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

Final Report

(Province-1)

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

January 2021

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Executive Summary

Global Energy Outlook and Current National Energy Overview

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. 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 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). 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 1

Province 1 lies in the eastern region of Nepal ranging from mountainous and hilly to terai region. It covers an area of 25,905 km2. The province, according to the constitution of Nepal 2015 comprises of 14 districts (Figure 2.3:). Under the newly reformed local bodies, the province encompasses a total of 1 metropolitan city, two sub-metropolitans, 46 municipalities, and 88 rural municipalities. Biratnagar has been declared capital of the province by the provincial assembly in 2019. According to the 2011 census, there were around 4.5 million people in the province.

In terms of economic activity, province 1 is the second-most active province with a GDP share of 17.5% (NRB, 2018). The economic sectors diversify according to the geographic conditions. Terai and hilly regions in the border area are the corridor for international trade. The Terai regions dominate in industrial as well as agricultural activities, wherein hilly and Terai regions, other commercial activities such as tourism and small enterprises are concentrated. In terms of energy, this province has the most diversified energy resources as well as energy demand pattern due to varying geographical situations. The mountain regions are known to be remotely accessible. Thus, there are a lesser number of industries, and primary energy resources are traditional biomass. However, due to mountainous geography, there is a significant potential for hydro and solar energy. As moving towards Terai, the energy pattern differs, as there is more commercial energy consumption than in mountainous and hilly regions. It is not only due to easy accessibility, but also the presence of industrial, commercial, and transport activities.

According to National Economic census, among the registered institutions in province 1, more than 80% are commercial institutions, around 12% are industries, 3% of institutions involved in agriculture while construction and mining account for less than 1%. Meanwhile, in economic terms, the largest share of GDP is from the commercial sector (46%) followed by agriculture (37%), construction and mining (9.5%) and industry (7.8%) in 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 1.

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

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

Table1. District Wise Population and Household Status in Province 1

Geographical Region	District	2011		2019	
		Population	Households	Population	Households
Mountain	Sankhuwasabha	158,742	34,624	176,718	38,417
	Solukhumbu	105,886	23,785	117,877	25,625
	Taplejung	127,461	26,509	141,895	30,847
Hill	Bhojpur	182,459	39,419	203,121	44,157
	Dhankuta	163,412	37,637	181,917	39,547
	Ilam	290,254	64,502	323,123	70,244
	Khotang	206,312	42,664	229,675	49,929
	Okhaldhunga	147,984	32,502	164,742	35,813
	Panchthar	191,817	41,196	213,539	46,422
	Terhathum	101,577	22,094	113,080	24,583
	Udayapur	317,532	66,557	353,490	76,846
Terai	Jhapa	812,650	184,552	904,677	196,669
	Morang	965,370	213,997	1,074,692	233,629
	Sunsari	763,487	162,407	849,947	184,771
	Total	**4,534,943**	**992,445**	**5,048,494**	**1,097,499**

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 1.

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 1, 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 divisions for Province 1 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. 1 (MoF, 2019)

(In Million Rs. at 2017/18 prices)	
Industrial Classification	**2018/19**
Agriculture and forestry	176,095
Fishing	1,858
Mining and quarrying	2,528
Manufacturing	37,640
Electricity gas and water	8,352
Construction	43,776
Wholesale and retail trade	46,179
Hotels and restaurants	9,327
Transport, storage and communications	23,455
Financial intermediation	17,413
Real estate, renting and business activities	33,157
Public administration and defense	12,455
Education	33,821
Health and social work	10,025
Other community, social and personal service activities	28,059
Total GVA including FISIM	484,139
Financial Intermediation Services Indirectly Measured (FISIM)	11,565
Gross Domestic Product (GDP) at basic price	472,575
Taxes less subsidies on products	33,273
Gross Domestic Product (GDP)	**505,848**

Provincial gross value added by industrial division of Provinces No.1 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 software. 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.

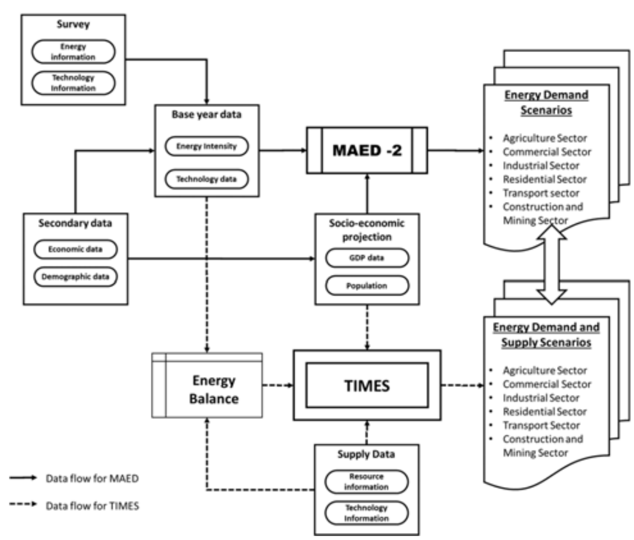

Figure 1. Methodological Framework for Energy Demand and Supply Scenario Development

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 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.

Energy Supply in Province 1

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 1 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

District	Forest area (ha)	stem volume m^3	Annual firewood production (m^3)	Annual firewood production of accessible forest (m^3)
Terai :accessible forest (100%)				
Jhapa	17,568	2,941,235	50,008	50,008
Morang	44,075	7,379,037	125,461	125,461
Sunsari	21,653	3,625,145	61,636	61,636
Total	83,296	13,945,416	237,106	237,106
Middle mountain: accessible forest (90%)				
Udayapur	148,411	18,441,551	112,598	101,338
Ilam	93,467	11,614,209	70,912	63,821
Dhankuta	36,724	4,563,324	27,862	25,076
Terhathum	32,821	4,078,337	24,901	22411
Bhojpur	73,037	9,075,578	55,412	49,871
Khotang	74,284	9,230,530	56,358	50,723
Okhaldhunga	52,286	6,497,058	39,669	35,702
Panchthar	71,774	8,918,637	54,454	49,009
Total	582,804	72,419,225	442,166	397,950
Higher mountain: accessible forest (70%)				
Sakhuwasabha	**190,052**	**42,807,312**	**554,195**	**387,936**
Solukhumbu	110,043	24,786,085	320,887	224,621
Taplejung	155,931	35,121,898	454,697	318,288
Total	456,026	102,715,296	1,329,779	930,845
Grand Total	**1,122,126**	**189,079,938**	**2,009,051**	**1,565,901**

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 Table6.9 Petroleum Sales in 2075-76 in Province 1. All the units for petrol or Motor Spirit (MS), Diesel and Super Kerosene Oil (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).

Table 6. Petroleum sales in 2075-76 in Province 1

Districts	MS	Diesel	SKO	LPG
	kL	kL	kL	tons
Taplejung	234	1,980	-	-
Sankhuwasabha	948	4,441	-	-
Solukhumbu	288	1,576	282	-
Okhaldhunga	816	5,722	168	-
Khotang	306	1,904	-	-
Bhojpur	288	3,113	-	-
Dhankuta	1,371	7,399	39	-
Terhathum	192	1,032	-	-
Panchthar	929	7,109	-	-
Ilam	2,245	6,487	-	-
Jhapa	27,102	66,017	777	20,824
Morang	25,507	71,727	1,528	9,358
Sunsari	21,557	59,436	1,019	51,994
Udayapur	3,622	15,950	-	-
Total	**85,405**	**253,891**	**3,813**	**82,176**

(Source: NOC 2020)

Electricity

Province 1, which have mountains and hills, has abundance of water resources and there are several potential sites for hydropower development. The average potential for hydropower plant is around 20,500 MW in province 1 (Kandel, 2018). In addition to that, 66 MW of small hydropower potential from 84 and nearly 70 sites for 1 MWp of solar PV sites has been identified for decentralized generation of electricity (NPC, 2018). There are 29 IPPs hydropower projects, 4 major hydro power plants and 5 small hydropower plants in province 1 (NEA 2019). There is 237.59 MW (226.796 MW from IPPs and 10.794 MW from NEA generation) installed capacity in the province. The district - wise electricity supply status as obtained from Nepal Electricity Authority for province1 is as shown in Figure 2.

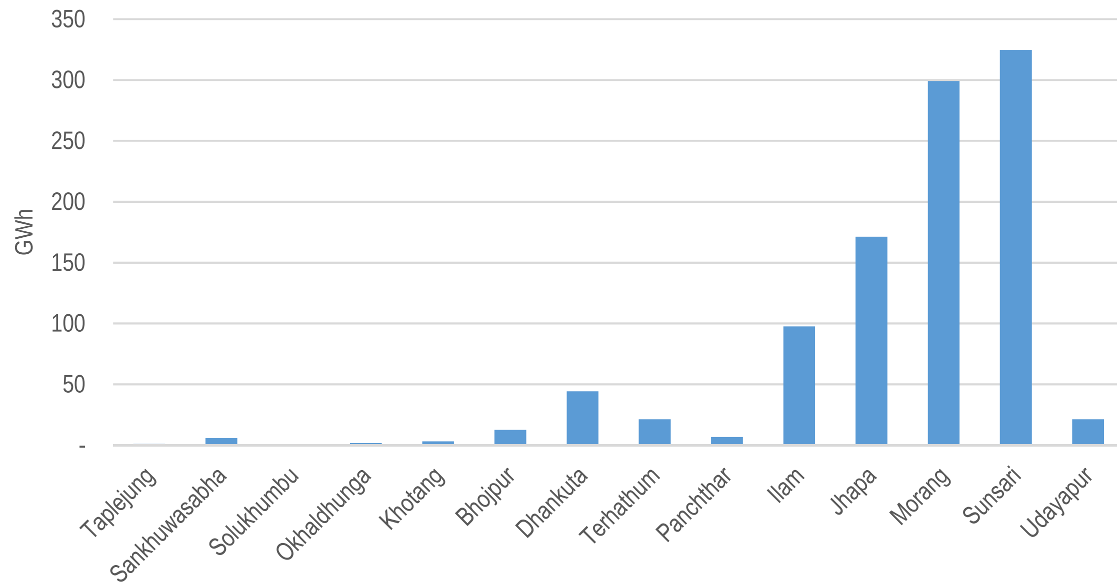

Figure 2. Electricity Consumption in Province 1 in 2075 (NEA, 2019)

Province 1 consumed 1,011 GWh of electricity including the consumption in all economic sectors (NEA database 2020). The three districts of Terai - Jhapa, Morang and Sunsari located in industrial zone consumed 79% of total electricity consumption. However, electricity consumption in mountainous region is extremely low. It could be due to poor access to electricity in remote areas. Comparatively, electricity consumption is lower in Hilly region than in Terai region.

As per NEA domestic consumption data, the electricity connection as per ampere capacity of households indicates that over 90% of the households lies within minimal amperage capacity of 5A, 7% are connected with 6-15 A connection. Less than 1% have electricity connection above 16A. In province 1, 76% 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 1 is as shown in Table 7. Approximately1,440 kWp from SHS, 243 kWp from SSHS and 311kWp form ISPS have been installed in Province 1. In addition to these, solar photovoltaic pumping system (SPVPS) has gained much popularity amongst farmers. The average size of ISPS is 2kWp.

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 1.

Recently 138 kW of solar mini-grid power plant has been installed in the province of which 43 kW is installed in Morang and 95kW in Panchthar.

Table 7. Number of Modern Renewable Technologies Installed in Province 1 (AEPC, 2019)

District	SHS	SSHS	ISPS	MUD ICS	Domestic biogas
Bhojpur	12,348	321	2	163	225
Dhankuta	1,650	183	5	234	2,059
Illam	5,136	570	23	711	6,306
Jhapa	651	596	20	0	18,752
Khotang	12,833	865	23	137	100
Morang	1,365	776	32	8	10,800
Okhaldhunga	10,244	155	26	1,737	413
Panchthar	7,751	140	6	344	1,064
Sankhuwasabha	8,700	50	3	643	536
Solukhumbu	4,117	0	2	896	107
Sunsari	1,186	80	5	0	4,126
Taplejung	6,268	661	10	1,050	233
Terhathum	1,760	223	4	193	799
Udayapur	22,024	254	13	57	5,953
Total	**96,033**	**4,874**	**174**	**174**	**51,473**

Energy Consumption in 2019

The total energy consumptions in 6 economic sectors in province 1 in 2019 are summed to about 74PJ. The energy consumption in the industrial sector has the highest share in this province followed by residential sector. Meanwhile, the solid fuels – firewood, biomass as well as coal dominated the energy source type, there is visible change in energy mix as compared to previous studies at national and regional levels (Figure 3 and Figure 4). Nearly 45% of the total energy demand is in industrial sector and 55% of energy coming from renewables and non-renewables at around 45% respectively. This contrast in high usage of non-renewable energy us due to the big industries and high economic activities - demanding more commercial forms of energy. 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.

Firewood is still the main source of energy in residential sector, while industrial sector thrives on use of coal and diesel, primarily for thermal energy and motive power. The commercial sector is highly dependent on electricity and LPG as sources of energy while the transport and agricultural sectors still show huge dependency on fossil fuels. The shift from petroleum-based water pumping system to solar PV powered can be seen in agricultural sector in this province as well, however, due to geographic conditions the penetration is lower.

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 1 contributing 48% and 45% each respectively. The contribution of new renewables which is mostly electricity and few solar is 7% in the province. The share of modern biomass (biogas and bio-briquettes) is less than 1%.

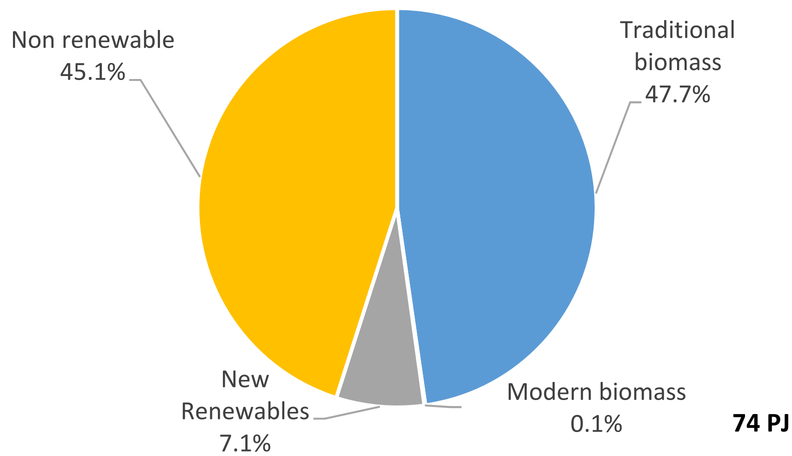

Figure 3. Energy Consumption Share in Province 1 by Fuel Group

Sector- wise, the industrial sector is predominant in terms of energy demand with nearly 45% consumption out of total final (Figure 7.2Figure 4). Due to highly industrial and commercial activities in this province, the energy share in residential sector comes to be much lower than the share at national average. Additionally, the reduction in energy consumption in residential sector also can be attributed to energy transition and energy efficiency, discussed in later section.

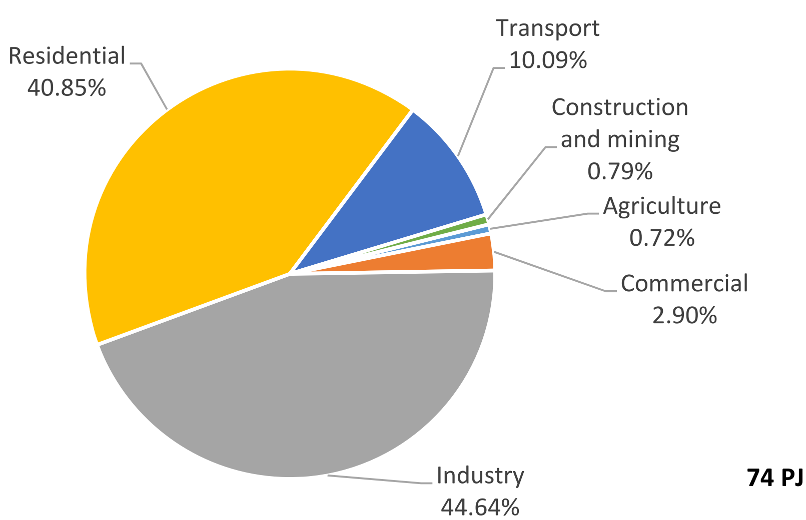

Figure 4. Energy Consumption Share in Province 1 by Sectors

The energy consumption by physiological region is as shown in Figure 5. It includes energy consumption in agriculture, residential, commercial and industry sectors in the province. Transport and construction and mining sectors are excluded since the survey for these two sectors was carried out at provincial level.

