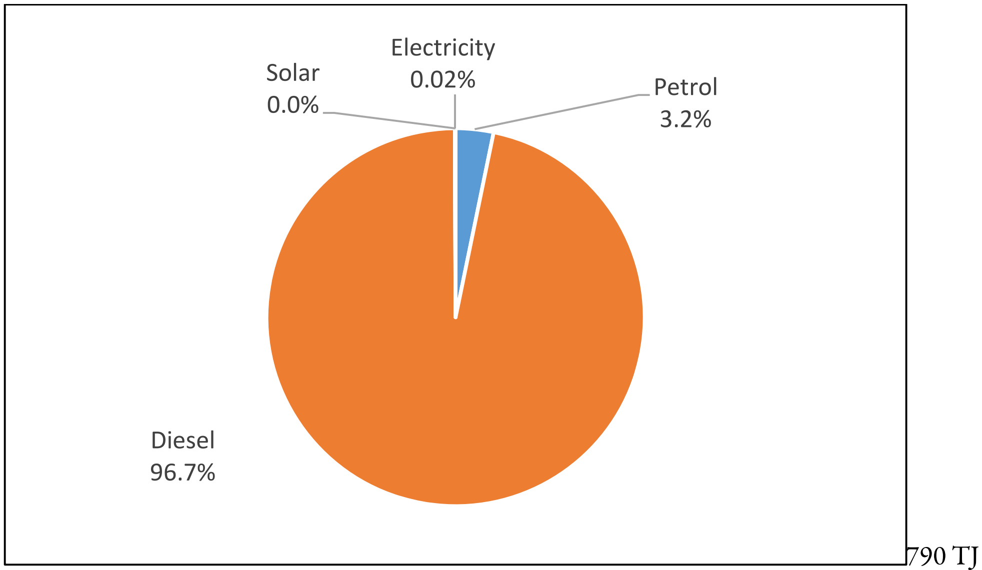


Figure 7.5 :Energy Mix in Agriculture Sector in Province 2

In large farmlands, the similar pattern follows the total energy mix (Table 7.4). Highest amount of energy we used for water pumping with the share of 57%. In energy mix, the diesel prevails the use of other sources of energy (excluding solar).

Table 7.4: Energy Consumption in Agriculture Sector – Large Farmland in Province 2 (TJ)

	Water pumping	Tilling	Threshing	
Petrol	0.24	-	-	0.24
Diesel	78	46	14	138
Electricity	0.01	0.00	-	0.01
	78	**46**	**14**	**138**

The total energy in medium farmland is higher than large owing to the facts that share of medium farms are higher. It consumed nearly 40% of the total energy consumption in agriculture sector in province 2 (Table 7.5). Here also, the highest energy consumption is in water pumping (55%) and including farm machineries, the primary source of energy is diesel (94%).

[3] The energy for solar water pumping were derived from data acquired from AEPC which does not show the size of farm, thus is included in total demand only henceforth.

Table 7.5: Energy Consumption in Agriculture Sector – Medium Farmland in Province 2 (TJ)

	Water pumping	Tilling	Threshing	
Petrol	25	-	-	25
Diesel	211	135	58	404
Electricity	0.01	-	0.01	0.01
	236	**135**	**58**	**429**

In small farmlands, however, the energy mix is quite different. Although the major energy source is diesel at nearly 100%, but the major energy us used for farm machineries – tillage (54%) and threshing (29%). The energy consumption is about 20% of the total energy consumption in agriculture sector in province 2 (Table 7.6).

Table 7.6: Energy Consumption in Agriculture Sector – Small Farmland in Province 2 (TJ)

	Water pumping	Tilling	Threshing	
Petrol	-	-	-	-
Diesel	37	120	64	222
Electricity	0.04	-	0.10	0.14
	37	**120**	**64**	**222**

Table 7.7gives the energy consumption for each district by end use in agricultural sector of province 2. The overall scenario indicates that majority of energy is used for water pumping, the highest amount of total energy consumption was in Dhanusa and Parsa followed by other districts. The accessibility of the pumping systems and farm machineries has main effect on energy consumption.

Table 7.7: District Wise Energy Consumption by End Use in Agriculture Sector of Province 2 (TJ)

District	Water pumping	Tilling	Threshing	Total
Bara	8.21	35.04	14.19	57.45
Dhanusa	145.55	28.36	19.68	193.60
Mahottari	42.25	15.82	3.84	61.91
Parsa	42.53	56.27	29.66	128.46
Rautahat	17.49	53.65	28.95	100.09
Saptari	25.74	6.13	9.96	41.84
Sarlahi	47.34	57.64	15.64	120.62
Siraha	23.23	47.78	14.62	85.63
	352.34	**300.71**	**136.54**	**789.59**

Table 7.8 gives the energy consumption for each district by the fuel type in agricultural sector of province 2. The table indicates that the agricultural sector in all district is predominantly dependent upon petroleum fuels – primarily diesel. The growing trend of solar is a positive sign in this sector.

Table 7.8: District Wise Energy Consumption by Fuel Type in Agriculture Sector of Province 2 (TJ)

District	Petrol	Diesel	Electricity	Solar PV pumping system	
Bara	0.24	57.20	-	0.01	**57.45**
Dhanusa	-	193.58	0.01	0.00	**193.60**
Mahottari	25.27	36.64	0.00	0.00	**61.91**
Parsa	-	128.27	0.14	0.05	**128.46**
Rautahat	-	100.02	0.00	0.07	**100.09**
Saptari	-	41.77	0.00	0.06	**41.84**
Sarlahi	-	120.54	0.00	0.08	**120.62**
Siraha	-	85.59	0.01	0.03	**85.63**
	25.52	**763.61**	**0.16**	**0.30**	**789.59**

In overall, the agricultural sector still consumptions on petroleum fuels. However, the shift to solar power is a positive indication clean and efficient indigenous use of energy. There is still opportunity for penetration of electric threshing machine and if possible, some electric tilling machines as well in coming future. The detailed district wise energy consumption in agricultural sector in province 2 is given in Annex IV.

7.2 Commercial sector

The commercial sector represents the major economic activity. Table 7.9 gives the energy consumption in commercial sector of province 2. It is seen that out of 2,178 TJ consumed by commercial sector, the majority is commercial sources of energy. The highest amount of energy used in commercial sector is electricity, by as much as 86% of total energy consumption, followed by LPG (14%). By end use, the highest amount of energy is consumed for electrical appliances (41%). Due to the province being hot region of the country, the next energy consuming end use is space cooling (34%). Cooking does not consume much energy as the only subsector that consumes energy massively in cooking is accommodation and food category. In 2011/12, the fuelwood was dominating energy resource followed by electricity in national context as well taking 48% and 40% shares respectively (WECS, 2013). Comparatively to national energy consumption pattern, share of wood is nominal in commercial sector in province 2 due to easy availability of LPG while restricted access to forest. The share of electricity is very high in province 2 – which is primarily due to use of cooling appliances in hot region of terai area.

Table 7.9: Energy Consumption in Commercial Sector in Province 2 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	
Wood	4	-	-	-	-	-	-	3.6
Coal	0.48	-	-	-	-	-	-	0.48
LPG	305	0.26	0.05	-	-	-	0.04	305
Electricity	15	1	25	733	205	889	-	1,869
Biogas	0	-	-	-	0.08	-	-	0.22
Solar thermal	-	0.00	-	-	-	-	-	0.00
	324	**0.9**	**25**	**733**	**205**	**889**	**0.0**	**2,178**

(Survey 2019)

Figure 7.6 show energy mix in 2019 in commercial sector. It indicates that wood, LPG and electricity are the dominating fuel source in this sector. Share of fuels like biogas, solar thermal, kerosene and briquettes is less than 0.01%.

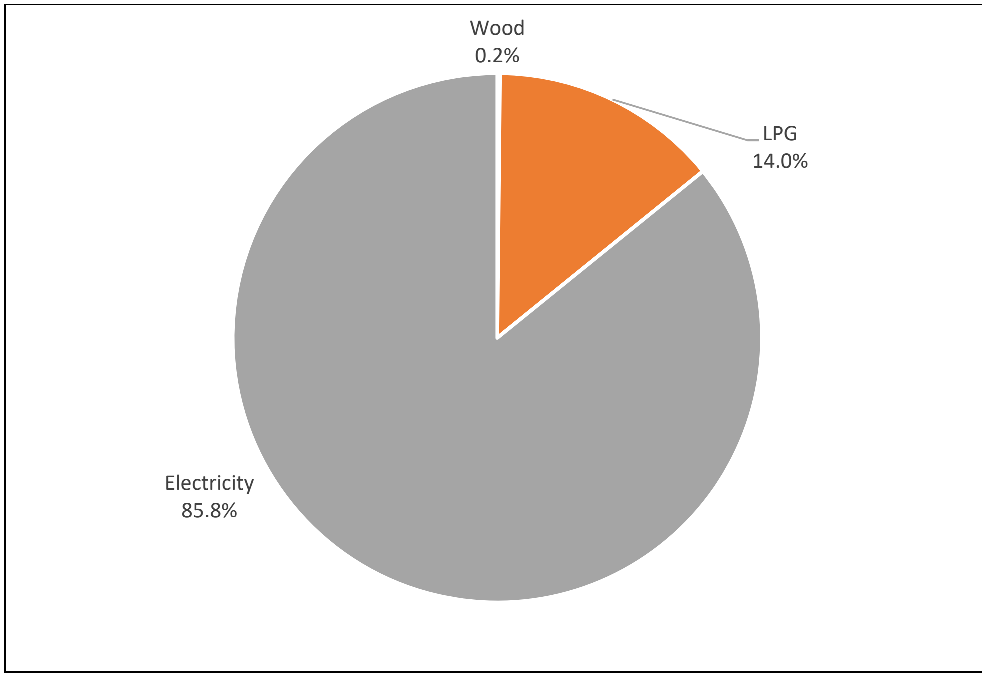


Figure 7.6:Energy Mix in Commercial Sectoring Province 2

Table 7.10 shows the energy mix in each subsector. It indicates that largest amount of energy is consumed in social service sector in province 2, owing to their highest value presence in economic activities. The consumption of electricity is high in energy sub sector except for accommodation and food where LPG dominates the energy mix.

Table 7.10: Energy Consumption for Each Subsector by Energy Types in Commercial Sector in Province 2 (TJ)

	Wood	Coal	LPG	Electricity	biogas	Solar thermal	
Trade and retails	1.84	-	30.51	432.35	0.14	-	465
Accommodation and food	0.07	0.48	128.12	83.61	0.00	0.00	212
Financial and real estate	-	-	17.82	308.04	0.04	-	326
Social services	1.68	-	110.40	682.88	0.03	-	795
Other services	-	-	18.01	361.96	0.01	-	380
	3.59	0.48	305	1,869	0.22	0.00	2,178

(Survey 2019)

Table 7.11 shows the energy mix by end use on each subsector of commercial sector in province 2. It shows that trade and retail is the highest electricity consumer, followed by social service sector and other services, while large amount of LPG is consumed in accommodation and food subsector and social services.

Table 7.11: Energy Consumption for Each Subsector by End Uses in Commercial Sector in Province 2 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	
Trade and retails	32	0.04	0.26	68	49	315	-	465
Accommodation and food	129	0.10	0.76	21	8.89	53	0.04	212
Financial and real estate	18	0.20	13	155	25	115	-	326
Social services	112	0	11	373	84	214	-	795
Other services	33	0.13	0.95	115	39	192	-	380
	324	**0.93**	**25**	**733**	**205**	**889**	**0.04**	**2,178**

(Survey 2019)

The energy intensities in commercial sector in province 1 is given in Table 7-12. It can be seen that, in Province 2, the most energy demanding sector is Accommodation and food. This subsector utilized high amount of energy for cooking purpose. Secondly, the office spaces is seen to be more energy intensive. This high energy intensity in service sector offices are basically for cooling purposes in hot terai region. The energy intensity in accommodation and food comes to 0.1 GJ per person, which is slightly less than that for developed countries like, USA and China, but is close to their range (SPL, 2019).

Table 7-12 Energy Intensities in Commercial Sector in Province 1.

	GJ per million NRs	GJ per person
Trade and retails	9.81	-
Accommodation and food	82.27	0.10
Financial and real estate	10.10	-
Social services	21.12	-
Other services	19.49	-

The district- wise energy mix in Table 7.13 by end use shows highest energy consumption in Dhanusa followed by Siraha, Rautahat and so on, accordingly. While in Bara and Mahottari, due to comparatively lower commercial activities than other districts, the energy consumption is also low.

Table 7.13: District Wise Energy Consumption by End Use in Commercial Sector of Province 2 (TJ)

District	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	
Bara	10	-	0.55	39	11	53	-	113
Dhanusha	153	0.08	0.74	173	24	83	-	434
Mahottari	13	0.09	4.52	36	17	50	0.04	120
Parsa	35	0.08	5.65	148	28	98	-	315
Rautahat	11	0.00	2.27	24	15	295	-	347
Saptari	15	0.11	0.00	63	23	136	-	237
Sarlahi	26	0.03	0.13	68	32	89	-	215
Siraha	62	0.54	12	183	56	85	-	398
	324	**0.93**	**25**	**733**	**205**	**889**	**0.04**	**2,178**

(Survey 2019)

Meanwhile, the Table 7.13 shows the district wise energy consumption by energy type. It indicates that Dhanusa has the highest consumption for LPG and electricity, while in other districts electricity consumption is highest.

Table 7.14: District Wise Energy Consumption by Fuel Type in Commercial Sector of Province 2 (TJ)

District	Wood	Coal	LPG	Electricity	biogas	Solar thermal	
Bara	1.8	-	8.3	103	-	-	113
Dhanusha	-	-	153	281	-	-	434
Mahottari	1.7	-	11	108	-	0.0	120
Parsa	0.1	0.5	34	280	-	-	315
Rautahat	-	-	11	336	-	0.0	347
Saptari	-	-	-	237	-	-	237
Sarlahi	-	-	26	189	0.1	-	215
Siraha	-	-	62	336	0.1	0.0	398
	3.6	**0.5**	**305**	**1,869**	**0.2**	**0.0**	**2,178**

(Survey 2019)

In aggregate, commercial sector is the topmost user of clean energy – electricity form hydropower. Thus, it is imperial to foresee the impact of commercial sector boom while planning for electricity development. Being an economic zone of country, more growth in energy consumption could be expected.

7.3 Industrial Sector

The industrial sector consumed 14,900 TJ of energy in Province 2. Table 6-13 shows fuel wise energy consumption in eight districts of the province. It shows that Dhanusa, Bara, Parsa, and Mahottari consume 25%, 24%, 17% and 11 %

respectively and remaining by the rest of the districts. Coal is consumed as a major source of energy in industry constituting a 45% share followed by diesel 8%, furnace oil 24%, and electricity 10% and remaining others. It clearly shows that the industrial sector still depends heavily on the non-renewable energy source.

Table 7.15: District Wise Energy Consumption in Industry Sector by Fuel Wise in TJ

District	Wood	Agricultural residue	Coal	LPG	Diesel	Furnace oil	Electricity	Total
Bara	-	340	237	-	325	1,428	1,210	3,539
Parsa	-	25	137	-	159	2,218	64	2,603
Dhanusa	559	-	2,762	49	246	-	56	3,672
Mahottari	35	-	1,186	-	351	-	15	1,587
Sarlahi	231	217	355	-	59	-	38	900
Siraha	4.9	-	584	10	52	-	19	669
Saptari	11	26	945	0.6	14	-	88	1,084
Rautahat	134	215	427	-	48	-	22	846
Total	**975**	**824**	**6,632**	**59**	**1,254**	**3,645**	**1,511**	**14,900.17**

(Survey 2019)

Energy mix in industrial sector is as shown in **Figure 7.7**. It shows that coal is the major source of fuel consuming 51% of total energy consumed in the sector. Coal is consumed large in bricks and cement industries. Primary solid fuels like wood and agri-residue are also consumed in large quantity in industries mostly in textile and leather industries. It constitutes 15% of total energy consumed in the sector. 17% of energy comes from petroleum products and 17% from electricity respectively. In national context in industrial sector, the energy consumption was dominated by coal at 46%, followed by 24% wood, 15%% diesel 14% electricity and rest by other petroleum products (WECS, 2013). This in contrast to province 2, although coal has highest share of energy consumption in this sector, the use of fuelwood and other biomass is comparatively low. This has been replaced by electricity primarily use in process heat and motive power, clearly indicating energy transition to cleaner fuels.

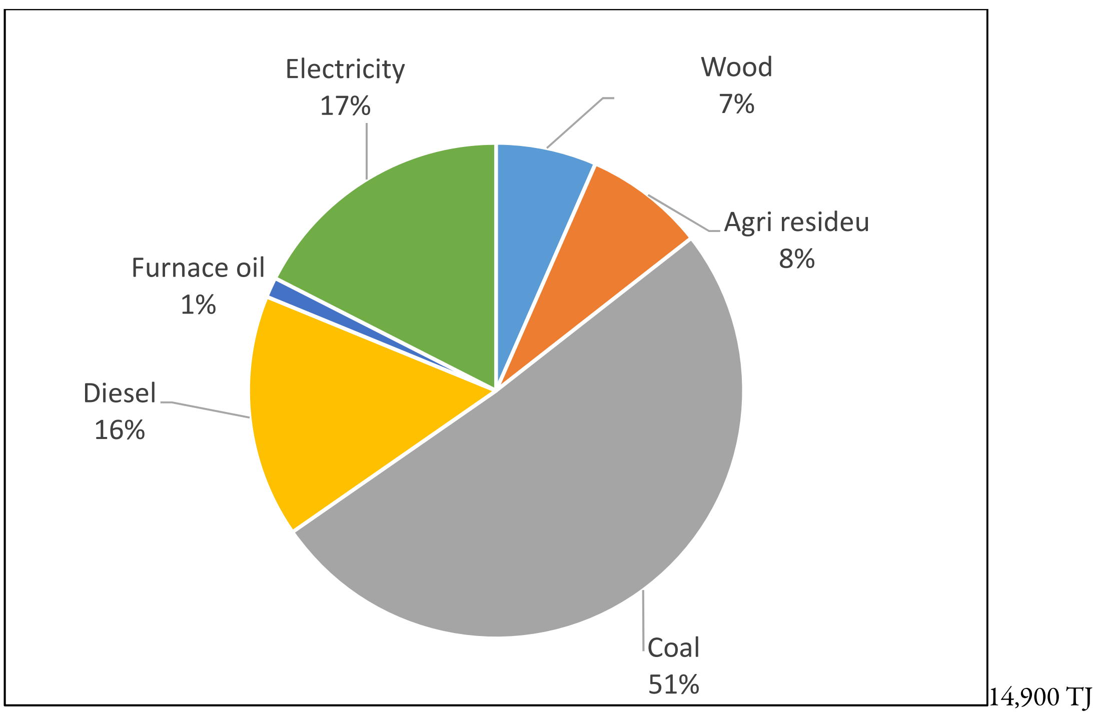


Figure 7.7: Energy Mix in Industrial Sectoring Province 2

Table 7.16 shows the total energy consumed in the industry by its end-use service. It shows that process heat consumes 10,887 TJ of energy which is 73% of total energy consumed in the sector. Motive power and Boiler consumed 17% and 9% of total energy respectively.

Table 7.16: District Wise Energy Consumption in Industry Sector by End-Use Service in TJ

District	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Bara	0.01	434	1,584	1,521	-	3,539
Parsa	0.01	36	2,385	171	12	2,603
Dhanusa	-	248	3,133	272	19	3,672
Mahottari	-	3.03	1,218	351	15	1,587
Sarlahi	0.03	340	479	78	2.24	900
Siraha	0.01	8.48	600	50	10	669
Saptari	0.01	5.61	953	0.01	125	1,084
Rautahat	0.01	245	536	65	-	846
Total	**0.09**	**1,321**	**10,888**	**2,509**	**183**	**14,900**

(Survey 2019)

All the manufacturing industries mentioned in Nepal Standard Industrial Classification are further categorized into 10 sub-sectors based on their energy intensity and type. The energy consumption based on its sub-sector is as shown in Table 7.16 Industrial bricks and structural clay products consume 7,571 TJ which is almost 51% of the total energy consumed in the sector. It consumed coal and diesel as the major source of energy. Industrial mechanical engineering and manufacturing consume 34%, consuming 97% of total furnace oil consumed in the industrial sector. Food beverage and tobacco consumes 8% of total energy followed by chemical rubber and plastic industry (3%) and remaining by the rest of the industries.

Table 7.17: Fuel Wise Energy Consumption in Industry Sector by Sub-Sector in TJ

	Wood	Agricultural residue	Coal	LPG	Diesel	Furnace oil	Electricity	Total
Food Beverage and Tobacco	308	691	5.61	49	53	1.23	98	1,205
Textile and Leather Goods	-	-	-	-	169	2.97	30	202
Chemical Rubber and Plastic	10	80	5.15	-	202	104	41	443
Mechanical Engineering and Manufacturing	-	-	77	-	200	3,537	1,187	5,001
Electrical Engineering Products	-	-	-	-	-	-	1.96	1.96
Wood Products and Paper	274	-	-	-	15	-	98	387
Bricks & Structural Clay Products	383	53	6,544	10	569	-	12	7,571
Other Manufacturing	-	-	-	-	46	-	42	89
Total	**975**	**824**	**6,632**	**59**	**1,254**	**3,645**	**1,511**	**14,900**

(Survey 2019)

Table 7.18 shows energy consumption in the industrial subsector by its end-use service. It shows that the process heat consuming highest energy is consumed in industrial bricks and structural clay (64%) and mechanical engineering and manufacturing subsector (33%). 77% of the total energy consumed in motive power is also shared by the same two industries. Food beverage and tobacco, chemical rubber and plastic and wood products and paper industries consumed 98% of total energy consumed in Boiler.