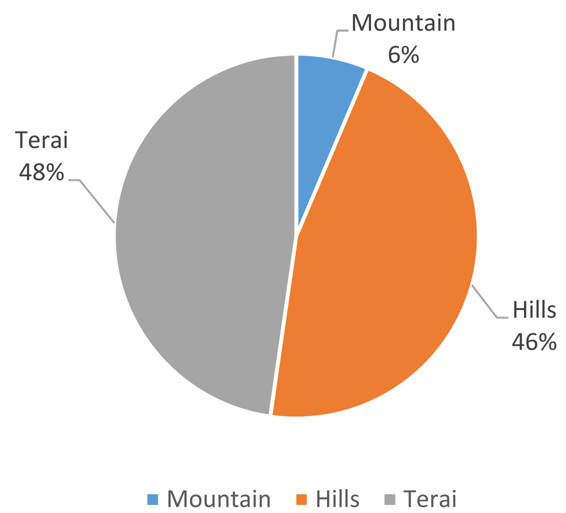

Figure 5. Energy Consumption Share in Province 1 by physiological region

Sankey diagram in Figure 6 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 followed by the industrial sector. While in demand side, industrial sector takes a large volume of energy, while agriculture sector seems to be relying on non-machinery power like animals and human.

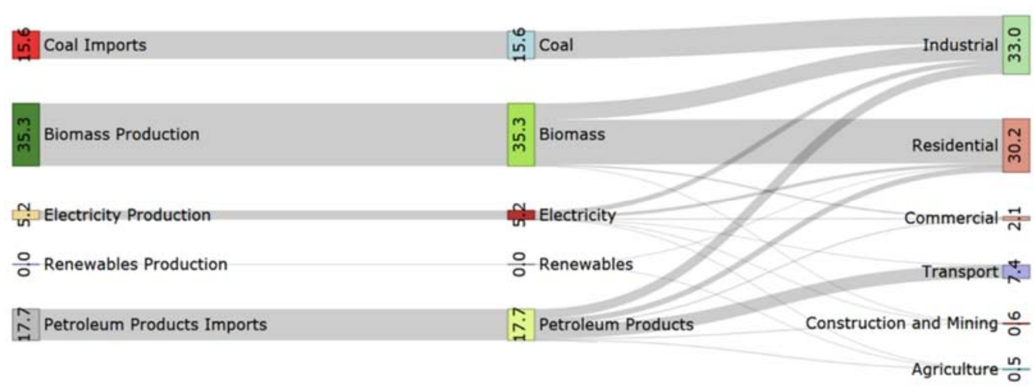

Figure 6. Sankey diagram for flow of energy in Province 1 (PJ)

Table 8 shows the energy consumption indicators which highlight the status of energy consumption in Province 1. The total final energy demand per capita of 14.5 GJ near to the previous national average. This is however due to high amount of energy consumed in industrial sector, unlike that in residential sectors in the national context. The electricity demand per capita also comes to be higher than national average of 224 kWh (NEA, 2019; CBS, 2014). This is mainly due to higher electricity demand 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, 2015).

Table 8. Energy Consumption Indicators

Parameter	Value	Unit (per annum)
Energy per capita	14.52	GJ per capita
Energy per GVA	163	GJ per million NRs
Share of conventional renewable energy in total	54.9%	
Share of modern and new renewable energy	7.2%	
Electricity Consumption (Total)	286	kWh per capita
Electricity Consumption (Residential)	391	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 1 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 1 is expected to grow from the current level of 74 PJ in 2019 to 105 PJ in 2030 and 298 PJ in year 2050 which account for almost four folds of increase. The average annual growth rate of energy demand is 4.6% for the reference case. Per capita energy demand is expected to grow from 15 GJ in 2019 to 39 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*	35.24	35.76	39.7	45.87	54.15	65.41	80.87	102.39
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.09
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
			Grid Electricity	5.24	5.32	6.17	7.72	9.91	13.05	17.51	23.92
Non-renewable			Petrol	1.87	1.92	2.05	2.2	2.36	2.54	2.73	2.94
			Diesel	10.15	10.33	12.12	15.48	20.26	27.17	37.07	51.31
			Kerosene	0.13	0.13	0.15	0.19	0.25	0.34	0.46	0.63
			Furnace Oil	1.16	1.18	1.44	1.93	2.64	3.69	5.2	7.39
			ATF**	0.56	0.57	0.61	0.65	0.7	0.75	0.8	0.85
			LPG	3.78	3.83	4.19	4.69	5.34	6.18	7.3	8.82
			Coal	15.62	15.9	19.29	25.91	35.54	49.6	69.91	99.35
Total				73.83	75.02	85.83	104.76	131.23	168.83	221.96	297.73

*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 10.810. The total energy demand in 2030 and 2050 is expected to be 95 PJ and 256 PJ respectively. Per capita energy demand is expected to be 33 GJ in 2050 in the Sustainable Energy Development Scenario (SEDS), whereas it would be 39 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*	35.24	34.84	33.60	33.20	32.88	32.65	32.123	31.23
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	Biogas	0.06	0.09	0.23	0.40	0.59	0.81	1.05	1.32
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.01	0.01	0.02	0.05	0.08	0.14	0.24	0.39
			Grid Electricity	5.24	6.14	12.27	22.26	38.00	63.08	102.83	165.85
Non renewable			Petrol	1.87	1.92	1.8	1.67	1.5	1.31	1.1	0.85
			Diesel	10.15	10.19	10.84	12.33	14.1	16.08	18	19.4
			Kerosene	0.13	0.13	0.15	0.18	0.23	0.3	0.41	0.57
			Furnace Oil	1.16	1.16	1.24	1.44	1.68	1.92	2.1	2.14
			ATF**	0.56	0.57	0.61	0.65	0.7	0.75	0.8	0.85
			LPG	3.78	3.72	3.46	3.19	2.84	2.36	1.66	0.62
			Coal	15.62	15.56	16.8	19.79	23.32	27.22	30.85	33.17
Total				73.83	74.32	81.04	95.16	115.93	146.61	191.28	256.40

*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 in Province 1. 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 to over 6,000 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 decreases to 41% of total energy from 49% in reference scenario in 2030 and to 22% in 2050. On other hand, use of national resources increases with increase in use of renewables to 65% in 2050 as compared to only 8% 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	14.52	14.42	14.70	16.15	18.40	21.76	26.54	33.27
Final electricity demand	kWh/capita	287	331	620	1,051	1,678	2,606	3,973	5,993
Final energy demand	GJ/million NRS	1,825	1,805	1,623	1,419	1,260	1,142	1,056	997
Final Electricity Demand	kWh/million NRS	36,068	41,481	68,406	92,353	114,972	136,728	158,134	179,492
Total Electricity Used/household	kWh/HH	654	701	934	1,167	1,400	1,633	1,865	2,098
share of non-carbon energy in primary supply	per cent	7.11%	8.28%	15.18%	23.44%	32.84%	43.12%	53.89%	64.84%
Share of renewable energy in final total energy demand	per cent	7.20%	8.39%	15.47%	23.86%	33.36%	43.67%	54.44%	65.35%
the ratio of net import to total primary energy supply	per cent	45.07%	44.73%	43.06%	41.25%	38.27%	34.06%	28.71%	22.47%
GHG emission	GHG in Kg/capita	584	575	563	590	622	653	671	658

GHG emissions per capita flattens till 2030 and increases hardly afterwards because of clean and renewable energy interventions. Per capita electricity consumption rises to 6,000 kWh in 2030 due high electrification in all economic sectors. Total electricity consumption per household will triple by 2050 to 2,100 kWh which will be more than three times that of the base year value. This is still below 5 -tier value of electric consumption of above 3,000 kWh per household as per World Bank/ESMAP.

Comparative Analysis

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 Reference Economic Growth Scenario.

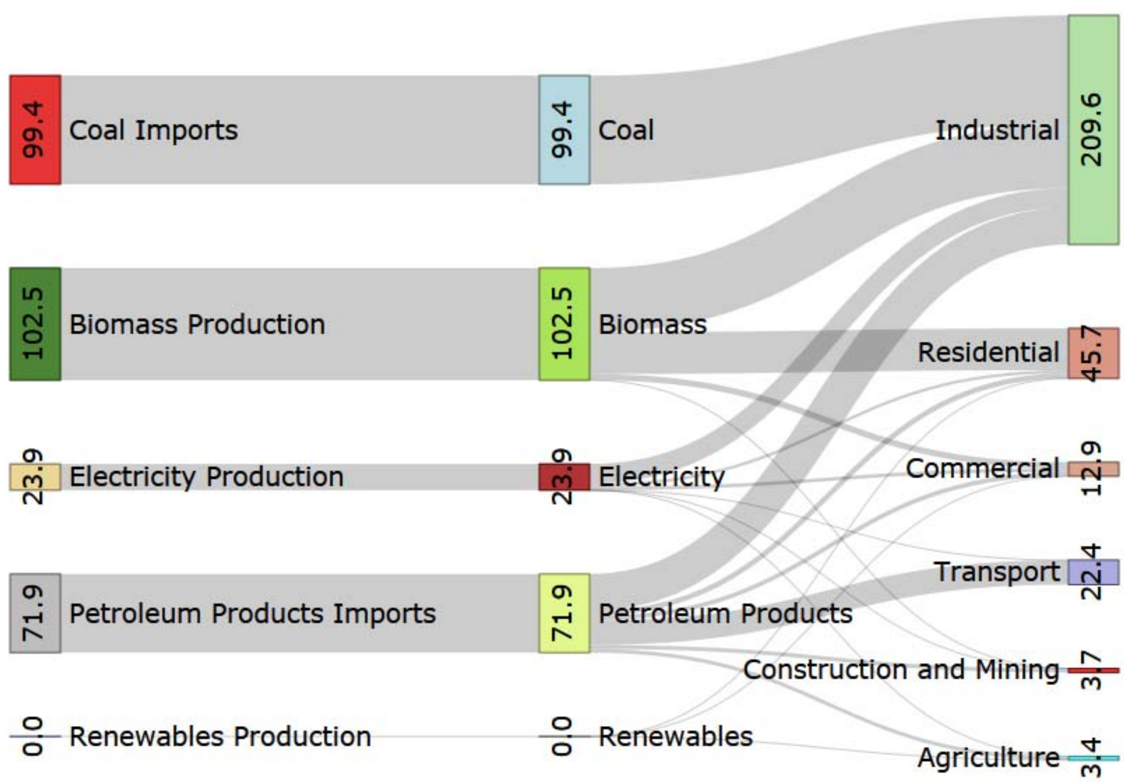

Figure 7. Sankey diagram for flow of energy in Province 1 for the Reference Economic Growth Scenario in 2050 (PJ)

It is evident from Figure 7 that without policy intervention for the clean and renewable energy Province 1 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 Province 1 and furthermore, one can wonder whether Province 1's economy could sustain imports of such huge quantities of fossil fuels in the long run.

Figure 8 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.

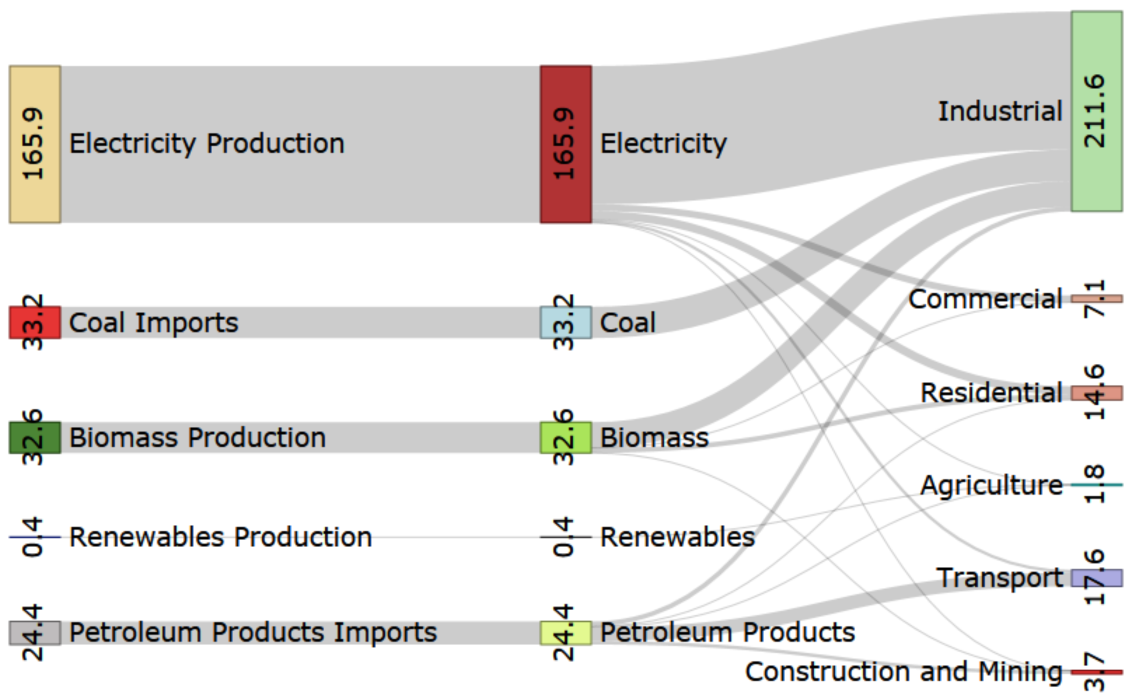

Figure 8. Sankey diagram for flow of energy in Province 1 for the SED Scenario in 2050 (PJ)

Sankey diagram in Figure 8 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 1.

Figure 9 depicts the electricity demand per capita in compared scenarios which shows that in the SEDS, the electricity demand per capita reaches 6,000 kWh in 2050 and household electricity demand of 2,100 kWh/HH comes to the Tier-4 criteria by the World Bank (WB/ESMAP, 2019). Additionally, the growth in access to electricity means increase in demand for nationally available hydroelectricity production.

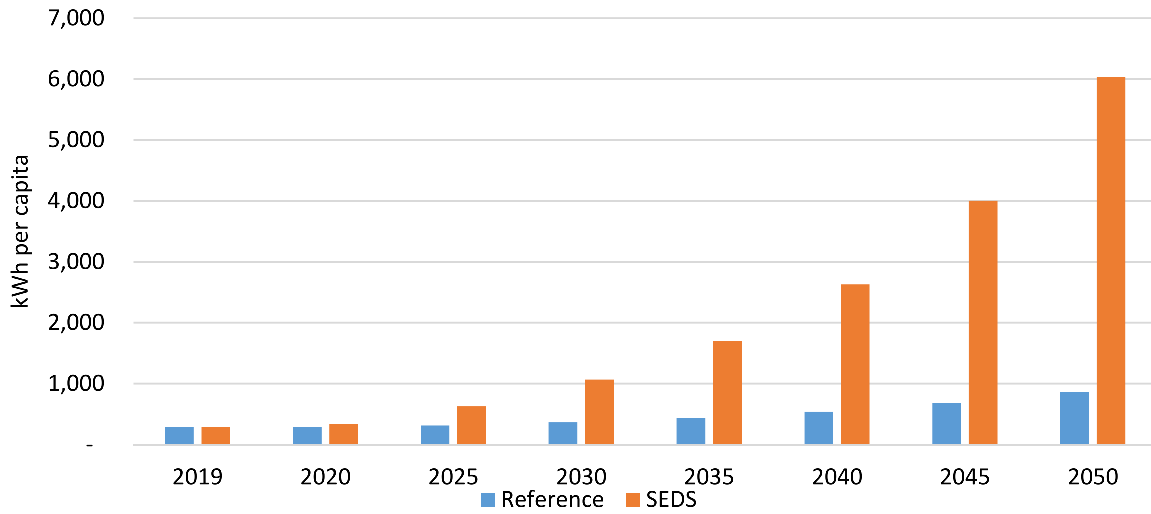

Figure 9. Electricity demand per capita in Province 1

Figure 10 shows the impact in GHG emissions dues to policy interventions of clean energy. Emissions which were growing at the rate of 5.4% in the Reference Economic Growth Scenario would increase at the rate of only 1.7% resulting in the GHG emission reduction of 24% in year 2030 and up to 67% 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.

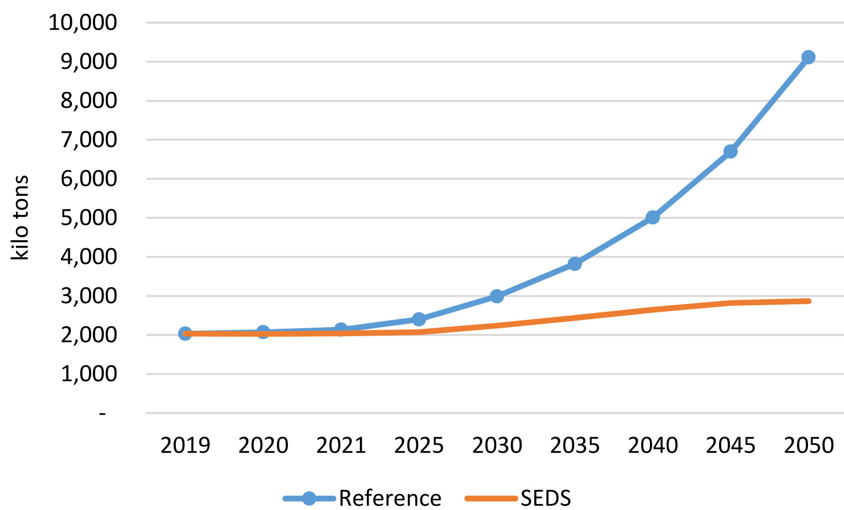

Figure 10. GHG emission in Province 1

To meet the larger share of the energy requirements in the SEDS and to achieve the development goals described above, the development of hydropower plants is essential. With respect to reference case, the hydro power plant capacity in the SEDS would be almost three times the value of the REF scenario in 2030 and up to 7 times the value in the REF scenario in 2050 respectively as shown in Figure 11.

In the Reference Economic Growth Scenario, the total final energy demand reaches 105,000 TJ in 2030 increasing to 298,000 TJ in 2050 respectively. Similarly, in the Low Economic Growth Scenario, the total final energy demand attains 101,000 TJ in 2030 and it reaches to 252,000 TJ in 2050. In the context of High Economic Growth case, the final energy demand is expected to reach 106,000 TJ and reaching 329,000 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.

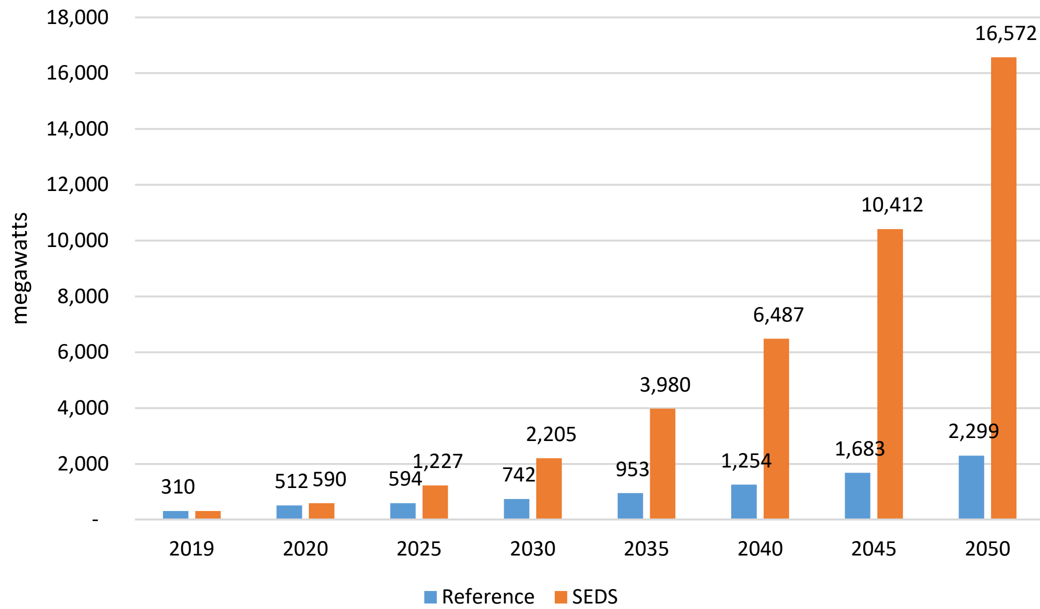

Figure 11. Power plant requirement in Province 1

In the REF scenario, the gross investment share in supply technologies is around 3 % 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 from current 2% of GDP to 9% by 2030 and 17.6% 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. These figures can be accounted for the large-scale investment required in the hydropower development and industrial capital costs (Table 12).

In the case of Province 1, which have huge resources and feasibility for development of hydropower plants, the province needs to invest on hydropower development. Thus, the capital investment as given in Table 12, would be required to develop the power plants in the province. In addition to this, the province can build up solar power plants (off grid and utility) within the region for daytime supply at peak solar insolation hours of the day. It is expected that by 2050, there will be around 3,000 MW of electricity from grid and off-grid solar PV.

Table 12. Total Technology Cost for different scenarios

	2020	2025	2030	2035	2040	2045	2050
REF	10.82	16.03	24.26	34.55	48.08	66.26	92.22
Capital Investment as % of GDP	2.19%	2.68%	3.02%	3.14%	3.13%	3.06%	2.99%
SEDS	13.53	35.59	70.77	124.17	207.31	337.27	542.45
Capital Investment as % of GDP	2.75%	5.95%	8.81%	11.27%	13.49%	15.57%	17.62%

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 amounting over 23 billion NRs in 2030 and 417 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 33% investment required in 2030 for clean power plant development, while in 2050 the saving can contribute nearly

77% of the investment required. This indicates significant reduction in dependency on imported fuel. 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.

In addition to savings form import of fuel and the value addition to national economy by trading of electricity produced 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 benefits from carbon trading will be NR 2 billion and NR 55 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 1 makes investments in hydropower/renewable energy development in its own territory. After 2040, the benefits of from savings from fuel imports and carbon trading can almost match the incremental capital costs required for clean and renewable energy development till 2050.

Conclusion and the Policy Implications

In year 2018/2019, it is seen that the total final energy demand of the Province 1 was 73,835 TJ which accounts for 14.5 GJ per capita. This energy demand per capita seems to be in line with the national averages from previous studies. The shares of energy consumptions in economic sectors of the Province 1 indicate some differences from the national level energy consumption pattern. Industrial sector is the most energy consuming sector with 45% of total energy consumption. However, different from the previous national average, the share of residential sector is about 41% while that of transport sector demand is 10% and commercial 3% respectively. This is primarily because Province 1 is an economic hub for industry. Thus, it is obvious that the demand for economic sectors would be higher. As for energy demand by fuel types, the use of biomass is still prevalent at around 48%. Petroleum products are 24% of the total energy consumed in the Province, and coal is 21% and new renewables including electricity is 7%.

As per ecological regions, Terai region has the highest consumption with 43% of the total consumption in Province 1, which is followed by hilly region at 41% and mountain region at 6% respectively. Hilly region consumes firewood significantly at almost 24% of the total energy consumed in the province, while fossil fuels and electricity consumptions in the Terai region are high with 24% of the total which is understandable with the concentration of industries in the region. Fossil fuel consumption in the mountain region is virtually non-significant. LPG consumption in Terai region is around 3% of the total, followed by 1.7% in the hilly region, respectively.

In the Reference Economic Growth Scenario, the total final energy demand reaches 105,000 TJ in 2030 increasing to 298,000 TJ in 2050 respectively. Similarly, in the Low Economic Growth Scenario, the total final energy demand attains 101,000 TJ in 2030 and it reaches to 252,000 TJ in 2050. In the context of High Economic Growth case, the final energy demand is expected to reach 106,000 TJ and reaching 329,000 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 95,000 TJ in 2030 and 256,000 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 65% in 2050 respectively. The power plant requirements reach 2,205 MW in 2030 and will be attaining 16,572 MW in 2050. In the SEDS, per capita electricity demand will reach 6,000 kWh in 2050 and the electricity demand per household reaches 2,100 kWh which indicates the transition towards the tier 5- electricity consumption of household as per the World Bank/ESMAP. The electricity demand in the industrial sector is expected to be very high as a consequence, even in 2030, per capita electricity consumption will be 1,100 kWh which comes close to the target of 1,500 kWh per capita set by the National Planning Commission of Nepal in its roadmap for achieving SDGs in Nepal.

Comparative analysis of the SEDS with the Reference Scenario shows that energy demand in SEDS is reduced by 9% in 2030 and the reduction reaches 14% in 2050. In the SEDS, net fuel import ratio comes down to 22% compared to the Reference case of 58% in 2050 which no doubt indicates positive impact in the balance of payment condition and enhances energy security in the Province 1 and in the country. GHG emissions are reduced by 24% in 2030 – a reduction 1,100 ktons of CO2 equivalent from the value in the Reference Scenario. The reduction attains 67% in 2050 compared to the Reference case value of 15,200 ktons of CO_2 equivalent. Furthermore, energy intensity in the SEDS improves to 996 GJ/NRS millions of GDP in 2050, which is 45% less than the base year value of 1,825 GJ/NRS million GDP. GHG emissions per capita is 657 kg CO_2 equivalent in 2050 in the SEDS, whereas in the Reference Economic Growth Scenario GHG emissions per capita will be almost 2,000 kg/capita – a massive reduction of 65% in GHG emissions in 2050, which is in line with the low carbon emissions target of the international guidelines.

Overall, the energy consumption analysis in the base year 2019 and the policy measures taken in the future energy development in the Province 1 indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and integratedly, for the sustainable energy development in the national context. This study also indicates that with the core focus on energy security, reliability, and sustainability, Province 1/ 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.

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Annexes:

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	House Holds
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
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	Photovoltaic
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 sorcerer among the Asian countries with a 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 during 2020, 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- related documents and programs of Nepal have 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 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) 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 firewood 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, 2015).

2 The Status Quo

2.1 Energy Demand 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 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 2018). 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.

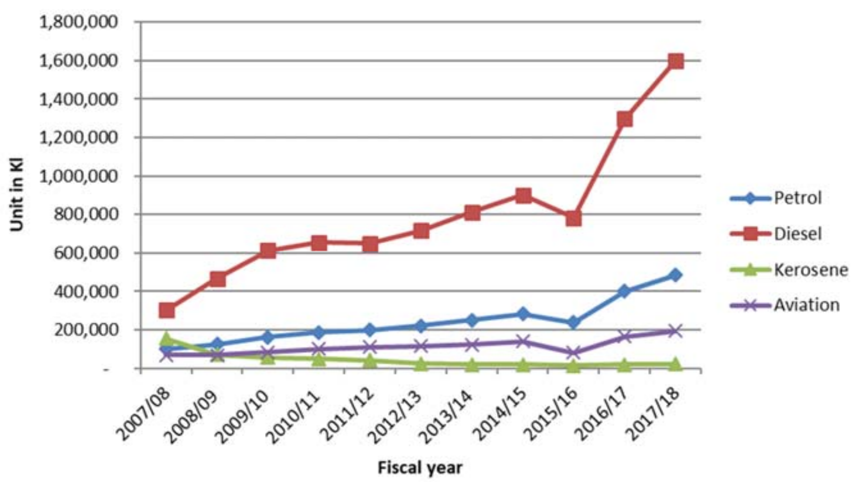

Figure 2.1: Primary Supply of Petroleum Products (Nepal Oil Corporation)

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 3.57million to 3.91million in total number of consumers has been observed. As usual, with 3.66million 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 1 has around 76% of its population electrified (NEA, 2019).

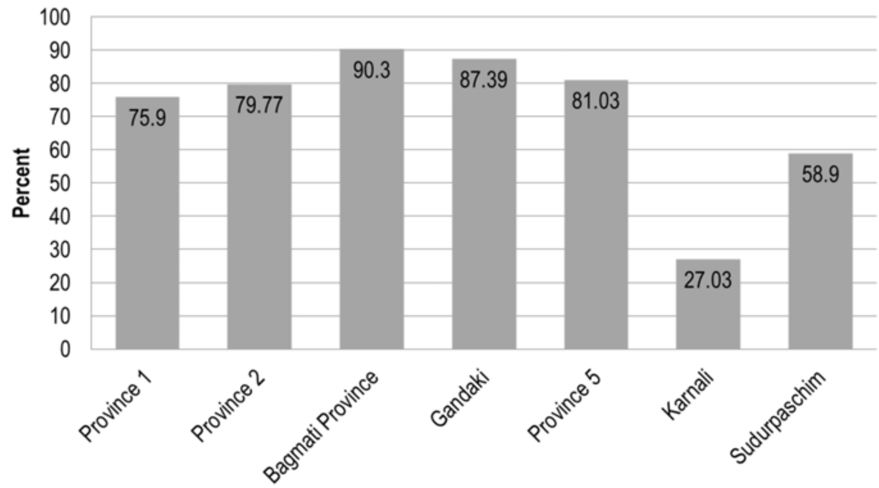

Figure 2.2: Province Wise Electrification by Households (NEA, 2019)

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 1

Province 1 lies in the eastern region of Nepal ranging from mountainous and hilly to terai region. It covers an area of 25,905 km^2. The province, according to the constitution of Nepal 2015 comprises of 14 districts (Figure 2.3:). Under the newly reformed local bodies, the province encompasses a total of 1 metropolitan city, two sub-metropolitans, 46 municipalities, and 88 rural municipalities. Biratnagar has been declared capital of the province by the provincial assembly in 2019. According to the 2011 census, there were around 4.5 million people in the province.

In terms of economic activity, province 1 is the second-most active province with a GDP share of 17.5% (NRB, 2018). The economic sectors diversify according to the geographic conditions. Terai and hilly regions in the border area are the corridor for international trade. The Terai regions dominate in industrial as well as agricultural activities, wherein hilly and Terai regions, other commercial activities such as tourism and small enterprises are concentrated. In terms of energy, this province has the most diversified energy resources as well as energy demand pattern due to varying geographical situations. The mountain regions are known to be remotely accessible. Thus, there are a lesser number of industries, and primary energy resources are traditional biomass. However, due to mountainous geography, there is a significant potential for hydro and solar energy. As moving towards Terai, the energy pattern differs, as there is more commercial energy consumption than in mountainous and hilly regions. It is not only due to easy accessibility, but also the presence of industrial, commercial, and transport activities.