Table 7.18: End-Use Wise Energy Consumption in Industry Sector by Sub-Sector in TJ

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Food Beverage and Tobacco	0.04	846	204	85	71	1,205
Textile and Leather Goods	-	20	-	180	2.05	202
Chemical Rubber and Plastic	0.01	212	21	207	3.24	443
Mechanical Engineering and Manufacturing	-	-	3,617	1,380	4.51	5,001
Electrical Engineering Products	-	-	-	1.96		1.96
Wood Products and Paper	0.01	243	30	43	71	387
Bricks & Structural Clay Products	0.03	-	7,000	554	17	7,571
Other Manufacturing	0.01	-	16	58	15	89
Total	**0.09**	**1,321**	**10,888**	**2,509**	**183**	**14,900**

(Survey 2019)

Briefly, the major use of energy in industry sector is for thermal purpose – be it in direct heat or for boilers. This huge amount of heat energy is obtained from fossil fuels – primarily from coal and furnace oil. In addition to that, diesel is also used for thermal use in addition to use to motive machines and electricity generation. Thus, the major point for energy efficiency in industry sector could be in using electric furnace and heaters for thermal purpose – while electricity being generated from hydropower plants only, replacing the need of decentralized generators. Alternatively, sugarcane industry could be the source of electricity. It has been estimated that sugarcane industry has the potential to generate 209-313 GWh electricity in Nepal(Khatiwada, et al., 2012). Sugarcane industry produced 34-35% of bagasse per ton of cane. Depending on the operating conditions, 227-427 kW of electricity could be generated per ton of bagasse. Due to higher per unit cost of electricity generation, most of the industry rely on the grid electricity.

District wise energy consumption by its sub-sector, fuel use and end-use service is given in Annex IV.

7.4 Residential Sector

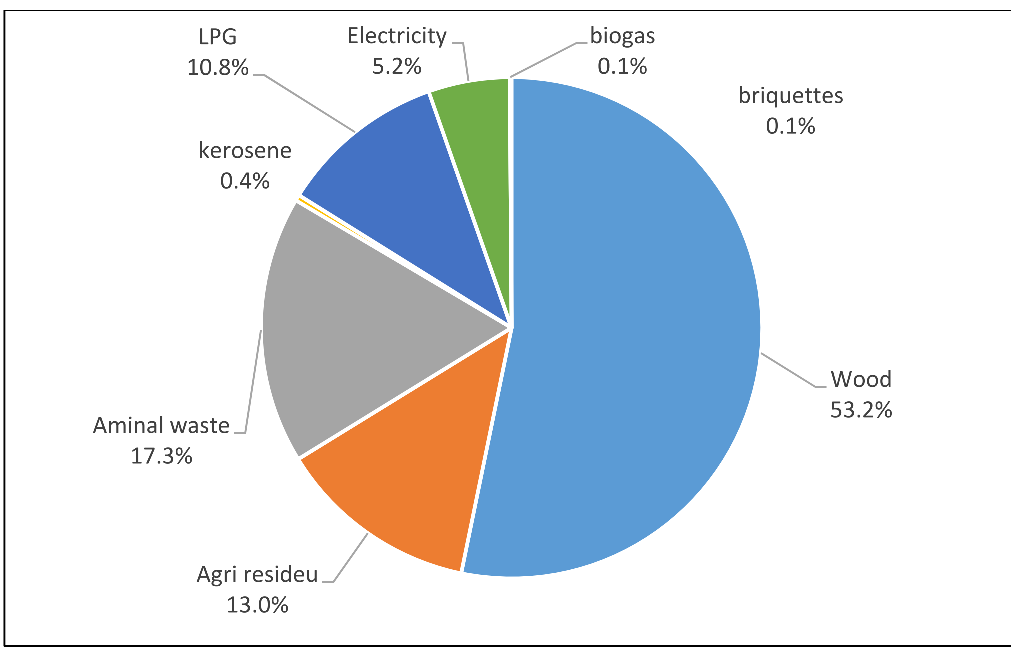
The residential sector is still the most energy consuming sector in the province. The province 2 consumed about 39,248 TJ of energy in residential sector (Table 7.19) It is seen that wood is still the predominate energy source. Nearly 50% of the energy comes from wood and 30% from other biomass – totaling 80% of total energy consumption. Most of the rural and neo-urban population still depends on indigenously available free source of fuel. Also, most of them have livestock farming whose waste is use as source of fuel mostly in cooking and animal feed preparation. In addition, the energy content of primary solid fuels (wood, agriculture residue and animal waste) is comparatively lower than modern energy sources and the efficiencies of traditional technologies are lower by many folds. Thus, although total useful energy from traditional fuels is lower, the actual amount of fuel required sums up to a higher quantity than modern fuels like LPG and electricity.

This is a change in pattern than indicated by previous statuses. For decrease in wood, the share of commercial energy has increase to 11% of LPG and 5% electricity with total of 16% in total energy mix. However, due to high accessibility to agricultural residue and animal wastes, the share of these are also significant at 13% and 17% respectively. The highest amount of energy is consumed for cooking at 85% followed by animal feed preparations. Being in tropical climatic zone, the energy consumption in space cooling is also comparatively high as compared to national share in previous studies.

Table 7.19: Energy Consumption in Residential Sector of Province 2 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Animal feed preparation	Agro and food processing	Social events	Total
Wood	20,011	1.4	20	-	-	-	744	-	104	20,880
Agricultural residue	4,821	0.6	-	-	-	-	278	1.4	-	5,101
Animal waste	5,857	0.3	-	-	-	-	920	-	-	6,777
Coal	5.6	-	-	-	-	-	-	-	-	5.6
kerosene	5.5	-	-	-	145	-	-	-	-	151
LPG	2,846	1.6	3.2	-	-	-	327	-	1,041	4,220
Electricity	74	0.9	89	1,197	464	231	0.0	0.0	0.1	2,057
biogas	0.2	-	-	-	26	-	1.1	-	0.4	28
briquettes	1.5	-	-	-	-	-	18	-	1.4	21
Solar thermal	-	-	-	-	-	-	-	-	-	-
Solar PV	-	-	-	-	7.4	-	-	-	-	7.4
	33,622	**4.8**	**113**	**1,197**	**643**	**231**	**2,288**	**1.4**	**1,147**	**39,248**

Energy mix in residential sector is as shown in **Figure 7.8.**It shows that wood is the major source of fuel in this sector consuming 83% of total energy consumed followed by LPG (11%). There is consumption 5% electricity in this sector. Modern renewables like biogas, briquettes, solar PV, solar thermal is also consumed, however the share is less than 1% of total residential energy consumption. In national scenario in 2011/12, fuelwood had the largest share of 84%, other biomass at 11%, LPG 2% and electricity at 1.6% (WECS, 2013). Comparing that to the Province 2 at current situation, the consumption of wood is still high, but lower than national share, while that of use of animal waste is still high due to easy availability of animals in terai households, which are still highly dependent in agricultural practices. The share of other biomass as well as wood has decreased and is replaced by use of electricity and LPG.



39,248 TJ

Figure 7.8: Energy Mix in Residential Sectoring Province 2

Residential sector in province 2 can be broadly subdivided into 2 subcategories – urban and rural areas as per administrative boundaries. Table 7.20 and Table 7.21 shows the energy consumption in each of the subsector of residential sector. Urban sector consumed about 67% of total residential energy consumption in province 2. Among this, the share of biomass is still highest here with wood at about 51%, agricultural residue at 12% and animal waste at

18%. The use of commercial energy is growing with LPG consumption at 11% and electricity at 6%. By end use, cooking is still the mist energy consuming activity with 85% energy consumed in it alone. Being in tropical climate, the energy for space cooling is also higher than national average.

Table 7.20: Energy Consumption in Urban -Residential Sector of Province 2 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Animal feed preparation	Agro and food processing	Social events	Total
Wood	12,866	0.4	0.7	-	-	-	571	-	67	13,506
Agricultural residue	3,023	0.0	-	-	-	-	240	1.4	-	3,264
Animal waste	4,230	0.0	-	-	-	-	722	-	-	4,952
Coal	-	-	-	-	-	-	-	-	-	-
kerosene	1.6	-	-	-	101	-	-	-	-	103
LPG	2,081	1.5	3.2	-	-	-	225	-	672	2,983
Electricity	68	0.6	81	918	314	163	-	0.0	0.1	1,544
biogas	-	-	-	-	-	-	-	-	0.2	0.2
briquettes	1.5	-	-	-	-	-	1.9	-	0.6	4.0
Solar thermal	-	-	-	-	-	-	-	-	-	-
Solar PV	-	-	-	-	0.9	-	-	-	-	0.9
	22,272	**2.5**	**85**	**918**	**416**	**163**	**1,760**	**1.4**	**740**	**26,357**

(Survey 2019)

The rural sector also presents similar energy mix. However, the shares of biomass are higher than in urban sector with wood at 57%, agricultural residue and animal waste at 14% each. The use of commercial energy is growing in rural sector as well with LPG consumption at 9.5% and electricity at 4%. By end use, cooking is still the most energy consuming activity with 88% energy consumed in it alone. Unlike urban sector, the consumption for space cooling is lower in rural population.

Table 7.21: Energy Consumption in Rural - Residential Sector of Province 2 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Animal feed preparation	Agro and food processing	Social events	Total
Wood	7,145	1.0	20	-	-	-	173	-	37	7,374
Agricultural residue	1,798	0.5	-	-	-	-	38	-	-	1,837
Animal waste	1,627	0.3	-	-	-	-	198	-	-	1,825
Coal	5.6	-	-	-	-	-	-	-	-	6
kerosene	3.9	-	-	-	44	-	-	-	-	48
LPG	765	0.1	-	-	-	-	103	-	369	1,236
Electricity	6.4	0.3	8.3	280	151	68	0.0	0.0	0.0	513
biogas	0.2	-	-	-	26	-	1.1	-	0.2	28
briquettes	-	-	-	-	-	-	16	-	0.8	17
Solar thermal	-	-	-	-	-	-	-	-	-	-
Solar PV	-	-	-	-	6.6	-	-	-	-	6.6
	11,350	**2.2**	**28**	**280**	**228**	**68**	**528**	**0.0**	**407**	**12,891**

(Survey 2019)

The residential sector shows two peculiar features – first, they still tend to prefer traditional biomass for fuel – majorly due to affordability and accessibility. Secondly, however, there is clear picture of energy transition to modern fuels – LPG and electricity. Given that the income level of people increases and supply of electricity is reliable, the shift toward electricity seems to be inevitable.

7.5 Transport Sector

The transport sector can be categorized in several ways based on its ownership, technology type, fuel type, operation type and so forth. However, the transport sector can be categorized into four major sub-sectors:

a. Road transport
b. Air transport
c. Water transport
d. Cable transport

Road transport dominates all modes of transport in Nepal. There is only one international airport under operation currently. However, the construction of two other international airports is under construction phase. Water transport is not yet popular in Nepal. But cable transport like cable car, ropeways and twin crossing are still in use in many parts of Nepal. In this energy consumption survey, for province 2, road transport is emphasized due to its major share in overall transportation. For this purpose, road transport is disaggregated into following categories (Table 7.21)

Table 7.22: Vehicle Categories

Sub-sectors	Devices	End-use
Service Type		
Private Personal	car, jeep, van, motorcycle, bus, minibus, tempo, etc	Passenger
Private Institutional	car, jeep, van, pickup, etc	Passenger/Freight
Public Local-Short Distance	Bus, minibus, jeep, van, tempo, etc	Passenger
Public Long Distance	Bus, minibus, jeep, van,etc	Passenger
Freight	Truck, minitruck, pick-up, cargo van	Freight
Fuel type		
Diesel	car, jeep, van,bus, minibus,etc	Passenger/Freight
Petrol	car, jeep, van, motorcycle,etc	Passenger/Freight
LPG	Tempo	Passenger
Electric	Rickshaw	Passenger

Vehicle Registration

The total number of the vehicle registered in the country as obtained from the Department of Transport Management (DOTM) is as shown in Annex IV, and the provincial vehicle registration data is as shown inTable 7.23. Approximately 27% of total registered vehicles are registered in province 2.

Table 7.23: Provincial Vehicle Registration in 2074-75

	Bus	Minibus/Mini Truck	Crane/Dozer/Roller/Excavator/Loader/Grader	Car / Jeep/Van	Pickup	Micro Bus	Tempo	Motorcycle	Tractor/Power Trailer	E-Rickshaw	Others	FY Total	Total
Sagarmatha	20	15	74	146	205	7	352	10,471	890	1,590	21	13,791	70,478
Janakpur	23	14	228	137	94		712	16,589	646	3,936	7	22,386	80,209
Narayani	456	527	3,746	4,320	2,045	248	1,720	70,768	4,197	4,550	31	92,608	717,697
Total	**499**	**556**	**4,048**	**4,603**	**2,344**	**255**	**2,784**	**97,828**	**5,733**	**10,076**	**59**	**128,785**	**868,384**

Aviation

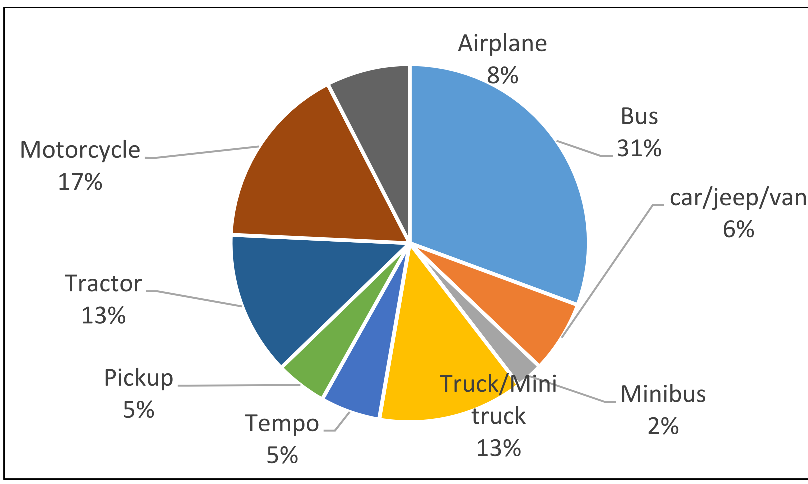
There are total three airports in operations, where only domestic flights take place. The data regarding aircraft are published by Civil Aviation Authority of Nepal (CAAN). The data shows the total aircraft movement, passenger movement and cargo movement as given in Table 7.24.

Table 7.24: Aviation Sector Activity(CAAN, 2018)

Airport	Aircraft movement	Passenger movement	Cargo movement (in kg)
Janakpur	3,975	79,296	79,188
Simara	9,500	23,129	131,403
Rajbiraj	264	10,003	2,832
Province 2	13,739	112,428	213,423

7.5.1 Transport Sector Energy Consumption by Fuel Types

The modal mix based on energy consumption is as shown in Figure 7.9. It shows that bus consumed large share of energy consumed in transport sector followed by motorcycles. Freight vehicle (truck, mini truck, tractor and pickup) consumed 31% of total energy consumed in this sector. Private car/jeep/van together consumed 6% of the energy.



5,812 TJ

Figure 7.9: Energy Mix in Transport Sector in Province 2

The total energy consumption in the transport sector is as shown in Table 7.25. It shows that the total energy consumed in the transport sector accounts for 5,812 TJ, of which 45% are from diesel, 51% from petrol, 2% electric and 1% ATF. The total transport energy consumption in 2000 was 15,500 TJ at national level, contributed by 75% diesel, 11% gasoline, 13% ATF and less than 1% by electricity and LPG (WECS, 2000). While in 2011/12, the total consumption in transport sector raised to 26,750 TJ with diesel contributing 60%, gasoline 24%, ATF 15% and nearly 1% by LPG and electricity (WECS, 2013). These show that, along with national trend, the consumption of diesel is still high in Province 2, but with higher growth in petrol vehicles, consumption of gasoline have surpassed the diesel as primary transportation fuel. The average fuel economy and average distance traveled per year are also obtained from the field survey. According to Nepal oil corporation, sales data and fuel consumption survey results 99% of gasoline sales in province 2 is used for the transport sector, whereas only 24% of diesel sales are used in the transport sector.

Table 7.25: Total Transport Sector Energy Consumption by Fuel Types

Diesel				
Row Labels	**Average Distance Travelled**	**Km/lt**	**TJ**	**lt**
Bus	57,791	4.8	395.15	10,798,509
Car	23,657	14.4	87.22	2,383,582
Cargo van	29,250	13.5	19.42	530,813
Jeep	38,577	10.7	50.05	1,367,829
Microbus	76,974	11.9	120.45	3,291,659
Minibus	44,691	6.6	143.07	3,909,672
MiniTruck	23,149	6.9	47.20	1,289,871
Pickup	12,042	10.9	335.82	9,177,269
Tempo	3,333	13.4	69.61	1,902,222
Tractor	7,535	6.5	666.29	18,208,183
Truck	18,450	4.6	682.90	18,662,333
Van	34,823	11.3	20.42	557,957
Total			**2,638**	**72,079,901**
Petrol				
Row Labels	**Average Distance Travelled**	**Km/lt**	**TJ**	**lt**
Car	7,913	13.8	93.89	2,831,505
Motorcycle	9,546	45.6	2,731.90	82,386,759
Tempo	14,708	19.1	130.01	3,920,688
Van	27,758	12.7	27.95	842,921
Total			**2,984**	**89,981,873**
Electricity				
Electric	**Average Distance Travelled**	**Km/kWh**	**TJ**	**kWh**
E rickshaw	61,618	85	128.51	71,395,966
Grand Total			**5,749.86**	

The energy consumption in transport by subsector and fuel types is as shown in Table 7.26. It shows that private passenger vehicles consume high energy in passenger transport and freight consume 66% of total diesel fuel consumed in the transport sector. Motorcycle alone accounts for 91% of total petrol fuel consumed in the transport sector.

Table 7.26: Total Transport Sector Energy Consumption by Subsector and Fuel Types(TJ)

Sub-sector		Diesel	Petrol	ATF	Electric	
Public Passenger	Bus	395				395
	Microbus	120				120
	Minibus	143				143
	Tempo	70	130			200
	E rickshaw				129	129
Total		**728**	**130**		**129**	**987**
Private Passenger	Car	87	94			181
	Jeep	50				50
	Van	20	28			48
	Motorcycle		2,732			2,732
Total		**158**	**2,854**		**-**	**3,011**
Freight	Truck	683				683
	Mini Truck	47				47
	Tractor	666				666
	Pickup	336				336
	Cargo van	19				19
Total		**1,752**	**-**		**-**	**1,752**
Aviation				**62**		
Grand Total		**2,638**	**2,984**	**62**	**129**	**5,812**

(Survey 2019)

In overall, the energy consumption in transport sector is dominated by private passenger vehicles, which are considered inefficient, majorly because of low load factor – they are not utilized at optimum capacity it can handle. The transport sector being heavily dependent on imported petroleum products, there is huge opportunity to switch to electric mobility. The advent and use of e-rickshaw is getting popular, but it is essential that this trend is affecting the high-density passenger carriers such as buses and it seems better that e-rickshaws are also affecting highly populated vehicle category – i.e. motorcycles and cars which are of course not fuel efficient.

7.6 Construction and Mining

The construction and mining industry heavily rely on heavy equipment. These machineries are usually operated by diesel engines and only some by electricity. In addition to those, LPG is used in some operating activities and for cooking for the on-site workers. Additionally, kerosene is also used in other minor activities. Thus, total energy consumed in construction and mining sector totals to be around 268 TJ with highest consumption of diesel followed by LPG and Electricity Table 7.27.

Table 7.27: Energy Consumption in Construction and Mining Sector in Province 2 (TJ)

Diesel	186.5
Electricity	23.0
LPG	54.3
Kerosene	3.6
Total	267.5

(Survey 2019)

Figure 7.10 depicts the shares of energy types in construction and mining sector, which clearly shows that this sector entirely depends on commercial sources of fuel, of which the imported petroleum is the highest.

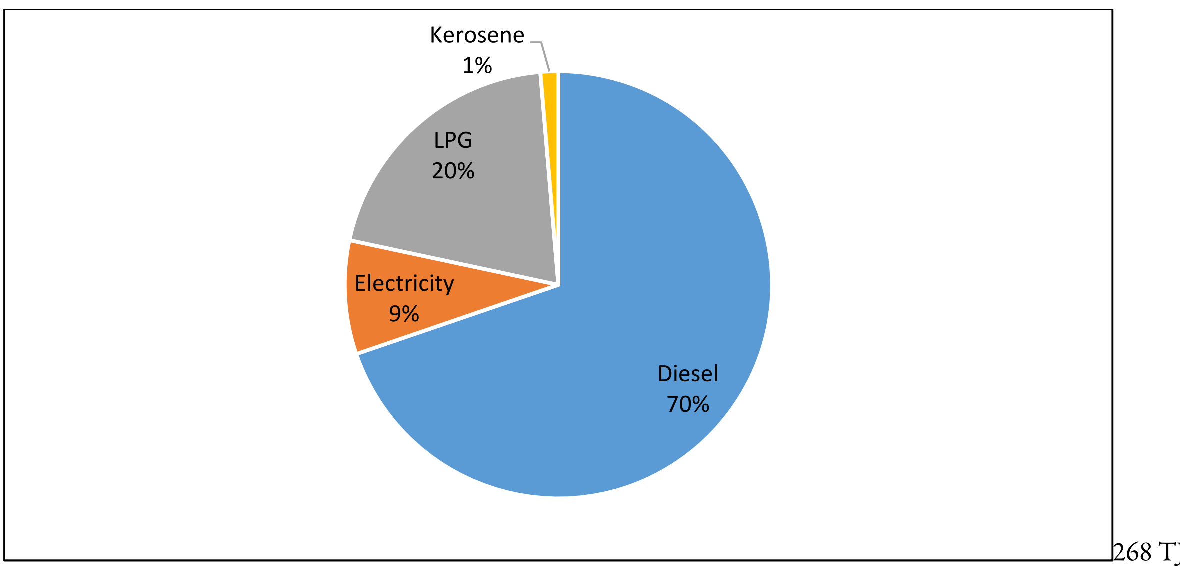


Figure 7.10: Energy Mix in Construction and Mining Sector

8 Socio-economic and Technical Analysis

8.1 Socio-economic Status

Province 2 lies totally in Terai region of Nepal and touches border of Nepal-India by every district. Due to this, there is large social influence of Nepal-indo culture, and it reflects in social structure as well. As shown in Figure 8.1, the majority of respondents belongs to ethnic group specific to Terai region. The largest share of respondents was from Yadav, Shah etc. group in overall, and they reside specifically in districts like Sarlahi, Rautahat, Mahottari and Parsa. The next in overall share is Terai Dalit and Terai Janajati groups who are dominant groups in Siraha, Saptari and Bara. However, the respondents also include other ethnic groups ranging to Hill Janajati and Hill Dalit groups as well.

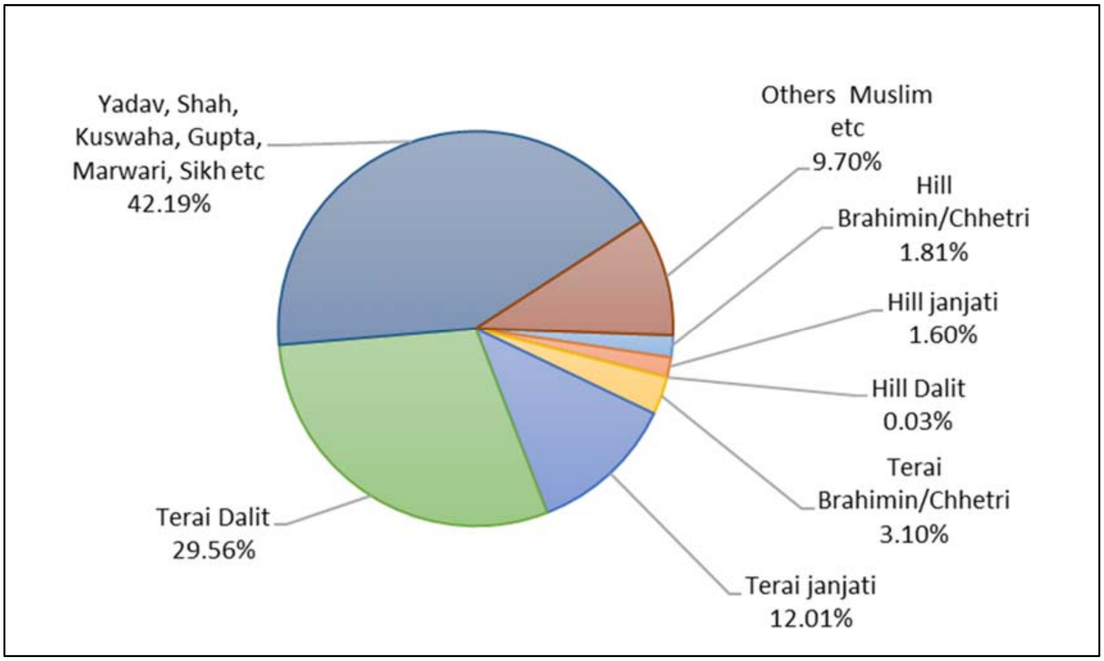


Figure 8.1: Mix of Respondents by Ethnic Group

It is evident that education level has influence on decision making. Thus, looking at the education level of household heads in province 2, it was seen that majority of the household heads have no formal education followed by partially literate. More than 50% of household's heads do not have formal education (Figure 8.2). And the impact can be seen in the energy mix – wood and other biomass still being predominant in the energy mix.

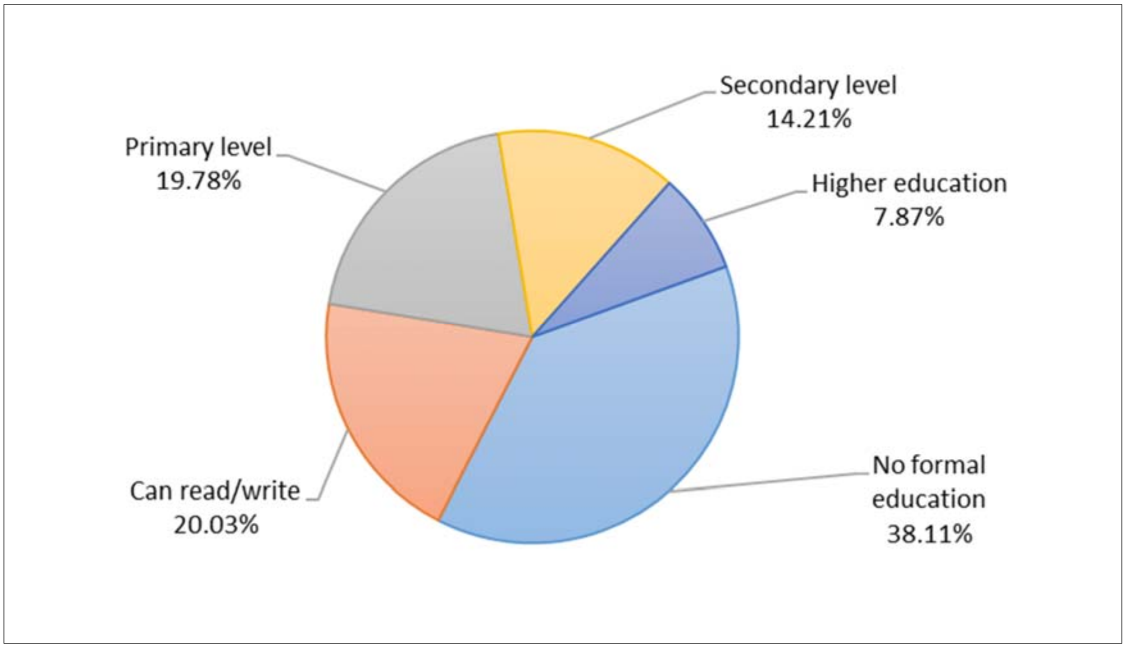


Figure 8.2: Mix of Respondents by Education Level of Household Head

Another important aspect of socio-economic behavior is sources and level of income. The major source of income of the respondents was agriculture and other – which includes labor in wage basis. Very low share of people had their own business while income through remittance is also significant as seen in Figure 8.3.

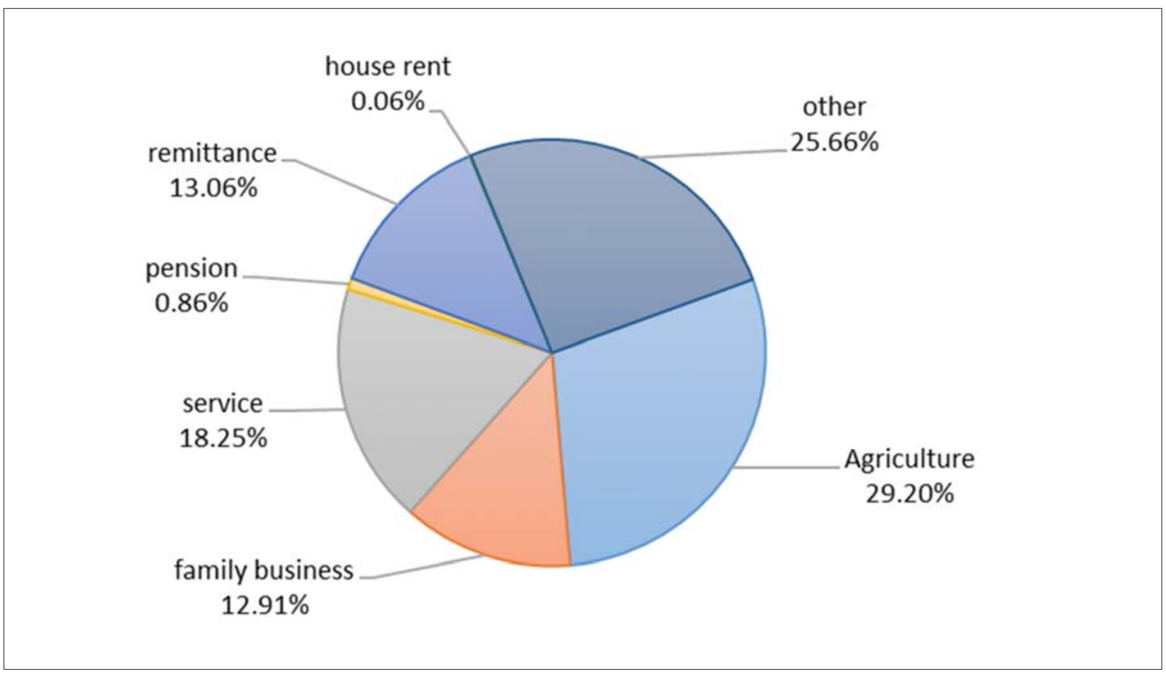


Figure 8.3: Mix of Respondents by Major Source of Income

The average monthly family income level ranges from as low as 11,000 per month to highest of 42,000 (at average). Thus sums to an average of NRs 272,000 annual income per household in Province 2. This income level is near to par with reference to the income level as per National Living Standards survey (CBS, 2011).However, there is huge variance from mean level of income in most of the cases as seem in Figure 8.4.

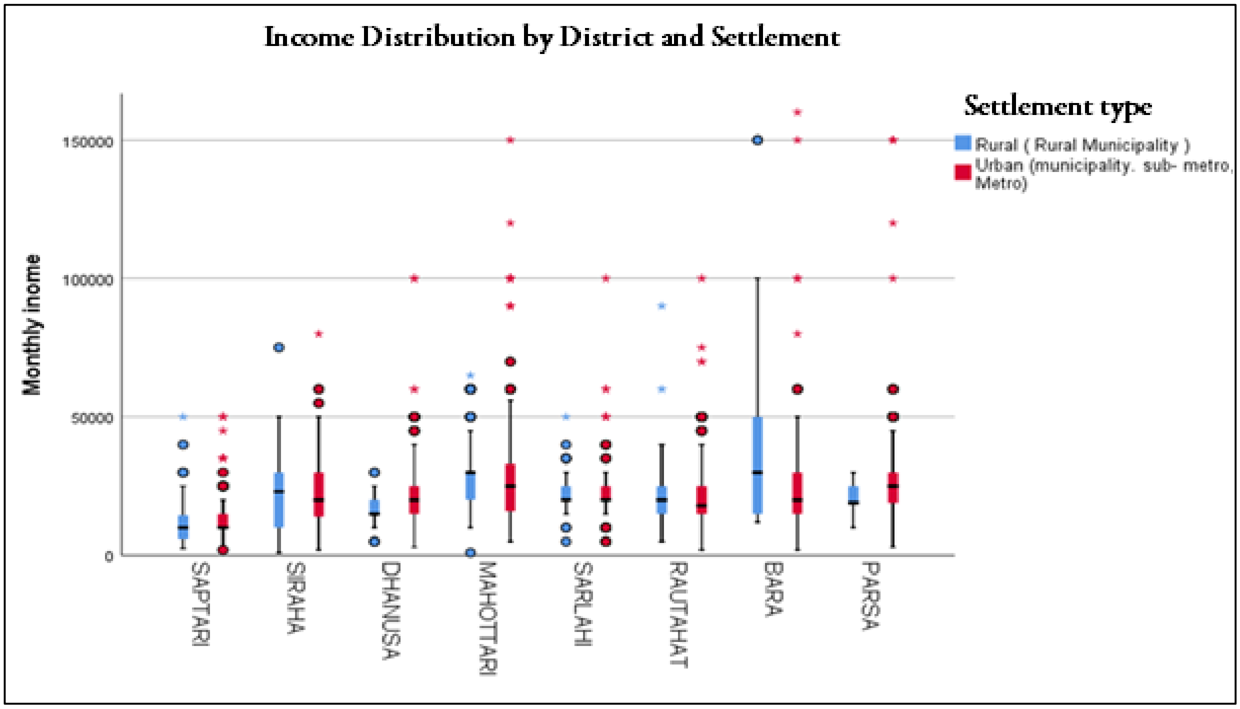


Figure 8.4: Average Monthly Income of Households in Province 2

In province 2, nearly 50% of the surveyed household found were made of bamboo or wood, based on availability asper guidance for sample collection (Figure 8.5). However, the share of RCC frame with cement mortar is seen to be in increasing trend, especially after earthquake back in 2015.

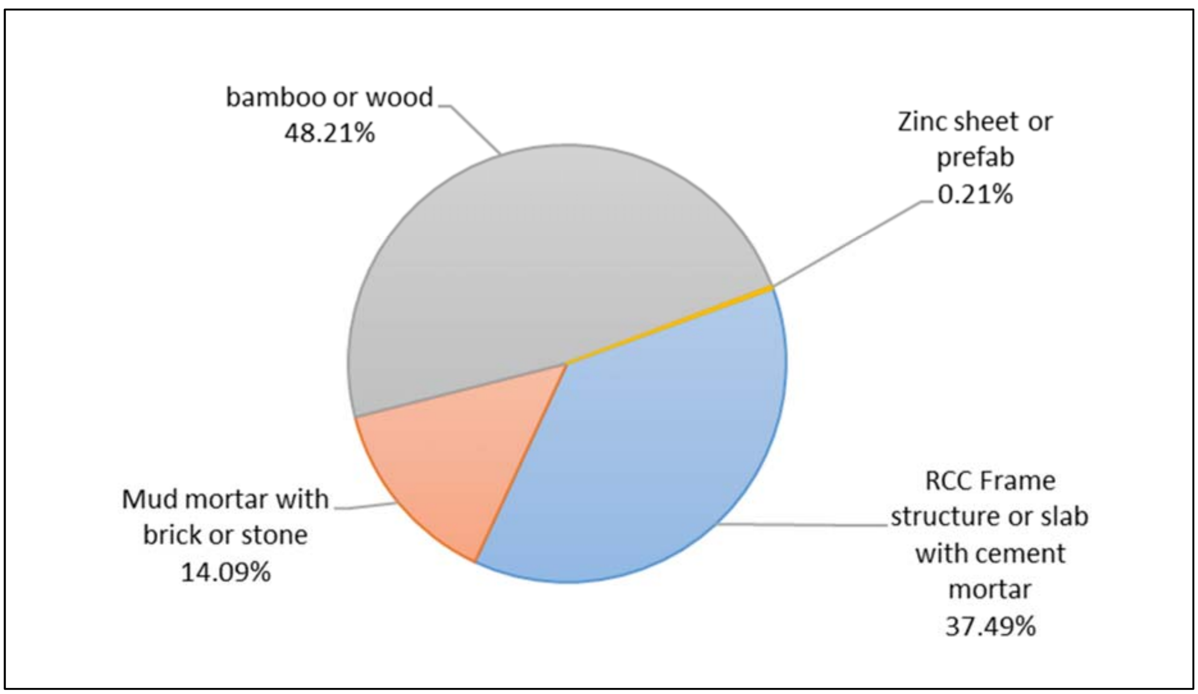


Figure 8.5: Mix of Respondent Household by Build Type

Meanwhile, for roof, majority of household still used galvanized iron sheet or tile or slate followed by RCC and then thatched roof in older houses (Figure 8.6).

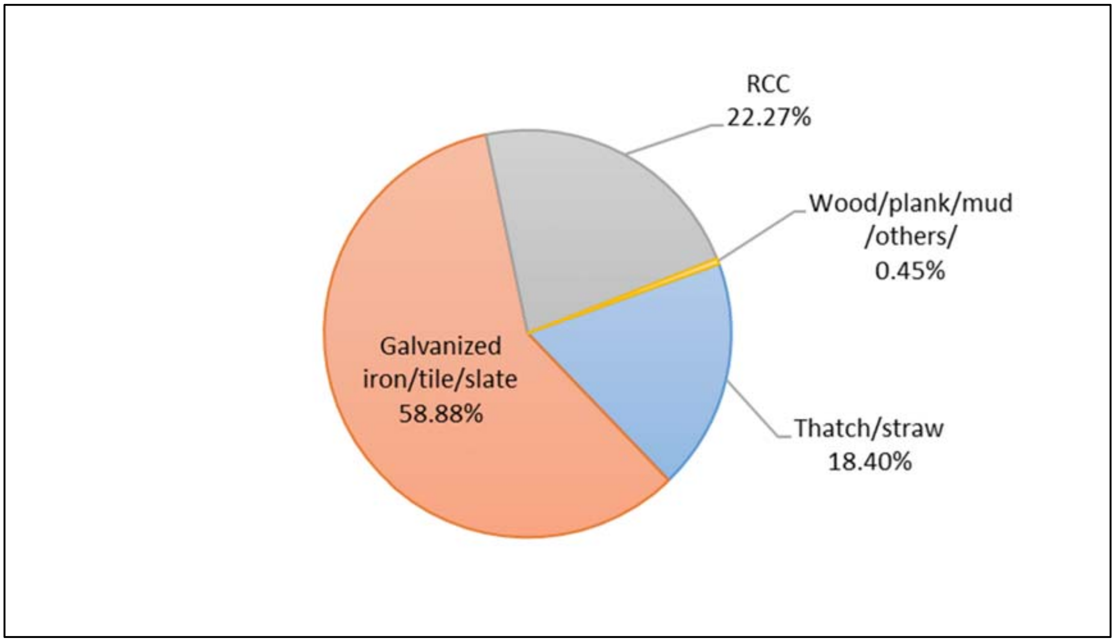
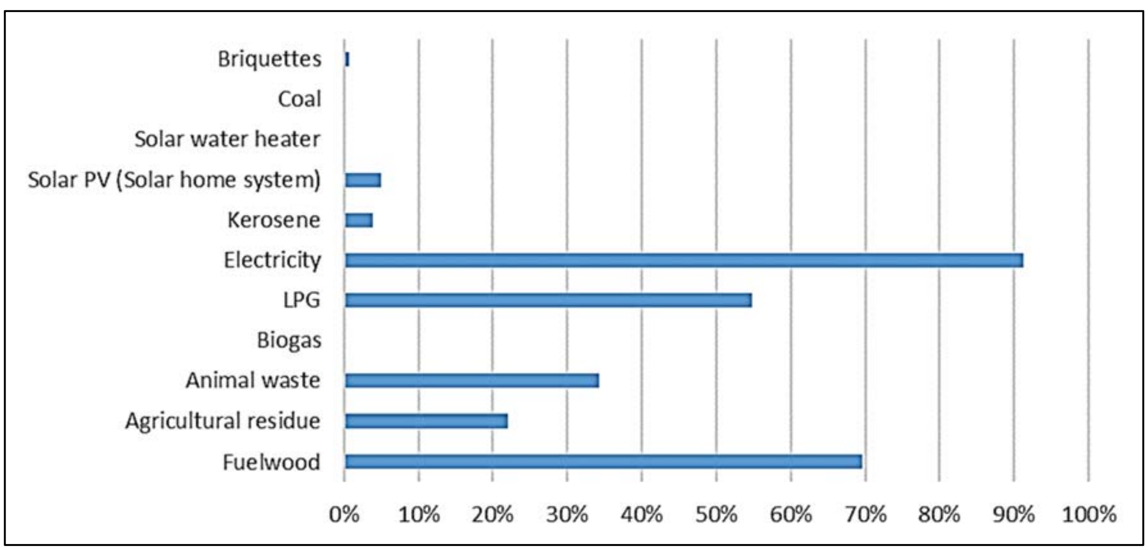


Figure 8.6: Mix of Respondent Households by Roof Type

8.2 Society and Energy Technology

Figure 8.7 shows the penetration of energy types in the province 2. It can be seen that over 90% of population has access to electricity. Second to that is the use of wood, where nearly 70% of the respondents still use wood as source of energy. Following is the LPG at nearly 55%. This energy mix shows that the society in province 2 is still at phase of energy transition from traditional to modern fuels. Even though reach of electricity is higher than wood but in energy terms, use of wood and other biomass is higher is due to the facts that – firstly, traditional technology is very much energy inefficient and thus demands higher energy consumption and secondly, the traditional energy sources are usually taken as free of cost if opportunity cost of fuelwood collection is not considered. Thus, people tend to use these sources more often. This also reflects the influence of education level and income status. The district wise penetration of energy sources is given in Annex VI.