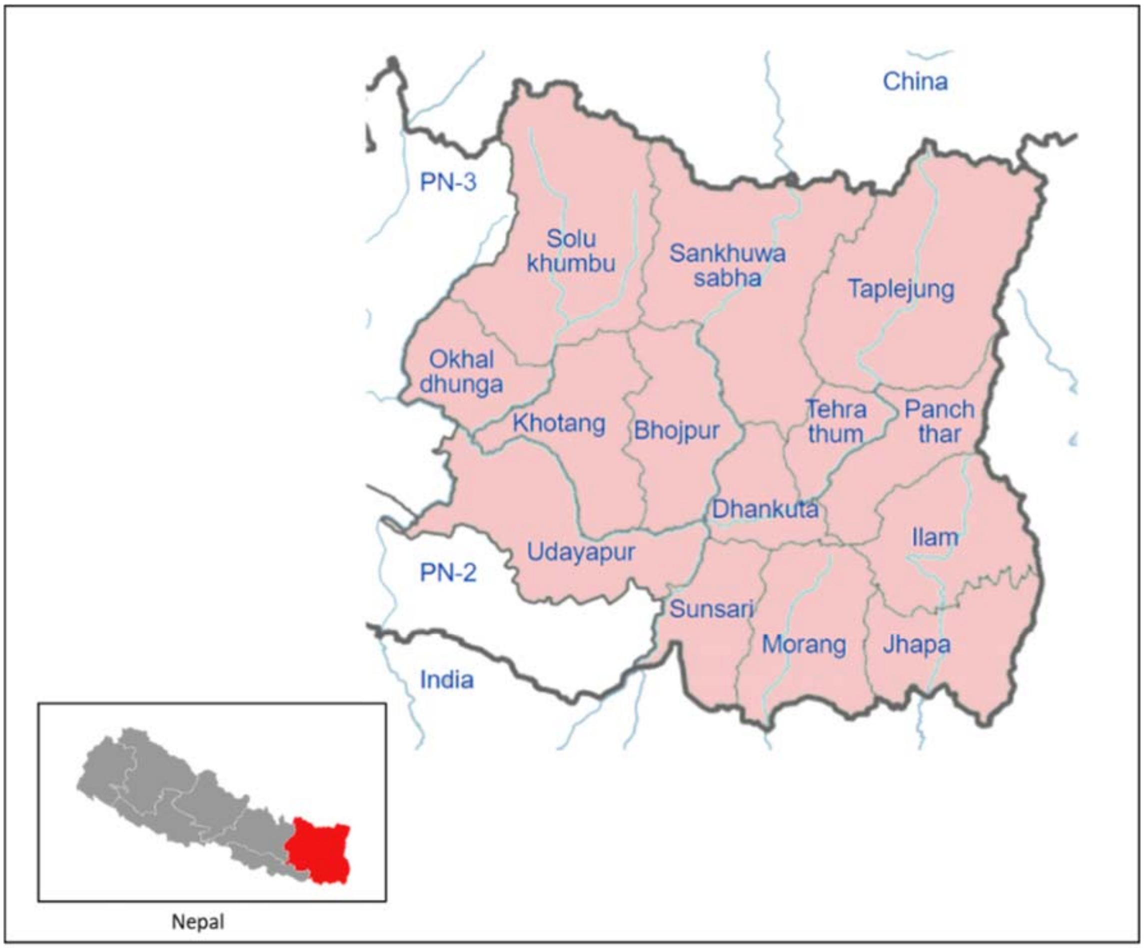

Figure 2.3: Province 1 – Location and Administrative Boundaries

According to National Economic census, there was a total of 168,518 registered institutions in Province 1. Among them, more than 80% are commercial institutions; around 12% are industries, 3% of institutions involved in agriculture while construction and mining account for less than 1%[1]. Meanwhile, in economic terms, the largest share of GDP is from the commercial sector (46%) followed by agriculture (37%), construction and mining (9.5%) and industry (7.8%) in 2019 [2].

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- related documents and programs of Nepal have 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.

[1]National Economic Census 2018, CBS, 2019

[2]Regional-Provincial-National-Accounts-2019., CBS 2019

As per the Policy and Programs ratified by the Parliament, The Federal Government of Nepal, in June 2020, the government of Nepal has amply put focus on the development of hydropower in Nepal. Especially upper Tamakoshi Hydropower project will be commissioned during the fiscal year 2020-21, Budhigandaki and West Set storage hydropower projects will be propelled for further development through external financial resources. The GoN will be prioritizing development of effective and reliable infrastructure development in the transmission and distribution systems. There will be full electrification in Bagmati, Gandaki, Provinces 2 and 5 within this fiscal year, andProvince1,Karnali and Sudur Paschim will have full electrification within 2 years.[3]

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. 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. As per Climate Action Tracker, NDC submitted by Nepal could not be rated as it did not quantify Nepal's contribution in GHG emissions target. As per National Action Plan for Electric Mobility of Nepal Government in 2018 and as per afforestation activities in Nepal– the growth in forest areas has increased to 45% of land area in 2016 from 26% in 1992, the Climate Action Tracker projects that the Nepal's emissions in 2030 will be "1.5^0 C Paris Agreement compatible"[4].

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[3]Unofficial-Translation-of-Policy-and-Programme-2077-78_of Nepal_17May2020

[4]https://climateactiontracker.org/countries/nepal/; accessed 6.11 PM 6/20/2020

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 reducing 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 35MW 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

Key Plans, Policies, programs	Features
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 • 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

Key Plans, Policies, programs	Features
	• 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
Electricity Tariff Fixation by Electricity Regulatory Commission of Nepal, 2020	• Minimum charges for domestic consumers have been declined in the range of 11% to 33%, similarly energy charges have been reduced by 5% to 11%. • Dedicated feeder line charges have been abolished and industrial consumers will be benefited by decline in power tariff in the range of 51% to 56%. • In order to motivate electric mobility in transport sector, off-peak time energy charges have been reduced by 60% in rainy season[5]

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 the government, the study team has looked upon for clean accessible energy for all. The future energy supply plan will be based on current energy consumption as analysed 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.

[5]http://erc.gov.np/storage/listies/May2020/Tariff-Order-Final-Commission.pdf; accessed on 20 June 2020:7:25 PM

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 1.

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 1, the population growth rate of 1.35% per annum, and household size of 4.6 are used. 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 1

Geographical Region	District	2011		2019	
		Population	Households	Population	Households
Mountain	Sankhuwasabha	158,742	34,624	176,718	38,417
	Solukhumbu	105,886	23,785	117,877	25,625
	Taplejung	127,461	26,509	141,895	30,847
Hill	Bhojpur	182,459	39,419	203,121	44,157
	Dhankuta	163,412	37,637	181,917	39,547
	Ilam	290,254	64,502	323,123	70,244
	Khotang	206,312	42,664	229,675	49,929
	Okhaldhunga	147,984	32,502	164,742	35,813
	Panchthar	191,817	41,196	213,539	46,422
	Terhathum	101,577	22,094	113,080	24,583
	Udayapur	317,532	66,557	353,490	76,846
Terai	Jhapa	812,650	184,552	904,677	196,669
	Morang	965,370	213,997	1,074,692	233,629
	Sunsari	763,487	162,407	849,947	184,771
	Total	**4,534,943**	**992,445**	**5,048,494**	**1,097,499**

The projected urban and rural population in 2019 in Province 1 is as shown in Table 3.2

Table 3.2: District Wise Urban and Rural Population in Province 1

	Rural	Urban
Terhathum	72,277.41	41,171.35
Bhojpur	137,731.00	66,168.04
Dhankuta	87,647.61	93,943.76
Ilam	131,847.77	192,108.95
Jhapa	310,203.31	621,316.84
Khotang	144,903.61	85,998.19
Morang	329,054.62	750,570.10
Okhaldhunga	133,696.34	31,497.61
Panchthar	158,967.55	55,356.80
Sankhuwasabha	55,705.59	122,312.42
Solukhumbu	95,319.78	22,951.23
Sunsari	254,370.59	593,115.83
Taplejung	112,558.79	29,709.80
Udayapur	90,871.07	264,022.95
Total	2,115,155.04	2,970,243.86

3.2.1 Survey Design

The questionnaire survey has been carried out in each province using the survey design, as shown in **Figure 3.1**. 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 1. 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

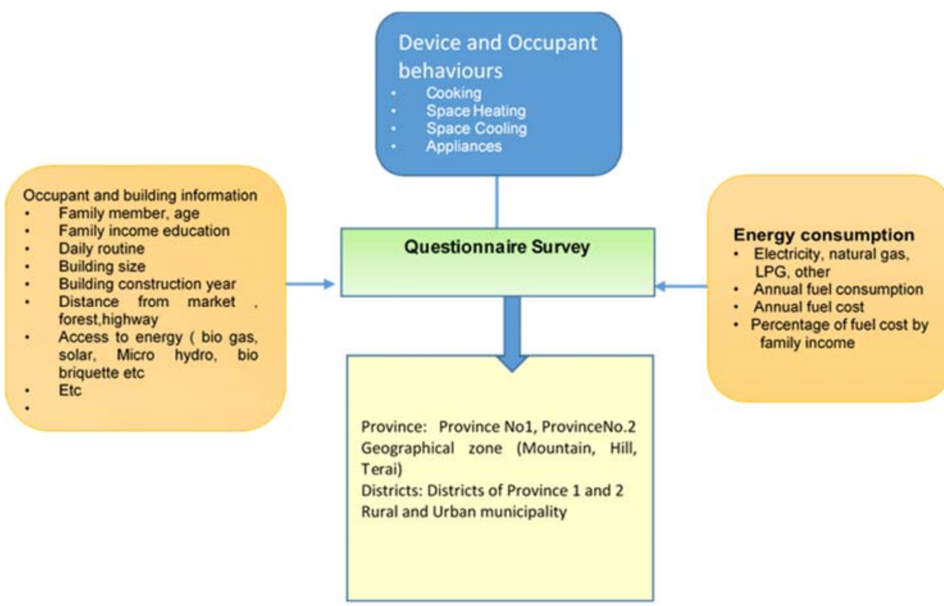


Figure 3.1: Questionnaire Survey Design

3.2.2 Data Collection Method

Six structure questionnaires were prepared for six sectors and these questionnaires were administered in 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. 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 1

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

Equation 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 province-1of Nepal. For the sampling frame of (HECS) several dwellings of Province 1during census 2011are considered as population size. Primary sample unit (PSU) considers dwellings of Province 1. Each district of Province 1 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 384samples 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

Geographical Region	District	Total Household	sample size
Mountain	Sankhuwasabha	34,624	384
	Solukhumbu	23,785	384
	Taplejung	26,509	384
Hill	Bhojpur	39,419	384
	Dhankuta	37,637	384
	Ilam	64,502	384
	Khotang	42,664	384
	Okhaldhunga	32,502	384
	Panchthar	41,196	384
	Terhathum	22,094	384
	Udayapur	66,557	384
Terai	Jhapa	184,552	384
	Morang	213,997	384
	Sunsari	162,407	384
	Total	992,445	5,376

Energy demand was calculated from the 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 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 specific outputs. Thus, for simplicity of energy analysis, the industries have been grouped into 8 categories based on type of output and energy activity they utilize. **Table 3.4** shows the categorization for each of the industry type.

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 III.

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
	Manufacture of motor vehicles, trailers and semitrailers
	Manufacture of other transport equipment
	Repair and installation of machinery and equipment
Electrical Engineering	Manufacture of computer, electronic and optical products
	Manufacture of electrical equipment
Cement, Bricks and Clay products	Manufacture of other non-metallic mineral product
Other products	Printing and reproduction of recorded media
	Other manufacturing

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

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

Equation 3

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

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

Equation 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/secondhand 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

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

Equation 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, 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

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

Equation 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 was under mining sector in the 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 1, 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. The sample size will be revised and refined once the consultant gets the data regarding list of projects being carried on in each province along with inventory of equipment being used. The preliminary 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 1 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 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. Survey responses have been provided in the Annex III.

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.

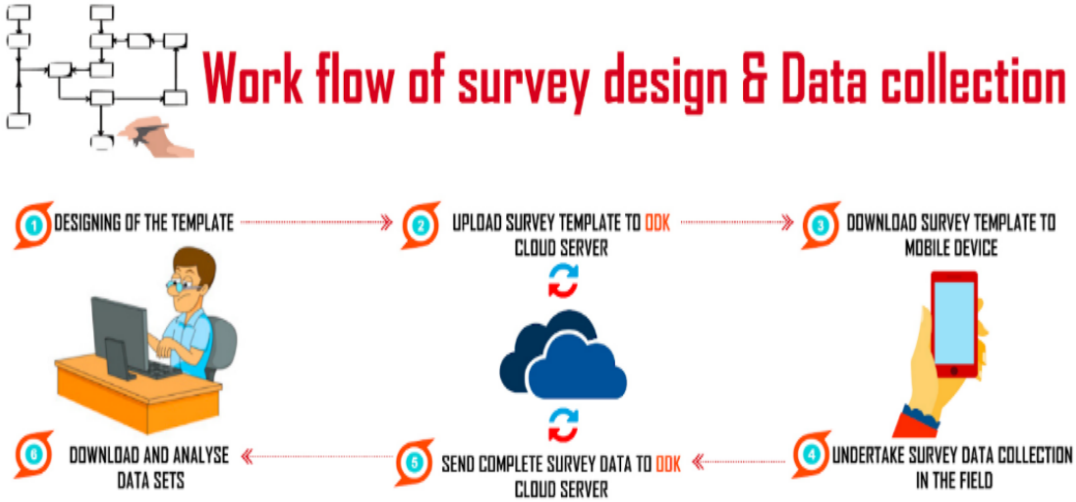


Figure 3.2: Workflow of Survey Design

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 1, 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. 1 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. 1 (MoF, 2019)

(In Million Rs. at 2017/18 prices)	
Industrial Classification	**2018/19**
Agriculture and forestry	176,095
Fishing	1,858
Mining and quarrying	2,528
Manufacturing	37,640
Electricity gas and water	8,352
Construction	43,776
Wholesale and retail trade	46,179
Hotels and restaurants	9,327
Transport, storage and communications	23,455
Financial intermediation	17,413
Real estate, renting and business activities	33,157
Public administration and defense	12,455
Education	33,821
Health and social work	10,025
Other community, social and personal service activities	28,059
Total GVA including FISIM	484,139
Financial Intermediation Services Indirectly Measured (FISIM)	11,565
Gross Domestic Product (GDP) at basic price	472,575
Taxes less subsidies on products	33,273
Gross Domestic Product (GDP)	505,848

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 4.2** and **Table 4.3.**

Table 4.2: List of Policy Variables and other exogenous variables

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

Table 4.3: List of Endogenous Variables

CPI	Consumer Price Index
DCG	Government Consumption Expenditures
DCP	Private Consumption Expenditures
DCST	Change In Stocks
DCTOT	Total Consumption Expenditures
DGFCF	Gross Fixed Capital Formation
DGFCFG	Government Gross Fixed Capital Formation
DGFCFP	Private Gross Fixed Capital Formation
DMGS	Imports Of Goods And Services In Real Sector
DTINV	Gross Capital Formation
DXGS	Exports Of Goods And Services In Real Sector
FCAB	Current Account Balance
FGSB	Balance On Goods And Services
FKFAB	Capital And Financial Account Balance
FMGS	Imports Of Goods And Services In External Sector
FOB	Overall Balance In External Sector
FTRB	Current Transfers Net
FYB	Primary Income Net
GCASHBAL	Budgetary Cash Balance
GDBOR	Domestic Borrowing
GDTX	Direct Taxes
GFAID	Foreign Aids
GFISCBAL	Budgetary Fiscal Balance
GFLOAN	Foreign Loans
GGEXP	Total Government Expenditure
GGOVRECI	Total Government Receipts
GGREV	Government Revenue
GINDTX	Indirect Taxes
GKEXP	Government Capital Expenditures
GNTXREV	Non-Tax Revenue
GOVSAV	Government Saving
GPR	Principal And Interest Repayment
GREXP	Government Regular Expenditures
GTRAF	Government Transfers (Government Subsidies)
GTXREV	Tax Revenue
LAG	Employment In Agriculture Sector
LIND	Employment In Industry Sector
LSERV	Employment In Service Sector
LTOT	Total National Employment
MM2	Broad Money Supply (M2)
PSAV	Private Savings
PY	Implicit GDP Deflator
RGAP	Resource Gap
Y	Gross National Income
YAG	Value Added In Agriculture Sector
YBP	Gross Domestic Product At Basic Prices
YDI	Gross National Disposable Income
YDIP	Per Capita Gross National Disposable Income
YDIP$	Per Capita Gross National Disposable Income In US Dollar
YDSAV	Gross Domestic Saving
YFC	Gross Domestic Product At Factor Cost (Including FISIM)
YFISIM	Financial Intermediation Services Indirectly Measured (FISIM)
YIND	Value Added In Industry Sector
YINDTXN	Indirect Tax (Net) (Tax Less Subsidies On Products)
YNSAV	Gross National Saving
YP	Per Capita Gross National Income
YP$	Per Capita Gross National Income In US Dollar
YPP	Gross Domestic Product At Producers' Prices
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.

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 is 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 is 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 is 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. 1 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 GVA and GDP are given in Annex VII.

Table 4.8: Economic Growth Rates in Province 1 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. 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	(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	

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[6], 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 software. Secondly, TIMES model is used as the MAED is

[6] 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.

limited or demand projection only, while the TIMES model can analyze 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.