(Survey 2019)

Figure 8.7: Penetration of Energy Types in Province 2

Table 8.1 shows how much people pay for the commercially traded energy sources. At current times, even wood is being traded at an average rate of NRs. 509 per bhari. Meanwhile the LPG in province 2 costs at around NR 1408 per cylinder, with transportation cost. These account for nearly NRs 1 per MJ of energy for fuelwood, while more than NR 2 per MJ of LPG. Thus, the upfront cost of commercial energy still seems high. But if we take energy efficiency into consideration, the cost of useful energy would be much lower for commercial energy.

Table 8.1: Cost of Commercially Traded Fuels in NR

	Per (unit)	Saptari	Siraha	Dhanusa	Mahottari	Sarlahi	Rautahat	Bara	Parsa
Wood	bhari(40 kg)	504	421	477	502	388	650	552	577
Bio briquettes	kg	150	-	-	-	-	-	-	-
Kerosene	liter	102	121	102	110	110	114	118	120
LPG	cylinder	1,384	1,392	1,428	1,423	1,420	1,438	1,367	1,417
coal	kg	30	-	-	-	-	-	-	-

Figure 8.8 shows that share of ampere capacity of households who have electricity access – at the center it shows the households not having access to electricity. It can be seen that over 90% of the households lies within minimal amperage capacity of 5 A. This capacity is sufficing only for basic electricity appliances. This ampere capacity cannot withstand the higher demand of new technologies such as cooking on electricity. Thus, it is essential to upgrade the capacity of electricity supply before successful implementation of electrification policies in Province 2.

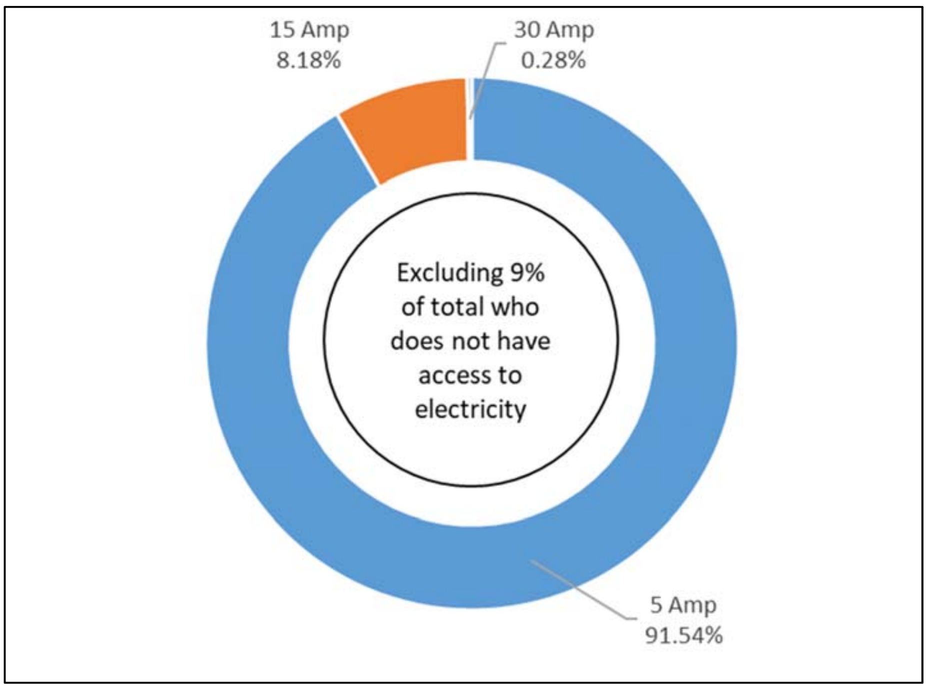


Figure 8.8:Mix of Ampere Capacity of Households with Electricity Access

9 Energy Scenario Analysis

9.1 Scenario Development

In developing the scenarios, three different sets of possible future energy demands have been considered – each of which corresponds to a future economic growth scenario. These are:

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

In addition to these three, an additional scenario has been explored to analyze the impact of strategic interventions in the energy sector. For combined policy analysis, reference case of 6.3% GDP growth rate is taken as the policy intervention scenario called Sustainable Energy Development Scenario (SEDS) and its results will be compared with those of the Reference Economic Growth Scenario.

The major strategic interventions taken in the Sustainable Energy Development Scenario (SEDS)are:

- Replacement of traditional and fossil fuels by clean energy alternatives – electricity, LPG and ICS.
- Replacement of incandescent bulbs by CFL and LED.
- Promotion of electrification in all 5 sectors for lighting, heating, and other purposes.
- Intervention of more efficient process technologies in industries
- Intervention of mass transportation system
- Introduction of new electric transportation technologies

The detailed interventions in policy scenario are given in section 9.1.4. .

9.1.1 Reference Economic Growth Scenario

The following are the major assumptions of this scenario:

- Average GDP growth rate of 6.3%
- The shares of each demand technology in the energy supply in future years will became as in the base year

The Table 9.1 below shows the total energy demand for the reference growth case of various fuel types from base year to year 2050. The total energy demand in province 2 is expected to grow from current level of 63.2PJ in 2019 to 83 PJ in 2030 and189 PJ in year 2050 which accounts for three folds of increase. The average annual growth rate of energy demand is 3.6% for the case. The per capita energy demand is expected to grow from 10 GJ in 2019 to 21 GJ in 2050 in this scenario.

Table 9.1:Fuel Demand in Reference Economic Growth Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	34.56	35.04	37.73	40.96	44.7	49.14	54.49	61.11
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05
			Bio briquettes	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
			Grid Electricity	5.59	5.68	6.46	7.81	9.68	12.32	16.03	21.31
Non renewable			Petrol	3.01	3.1	3.38	3.7	4.04	4.43	4.85	5.33
			Diesel	4.84	4.92	5.87	7.66	10.25	13.99	19.36	27.11
			Kerosene	0.15	0.15	0.17	0.18	0.19	0.21	0.23	0.25
			Furnace Oil	3.65	3.71	4.5	6.05	8.29	11.57	16.31	23.18
			ATF**	0.06	0.06	0.07	0.08	0.08	0.09	0.1	0.11
			LPG	4.64	4.7	5.09	5.58	6.18	6.92	7.85	9.05
			Coal	6.63	6.75	8.19	11	15.09	21.06	29.68	42.18
Total				63.19	64.17	71.51	83.08	98.58	119.8	149	189.73

**PSF (Primary Solid Fuels) : Fuelwood, Agricultural Residue, Animal Residue*

***ATF : Aviation Turbine Fuel*

The share of primary solid biomass (wood, agri residue and animal dung) is high throughout the period except in 2050 where petroleum products overtake solid biomass by 4%. Petroleum and coal demand are expected to grow at the rate of 4% and 6% respectively whereas solid biomass would grow at 2% per annum Figure 9.1. The share of electricity would increase by nearly 1.4 times in 2030 and four-fold in 2050.

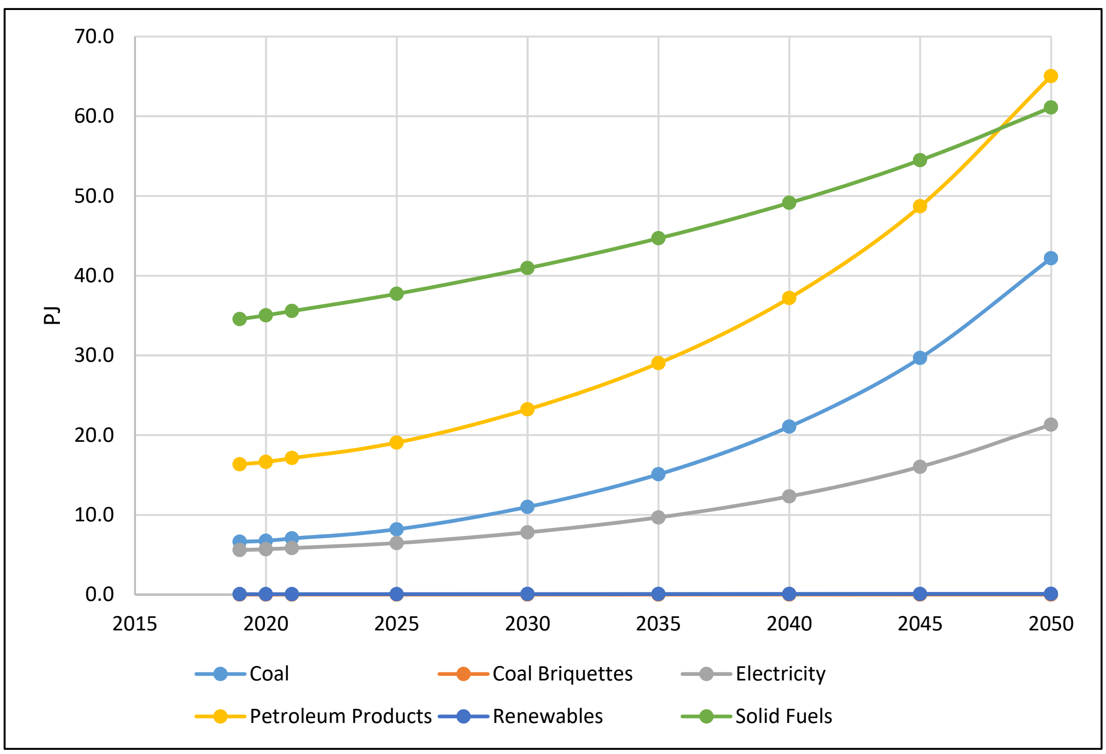
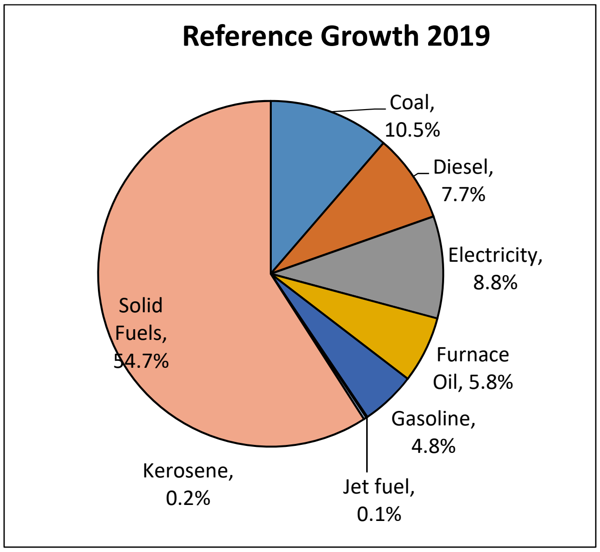
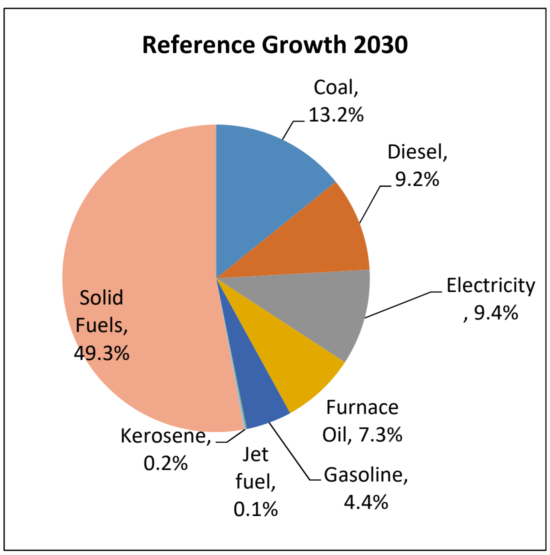


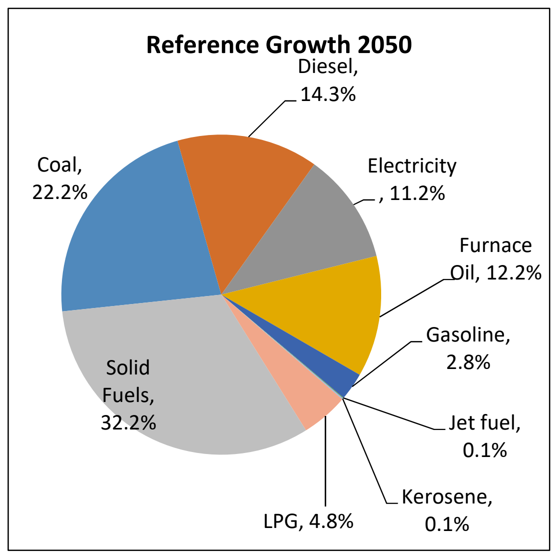
Figure 9.1:Fuel Demand Trend at Reference Economic Growth Scenario

The Figure 9.2show the energy mix in the total fuel consumptions for 2019, 2030 and 2050 years. The consumption of fuelwood is expected to decrease to 49% in 2030 and 33% in year 2050 respectively. The consumption of coal and diesel would grow by 66% and 56% respectively in 2030. The electricity consumption would be 9% in 2030 and 11% in 2050 respectively and would be growing at the rate of 4% per annum.



(a) Total Final Energy Demand = 63 PJ





(b) Total Final Energy Demand = 83 PJ

(c) Total Final Energy Demand = 189 PJ

Figure 9.2:Fuel mix at Reference Economic Growth Scenario

Table 9.2 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 32% in 2050 from 62% in 2019. Meanwhile, industrial sector share of energy demand will increase to 30% in 2030 and 51% in 2050. Whereas the share of Energy demands in the commercial sector will increase more than4 folds in 2050 from its base year value. There will be 36% growth of energy demand in transport sector in 2030.

Table 9.2: Sectoral demand at Reference Economic Growth Scenario (PJ)

	2019	2020	2025	2030	2035	2040	2045	2050
Agriculture	0.79	0.80	0.98	1.31	1.80	2.51	3.54	5.03
Commercial	2.18	2.21	2.57	3.23	4.17	5.51	7.43	10.178
Construction and Mining	0.27	0.27	0.33	0.44	0.61	0.85	1.20	1.70
Industry	14.90	15.17	18.40	24.72	33.90	47.31	66.69	94.77
Residential	39.24	39.77	42.52	45.48	48.63	52.00	55.61	59.47
Transport	5.81	5.94	6.71	7.89	9.47	11.61	14.54	18.59
Total	63.19	64.17	71.51	83.08	98.58	119.80	149.00	189.73

Sub sectoral energy demand projection is given in Annex VIII

Figure 9.3 shows the power plant capacity required for the study period. The demand for grid electricity is expected to increase at the average annual rate of 6%. The required peak power plant in 2019 was 304 MW. The future power requirement would be 708 MW in 2030 and 1,931 MW in 2050. The electricity consumption per capita is seen to be growing by over two folds during the study horizon from current value of 256 kWh to 644 kWh by2050.

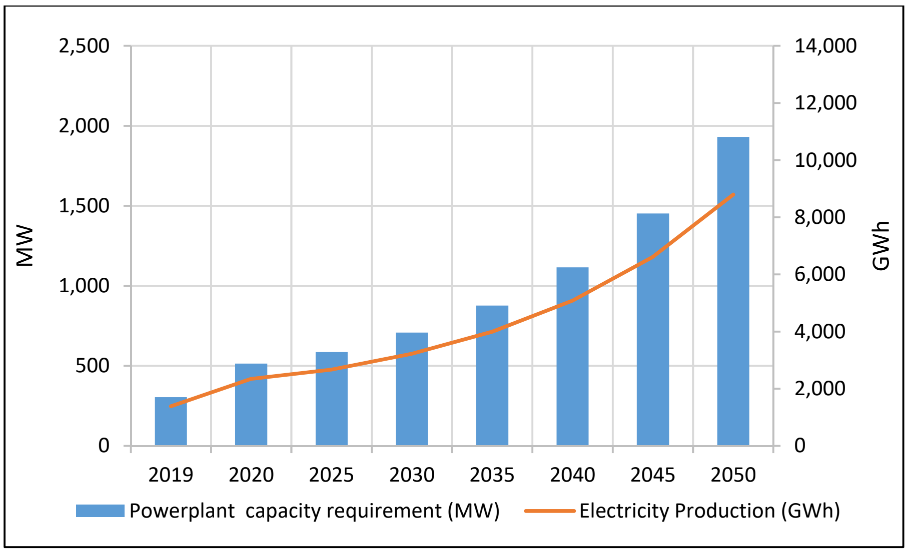


Figure 9.3:Peak Power Plant Capacity at Reference Economic Growth Scenario

GHG emission trend in Reference Economic Growth Scenario is as shown in Figure 9.4.GHG emissions would increase from 2,033 kt in 2019 to 2,988 kt in 2030 and is reaching 9,110 kt in 2050. The GHG emissions would grow at an average growth rate of 5% during 2019-2050. There will be 4.5 times growth in GHG emissions in 2050 from its base year and it is mainly attributed to the high demand in fossil fuels in the Province 2.

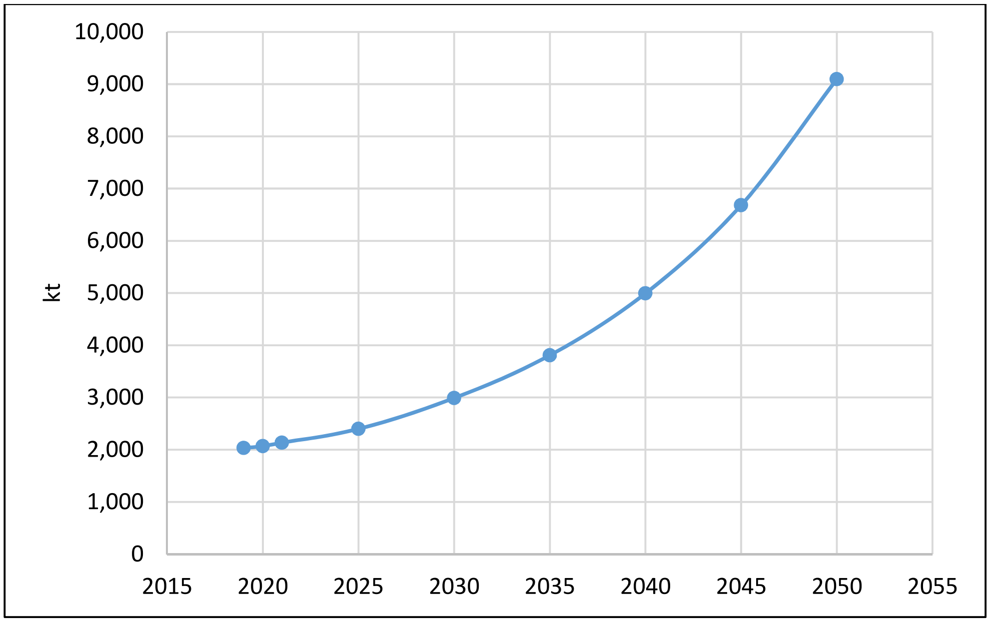


Figure 9.4: GHG emissions at Reference Economic Growth Scenario

9.1.1.1 Energy Indicators in the Reference Economic Growth Scenario

Table 9.3gives the energy indicators for Reference Economic Growth Scenario which shows that under normal circumstances, which no intervention in energy sector, the energy demand would increase such that the per capita energy demand would be double in 2050 with respect to current demand. With electricity demand for household remaining constant, the demand for other form of energy would grow. Meanwhile, the share of renewables is also expected to increase slightly in years coming by, but in the other hand the net import of fuel in also seen to reach 56% from 36%, all due to increase in demand for energy, but no supply of regionally or nationally produced energy. This being said, the imported carbon-based fuels and its use is also going to impact per capita GHG emissions reaching almost three times by 2050 from the current baseline values.

Table 9.3: Energy Indicators in Reference Economic Growth Scenario

Energy Indicators									
		2019	2020	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	10.42	10.44	10.88	11.82	13.11	14.90	17.33	20.64
Final electricity demand	kWh/capita	256	257	273	309	358	426	518	644
Final energy demand	GJ/million NRS	1,791	1,787	1,642	1,420	1,228	1,070	944	846
Final Electricity Demand	kWh/millio n NRS	44,048	43,983	41,234	37,108	33,532	30,569	28,224	26,398
Total Electricity Used/household	kWh/HH	629	629	629	629	629	629	629	629
share of non-carbon energy in primary supply	per cent	8.85%	8.86%	9.04%	9.41%	9.83%	10.29%	10.77%	11.24%
Share of renewable energy in final total energy demand	per cent	8.93%	8.94%	9.12%	9.48%	9.89%	10.35%	10.82%	11.28%
the ratio of net import to total primary energy supply	per cent	36.37%	36.45%	38.07%	41.11%	44.60%	48.43%	52.37%	56.25%
GHG emission	GHG in Kg/capita	335	336	365	425	508	623	779	991

9.1.2 Low Economic Growth Scenario

The following are the major assumptions in this scenario:

- Average GDP growth rate of 5.6%

The shares of each demand technology in the energy supply in future years will be same as in the base year Table 9.4below shows the total energy demand for the low growth case of various fuel types from the base year to 2050. The total energy demand in province 2 is expected to grow from the current level of 63.2PJ in 2019 to 167PJ in 2050 which accounts for more than two folds of increase. The average annual growth rate of energy demand is 3.2% in this scenario.

Table 9.4: Fuel Demand in Low Economic Growth Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	34.56	35.04	37.69	40.79	44.32	48.39	53.18	58.97
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
			Bio briquettes	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
			Grid Electricity	5.59	5.68	6.4	7.56	9.12	11.22	14.11	18.17
Non renewable			Petrol	3.01	3.1	3.38	3.69	4.04	4.42	4.84	5.3
			Diesel	4.84	4.92	5.77	7.29	9.39	12.31	16.42	22.3
			Kerosene	0.15	0.15	0.17	0.18	0.19	0.21	0.22	0.24
			Furnace Oil	3.65	3.71	4.42	5.71	7.52	10.06	13.67	18.86
			ATF**	0.06	0.06	0.07	0.08	0.08	0.09	0.1	0.11
			LPG	4.64	4.7	5.08	5.54	6.09	6.74	7.54	8.55
			Coal	6.63	6.75	8.03	10.39	13.68	18.31	24.87	34.31
Total				63.19	64.17	71.07	81.3	94.5	111.82	135.06	166.9

**PSF (Primary Solid Fuels) : Fuelwood, Agricultural Residue, Animal Residue*

***ATF : Aviation Turbine Fuel*

The highest share in all years is of solid biomass followed by petroleum products. The demands of coal, petroleum products and grid electricity are seen to be increased to nearly three folds from the base year value to 2050. The fuel demand trend in this scenario is as shown in Figure 9.5.

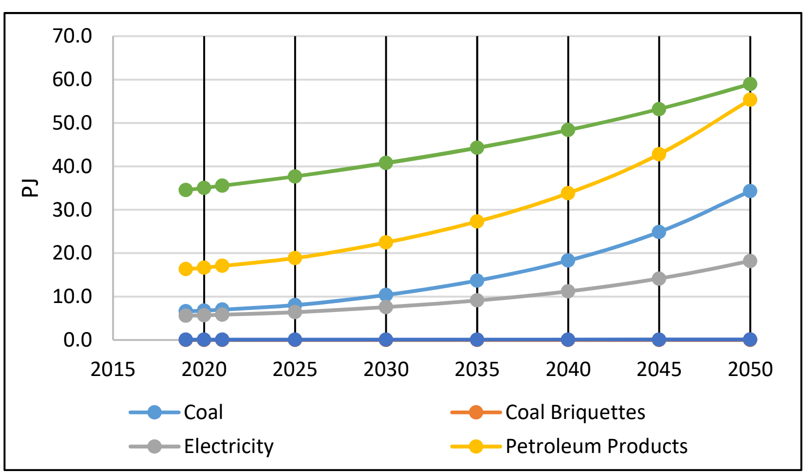
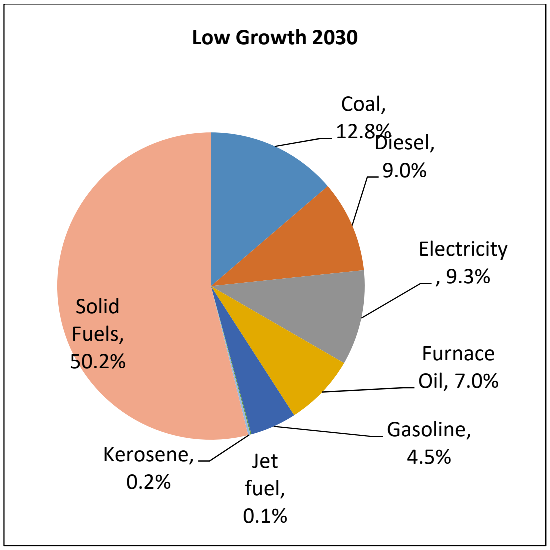
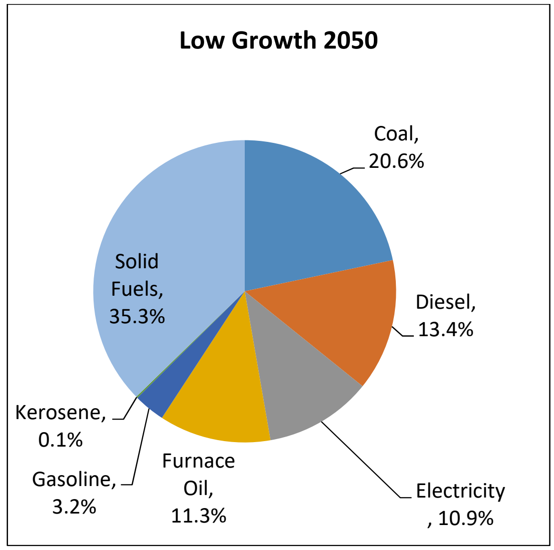


Figure 9.5:Fuel Demand Trend at Low Economic Growth Scenario

The Figure 9.6 show the energy mix in the total fuel demands for 2030 and 2050 years. The demand of solid biomass is expected to decrease to 51% in 2030 and 36% in 2050 respectively, whereas quantities of fossil fuels such as diesel and coal are expected to grow by 3 times in between 2030 and 2050. The share of electricity will be increased to 9% and 11%in 2030 and in 2050 respectively.



(a)Total Final Energy Demand = 81 PJ



(b)Total Final Energy Demand = 167 PJ

Figure 9.6: Fuel mix at Low Economic Growth Scenario

Table 9.5 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 36% in 2050 from 62% in 2019. Meanwhile, industrial sector share of energy demand will increase to 30% in 2030 and 47% in 2050. Whereas the share of Energy demands in the commercial sector will increase nearly by 4 folds in 2050 from its base year value.

Table 9.5: Sectoral Demand at Low Economic Growth Scenario

	2019	2020	2025	2030	2035	2040	2045	2050
Agriculture	0.79	0.80	0.96	1.24	1.63	2.18	2.96	4.09
Commercial	2.18	2.21	2.54	3.10	3.87	4.92	6.40	8.49
Construction and Mining	0.27	0.27	0.32	0.42	0.55	0.74	1.00	1.38
Industry	14.90	15.17	18.05	23.34	30.74	41.13	55.88	77.07
Residential	39.24	39.77	42.53	45.48	48.63	52.00	55.61	59.47
Transport	5.81	5.94	6.67	7.72	9.08	10.85	13.20	16.40
Total	0.79	0.80	0.96	1.24	1.63	2.18	2.96	4.09

Subsect oral energy demand projections are given in Annex VIII.

The power plant capacity required for the study period is as shown in Figure 9.7. The demand for grid electricity is expected to increase at the average annual rate of 5.5%. The required peak power plant in 2019 was 304MW. The future power requirement would be 686 MW in 2030 and 1,646 MW in 2050 respectively. The electricity demand per capita is seen to be growing by over two folds during the study horizon from current value of 256 kWh to 549 kWh in 2050.

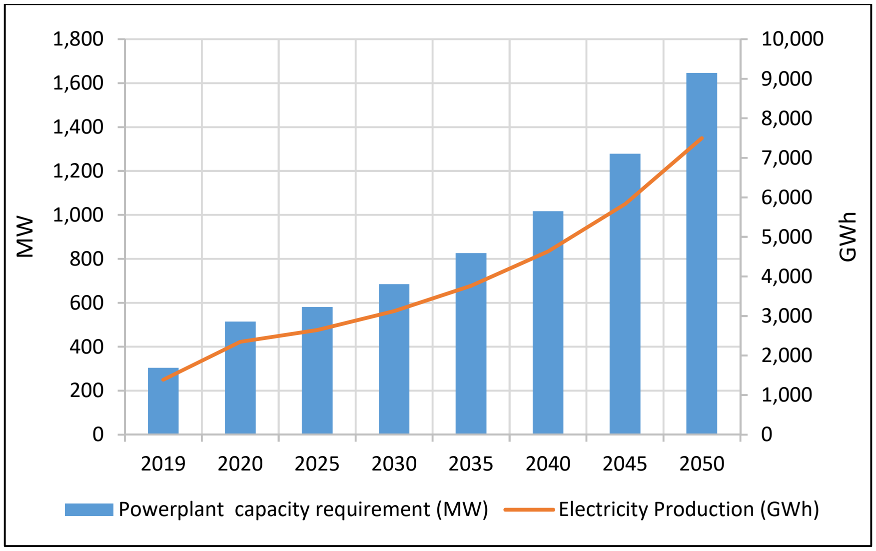


Figure 9.7:Peak Power Plant Capacity at Low Economic Growth Scenario

GHG emission trend in low economic growth scenario is as shown in Figure 9.8. GHG emissions would increase from 2033 kt in 2019 to 2,873 kt in 2030 and to 7,643 kt in 2050 respectively. The GHG emissions would grow at the average growth rate of 4% during 2019-2050.

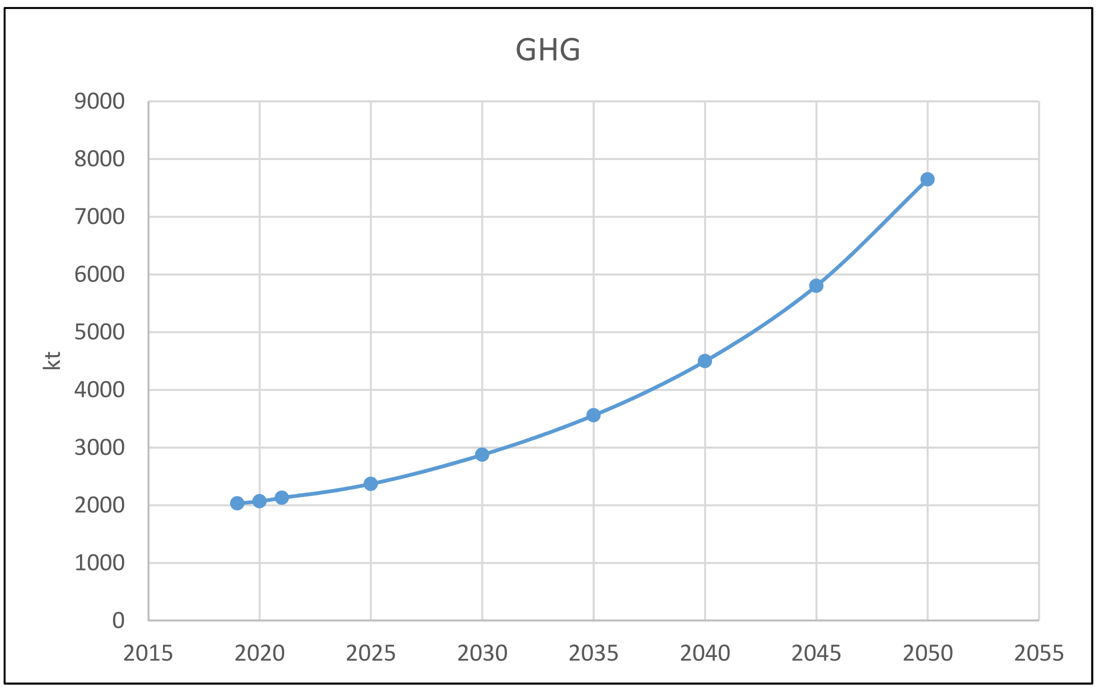


Figure 9.8: GHG Emissions at Low Economic Growth Scenario

9.1.3 High Economic Growth Scenario

The following are the major assumptions in this scenario:

- Average GDP growth rate of 6.7%
- The shares of each demand technology in the energy supply in future years will remain the same as inthe base year

Table 9.6 below shows the total energy demand for the high growth case of various fuel types from base year to year 2050. The total energy demand in province 2 is expected to grow from current level of 63.2PJ in 2019 to 205PJ in 2050 which accounts for more than three folds of increase. The average annual growth rate of energy demand is 3.9% in this scenario.

Table 9.6: Fuel Demand in High Economic Growth Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	34.56	35.04	37.74	40.99	44.8	49.4	55.17	62.58
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05
			Bio briquettes	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
			Grid Electricity	5.59	5.68	6.48	7.86	9.83	12.71	17.03	23.47
Non renewable			Petrol	3.01	3.1	3.38	3.7	4.04	4.43	4.86	5.35
			Diesel	4.84	4.92	5.89	7.74	10.48	14.59	20.89	30.43
			Kerosene	0.15	0.15	0.17	0.18	0.19	0.21	0.23	0.25
			Furnace Oil	3.65	3.71	4.52	6.12	8.5	12.11	17.69	26.17
			ATF**	0.06	0.06	0.07	0.08	0.08	0.09	0.1	0.11
			LPG	4.64	4.7	5.09	5.59	6.2	6.98	8.01	9.39
			Coal	6.63	6.75	8.22	11.13	15.47	22.04	32.19	47.61
Total				63.19	64.17	71.62	83.45	99.69	122.65	156.25	205.47

**PSF (Primary Solid Fuels) : Fuelwood, Agricultural Residue, Animal Residue*

***ATF : Aviation Turbine Fuel*

The impact of economic growth is observed directly in highly increasing trends of petroleum products and coal-petroleum products even surpassing solid biomass fuels in 2050. Since Coal and petroleum products are the major source of fuel in industry, their demand increases with growth in economic activities. It is seen that there is a four-fold increase in petroleum products and a seven-fold increase of coal in 2050 from its base year value. Electricity requirement is expected to grow by four-fold in this scenario, mostly due to growth in economic activities in commercial and industrial sector. Since Residential sector is major sector consuming solid biomass fuel, the growth in fuel demand in this sector is affected mostly by the demographic drivers. Petroleum products consumption is thus higher than that of solid biomass fuels in 2050. The fuel demand trend in this scenario is as shown in Figure 9.9.

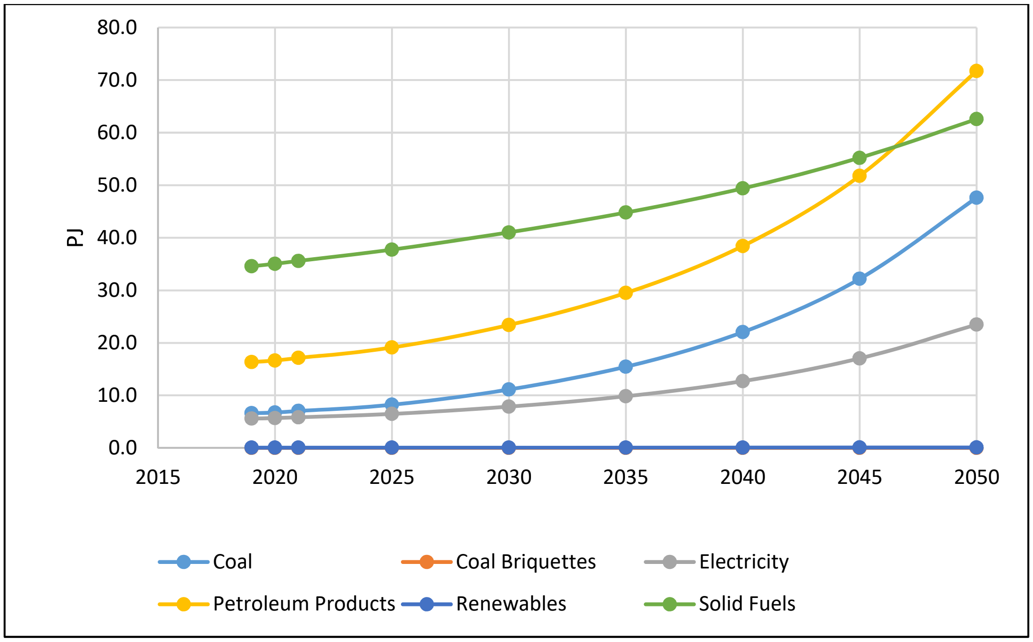
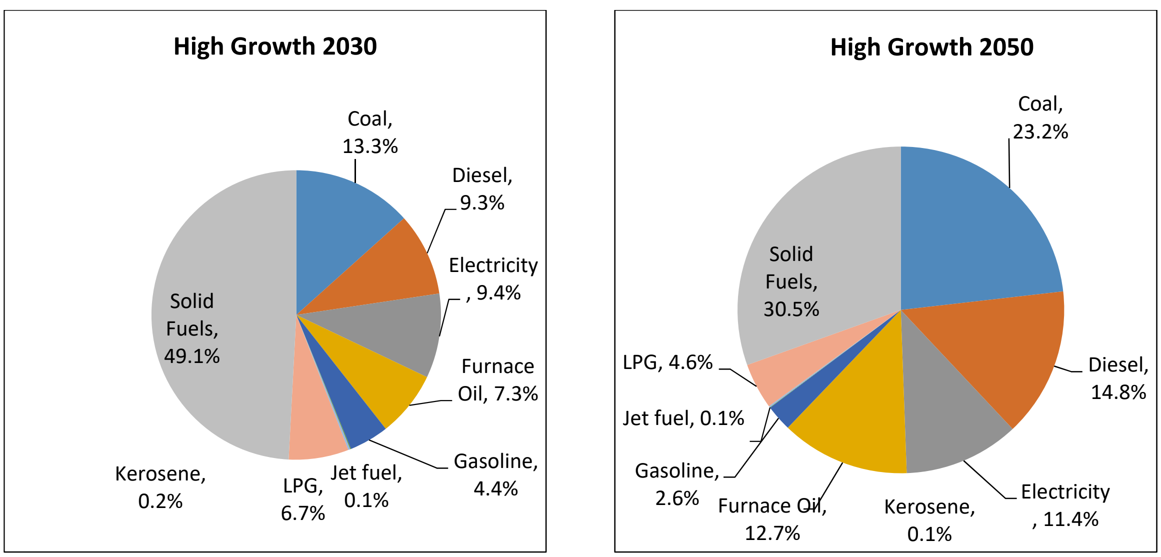


Figure 9.9: Fuel Demand Trend at High Economic Growth Scenario

The Figure 9.10 below show the energy mix in the total fuel demands for 2030 and 2050. The demand for solid biomass fuels is expected to be49% in 2030 and 31 % in 2050, respectively. In this scenario, fossil fuels like diesel and coal increase by more than 5 folds. The share of electricity will increase to 9% and 11% in in 2030 and 2050, respectively.



(a)Total Final Energy Demand = 83 PJ (b)Total Final Energy Demand = 205 PJ

Figure 9.10: Fuel Mix at High Economic Growth Scenario

The Table 9.7 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 29%% in 2050 from 62% in 2019. Meanwhile, industrial sector share of energy demand will increase to 30% in 2030 and 53% in 2050 respectively. Whereas the share of Energy demands in the commercial sector will increase by more than 5 folds in 2050 from its base year value.

Table 9.7: Sectoral Demand at High Economic Growth Scenario (PJ)

	2019	2020	2025	2030	2035	2040	2045	2050
Agriculture	0.79	0.80	0.98	1.33	1.84	2.63	3.84	5.67
Commercial	2.18	2.21	2.58	3.26	4.25	5.72	7.96	11.34
Construction and Mining	0.27	0.27	0.33	0.45	0.62	0.89	1.30	1.92
Industry	14.90	15.17	18.48	25.01	34.76	49.52	72.31	106.97
Residential	39.24	39.77	42.53	45.48	48.63	52.00	55.61	59.47
Transport	5.81	5.94	6.72	7.93	9.58	11.89	15.24	20.11
Total	63.19	64.17	71.621	83.455	99.688	122.65	156.25	205.47

Sub sectoral energy demand projection is given in Annex VIII.

The power plant capacity required for the study period is as shown in Figure 9.11. The demand for grid electricity is expected to increase at the average annual rate of 6%. The required peak power plant in 2019 was 304 MW. The future power requirement would be 712 MW in 2030 and 2,127 MW in 2050. The electricity consumption per capita is seen to be growing by over two folds during the study horizon from current value of 256 kWh to 710 kWh in 2050.

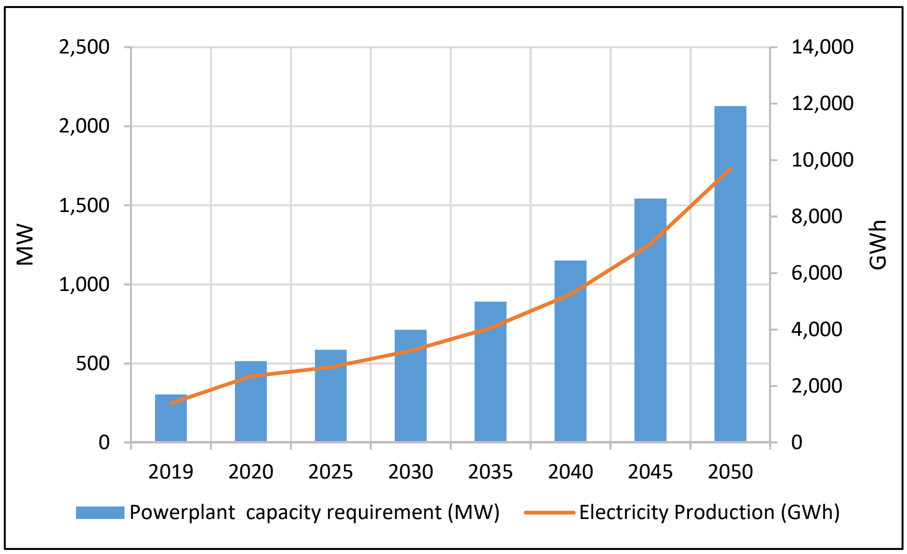


Figure 9.11:Peak Power Plant Capacity at High Economic Growth Scenario

GHG emission trend in high economic growth scenario is as shown in Figure 9.12. GHG emissions would increase from 2,033 kt in 2019 to 3,012 kt in 2030 and to 10,119 kt in 2050. The GHG emissions would grow at the average growth rate of 5% during 2019-2050. GHG emissions will be growing exponentially between the period 2030 to 2050 as a consequence of high GDP growth and higher demand for fossil fuels in the Province 2.