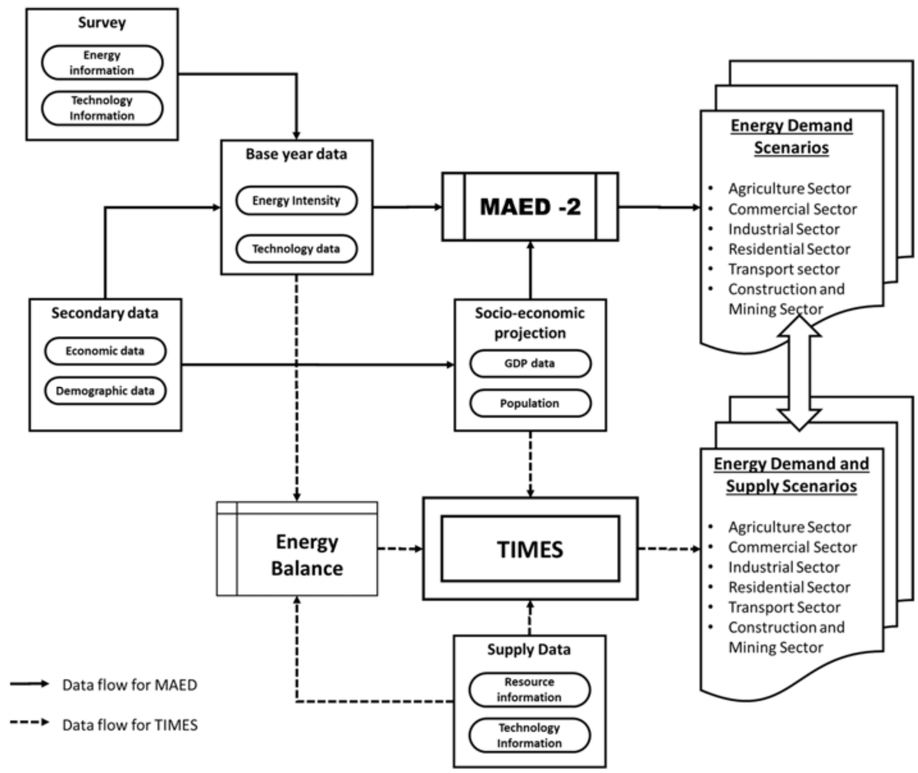


Figure 5.1: Methodological Framework of Projection in MAED and TIMES

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 has 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 (**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 affect 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 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**).

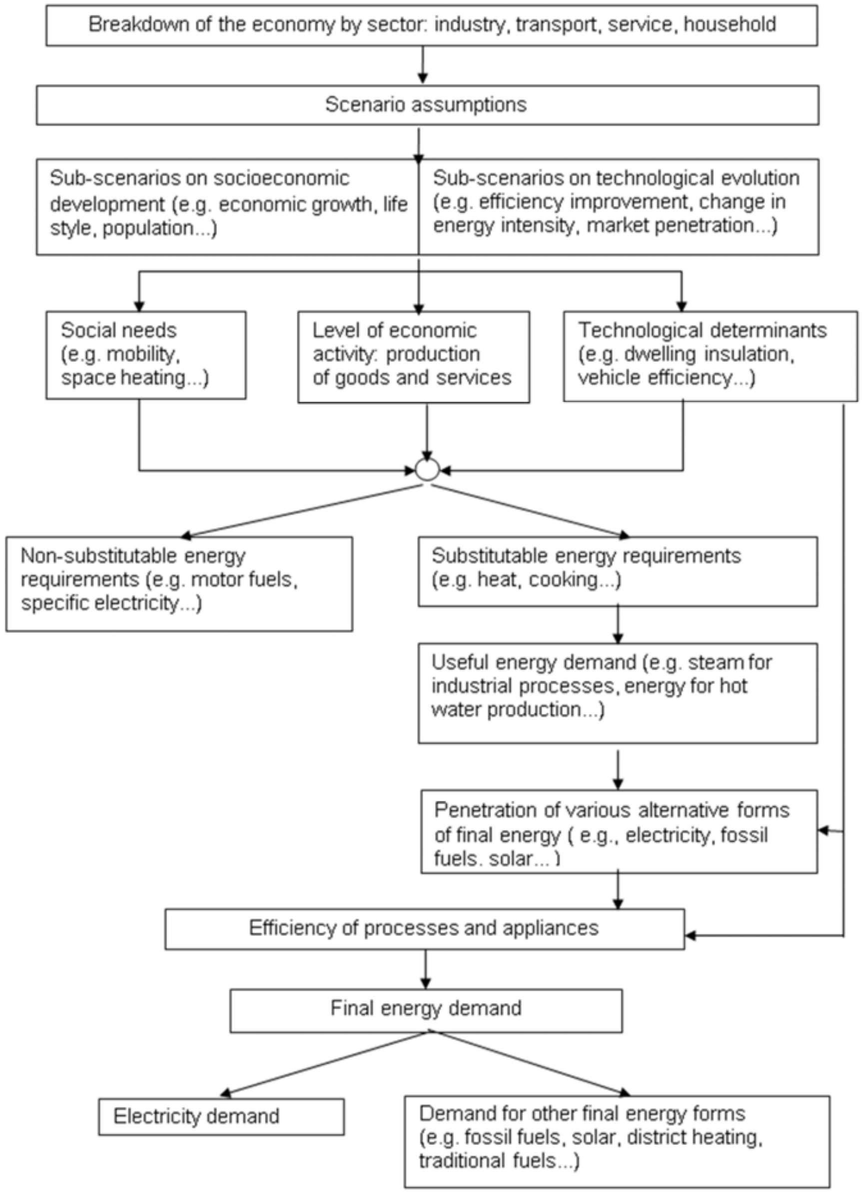


Figure 5.2: Scheme Used to Project Useful and Final Energy Demand in Module 1 of MAED

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 .**

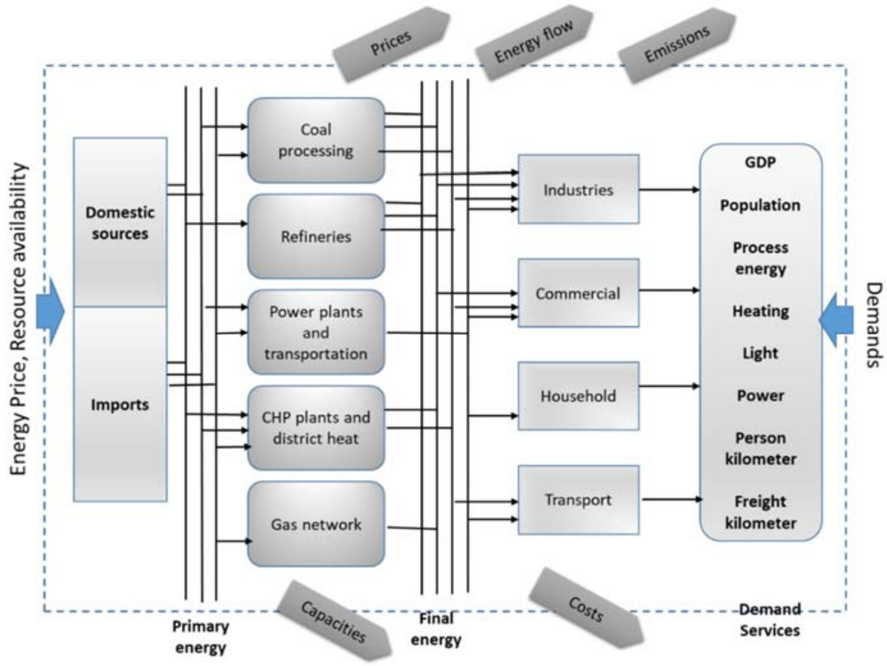


Figure 5.3: Structure of TIMES Framework

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

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

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

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

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 plus variables 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 firewood, 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.**

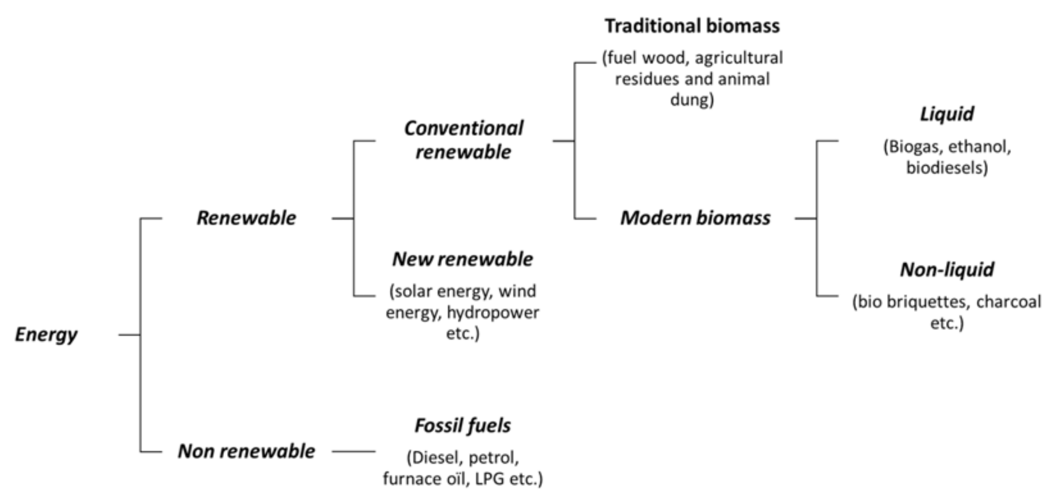


Figure 6.1: Energy Classification for Nepal[7]

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

6.1 Solid Biomass

Province I of Nepal is blessed by nature from high to low altitudes. Terai region has good sunlight, enough water and alluvial soil. There are geographic regions from Chure, Mid hills, high altitudes to high Himalayan range. Therefore, there are exceptionally good forests plants and animals ranging from tropical animals such as elephants and tigers to temperate animals like now leopard, musk deer, etc. in the province. Similarly, Province I has tropical vegetation like sal forests to alpine vegetation like grass lands, betula forests, etc. But urbanization and agriculture has impacted good forests, and some of good forests are denuded. Similarly, human pressure for firewood in the past changed the good forests into degraded ones. Jhapa, Morang and Sunsari once used to be dense forests. Due to the better ecological conditions for plant growth in Terai regions and large areas of forests, Province I still has good potential for proper forest management and firewood production. From the perspective of energy, these forests have remarkably high potentials. On the other hand, most of the people in the remote area of the province are poor, therefore they still depend upon bio-energy and forestry is very important for them.

[7] As per Terms of Reference

6.1.1 Physical Environment

Broadly Province I is divided into 3 physio-graphic zones viz. Terai, middle mountain (Hills) and higher mountains.

The Terai comprises of a narrow belt of flat and fertile land in the southernmost part of the country around 500 meters above from the sea level. In terms of morphology, the forests in Terai consist of gently sloping, recent and post-Pleistocene alluvial deposits which form a predominant plain south of the Himalayan. (LRMP, 1986). The Terai physio graphic zone is divided into three sub zones: The Bhabar, the Terai and the Southern Terai (Jackson, 1994). Bhabar sub zone 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.

Climate in the Terai is hot in summer and warm in winter. Terai districts are comparatively warmer than hill districts. Plant species which grow in Terai, generally need hot temperature and high moisture in soil.

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

Forests in the hill areas are predominantly composed of Sal (*Shorea robusta*), followed by *Terminalia-Anogeissus* and *Acacia catechu* and *Dalbergia sissoo* forest along stream banks and riverbeds. The other species generally grown there are haldu, harro, barro, simal, kadam, jamun, kusum, etc 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 particularly good for furniture and khayar fletches high price due to kattha content in firewood, 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.

6.1.2 Forest in the Province 1

Subtropical broad-leaved forests occur mainly between 1,000 meters and 2,000 meters and are dominated by *Schima wallichii* and *Castanopsis indica*. Riverine forests of *Cedrela toona* are common along river valley sides, while *Alnus nepalensis* is widespread along streams and moist places. Subtropical conifer forests primarily consist of *Pinus roxburghii* forests that occur in southern dry slopes between 1,000-2,000 meters.

Lower temperate broadleaved forests are generally confined between 1,700 meters and 2,500 meters. *Castanopsis tribuloides, Castanopsis hystrix* and *Quercus lamellosa* are the main tree species in these forests.

Upper temperate broadleaved forests are found in drier south-facing slopes between 2,200-3,000 meters. *Quercus semecarpifolia* is the main tree species in these forests, except in higher rainfall areas such as the hills to the north of upper Arun and Tamor valleys.

Upper temperate mixed broadleaved forests occur in moister North and West facing slopes in between 2,500 to 3,500 meters and are dominated by Acer and Rhododendron species.

Altitude of the middle mountain ranges from 3,000 m to 5,000 m and climate comprises of subalpine and alpine ecological zones of Nepal. The High Mountains zone can be characterized by high steep slopes and deep gorges. The zone comprises subalpine and alpine climates and associated vegetation types. The higher elevation areas include biologically diverse summer grazing pastures. At the lower elevation, the zone harbors luxuriant natural conifer and mixed forests in some locations. The soils can be characterized by Precambrian metamorphosed gneisses and micas

Subalpine forests occur between 3,000 – 4,100 meters and are mainly comprised of small and generally ill-formed trees of *Abies spectabilis, Picea smithiana, Betula utilis,* and Rhododendron species. Alpine scrub vegetation occurs between the tree line (around 4,000 meters) and snowline (around 5,500 meters) in the eastern half of the Province. The **Table 6.1** below show forest area and major species of Province I.

Table 6.1: Summary of Physiographic Zone of the Province I

SN	Physiographic Zone	Altitude (m)	Districts	Forest Area (ha)	Major Species	Stem Volume (m3)	Growth Rate %
1.	Terai	500	Jhapa, Morang and Sunsari	83,296	sal, sisoo, khair, asna	167.42	fast
2.	Middle mountain	500-3000	Udayapur, Ilam, Dhankuta, Pachthar, Khotang, Okhaldhunga, Tehrathum	582,804	chima-castanopsis, pinus, oak, alnus	124.26	medium
3.	Higher mountain	3000-5000	Taplejung, Sankhuwasabha, Solukhumbu	456,026	rhododendron, abies, acer, betula, picea	225.24	slow

Forest resources are especially important for ecosystem balance and people's livelihood in Nepal and this fact applies also for Province I. Reliable and up-to-date information on forest resources is essential for supporting policy formulation, strategic energy planning, and sustainable forest management. Such information can ultimately guide in wise decision-making aiming at support 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 reporting on its international obligations and initiatives such as the Global Forest Resource Assessment, Sustainable Development Goals(SDGs), Nationally Determined contribution (NDC), 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 1

Sagarmatha National Park and Makalu Barun National Park, Kanchanjungha Conservation Area and Koshi Tappu Wildlife Reserve are the protected areas in the province, which is managed for biodiversity conservation. All remaining forests are managed for production which include timber, firewood, and non-timber forest products. Most prominent forest management type in Province I is community forest followed by Collaborative Forest Management, block forest management and leasehold forest.

Area of forests in Province I under community forest management is given in Table 6.2. The table shows the 536,680 ha of forests are managed by 3,675 forest user groups (DoF, Data base 2019).

Table 6.2: Districts and Community Forests

S.no.	District	CF number	Area in Ha
1	Jhapa	59	15,797
2	Morang	131	20,403
3	Sunsari	68	9,752
4	Udayapur	345	77,732
5	Ilam	236	47,375
6	Dhankuta	386	30,399
7	Terhathum	337	18,964
8	Bhojpur	562	42,220
9	Khotang	411	163,889
10	Okhaldhunga	348	29,940
11	Pachthar	205	13,767
12	Sakhuwasabha	291	31,815
13	Solukhumbu	184	27,291
14	Taplejung	112	7,336
	Total	3675	536,680

In addition, trees outside forests are also particularly important for Teri, especially for southern villages.

6.1.4 Firewood 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 firewood is the main source of energy in rural Nepal. Firewood 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. Firewood 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 like firewood and other bio-mass resources (AEPC, 2000). Most of the fuel firewood 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 firewood 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 firewood in the country has rapidly increased due to population growth and has resulted tremendous pressure on existing forests. Local community brings hundreds of cycles loaded of fuel firewood to their villages from forests in Terai districts. The demand for fuel firewood will continue to increase significantly due to population increase in Terai.