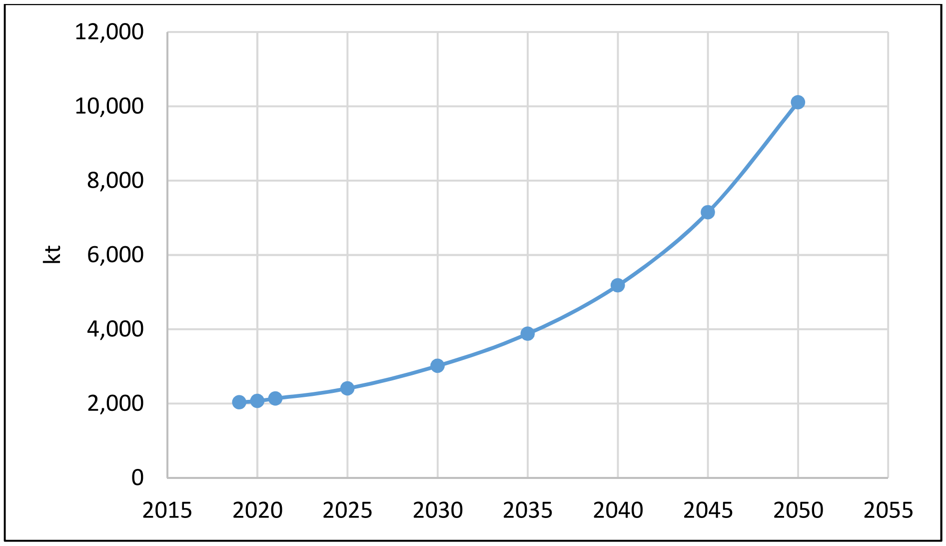


Figure 9.12: GHG Emissions at High Economic Growth Scenario

9.1.4 Sustainable Energy Development Scenario (SEDS)

In this scenario all combined policy measures are considered at an average annual GDP growth of 6.3% for various technology Interventions. The major focus is on electrification by renewable energy and energy efficiency in various demand technologies. The assumptions are in line with the various published reports and documents of Nepal Governmental agencies, IEA, IRENA, Paris Agreement, UN's SDGs programs, and other international energy and emissions-related programs.

The following are the major assumptions of this scenario.

- GDP growth rate according to reference case i.e. 6.3%.
- The shares of energy technologies vary in line with intervening strategies which are given below.

Agriculture:

- 50% Electrification in water pumping by 2050
- 50% Solar water pumping by 2050

Commercial sector

- 100% electrification by 2050

Transportation

- Intercity transport
    - 80% intercity passenger vehicle by public bus
    - 50% electric bus by 2050,
    - 10% electric car by 2050
    - 2.5% electric two wheelers by 2050
- Intercity transport
    - 5% electric car by 2050,
    - 5% electric train by 2050
- Freight transport
    - 30% electric train by 2050

Industry:

- Boiler
  - electric boiler in food beverage and tobacco and 100% share by 2050
  - electric boiler in textile and leather and 100% share by 2050
  - electric boiler in chemical rubber and plastic and 100% share by 2050
- Motive power and other
  - 100% electrification by 2050
- Process Heat
  - 70% electrification by 2050

Residential sector:

- Rural cooking:60% electric, 10% fuelwood and 20% LPG by 2050
- Rural space heating: 100% electrification by 2050
- Rural water heating: 100% electrification by 2050
- Rural Animal Feeding:10% LPG, 10% wood, 50% Electric, 30% Biogas by 2050
- Rural others: 100% electrification by 2050
- Urban cooking: 100% electrification by 2050
- Urban space heating: 100% electrification by 2050
- Urban water heating: 100% electrification by 2050
- Urban Animal Feeding:10% LPG, 50% Electric, 40% Biogas by 2050
- Urban others: 100% electrification by 2050

The final demands of various fuels in this scenario have been given in Table 9.8. The total energy consumption in 2030 and 2050 is expected to be 71 PJ and 144PJ respectively. Per capita energy demand is expected to be 16 GJ in 2050 in the Sustainable Energy Development Scenario (SEDS), whereas it would be 21 GJ in the Reference Economic Growth Scenario.

Table 9.8:Fuel Demand in Sustainable Energy Development Scenario(PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	34.56	33.97	30.87	27.33	23.12	18.09	12.04	4.63
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.03	0.04	0.11	0.19	0.28	0.38	0.49	0.62
			Bio briquettes	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0
	New Renewables		Solar PV	0.01	0.01	0.02	0.04	0.08	0.14	0.23	0.39
			Grid Electricity	5.59	6.23	10.61	17.33	27.38	42.73	66.29	102.72
Non renewable			Petrol	3.01	3.1	2.9	2.65	2.33	1.92	1.42	0.8
			Diesel	4.84	4.86	5.38	6.44	7.76	9.4	11.29	13.35
			Kerosene	0.15	0.15	0.13	0.12	0.1	0.07	0.05	0.02
			Furnace Oil	3.65	3.62	3.85	4.44	5.08	5.69	6.04	5.78
			ATF**	0.06	0.06	0.07	0.08	0.08	0.09	0.1	0.11
			LPG	4.64	4.57	4.23	3.86	3.41	2.87	2.19	1.33
			Coal	6.63	6.61	7.14	8.41	9.92	11.59	13.16	14.19
Total				63.19	63.24	65.33	70.89	79.55	92.98	113.32	143.96

**PSF (Primary Solid Fuels) : Fuelwood, Agricultural Residue, Animal Residue*

***ATF : Aviation Turbine Fuel*

In this scenario, the final energy demand would grow at the rate of 3% per annum whereas electricity demand grows at an average rate of 10% per annum during 2019-2050. Compared to other energy carriers, electricity demand will be surpassing their demands by 2035. The primary solid biomass (wood, agri -residue and animal dung) demand is expected to reduce at the rate of 6% during the same period due to clean energy technology intervention in all major sectors. Policy intervention to reduce petroleum demand mainly in industry and transport significantly shows reduction of its demand in future years. Modern renewables are expected to grow at the rate of 10% per annum during the analysis period. The energy demand trends are highlighted in Figure 9.13.

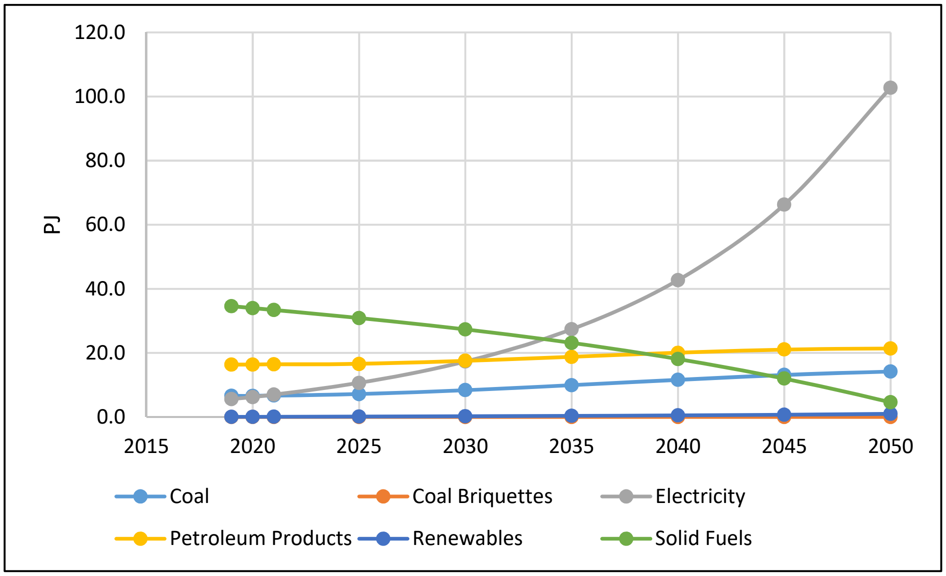
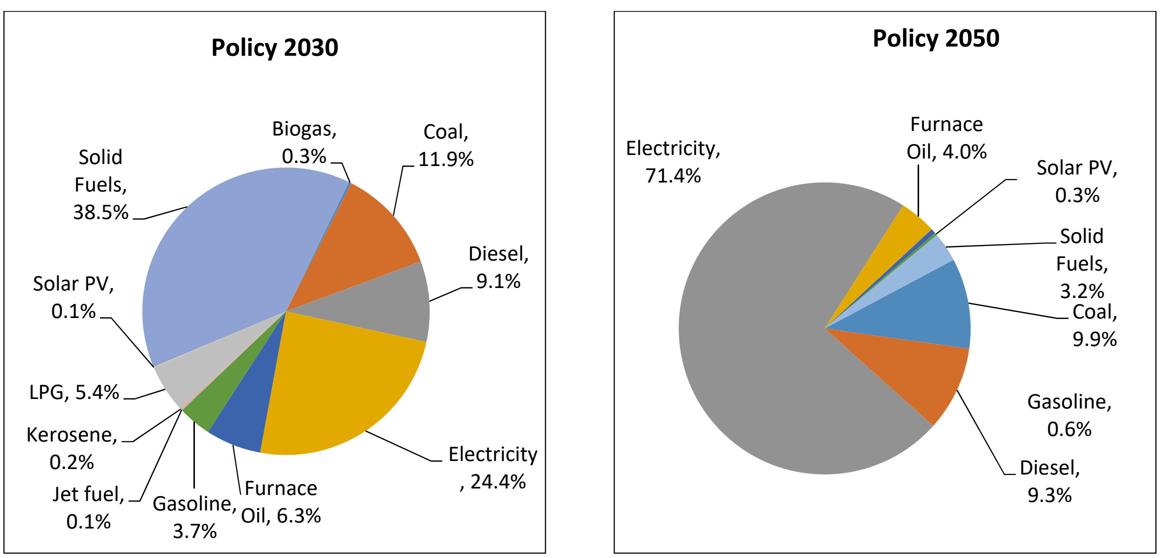


Figure 9.13:Fuel demand trend at Sustainable Energy Development Scenario (SEDS)

The Figure 9.14 below show the energy mix in the total energy demands for 2030 and 2050 years. The demand of fuelwood is expected to be decreased to 39% in 2030 and 3% in 2050, respectively. The electricity demand would be 24% in 2030 and 72% in 2050 respectively.



(a)Total Final Energy Demand = 71 PJ (b)Total Final Energy Demand = 144 PJ

Figure 9.14:Fuel Mix at Sustainable Energy Development Scenario (SEDS)

The Table 9.9 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 12% in 2050 from 62% in 2019. Meanwhile, industrial sector share of energy demand will increase to 35% in 2030 and 68% in 2050respectively, Whereas the share of Energy demands in the commercial sector will increase almost 5 folds in 2050 from its base year value.

Table 9.9: Sectoral Demand at Sustainable Energy Development Scenario (SEDS) (PJ)

	2019	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Agriculture	0.79	0.80	0.91	1.14	1.47	1.90	2.48	3.23
Commercial	2.18	2.21	2.56	3.20	4.10	5.38	7.20	9.78
Construction and Mining	0.27	0.27	0.33	0.44	0.61	0.85	1.20	1.70
Industry	14.90	15.18	18.48	24.93	34.32	48.09	68.04	97.06
Residential	39.24	38.84	36.56	33.79	30.45	26.49	21.83	16.40
Transport	5.81	5.94	6.48	7.39	8.60	10.27	12.58	15.79
Total	63.19	63.24	65.33	70.89	79.55	92.98	113.32	143.96

The power plant capacity requirement in this scenario is as shown in Figure 9.15. The base year power requirement is 304 MW in Province 2. The power plant requirement for 2030 will be 1,699MW, and it will be 9,649 MW by 2050. Out of total power plant requirement approximately 10% will be fulfilled by solar power plant (gdid and off-grid). The requirement is almost 5times more than the requirement in the reference case in 2050. The power plant requirement would grow at the rate of 12% per annum during 2019-2050. Industrial sector occupies the highest energy demand quantitatively compared to energy demands in other economic sectors from 2035 onwards.

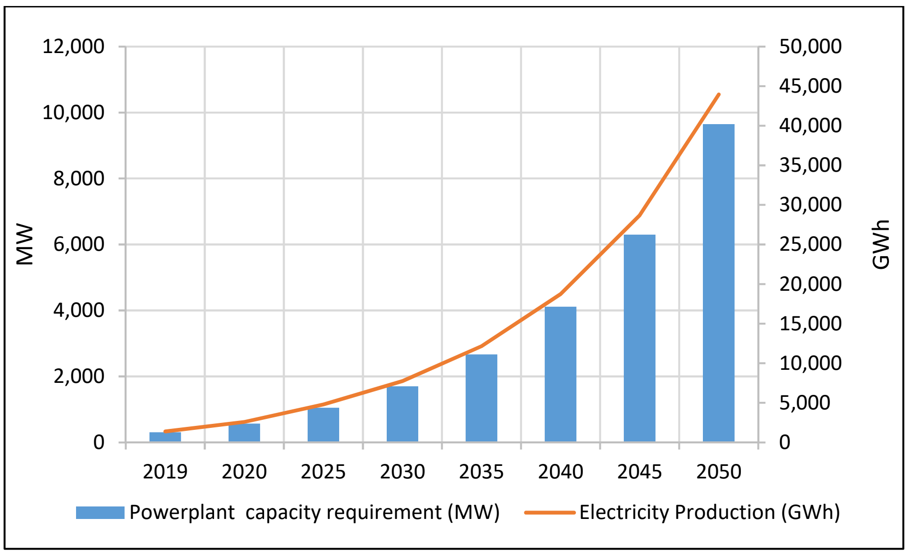


Figure 9.15:Power Plant capacity in Sustainable Energy Development Scenario (SEDS)

GHG emission trend in Sustainable Energy Development Scenario (SEDS)is shown in Figure 9.16. GHG emissions would increase from 2,033 kt in 2019 to 2,039 kt in 2030 and to 2,867 kt in 2050. The GHG emissions would grow at the average rate of 1% during 2019-2050. Compared to the Reference Economic Growth Scenario, GHG emissions in SEDS would be reduced by 25% in 2030 and by 68% in 2050 respectively. Province 2 has industrial sector as a prominent economic sector. Because of the focus on electrification through renewable energy and energy efficiency in all sectors, economic development has less impact on GHG emissions. This is also in line with the national and international programs in achieving SDGs and mitigation of effects of climate change (Harvey et al., 2018; IEA, 2017; UN, 2015; IEA, 2020; LIFE-AR, 2019; NPC,2016; WB,2020).

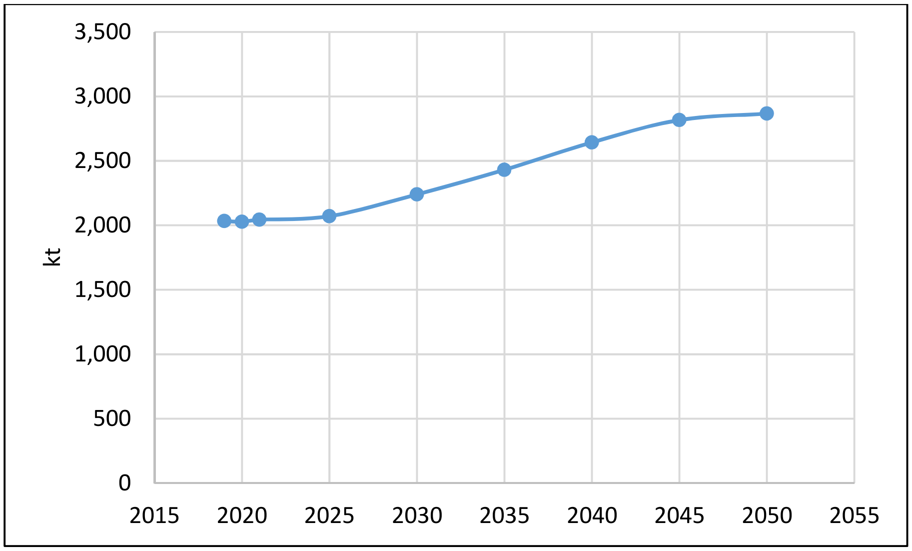


Figure 9.16: GHG Emissions at Sustainable Energy Development Scenario (SEDS)

9.1.4.1 Energy Indicators in the Sustainable Energy Development Scenario (SEDS)

Table 9.10 shows the energy indicator for policy scenario i.e. SEDS which clearly presents that impacts of strategic interventions in energy sector. Per capita final energy demand is 3/4th of that in Reference Economic Growth Scenario in 2050, while the electricity – which comes from clean renewable resources – increases by nearly 5 folds to over 3,000 kWh per capita. The impact of energy efficiency is visible in energy demand per capita as well as energy required per millions of GDP as well. In addition to this, the share of fuel imports nearly flat lines till period of 2030 and decreases to by one third in 2030. On other hand, use of national resources increases with increase in use of renewables to 72% in 2050 as compared to only 11% in the Reference Economic Growth Scenario.

Table 9.10: Energy Indicators in Sustainable Energy Development Scenario (SEDS)

Energy Indicators									
		2019	2020	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	10.42	10.29	9.94	10.08	10.58	11.57	13.18	15.66
Final electricity demand	kWh/capita	256	282	449	686	1,014	1,481	2,149	3,116
Final energy demand	GJ/million NRS	1,791	1,761	1,500	1,212	991	830	718	642
Final Electricity Demand	kWh/million NRS	44,049	48,238	67,798	82,465	95,027	106,298	117,042	127,671
Total Electricity Used/household	kWh/HH	629	689	988	1,288	1,588	1,888	2,187	2,487
share of non-carbon energy in primary supply	per cent	8.85%	9.86%	16.27%	24.50%	34.51%	46.10%	58.70%	71.63%
Share of renewable energy in final total energy demand	per cent	8.93%	9.96%	16.47%	24.79%	34.88%	46.51%	59.14%	72.06%
the ratio of net import to total primary energy supply	per cent	36.37%	36.31%	36.27%	36.65%	36.06%	34.02%	30.23%	24.72%
GHG emission	GHG in Kg/capita	335	330	315	319	324	329	328	312

9.2 Comparative Analysis

Figure 9.17 shows the final energy demand for the reference and policy scenarios which clearly shows the impact of fuel switching and energy efficiency. In short term, the total final energy demand could be reduced by nearly 15% in 2030 to nearly 24% energy saving in 2050 in long term.

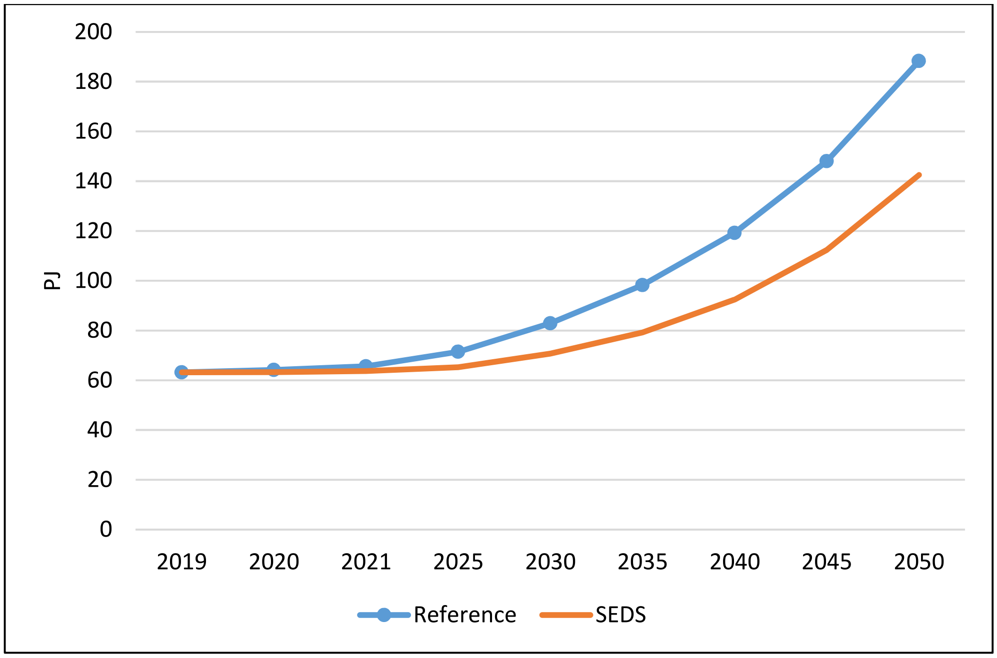


Figure 9.17: Total Final Energy Demand in Province 2

Per capita energy demand in Figure 9.18 also shows similar pattern as above, but peculiarly per capita energy demand can be seen to be decreased till 2025, which is good sign of impact of energy efficiency. This is positive sign in double way - that there is energy saving in one hand, and on the other hand, economic development activities are moving forward.

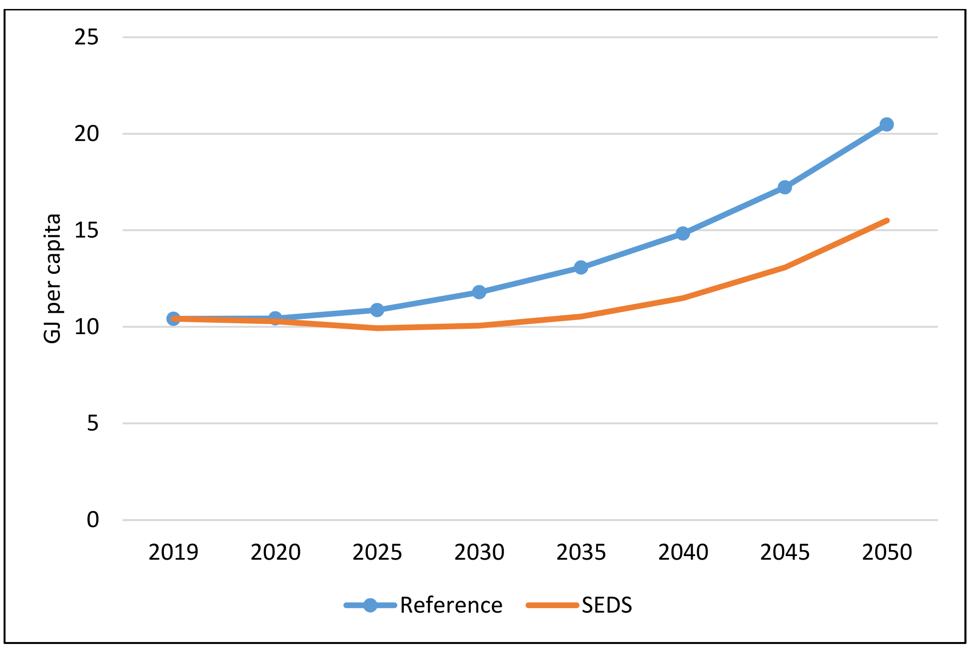


Figure 9.18: Final Energy Demand Per Capita in Province 2

Figure 9.19 depicts the electricity demand in compared scenarios which shows that in the SEDS, the household electricity demand of 2,500 kWh/HH comes near to the Tier-5 criteria of 3,000kWh/HH by the World Bank (WB/ESMAP, 2019). Additionally, the growth in access to electricity means increase in demand for nationally available hydroelectricity production.

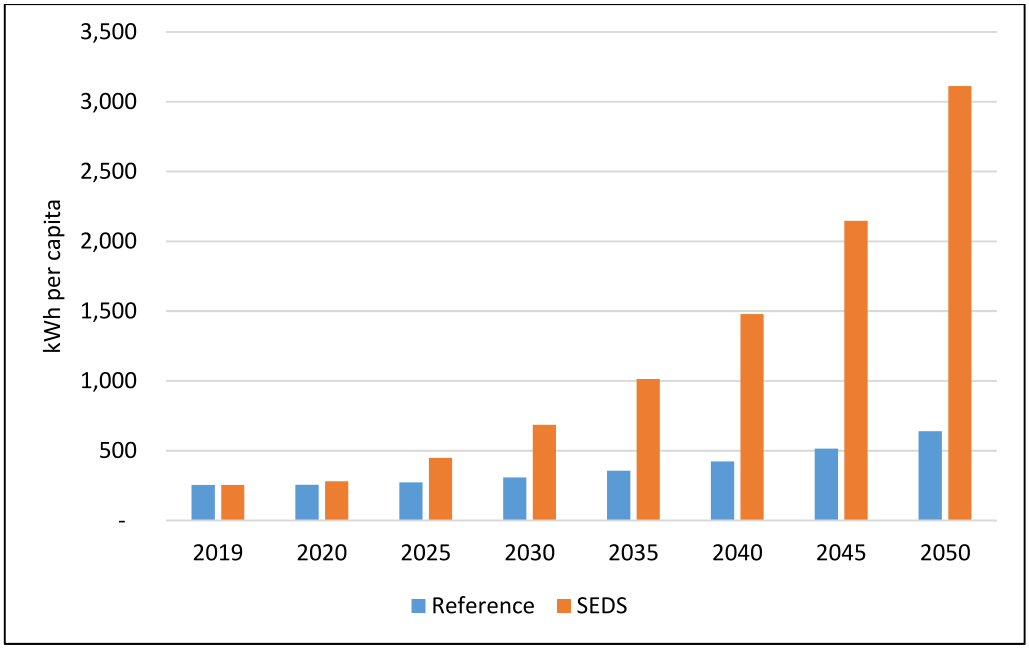


Figure 9.19: Electricity Demand Per Capita in Province 2

With the intervention of electric technologies and development in indigenous production of electricity from hydropower and other renewable energy, the share of renewable energy would increase as shown in Figure 9.20. the share of clean renewable energy would increase from less than 10% in 2019 to more than 70% in 2050, provided that enough hydropower and power from solar PV are developed provincially and nationally.

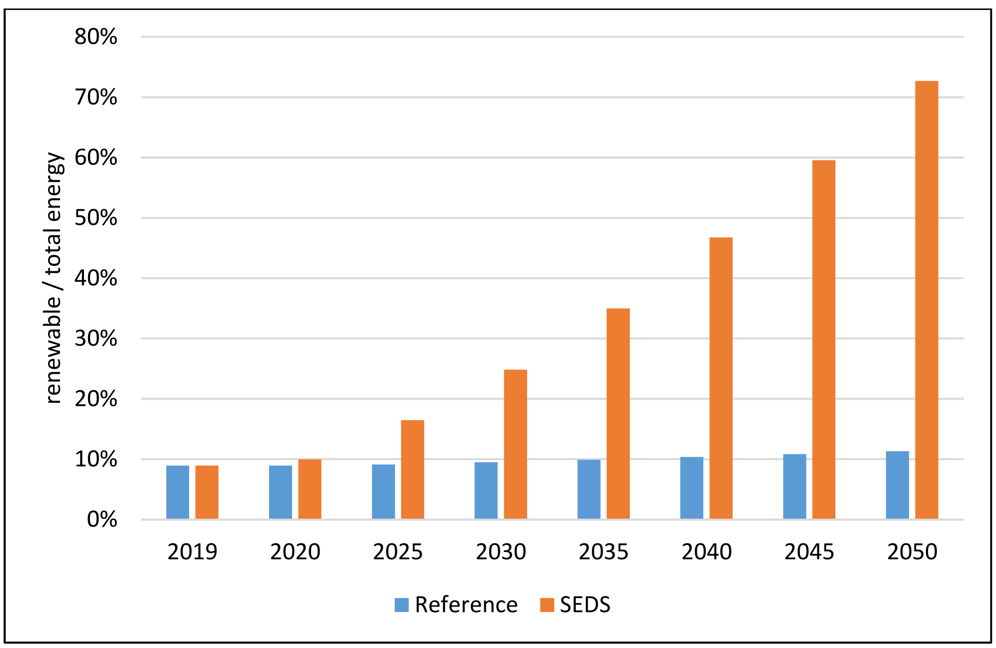


Figure 9.20: Renewable Energy to Total Energy Demand Ratio in Province 2

The effect of energy development and production from indigenous resources reduces the pressure on fuel dependency which is depicted in Figure 9.21. The net fuel import ratio of 57% in the Reference scenario would come down to 25% in the SEDS in 2050 with the enforcement of policy actions and thus, strengthening the energy security of the country and reducing outflow of foreign currency. As a consequence, it enhances the balance of the payment of the Province 2 and the country.

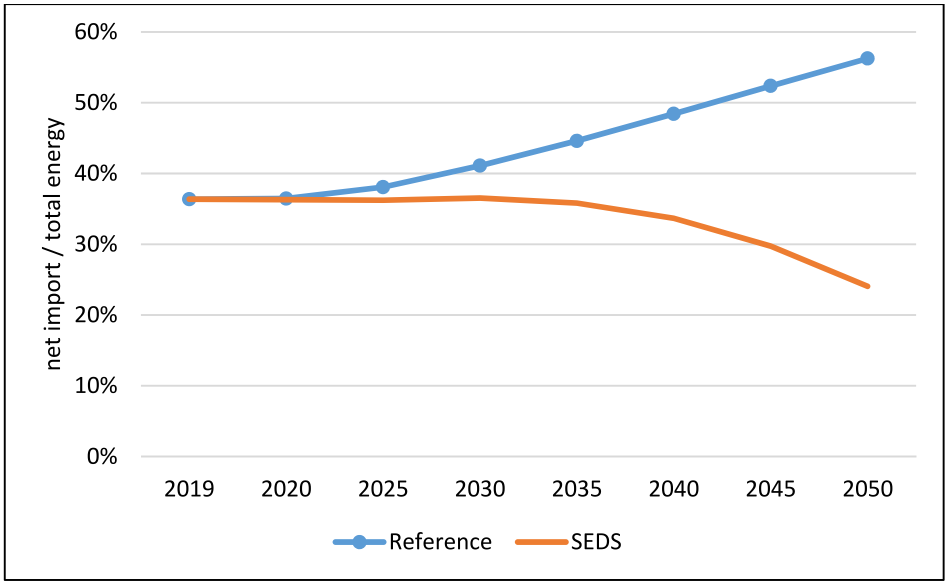


Figure 9.21:Petroleum Import to Total Energy Ratio in Province 2

Figure 9.22 shows the impact in GHG emissions dues to policy interventions of clean energy. Emissions which were growing at the rate of 22% in the Reference Economic Growth Scenario would increase at the rate of only 1% resulting in the GHG emission reduction of 25% in year 2030 and up to 69% in year 2050. This reduction in GHG emissions is not only beneficial for climatic reasons, but also for (a) health perspective – since use of carbon based fuels emit other pollutants that directly affect health of local population and users, and (b) economic perspective - by monetizing the emission reduction by carbon trading.

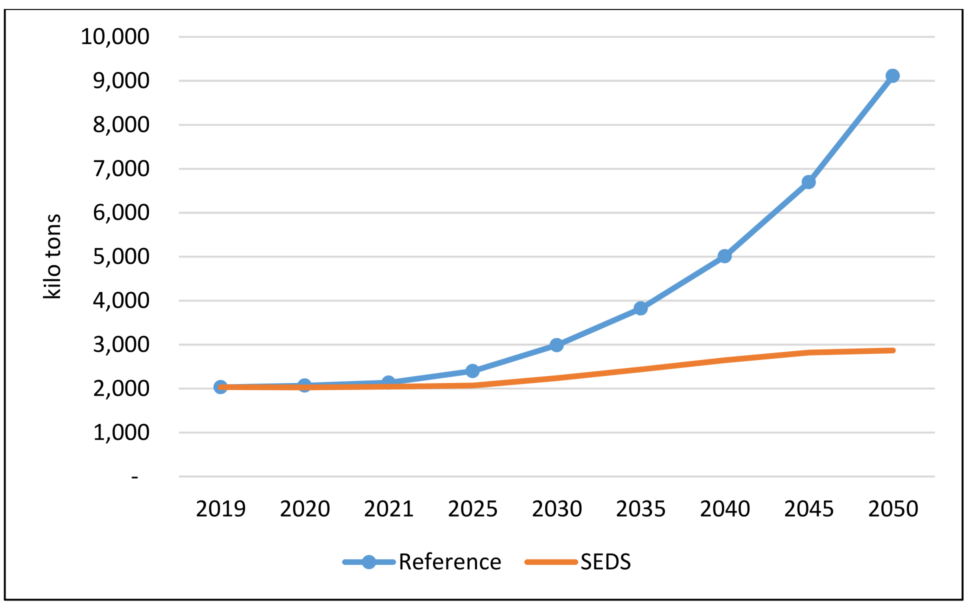


Figure 9.22: GHG Emission in Province 2

To meet large share of the energy requirements in the SEDS and achieve the goals descripted in above paragraphs, the development of hydropower plant is essential. With respect to reference case, the hydro power plant capacity requirement in policy scenario in 2030 and 2050 would be 2.4 times and 5 times respectively than that of reference scenario as shown in Figure 9.23.

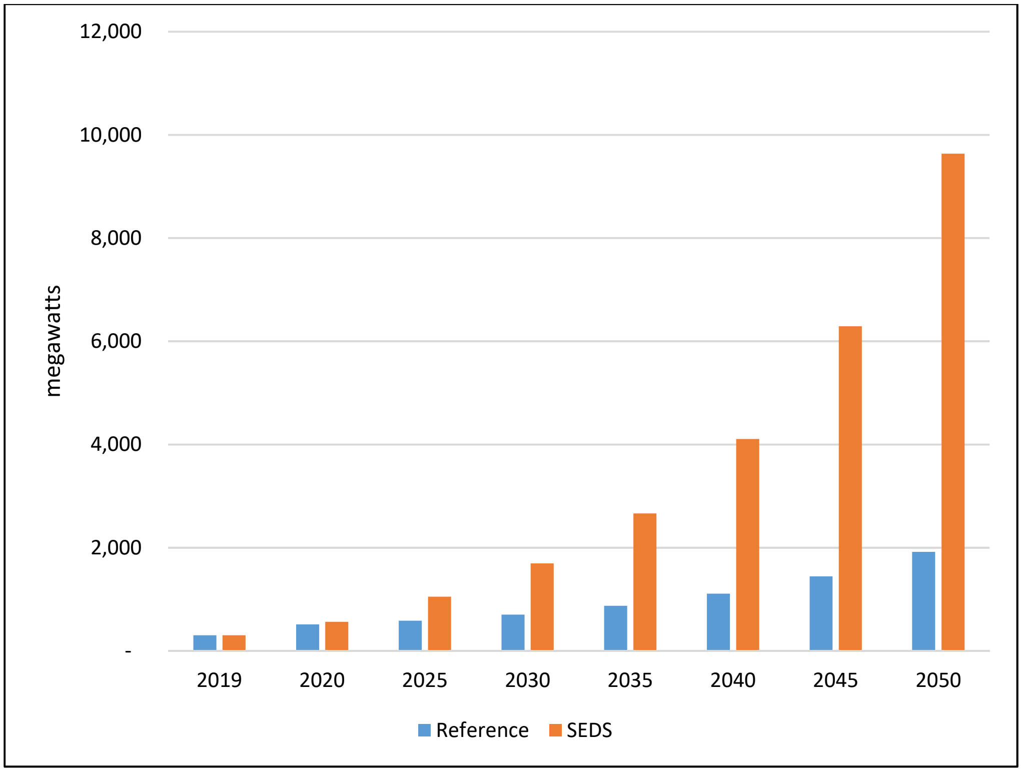


Figure 9.23:Power Plant Capacity Requirement in Province 2

10 Economic Analysis

There are strong interactive linkages among energy, economics, and environment. A comparative analysis has been conducted between these segments in the Reference scenario and the SEDS. This kind of analysis is very essential for the policymakers to take necessary implementation actions in energy sector of the Province 2. Table 10.1 shows the total investment cost for supply technologies in 2018 constant prices compared to the GDP under respective years. GDP is expected to increase by 1.6 folds and 6.4 times by 2030 and 2050 respectively from the base year value with average economic growth rate of 6.3% in reference scenario.

10.1 Capital Investment

In REF scenario, the gross investment share in supply technologies is around 4 % of GDP on average. In the SED scenario, new and efficient technology interventions are done. To achieve the sustainable developments goals, the capital investment should increase form current 3.5% of GDP to 8.5% by 2030 and 12.6% by 2050 respectively. The high investment in the SED scenario is mainly due to the investments required in developing hydropower and other renewable energy plants to meet the growing electricity demand because of electrification in all major end uses in all economic sectors (Table 10.1).

In case of the Province 2, which have very limited resources and feasibility for development of hydropower plants, the province basically needs to bring in the electricity from other provinces. Thus, the capital investment as given in Table 10-1, is not the actual investments needed to be put upon by the province 2 itself and the province does not need to bear all the capital costs of the hydropower development, however, the grid capacity development has to be done within the province for improvement to meet larger electricity demand. In addition to this, the province can build up solar power plants within the region for daytime supply at peak solar insolation hours of the day, but still needs to reply on national grid for major part of power supply.

Table 10.1: Total Technology Cost for different scenarios

	2020	2025	2030	2035	2040	2045	2050
REF	12.91	23.13	35.46	48.37	63.18	82.11	108.66
Capital Investment as % of GDP	3.12%	4.61%	5.26%	5.23%	4.89%	4.51%	4.20%
SEDS	14.65	31.76	57.30	91.25	139.76	212.39	325.02
Capital Investment as % of GDP	3.54%	6.32%	8.49%	9.86%	10.82%	11.67%	12.56%

The high capital costs required in electricity production in years 2030 onwards are huge and looks beyond its capacity for the Provincial Government. As development of large hydropower plants are under the purview of the Federal Government, the capital investments for electricity production will be within the range of 6% of the GDP as envisaged by a policy research working paper of the World Bank (WB, 2015) in the South Asia Region.

10.2 The Marginal Abatement Cost

GHG emissions for reference scenario and SEDS scenario is shown in Figure 10.1. It shows that there is substantial reduction of GHG emission in SEDS scenario. In 2030, the reduction of emission compared to that of base case scenario is 25%, and 69% in 2050. This considerable reduction of GHG emission accounts to efficient and modern technology.

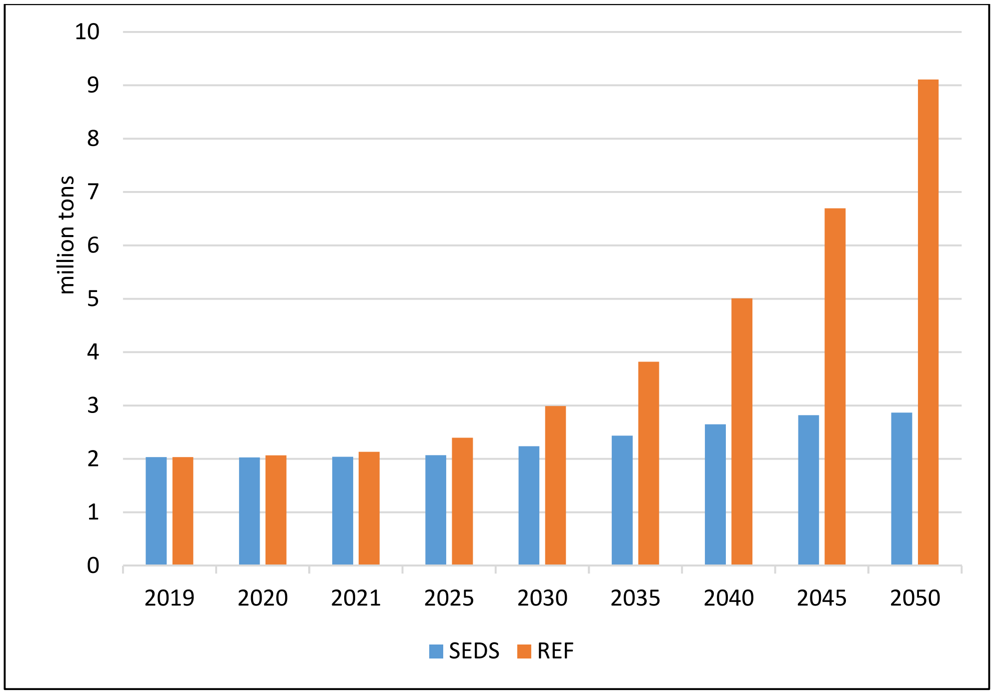


Figure 10.1: GHG Emission for Different Scenarios

However, this reduction in emissions comes at a cost viz. – replacement of old energy using technologies by new cleaner technologies and development of clean energy sources i.e. hydro power plant and solar power plants. Thus, it is essential to measure the amount of investments required to understand the applicability of the strategic actions for reduction of emissions. Table 10.2 gives the information on the cumulative marginal abatement cost (MAC) required for reducing each ton of GHG emissions in the different periods of time. The incremental investments depict the difference in cost of old technologies and the new technologies, that replaces the technologies that would have existed in reference scenario under no interventions. The MACs are in the range as calculated for other developing countries.

Table 10.2: MAC ("000 NRs. Per tons of CO2e)

	2020	2025	2030	2035	2040	2045	2050
Incremental Investments	1.74	8.63	21.84	42.88	76.58	130.28	216.36
GHG abated	41.38	327.52	748.85	1383.38	2360.77	3876.21	6242.67
MAC ('000 NPR/ton of CO2e)	42.05	26.35	29.17	31.00	32.44	33.61	34.66

10.3 Net Fuel Import Cost

Figure 10.2 shows the implication of SEDS scenario in terms of saving in net import of petroleum fuels. It is seen that the saving is substantial under the SEDS scenario counting over 19 billion NRs in 2030 and 289 billion NRs in 2050 from that of the REF scenario. All the cost incurred are at constant price of 2018. This cost benefits can be invested in development of the electricity generation and distribution system for quality supply of the energy. Comparing the savings to the investment required for power plant development, the savings can account for more than 30% investment required in 2030 for clean power plant development, while in 2050 the saving can contribute nearly 90% of the investment required. This indicates significant reduction in dependency on imported fuels. Policy intervention to promote modern and efficient indigenous energy sources will hence improve energy security of the nation. These highlights need of proper energy policy in the future. Furthermore, detailed analysis for the strategic actions plans for investment from cost savings needs to be carried out for proper implementation and achievement of the clean and energy efficient targets.