6.1.5 Effect of Firewood Collection to Forest

Deforestation, meaning changing forests into other land use and forest degradation, meaning deteriorating in quality of forests, is one of the biggest socio-economic and environmental problems in Nepal. Between 1990 and 2000, Nepal lost an average of 91,700 hectares of forest per year. This amounts to an average annual deforestation rate of 1.90%. The annual deforestation rate was estimated to be 1.7% during the 1980s to mid-1990s (DFRS, 1999a). However, deforestation rates and causes differ according to physiographic regions. For instance, from 1978 to 1994, the rate of estimated annual deforestation varied greatly between the Hills (2.3%) and the Terai (1.3%) (DFRS, 1999a). The highest rate of deforestation that Nepal witnessed was between 1947 and 1980, where Nepal's forest cover declined at an annual rate of 2.7% (from 57% to 23% of the national territory), and subsequently at an annual rate of 1.8% between 1980 and 2000 (UNEP, 2001). However, between 2000 and 2005, the rate of deforestation decreased by 28.9% to 1.35% per year. In general, main causes of deforestation are agricultural production, need of firewood, forage for livestock as well as local unemployment and lack of management from the government. There are also other reasons which include political instability, politician's attitude, fire, shifting cultivation, natural process, forest rewards, attitude of individuals, donor's role and government policy.

In the Terai and Siwalik deforestation is widespread legally due to government resettlement programs and illegally clearing of forest for agriculture. 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 1also the land under cultivation increased at cost of forest land. On the other hand, due to poverty, the demand for firewood increased in spite of the rapid growth in the commercial energy sector in the Terai region, because the firewood is practically free if people afford time for collection. Large quantity of firewood is being collected from community managed and government managed forest by the local people.

6.1.6 National Demand and Supply Situation

Assessing true state of firewood resources in Nepal is a difficult task (Thompson and Warburton 1985) because forest use is diverse and an integral part of the subsistence economy. The government of Nepal is the predominant supplier of firewood products in Nepal. The supply of fuel firewood 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 firewood demand is a function of households, their firewood use and per capita consumption.

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

6.1.7 Firewood from Community Based Forests

Most of the forest product in Province 1 come either from community forests or collaborative forests or private forests. These government forests are mostly over matured and degraded. In the past, although forest management plans are made, forests were not managed on a sustainable 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 firewood.

Major volume of firewood is expected to come from private forests, because they go on cutting followed by planting. As firewood is a 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 most of the firewood coming from government forests depends upon sites to be converted for non-forestry purposes, annual data on firewood production in different districts do not match with forest areas. Table 6.3. indicates the forest areas and potential firewood production in Province 1.

Table 6.3: Forest Area and Potential Firewood Production in Current

District	Forest area (ha)	stem volume m³	Annual firewood production (m³)	Annual firewood production of accessible forest (m³)
Terai :accessible forest (100%)				
Jhapa	17,568	2,941,235	50,008	50,008
Morang	44,075	7,379,037	125,461	125,461
Sunsari	21,653	3,625,145	61,636	61,636
Total	83,296	13,945,416	237,106	237,106
Middle mountain: accessible forest (90%)				
Udayapur	148,411	18,441,551	112,598	101,338
Ilam	93,467	11,614,209	70,912	63,821
Dhankuta	36,724	4,563,324	27,862	25,076
Terhathum	32,821	4,078,337	24,901	22411
Bhojpur	73,037	9,075,578	55,412	49,871
Khotang	74,284	9,230,530	56,358	50,723
Okhaldhunga	52,286	6,497,058	39,669	35,702
Panchthar	71,774	8,918,637	54,454	49,009
Total	582,804	72,419,225	442,166	397,950
Higher mountain: accessible forest (70%)				
Sakhuwasabha	**190,052**	**42,807,312**	**554,195**	**387,936**
Solukhumbu	110,043	24,786,085	320,887	224,621
Taplejung	155,931	35,121,898	454,697	318,288
Total	456,026	102,715,296	1,329,779	930,845
Grand Total	**1,122,126**	**189,079,938**	**2,009,051**	**1,565,901**

Thus, annual firewood increment from whole Province I is 1,565,901m3(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 1565901 m3. Thus, obtained value is converted to the kilogram and or tone using firewood density (average 1 m3 =836 kg) and totaled to final firewood to 1,309,093 tons or 1,309 kilo tons.

6.1.8 Firewood from Tress Outside Forests

Like in other parts of Nepal, trees outside forests (ToF) are also important source of firewood in Province I. The result from the TOF assessment in Morang district showed about 15 numbers of stems equivalent to 2.5 cubic meters of stem volume on a per hectare basis which is even less than 2% of the per hectare growing stock of natural forests of the same district. Per hectare total biomass is about 2.9 tons indicating a biomass expansion factor equal to about 1.16 including all parts of the tree (i.e. stem, branch and leaf). The rural stratum has more than 80% of the total stem number whereas the same stratum occupies only about 58% of the total stem volume and 55% of the total TOF area. The urban area is rich in terms of stem density stocking level among all three strata and the rural stratum is relatively poor in this regard.

But, as compared to large geographical area of Province I, trees outside forest is not important as in Province II, therefore, the component is not elaborated further.

6.2 Biogas in Province 1

Animal in the Province

From perspectives of emission of greenhouse gases (ghg), biogas production from animal dung is especially 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.

For this purpose, number of animals in different districts of Province 1 is given as below in **Table 6.4.**

Table 6.4: Numbers of Animals in Province I

District	Cattle	Buffaloes	Sheep	Goat	Pigs	Fowl	Duck
Taplejung	56,678	19,108	5,928	84,147	25,109	208,365	725
Sankhuwasabha	105,232	42,107	11,631	169,405	41,858	407,400	1,015
Solukhumbu	55,984	48,005	7,611	87,255	37,508	237,598	897
Panchthar	105,323	43,514	1,363	126,168	53,568	369,818	798
Illam	151,146	23,894	147	151,114	36,874	427,598	234
Terhathum	79,017	35,064	7,079	115,519	30,957	234,567	1,139
Dhankuta	95,676	20,876	561	186,192	28,556	695,825	3,051
Bhojpur	98,856	50,095	17,191	92,007	42,309	314,918	3,878
Khotang	92,687	61,858	9,163	119,450	35,634	256,025	1,987
Okhaldhunga	52,212	59,564	9,532	116,945	55,654	332,920	798
Udayapur	124,575	99,897	702	243,035	50,324	617,560	2,314
Jhapa	236,848	74,984	38	25,791	81,006	1,515,340	3,654
Morang	399,976	104,894	455	283,417	70,874	1,952,790	50,322
Sunsari	294,689	175,826	4,610	226,325	59,978	1,534,684	16,980
Total	1,948,899	859,686	76,011	2,026,769	650,209	9,105,408	87,792

(Source: Ministry of Agriculture and Livestock Development, July 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. This results in spread of dung in bigger geographic area and makes its collection exceedingly difficult.

Thus, production of biogas is estimated only from dung of cattle and buffalo. When considered, production of dung as 10 kg/day from cattle and 15 kg per day from buffalo (WECS, 2010), dung production for Province I can be estimated as shown in the Table 6.5.

Table 6.5: Dung production in Province I

	Cattle	Buffaloes	Dung produced from cattle tons/ year	Dung produced from buffalo tons/ year	Total dung production tons/Year
Taplejung	56,678	19,108	206,875	104,616	311,491
Sankhuwasabha	105,232	42,107	384,097	230,536	61,464
Solukhumbu	55,984	48,005	204,342	262,827	467,169
Panchthar	105,323	43,514	384,429	238,239	622,668
Illam	151,146	23,894	551,683	130,820	682,503
Terhathum	79,017	35,064	288,412	191,975	480,387
Dhankuta	95,676	20,876	349,217	114,296	463,514
Bhojpur	98,856	50,095	360,824	274,270	635,095
Khotang	92,687	61,858	338,308	338,673	676,980
Okhaldhunga	52,212	59,564	190,574	326,113	516,687
Udayapur	124,575	99,897	454,699	546,936	1,001,635
Jhapa	236,848	74,984	864,495	410,537	1,275,033
Morang	399,976	104,894	1,459,912	57,295	2,034,207
Sunsari	294,689	175,826	1,075,615	962,647	2,038,262
Total	1,948,899	859,686	7,113,481	4,706,781	11,820,262

6.2.1 Potential of Biogas Production Per Year

In order to estimate potential biogas in Province I, the growth rate of cattle and buffalo in the districts of the province is obtained from the number of livestock shown in **Table 6.6.**

Table 6.6: Livestock Numbers in Past Years

S.no.	Year	Cattle	Buffalo	Total
1	2008/09	7,175,198	4,680,486	11,855,684
2	2009/10	7,199,260	4,836,984	12,036,244
3	2010/11	7,226,050	4,993,650	12,219,700
4	2011/12	7,244,944	5,133,139	12,378,083
5	2012/13	7,274,022	5,241,873	12,515,895
6	2013/14	7,243,916	5,178,612	12,422,528
7	2014/15	7,241,743	5,167,737	12,409,480
8	2015/16	7,302,808	5,168,809	12,471,617
9	2016/17	7,347,487	5,177,998	12,525,485
10	2017/18	7,376,306	5,277,819	12,654,125

Above table shows average annual rate of increase of livestock is about 0.67% or very insignificant. As the grazing area is decreasing due to urbanization, the land available for cattle will not increase accordingly. Therefore, it is highly likely that the number of cattle and buffalo will remain same in coming years.

Considering biogas 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 estimated as below. Per cubic meter of biogas is further converted into the energy using conversion factor of 1 cubic meter of dung equals to 20 MJ (Vipul Vaid and Shivangi Garg, 2013), **Table 6.7** shows the potential energy production from biogas.

Table 6.7: Potential of Biogas in Current

	Total dung production "000" tons/Year	Bio gas in "000" cubic meter	Energy in "000" Gj per year	Potential percentage	Potential in 000 Gj
Taplejung	311	11,214	224.27	0.5	112.14
Sankhuwasabha	61	22,127	442.53	0.5	221.27
Solukhumbu	467	16,818	336.36	0.5	168.18
Panchthar	623	22,416	448.32	0.75	336.24
Illam	683	24,570	491.40	0.75	368.55
Terhathum	480	17,294	345.88	0.75	259.41
Dhankuta	464	16,686	333.73	0.75	250.30
Bhojpur	635	22,863	457.27	0.75	342.95
Khotang	677	24,371	487.43	0.75	365.57
Okhaldhunga	517	18,601	372.01	0.75	279.01
Udayapur	1,002	36,059	721.18	0.75	540.88
Jhapa	1,275	45,901	918.02	1	918.02
Morang	2,034	73,231	1,464.63	1	1,464.63
Sunsari	2,038	73,377	1,467.5	1	1,467.55
Total	**11,820**	**425,529**			**7,094.70**

Potential of biogas production is considered 50% for 3 high hill districts, 75% for 8 mid hill districts and 100 % for the remaining 3 Terai districts. As per **Table 6.7**, production of biogas for Province 1 is 7,095thousand GJ.

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 firewood will be still a source of energy for cooking food in many villages of Province 1.

6.3 Energy from Agriculture Residues

In 14 districts of province of area under different crop, their residue production in tons, potential energy production is given as below in **Table 6.8.**

Table 6.8: Potential Energy form Agri Residue

Crop type	Area	Total residue in ton	Energy in GJ	Percentage
Paddy	322,183	1,900,878	28,513,195	47.72
Maize	281,268	1,532,911	22,993,659	38.49
Wheat	59,997	202,190	3,032,848	5.76
Sugarcane	6,492	1,560,678	2,341,015	3.91
Buckwheat	2,683	4,024	60,367	0.10
Oil seed	37,871	48,475	727,123	1.22
Millet	72,017	136,832	2,052,485	3.44
Barley	1,385	2,077	31,163	0.05
Total	783,896	3,983,457	59,751,856	100

Table 6.8 shows that potential of agriculture waste can be a main source of fuel, if used. But, agriculture wastes are normally used immediately after harvest of the crop. In addition, only farmers possess such fuels. Due to light density, storage of agriculture waste takes large space and can become a problem in present context where space is limited. For storage of fuel, firewood is preferred than agriculture waste. Total source of agriculture residues and potential energy which could be produced from the agriculture waste is shown in **Table 6.8**. Total potential energy produced from such waste is 59.75 thousand GJ. Of this energy, about 48 % come from paddy straw and about 38.5 % come from maize.

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 mainly 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 2075-76are as shown in Table 6.9: Petroleum Sales in Province 1. All the units for MS, Diesel and 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 6.9: Petroleum Sales in 2075-76 in Province 1

Districts	MS	Diesel	SKO	LPG
	kL	kL	kL	tons
Taplejung	234	1,980	-	-
Sankhuwasabha	948	4,441	-	-
Solukhumbu	288	1,576	282	-
Okhaldhunga	816	5,722	168	-
Khotang	306	1,904	-	-
Bhojpur	288	3,113	-	-
Dhankuta	1,371	7,399	39	-
Terhathum	192	1,032	-	-
Panchthar	929	7,109	-	-
Ilam	2,245	6,487	-	-
Jhapa	27,102	66,017	777	20,824
Morang	25,507	71,727	1,528	9,358
Sunsari	21,557	59,436	1,019	51,994
Udayapur	3,622	15,950	-	-
Total	**85,405**	**253,891**	**3,813**	**82,176**

(Source: NOC 2020)

6.5 Electricity

Province 1, which have mountains and hills, has abundance of water resources and there are several potential sites for hydropower development. The average potential for hydropower plant is around 20,500 MW in province 1 (Kandel, 2018). In addition to that, 66 MW of small hydropower potential from 84 and nearly 70 sites for 1 MWp of solar PV sites has been identified for decentralized generation of electricity (NPC, 2018). There are 29 IPPs hydropower projects, 4 major hydro power plants and 5 small hydropower plants in province 1 (NEA 2019). There is 237.59 MW (226.796 MW from IPPs and 10.794 MW from NEA generation) installed capacity in the province. The hydropower plants with its installed capacity is given in **Table 6.10.**

Table 6.10: IPP's Hydropower Projects in Province 1

IPPs' Hydropower Projects in Province 1			
S.N.	**Hydropower Projects**	**Districts**	**Capacity (KW)**
1	Pikhuwa Khola	Bhojpur	5,000
2	Leguwa Khola	Dhankuta	40
3	Mai Khola	Illam	4,500
4	Upper Puwa-1	Illam	3,000
5	Mai Khola	Illam	22,000
6	Mai Cascade	Illam	7,000
7	Upper Mai	Illam	9,980
8	Jogmai	Illam	7,600
9	Upper Mai C	Illam	5,100
10	Puwa Khola-1	Illam	4,000
11	Mai sana	Illam	8,000
12	Super Mai	Illam	7,800
13	Super Mai 'A'	Illam	9,600
14	Super MaiCascade	Illam	3,800
15	Miya Khola	Khotang	996
16	Molung Khola	Okhaldhunga	7,000
17	Pheme Khola	Panchthar	995
18	Hewa Khola A	Panchthar	14,900
19	Tallo Hewa Khola	Panchthar	22,100
20	Piluwa Khola	Sankhuwasabha	3,000
21	Lower Piluwa Small	Sankhuwasabha	990
22	Hewa Khola	Sankhuwasabha	4,455

IPPs' Hydropower Projects in Province 1			
S.N.	Hydropower Projects	Districts	Capacity (KW)
23	Sabha Khola	Sankhuwasabha	4,000
24	Solu Khola	Solukhumbu	23,500
25	Phawa Khola	Taplejung	4,950
26	Sobuwa Khola-2 MHP	Taplejung	90
27	lwa Khola	Taplejung	9,900
28	Kabeli B-1	Taplejung	25,000
29	Upper	Terhathum	7,500
	Total		**226,796**

The list of major and small hydropower plants in province 1 is as shown in **Table 6.11**.

Table 6.11: Major and Small Hydro Power Plants in Province 1

Major and Small Hydro power plants in Province 1			
S.No.	Power Plants	Districts	KW
1	Bhojpur**	Bhojpur	250
2	Dhankuta***	Dhankuta	240
3	Puwa Khola	Illam	6200
4	Gorkhe(Illam)***	Illam	64
5	Okhaldhunga	Okhaldhunga	125
6	Phidim	Panchthar	240
7	Khandbari	Sankhuwasabha	250
8	Chatara	Sunsari	3200
9	Taplejung**	Taplejung	125
10	Terhathum	Terhathum	100
			107,94

** Leased to Private Sector ***Not in Normal Operation

(NEA, 2019)

With the increasing investment in hydropower plants, Ministry of Electricity, Water Resources, and Irrigation has plans to generate 3,751 MW of electricity from different hydropower plants of province 1 in next 15 years. As per Nepal Electricity Authority 2019, the planned and proposed hydropower plants are Upper Arun Hydroelectric plant (1,061 MW) in Sankhuwasabha and Dudhkoshi storage plant (635 MW) in Solukhumbu districts (NEA, 2019).

The district - wise electricity supply status as obtained from Nepal Electricity Authority for province1 is as shown in **Figure 6.2.** Province 1 consumed 1,011 GWh of electricity including the consumption in all economic sectors (NEA database 2020). The three districts of Terai Jhapa, Morang and Sunsari located in industrial zone consumed 79% of total electricity consumption. However, electricity consumption in mountainous region is extremely low. It could be due to poor access to electricity in remote areas. Comparatively, electricity consumption is lower in Hilly region than in Terai region.

Peak demand in 2019 in Nepal was 1,320 MW in wet season (NEA 2019). National sales data in the same show that there was demand of almost 6,340 GWh electricity in Nepal. Industry and household sectors consume 39% and 42% of total supply respectively in Nepal.

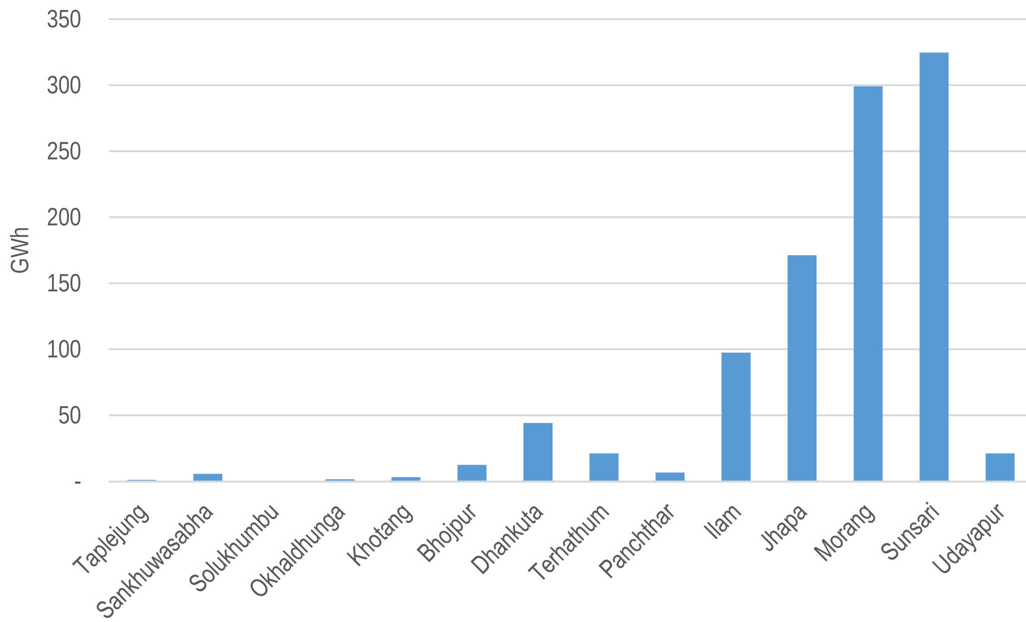


Figure 6.2: Electricity Consumption in Province 1 (NEA, 2019)

The sectoral electricity consumption in economic sectors in Province 1 is as shown in **Figure 6.3.** Industrial sector consumed 42% of total electricity consumed in the Province whereas its consumption in household sectors (43%), commercial 6%, agriculture 3% and others including non-commercial sector 6% respectively.

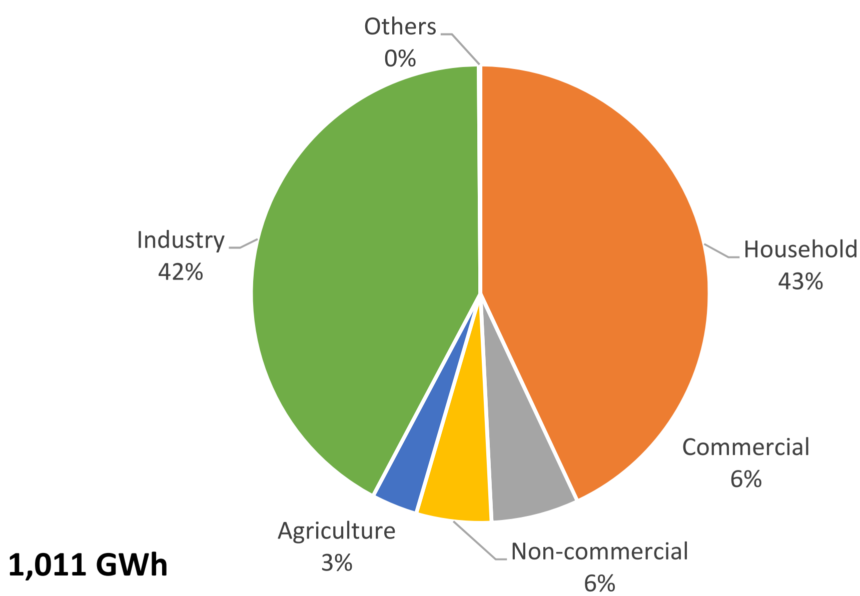


Figure 6.3: Economic Sector wise Electricity Consumption in Province 1 (NEA, 2019)

As per NEA domestic consumption data, the electricity connection as per ampere capacity of households who have electricity is as shown in Figure 6.4: Mix of Ampere Capacity of Households with Electricity Access (NEA, 2075)

. It shows that over 90% of the households lies within minimal amperage capacity of 5A, 7% are connected with 6-15A connection. Less than 1% have electricity connection above 16A. In province 1, 76% of household have access to electricity (NEA, 2019).

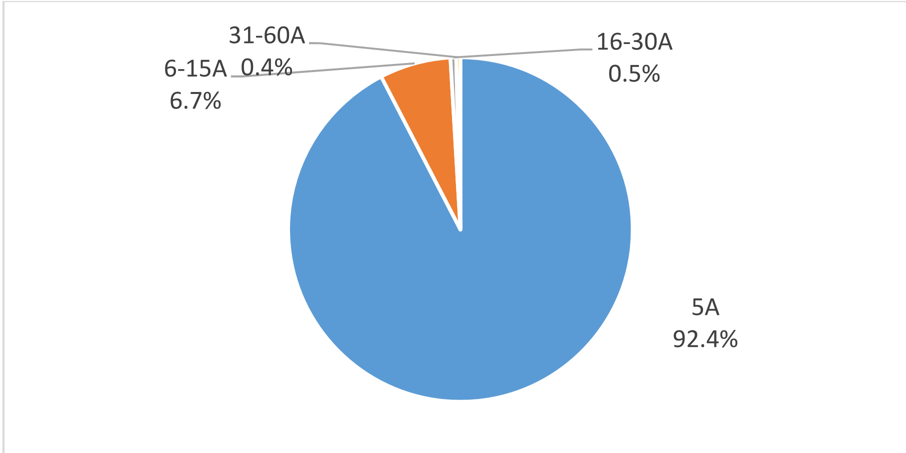


Figure 6.4: Mix of Ampere Capacity of Households with Electricity Access (NEA, 2075)

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 32 MW 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 1 is as shown in Table 6.12 Approximately1,440 kWp from SHS, 243 kWp from SSHS and 311kWp form ISPS have been installed in Province 1. In addition to these, solar photovoltaic pumping system (SPVPS) has gained much popularity amongst farmers. The average size of ISPS is 2kWp.

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 1.

Recently 138 kW of solar mini-grid power plant has been installed in the province of which 43 kW is installed in Morang and 95kW in Panchthar.

Table 6.12: Number of Modern Renewable Technologies Installed in Province 1 (AEPC, 2019)

District	SHS	SSHS	ISPS	MUD ICS	Domestic biogas
Bhojpur	12,348	321	2	163	225
Dhankuta	1,650	183	5	234	2,059
Illam	5,136	570	23	711	6,306
Jhapa	651	596	20	0	18,752
Khotang	12,833	865	23	137	100
Morang	1,365	776	32	8	10,800
Okhaldhunga	10,244	155	26	1,737	413
Panchthar	7,751	140	6	344	1,064
Sankhuwasabha	8,700	50	3	643	536
Solukhumbu	4,117	0	2	896	107
Sunsari	1,186	80	5	0	4,126
Taplejung	6,268	661	10	1,050	233
Terhathum	1,760	223	4	193	799
Udayapur	22,024	254	13	57	5,953
Total	**96,033**	**4,874**	**174**	**174**	**51,473**

There are 499 micro hydropower plants in the province benefiting approximately 2,600 households in different districts. There is an installed capacity of 358 kW micro hydropower in Province 1. The district wise installed number of power plants installed capacity and households benefitted is as shown in **Table 6.13.**

Table 6.13: Number of Micro Hydropower Plants Installed in Province 1 (AEPC, 2019)

Districts	Total no. of Projects	kW	HH
Bhojpur	41	40.00	270
Dhankuta	5	40.00	426
Ilam	92	5.00	41
Khotang	48	100.00	532
Nuwakot	1	3.00	32
Okhaldhunga	66	16.00	204
Panchthar	68	40.00	331
Sankhuwasabha	16	20.00	169
Solukhumbu	54	15.00	114
Taplejung	44	62.00	346
Terhathum	38	2.00	20
Udayapur	26	15.00	142
Total	**499**	**358.00**	**2,627**

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 6.14 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 1, residential sector is majorly dependent on external sources for wood, while use of animal waste and agricultural residue is less for energy production for residential activities. The agricultural from commercial production is diverted to industrial use as discussed in section 7.4 and 7.5.

Table 6.14 Energy Production at Household level

	tons per annum
Fuelwood	2.56
Animal Waste	4.80
Agricultural Waste	6.53

(From survey, 2019)

7 Energy Consumption in 2019

The total energy consumptions in 6 economic sectors in province 1 in 2019 are summed to about 74PJ **(Table 7.1)**. The energy consumption in the industrial sector has the highest share in this province followed by residential sector. Meanwhile, the solid fuels – firewood, biomass as well as coal dominated the energy source type, there is visible change in energy mix as compared to previous studies at national and regional levels **(Figure 7.1 and Figure 7.4)**. Nearly 45% of the total energy demand is in industrial sector and 55% of energy coming from renewables and non-renewables at around 45% respectively. This contrast in high usage of non-renewable energy us due to the big industries and high economic activities - demanding more commercial forms of energy. 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.

Firewood is still the main source of energy in residential sector, while industrial sector thrives on use of coal and diesel, primarily for thermal energy and motive power. The commercial sector is highly dependent on electricity and LPG as sources of energy while the transport and agricultural sectors still show huge dependency on fossil fuels. The shift from petroleum-based water pumping system to solar PV powered can be seen in agricultural sector in this province as well, however, due to geographic conditions the penetration is lower.

The energy mix in Province 1 shows dominance of traditional renewables (biomass) **(Figure 7.1)**. However, the share of firewood in total biomass seems lower than previous reference results. This could have happened because of stringent regulations regarding deforestation and access to agricultural residues as well as transition to modern commercial energy sources. The share of coal is high due to its demand in industries. The share of liquid petroleum products surpasses the share of electricity consumption. It can be seen that all sectors are still highly dependent on imported fossil fuels as shown **in Table 7.1.**

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 1, while that of petroleum is as twice as in 2011/12. In addition to that, the share of coal is also very high at 21% - nearly five times than that of national share, and that of electricity is nearly twice as much at 7%. The main reason behind this is the huge economic activities in industries and commercial sector in this province.

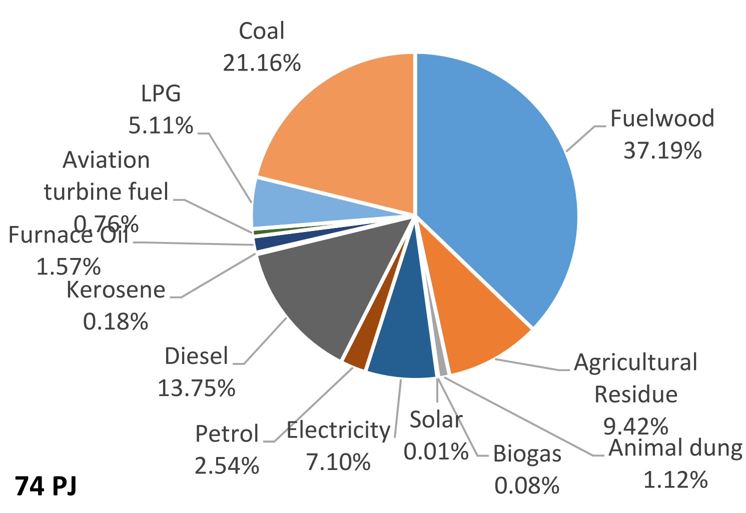


Figure 7.1: Energy Consumption Share in Province 1 by Energy Types

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 1 contributing 48% and 45% each respectively. The contribution of new renewables which is mostly electricity and few solar is 7% in the province. The share of modern biomass (biogas and bio-briquettes) is less than 1%.

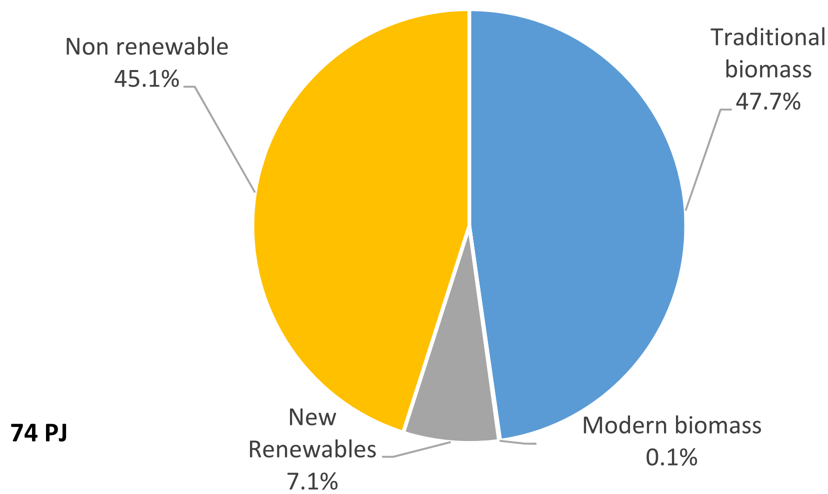


Figure 7.2: Energy Consumption Share in Province 1 by fuel group

The energy consumption by physiological region is as shown in Figure 7.3. It includes energy consumption in agriculture, residential, commercial and industry sectors in the province. Transport and construction and mining sectors are excluded since the survey for these two sectors was carried out at provincial level.

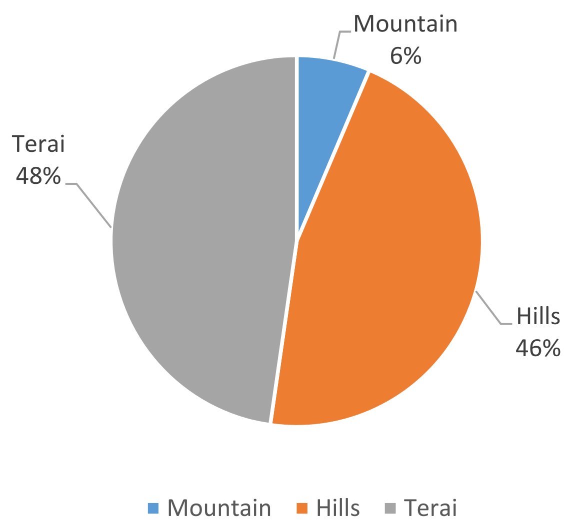


Figure 7.3: Energy Consumption Share in Province 1 by physiological region

Sector- wise, the industrial sector is predominant in terms of energy demand with nearly 45% consumption out of total final (Figure 7.4). Due to highly industrial and commercial activities in this province, the energy share in residential sector comes to be much lower than the share at national average. Additionally, the reduction in energy consumption in residential sector also can be attributed to energy transition and energy efficiency, discussed in later section. Comparing this result to the national level sectoral share of year 2011/12, we see that the share of residential energy consumption in almost half in Province 1, while that for industry is more than 5 times. 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 10% in provincial level as compared to 7% in national level.