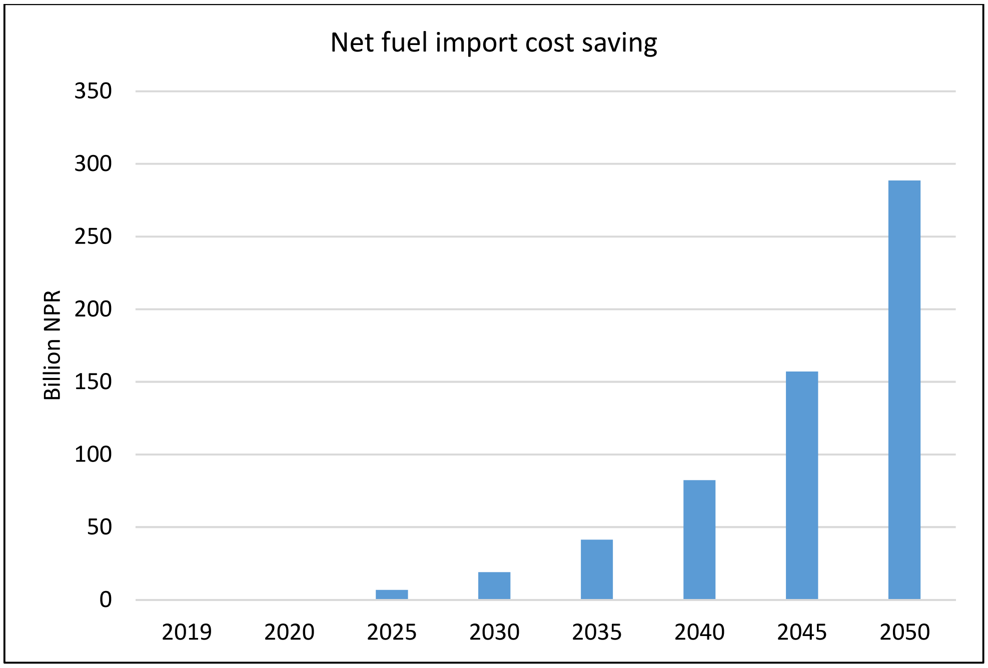


Figure 10.2: Net Fuel Import Cost Savings

10.4 Carbon Trading

In addition to savings form import of fuel and the value addition to national economy by trading of electricity produces within the nation's boundary, additional economic benefits can also be caught. The significant abatement of GHG emissions in SEDS compared to REF scenario can be traded as per international carbon pricing of $10. The benefit from carbon trading is as shown in Table 10.3

Table 10.3: Carbon Trading Benefits (billion Rs.)

	2025	2030	2035	2040	2045	2050
Carbon trading benefits (billion Rs)	0.52	1.55	3.18	8.12	17.21	35.78

In the decade from 2020-2030, incremental supply costs are higher than the savings from fuel imports and carbon trading if the Province 2 makes investments in hydropower development in other Provinces. Otherwise, if it purchases electricity from the national grid for meeting its demands and it does not have to invest in the other power development apart from the solar power plants, there are benefits higher than the investment costs in the Province 2 even in the decade 2020-2030. After 2040, there are huge benefits of NR 157 billion and NR 289 billion in 2045 and 2050, respectively. Overall, if the Province takes a pathway of sustainable energy development, Province 2 will be hugely benefited in the long run.

10.5 Limitations and Constraints of the Survey

The survey has faced several constraints and the data analysis had to be done within the perimeter of limited data acquired. Some of the major limitations and constraints arose in this study are listed below.

- The primary and secondary data on current situation of the province were not available at the most, that are needed during the pre-planning phase of the study and also required for the post analysis of the energy demand – such as the population; the gross value added of each type of economic sector and subsector; the number of transportation vehicles by type and registration; the types of household; the actual number of functioning institutions, as well as the supply database.

- Many respondents were reluctant to give information due to hesitation, mistrust, unwillingness to share personal information and even dissatisfaction from current situation as one of the major hurdles.
- Although the surveyors were technically sound and of same geographical background – which aided a fluent workout during survey, the social situation, mainly in rural area posed some problem. The residents would either be hesitant and/or have no idea on the specific questions asked.
- The economic sectors such as commercial and industrial sectors were reluctant to share their information. Either they denied giving information or had to have multiple visits. In industries, the data collection was most difficult. Sometimes access to industry premises and information were denied even at the requests from experts by telephone. The unavailability of concerned persons, no knowledge of required information and even not having authority to provide information were the responses posed upon by the respondents.
- In addition, much information provided by respondents was too dubious. Such data were had to be adjusted by expert judgement.
- The information provided by respondents themselves were not as accurate as they had to give a hunch based on the memory and in many cases such as residential, agriculture and small commercial entities do not keep record of their energy use.
- The newly added construction and mining sector also had major difficulties in collection of data. These sectorial entities either are not locally based and/or bring the equipment from other region when necessary for the limited time as per requirement. Thus, their energy demand had to be based more on overall yearly energy demand than by each end-use activity.
- Demand and the whole energy systems scenarios are developed based on the energy consumption survey in the Province 2, and availability of secondary data in the energy resources and other technology data in the literature review as to the best of knowledge of consultant experts. They are susceptible to the changes of these data in course of time.

11 Conclusion

The updated database of energy consumption/demand is a must for proper and dynamic energy planning of the whole energy systems. In the context of growing economy and increasing energy demand, the information of energy at local and provincial levels is vital, which can be used for regional energy planning and additionally, such database can be later integrated to the national energy systems planning for sustainable energy development and energy security in the country as a whole.

The study has focused primarily in six economic sectors of Nepal viz. – Agricultural, Commercial, Construction and Mining, Industrial, Residential, and Transport. The main demand driver of economically active sectors, i.e. except residential, is gross value added while that of residential sector is taken as population. In addition to that, socio-economic analysis in residential sector has been carried out.

The forest area and potential fuelwood production in current status show potential production of 481 kilo ton in province 2. The potential biogas production is estimated based on the number of livestock and the production factor of 0.036 cubic meters per kg of dung. There is potential production of 5,968 thousand GJ of energy from Biogas in province 2 while the total potential energy produced from agricultural waste is 67,208 TJ. More than half of this energy comes from paddy straw, and about 28 % come from sugar cane. As for supply of petroleum, the province also depends entirely on the import of petroleum products. There was supply of 90 million liters of petrol, 302 million liters of diesel, 5 million liters of kerosene and 815 MT of LPG in province 2. Meanwhile, the total sales of electricity in province 2 is 1,194 GWh. In renewable energy sector, approximately 190 kWp from SHS, 123 kWp from SSHS, and 184 kWp from ISPS have been installed in Province 2. In addition to that, nearly 500 SPVPS have been installed. Most of the biogas plants are sized 4 cubic meters in the province. Due to low land of the region, there are no micro-hydro plants installed in province 2.

In year 2018/2019, it is seen that the total final energy consumption of the Province 2 was 63,200 TJ which accounts for 10.4 GJ per capita. This energy consumption seems to be lower than the national averages from previous studies. This is primarily seen due to the energy transition to more efficient modern form of energies. The residential sector is still the most energy consuming sector. However, different from the previous national average, the share of residential sector is about 62% while that of industrial sector consumption is 23% and commercial 3%. This is primarily because Province 2 is an economic hub for industry and trade. Thus, it is obvious that the consumption for economic sectors would be higher. As for energy consumption by fuel types, the used of biomass is still prevalent at above 50%. Yet, there is also difference in energy mix as per to national mix due to reasons like – the region having high potential for forest and agricultural resources, the access to modern energy is easier and the region being industrially and commercially active. Therefore, there is higher usage of commercial energy sources such as fossil fuels and electricity. In residential sector there is seemingly transition from traditional to modern fuels while the agricultural sector has taken a leap forward towards the renewable energy by intervention of solar water pumps. Commercial sector is a huge electricity user with highest chances of intervention of solar PV system while industry is a largest consumption sector for electricity which would require dedicated large hydropower capacities.

Therefore, the total energy consumption in Province 2 shows an energy transition in residential sector with huge amount of energy being used for industrial and commercial sectors. The impact of energy efficiency can be seen due to shift to modern form of energy and energy accessibility.

Scenario planning is widely used for energy demand and supply planning in the global energy arena. It is a method for developing and thinking through possible future states based on different scenarios. MAED modelling framework was developed for projection of energy development scenarios for the Province 2 from 2019 to 2050 with the energy drivers – sectoral GVAs and population growth rates. It is based on the energy consumption and supply balance in 2019 obtained from the field survey and secondary data respectively. Sectoral GVAs based on three GDP growth rates at Low Economic (5.6%), Reference Economic (6.3%), and High Economic (6.7%) and population growth of 1.35% are taken as major economic and demographic assumptions. The energy demands thus obtained are exogenously integrated into TIMES supply modeling framework for supply side analysis based on least cost optimization of the whole energy systems. A Policy scenario – Sustainable Energy Development Scenario (SEDS)- is developed with the major policy measures such as electrification through renewable energy resources, energy efficiency measures, and discouragement in usage of fossil fuels. These policy measures are based on various national and international development programs.

In the Low Economic Growth Scenario, the total final energy demand reaches 81,000 TJ in 2030 increasing to 167,000 TJ in 2050. Similarly, in the Reference Economic Growth Scenario, the total final energy demand attains 83,000 TJ in 2030 and it reaches to 189,000 TJ in 2050. In the context of High Economic Growth case, the final energy demand is expected to reach 83,000 TJ and reaching 205,000 TJ in 2050.If the current trend of fossil fuels continues in the long run, they may surpass the demand for solid biomass in 2050.

In the SEDS, the final energy is projected to be 71,000 TJ in 2030 and 144,000 TJ in 2050 respectively. In the SEDS, demands for other energy carriers will be flattened or will be decreasing whereas electricity generated by renewable energy 24% of the total energy demand in 2030 and it will reach 72% in 2050 respectively. The power plant requirements reach 1,699MW in 2030 and will be attaining 9,649 MW in 2050. In the SEDS, per capita electricity demand will reach 3,100 kWh in 2050 and the electricity demand per household reaches 2,500 kWh which is near to the tier 5- electricity consumption of household as per the World Bank/EMAP. The electricity demand in the industrial sector is expected to be remarkably high.

Comparative analysis of the SEDS with the Reference Scenario shows that energy demand is reduced by 15% in 2030 and the reduction reaches 24% in 2050.In the SEDS, net fuel import ratio comes down to 24% compared to the Reference case of 56% in 2050 which no doubt indicates positive impact in the balance of payment condition and enhances energy security in the Province 2 and in the country. GHG emissions are reduced by 25% in 2030 – a reduction 750 ktons of CO2 equivalent from the Reference Scenario. The reduction attains 69% in 2050 compared to the Reference case value of 9,100 ktons of CO2 equivalent. Furthermore, energy intensity in the SEDS improves to 635 GJ/NRS millions of GDP in 2050, which is 65% less than in the base year value of 1,791 GJ/NRS million GDP.

Overall, the energy consumption analysis in the base year 2019 and the policy measures taken in the SEDS indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development. This study also indicates that with the core focus on energy security, reliability, and sustainability, Province 2 and Nepal's energy development should be geared towards 5 development aspects – (a) Sustainable Energy Development Policy, (b) Hydropower/renewable Energy Development, (c) Infrastructure Development, (d) Creation of Domestic Power Demand and Exploration of Power Markets in the South Asia, and (e) Reduction in Demands for Fossil Fuels.

12 Bibliography

ADB, 2015. *Asian development outlook 2015. Financing Asia's future growth,* s.l.: s.n.

ADB, 2018. *Asian Development Bank and Nepal: Fact Sheet8.* [Online] Available at: https://www.adb.org/sites/default/files/publication/27783/nep-2018.pdf [Accessed 2019].

Adhikari, N. P., 2019. *Integrating Renewable Energy and Energy Efficiency in mainstream energy to meet SDG Goals.* s.l., Presentation at UNESCAP workshop on SDGs in Kathmandu in August 2019.

AEPC, 2000. *Renewable energy perpective plan,* s.l.: Alternative Energy Promotion Center.

AEPC, 2018. *Progress at Glance A Year in Review FY 2074/75 (2017/18),* Kathmandu, Nepal: Alternative Energy Promotion Centre.

AEPC, 2019. *Progress at Glance: A year in Review FY 2075/76 (2018/19),* s.l.: Alternative Energy Promotion Center.

CAAN, 2018. *Annual Report 2018,* Kathmandu: Civil Aviation Authority of Nepal.

CBS, 2011. *Nepal Living Standards Survey 2010/11,* Kathmandu: Central Bureau of Statistics, National Planning Commission Secretariat, Government of Nepal.

CBS, 2012. *National Population and Housing Census 2011,* Kathmandu: Central Bureau of Statistic, National Planning Commission Secretariat, Government of Nepal.

CBS, 2014. *Population Monograph of Nepal ,* Kathmandu, Nepal: Central Bureau of Statistics.

CBS, 2014. *Population Projection 2011 – 2031,* Kathmandu: Central Bureau of Statistics.

CBS, 2016/17. *Annual Household Report ,* s.l.: Central Bureau of Statistics.

CBS, 2019. *National Economic Census 2018.* Kathmandu: Central Buraeu of Statistics.

CBS, 2019. *Regional-Provincial-National-Accounts.* s.l.:CBS.

CBS, 2020. *National Accounts of Nepal 2019/20,* Kathmandu: Central Bureau of Statistics.

Demirbas, M. F., Balat, M. & Balat, H., 2009. Potential contribution of biomass to the sustainable energy development.. *Energy Conversion and Management,* Volume 50, pp. 1746-1760.

DFO Bara, 2074. [illegible]. s.l.:District Forestry Office.

DFO Dhanusa, 2075. [illegible]. s.l.:District Forestry Office, Dhanusha.

DFO Parsa, 2069. [illegible]. s.l.:District Forestry Office.

DFO Rauthat, 2074. [illegible]. s.l.:District Forestry Office.

DFO Saptari, 2075. [illegible]. s.l.:District Forestry Office.

DFO Siraha, 2075. [illegible]. s.l.:District Forestry Office.

DoF, 2019. *Community Forestry Data base.* s.l.:Department of Forests.

FAO, 2019. *Food and Agriculture Organization.* [Online] Available at: http://www.fao.org/3/ae154e/ ae154e06.htm

FRA/DFRS, 2014. *Terai Forests of Nepal (2010e2012),* Babarmahal, Kathmandu: Forest Resource Assessment NepalProject/Department of Forest Research and Survey.

GoN, 2014. *Terai Forests of Nepal (2010 – 2012),* Kathmandu: Forest Resource Assessment, Department of Forest Resource and Survey.

GoN, 2015. *State of Nepal's Forests. Forest Resource Assessment (FRA), 2015,* Kathmandu: Department of Forest Research and Survey (DFRS).

IEA, 2018. *Global Energy and CO2 Status Report,* s.l.: International Energy Agency.

IEA, 2018. *World Energy Outlook 2018,* s.l.: International Energy Agency.

IEA, 2019. *World Energy Outlook 2019.* [Online] Available at: https://www.iea.org/reports/world-energy-outlook-2019 [Accessed 2019].

IEA, 2020. *World Energy Outlook 2020,* s.l.: International Energy Agency.

Khatiwada, D., Seabra, J., Silveira, S. & Walter, A., 2012. Power generation from sugarcane biomass - a complementary option to hydroelectricity in Nepal and Brazil.. *Energy.*

Lambrides, J., 2019. *Connected and Flowing: a renewable future for rivers, climate and people,* s.l.: World Wild Life Fund.

Lauri, P. et al., 2014. Woody biomass energy potential in 2050. *Energy Policy,* Volume 66, pp. 91-31.

Malla, S., 2014. Assessment of mobility and its impact on energy use and air pollution in Nepal. *Emergy,* p. 485e496.

MFSC, 2013. *Is demand and supply of wood a factor for redd+ project in Nepal? policy brief.* s.l.:Ministry of Forests and Soil Conservation REDD- Forestry and Climate Change Cell, Nepal.

MoAL, 2018. *Statistical Information on Nepalese Agriculture.* s.l.: Ministry of Agriculture and Livestock Development.

MoAL, 2019. *Livestock Population by district.* s.l.:Ministry of Agriculture and Livestock.

MOE, 2019. *Water Resources and Irrigation, FY 2018/19.* s.l.:Ministry of Energy.

MoF, 2016. *Economic Survey Fiscal Year 2015/16,* s.l.: Ministry of Finance, Government of Nepal.

MoF, 2018/19. *Economic Survey,* Kathmandu: GoN, Ministry of Finance, Nepal.

MoF, 2019. *Economic Survey 2018/19,* Kathmandu: Ministry of Finance.

MoF, 2020. *Economic Survey 2019/20,* Kathmandu: Ministry of FInance.

MoPE, 2016. *Renewable Energy Subsidy Policy,* s.l.: Ministry of Population and Environment.

MoPE, 2017. *National Population Report 2017,* Singha Durbar, Kathmandu: Ministry of Population and Environment (MoPE).

Nakicenovic, N., 2000. Energy scenarios. In: *World Energy Assessment: Energy and the Challenge of Sustainability.* New York: s.n., pp. 333-366.

NEA, 2019. *Annual Report 2018/19,* Kathmandu: Nepal Electricity Authority.

NEA, 2019. *Elelctricty sales.* s.l.:Nepal Electricity Authority.

NEA, 2019. *Fiscal year 2018/19.* Kathmandu: Nepal Electricity Authority.

NEA, 2019. *Nepal Electrification Statistics,* Kathmandu: Nepal Electricity Authority.

NOC, 2018. *Nepal Oil Corporation - Import and sales.* [Online] Available at: http://noc.org.np/import [Accessed 2019].

NPC, 2013. *An Approach Paper to the Thirteenth Plan (2013-2016),* Singh Durbar, Kathmandu, Nepal: National Planning Commission.

NPC, 2014. *An Approach to the Graduation from the Least Developed Country by 2022,* Kathmandu, Nepal: National Planning Commission.

NPC, 2016. *Nepal: Sustainable Development Goals – Status and Roadmap,* s.l.: National Planning Commission.

NPC, 2017. *14th Three Year Plan ,* Kathmandu, Nepal: National Planning Commission.

NPC, 2018. *Sustainable Development Goals, Status and Roadmap: 2016-2030.* Kathmandu, Nepal: National Planning Commission, Nepal Government.

opennepal, 2001. *District wise Land Use Pattern, 2001/data.* [Online] Available at: https://github.com/opennepal/odp-geography/blob/master/District%20wise%20Land%20Use%20Pattern%2C%202001/data.csv) [Accessed 2019].

PA, 2019. *Poor People's Energy Outlook,* Kathmandu: Practical Actions.

Panwar, N., Kaushik, S. & Kothari, S., 2011. Role of renewable energy sources in environmental protection: A review. *Renewable and Sustainable Energy Reviews,* Volume 15, pp. 1513-1524.

Parikka, M., 2004. Global biomass fuel resources. *Biomass Bioenergy,* Volume 6, pp. 613-620.

PDCCD, 2019. *Statistics and Analysis Section.* s.l.:Planning and Development Co-operation Co-ordination Division.

Porter, M. E., 1985. *Competitive Advantage: Creating and Sustaining Superior Performance.* s.l.:New York: The Free Press.

Schoemaker, P. J. H., 1995. Scenario Planning: A Tool for Strategic Thinking. In: *Sloan Management Review.* s.l.:s.n., pp. 25-40.

SPL, 2019. *Sustainable Development Report 2019,* Hong Kong: Swire Properties Limited.

Thompson, M. & Warburton, M., 1985. *Uncertainty on a Himalayan Scale.* s.l.:Mountain Research and Development.

UNDP, 2012. *A Global Action Agenda Pathways for Concerted Action toward Sustainable Energy for All,* s.l.: The Secretary-General's High Level Group on Sustainable Energy.

UNEP/GEF, 2008. *Solar and Wind Energy Resource Assessment in Nepal (SWERA),* s.l.: United Nations Environment Programme.

Vaid, V. & Garg, S., 2013. Food as Fuel: Prospects of Biogas Generation from Food Waste.. *International Journal of Agriculture and Food Science Technology (IJAFST) ISSN No. 2249-3050, Volume 4 No. 2 (2013) as below. Note: 1 kilowatt hour =3.6 mega.*

Wack, P., 1985. Scenarios: Uncharted waters ahead. In: *Harvard Business Review.* s.l.:s.n., pp. 73-89.

WECS, 1997. *Update and compilation of energy resources and consumption profile of Nepal,* s.l.: Water and Energy Commission Secretariate.

WECS, 2010. *Energy Sector Synopsis Report.* s.l.:Water and Energy Commission.

WECS, 2010. *Energy Sector Synopsis Report Nepal,* Kathmandu: Secretariat, Water and Energy Commission, Ministry of Energy, Government of Nepal.

WECS, 2013. *Nepal's Energy Sector Vision 2050 A.D.,* s.l.: s.n.

World Bank/ESMAP, 2019. *Beyond Connections: Energy Access Diagnostic Executive Summary Based on the Multi-Tier Framework,* s.l.: Energy Sector Management Assistance Program, World Bank.

World Bank, 2020. *Nepal Development Update: Post-Pandemic Nepal – Charting a Resilient Recovery and Future Growth Direction.* [Online]
Available at: https://www.worldbank.org/en/country/neNepal Development Updatepal/publication/nepaldevelopmentupdate
[Accessed November 2020].

Worldbank, 2013. *Managing Nepal's Urban Transition.* [Online]
Available at: https://www.worldbank.org/en/news/feature/2013/04/01/managing-nepals-urban-transition
[Accessed 2016].

Worlddata, 2019. *Energy Consumption.* [Online]
Available at: ttps://www.worlddata.info/asia/nepal/energy-consumption.php
[Accessed 10 2019].

Wulf, T., Meißner, P. & Stubner, S., 2010. *Scenario-based Approach to Strategic Planning – Integrating Planning and Process Perspective of Strategy,* s.l.: s.n.