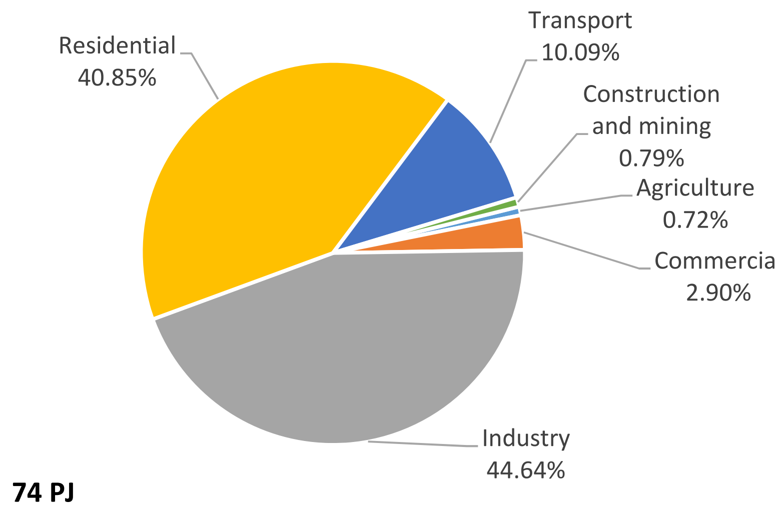


Figure 7.4: Energy Consumption Share in Province 1 by Sectors

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

Table 7.1: Energy Consumption in Province 1 by Sector and Fuel Type (TJ)

	Renewables							Non renewables								Total
	Conventional renewables					New Renewables										
	Traditional biomass			Modern biomass												
	Firewood	Agricultural Residue	Animal dung	Biogas	Bio briquettes	Solar	Electricity	Petrol	Diesel	Kerosene	Furnace Oil	Aviation turbine fuel	LPG	Coal		
Agriculture	-	-	-	-	-	0.09	0.08		534	-	-	-	-	-		534
Commercial	885	-	-	0.07	0.03	0.00	617	-	-	-	-	-	642	-		2,144
Industry	2,300	6,915	-	-	-	-	2,823	-	4,136	-	1,162	-	4	15,620		32,961
Residential	24,261	42	826	60.20	0.43	9.88	1,792	-	-	40	-	-	3,127	3.80		30,163
Transport	-	-	-	-	-	-	10	1,858	5,017	-	-	563	-	-		7,448
Construction and mining	13	-	-	-	-	-	2	16	462	89	-	-	2	-		585
Total	27,458	6,957	826	60	0.47	10	5,245	1,874	10,150	129	1,162	563	3,776	15,624		73,835

Figure 7.5 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 followed by the industrial sector. While in demand side, industrial sector takes a large volume of energy, while agriculture sector seems to be replying on non-machinery power like animals and human.

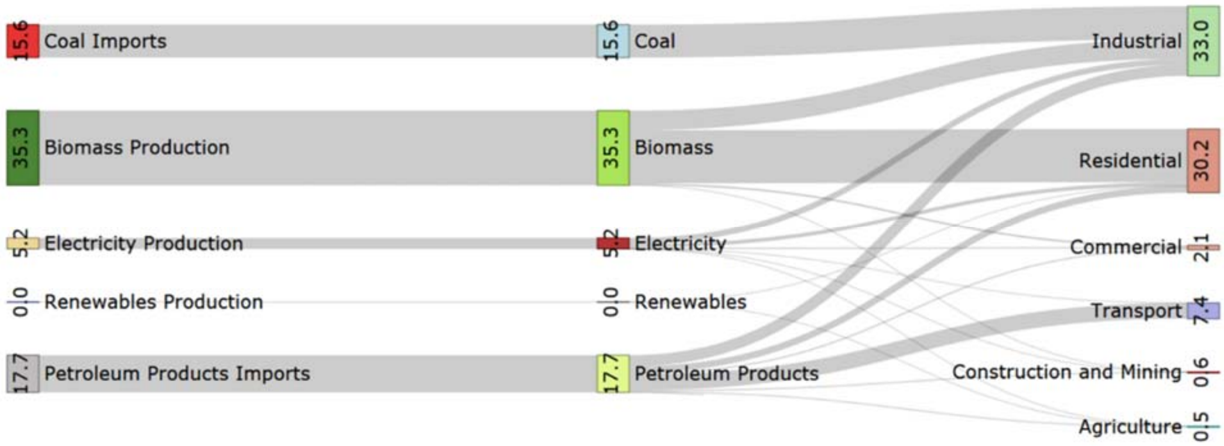


Figure 7.5: Sankey Diagram for Fuel Flow in Province 1 (PJ)

Table 7.2 shows the energy consumption indicators which highlight the status of energy consumption in Province 1. The total final energy demand per capita of 14.5 GJ near to the previous national average. This is however due to high amount of energy consumed in industrial sector, unlike that in residential sectors in earlier reporting. The electricity demand per capita also comes to be higher than national average of 224 kWh (NEA, 2019; CBS, 2014). This is mainly due to higher electricity demand 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, 2015).

Table 7.2: Energy Consumption Indicators

Parameter	Value	Unit (per annum)
Energy per capita	14.52	GJ per capita
Energy per GVA	163	GJ per million NRs
Share of conventional renewable energy in total	54.9%	
Share of modern and new renewable energy	7.2%	
Electricity Consumption (Total)	286	kWh per capita
Electricity Consumption (Residential)	391	kWh per HH

(Survey 2019, CBS 2011, MoF 2019)

7.1 Energy Consumption in Province 1 by Ecological Regions

Table 7.3 shows the description of energy consumption based on ecological regions. It is seen that Terai region has the highest amount of energy consumption, but hilly region energy consumption indicates the largest share accountable to firewood in the residential sector. Although Terai region also has higher firewood consumption in residential sector, it is still lower than in the hilly region due to transition to significantly usage of LPG in cooking, which can be seen from the table too. Energy consumption for industry is highest in industrial Terai region while the energy consumption for commercial sector is significant in service-oriented sector in hilly region. As for agriculture, there is very nominal quantity of energy technologies used in high altitude areas whereas energy consumption in the agriculture sector in the Terai region seems predominant with mechanization in farming.

Table 7.3: Energy Consumptions by Ecological Regions and Sectors (TJ)

	Firewood	Agri residue	Animal waste	Coal	Kerosene	LPG	Diesel	Gasoline	ATF	Furnace oil	Electricity	biogas	briquettes	Solar thermal	Solar PV	Total
Mountain	**3,764**	**-**	**10**	**19.80**	**1.30**	**337**	**19**	**-**	**-**	**-**	**54**	**1.44**	**0.44**	**0.00**	**1.10**	**4,208**
Agriculture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Commercial	434	-	-	-	0	133	-	-	-	-	8	-	0	0	-	**576**
Industrial	25	-	-	17	-	-	19	-	-	-	14		-	-	-	**75**
Residential	3,305	-	10	3.05	1.14	203	-	-	-	-	32	1.44	0.43	0.00	1.10	**3,558**
Hills	**17,509**	**0.28**	**0.69**	**9,337**	**39**	**1,249**	**318**	**-**	**-**	**54**	**1,663**	**16**	**0.03**	**0.00**	**8.64**	**30,194**
Agriculture	-	-	-	-	-	-	0.07	-	-	-	-	-	-	-	-	**0.07**
Commercial	368	-	-	-	-	292	-	-	-	-	236	0	0	0	-	**896**
Industrial	2,101	-	-	9,336	-	-	318	-	-	54	665		-	-	-	**12,475**
Residential	15,040	0.28	0.69	0.75	39	956	-	-	-	-	762	16	-	0.00	8.64	**16,823**
Terai	**6,172**	**6,957**	**815**	**6,268**	**0.09**	**2,188**	**4,333**	**0**	**-**	**1,108**	**3,516**	**43**	**-**	**0.00**	**0.24**	**31,400**
Agriculture	-	-	-	-	-	-	534	0.02	-	-	0.08	-	-	-	0.09	**535**
Commercial	83	-	-	-	-	216	-	-	-	-	373	-	-	0	-	**672**
Industrial	173	6,915	-	6,268	-	4	3,799	-	-	1,108	2,144		-	-	-	**20,412**
Residential	5,916	42	815	-	0.09	1,968	-	-	-	-	998	43	-	-	0.14	**9,782**
Province																
Transport	-	-	-	-	-	-	5,017	1,858	563	-	10	-	-	-	-	**7,448**
Construction and mining	13	-	-	-	89	2.46	462	16.20	-	-	2.32	-	-	-	-	**585**
Grand total	**27,458**	**6,957**	**826**	**15,624**	**130**	**3,776**	**10,150**	**1,874**	**563**	**1,162**	**5,245**	**60**	**0.47**	**0.00**	**10**	**73,835**

7.2 Agriculture Sector

The agriculture sector in Province 1 consumed only 535 TJ energy for agriculture activity **(Table 7.4).** The energy consumption pattern shows highest amount of petroleum used in machineries, primarily for water pumping with diesel. However, with accessibility of solar pumping technology, the use of solar pumping system is also increasing and reached higher than gasoline pumps. The other farm machineries still prevail in use of diesel in 2019. 99.9% of the total energy is from diesel.

Table 7.4: Energy Consumptions in Agriculture Sector in Province 1 (TJ)

	Water pumping	Tilling	Threshing	
Gasoline	0.0	-	-	**0.0**
Diesel	354	122.49	58.13	**534**
Electricity	0.08	0	-	**0.08**
Solar[8]	0.093	-	-	**0.093**
	354	**122.49**	**58.13**	**535**

Energy mix in agriculture sector is as shown in **Figure 7.6.** 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.

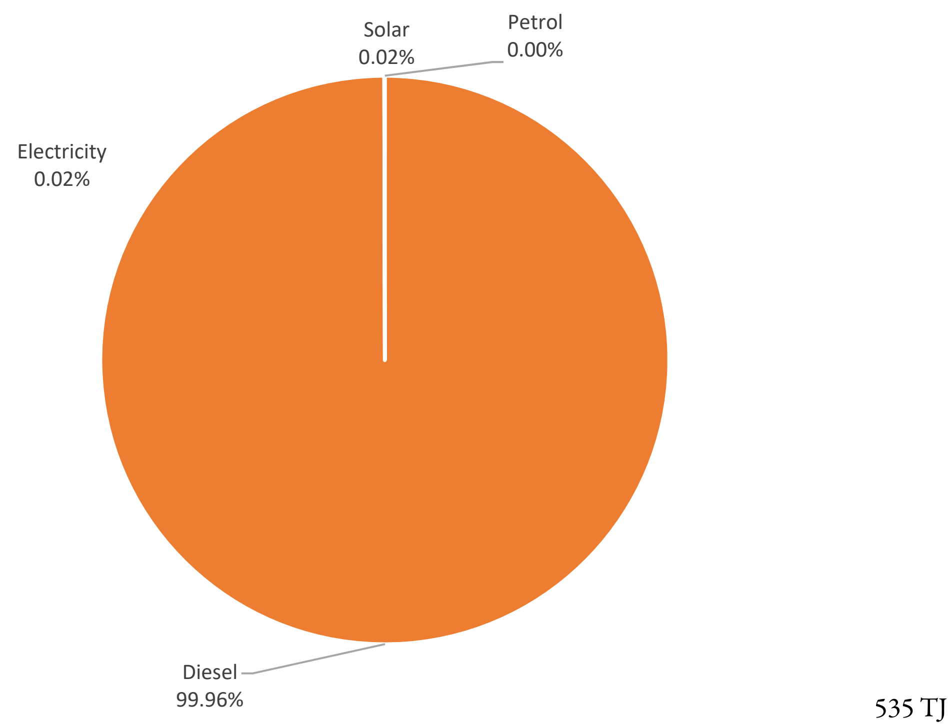


Figure 7.6: Energy Mix in Agriculture Sector in Province 1

The energy consumption in agriculture sector in physiographic region is as shown in Figure 7.7 .It shows that Terai region is the major area for agricultural activities in Province 1, consuming 99% of the sectoral energy.

[8] 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.

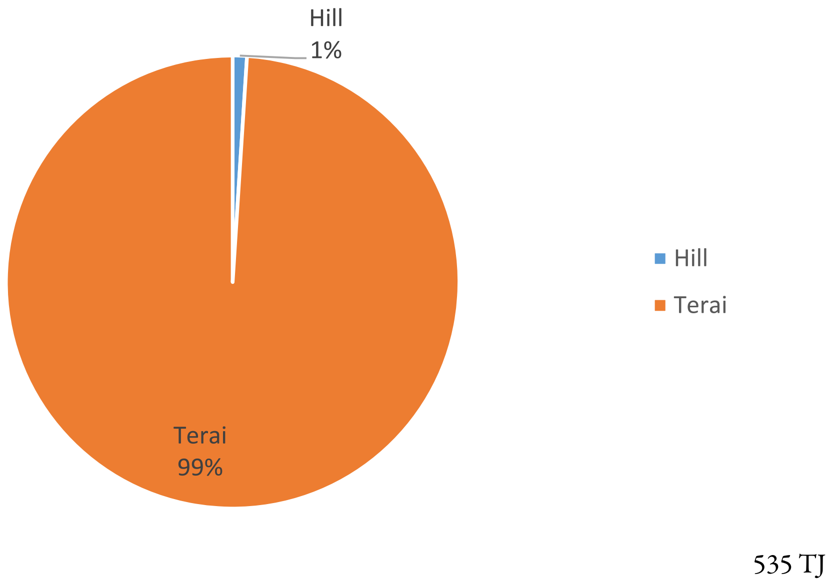


Figure 7.7: Energy Consumption in Agriculture Sector by Physiographic Region in Province 1

In large farmlands, the similar pattern follows the total energy mix (**Table 7.5**). Highest amount of energy used for water pumping by diesel in total energy consumption. Thus, in energy mix diesel prevails the use of other sources of energy (excluding solar).

Table 7.5: Energy Consumption in Agriculture Sector – Large Farmland in Province 1 (TJ)

	Water pumping	Tilling	Threshing	
Gasoline	0.01	-	-	**0.01**
Diesel	320.10	11.00	2.13	**333**
Electricity	0.01	0.00	-	**0.01**
	320	**11.00**	**2.13**	**333**

The total energy in medium farmland is lower than large farmlands. It consumed nearly 18% of the total energy demand (excluding solar) in agriculture sector in province 1 **Table 7.6.** Here, the highest energy demand is farm machineries and including water pumping, the primary source of energy is diesel.

Table 7.6: Energy Consumption in Agriculture Sector – Medium Farmland in Province 1 (TJ)

	Water pumping	Tilling	Threshing	
Gasoline	0.0	-	-	**0**
Diesel	33.6	50.8	30.8	**115**
Electricity	0.03	-	-	**0.03**
	33.6	**50.8**	**30.8**	**115**

In small farmlands also the energy mix is similar to medium farmland. The major energy source is diesel at nearly 100% and nearly half energy is used for tilling. The energy consumption is 14% of the total energy demand, (excluding solar) in agriculture sector in Province 1 (**Table 7.7**).

Table 7.7: Energy Consumption in Agriculture Sector – Small Farmland in Province 1 (TJ)

	Water pumping	Tilling	Threshing	
Gasoline	-	-	-	-
Diesel	-	60.66	25.25	**85.90**
Electricity	0.05	-	-	**0.05**
	0.05	**60.66**	**25.25**	**85.95**

Table 7.8 gives the energy consumption for each district by end use in agricultural sector of Province 1. The overall consumption indicates that majority of energy is used for water pumping, the highest amount of energy demand was in terai districts. The accessibility of the pumping systems and farm machineries and the physiography of farmlands have main effect on energy demand.

Table 7.8: District Wise Energy Consumption by End Uses in Agriculture Sector of Province 1 (TJ)

District	Water pumping	Tilling	Threshing	Total
Mountain	-	-	-	-
Taplejung	-	-	-	-
Sankhuwasabha	-	-	-	-
Solukhumbu	-	-	-	-
Hill	**0.04**	**3.16**	**2.21**	**5.41**
Okhaldhunga	-	-	-	-
Khotang	-	-	-	-
Bhojpur	-	-	-	-
Dhankuta	-	-	-	-
Terhathum	-	-	-	-
Panchthar				
Illam	0.00	3.08	-	3.09
Udayapur	0.03	0.08	2.21	2.32
Terai	**353.84**	**119.33**	**55.92**	**529.10**
Jhapa	81.75	18.05	1.73	101.53
Morang	146.19	24.83	2.51	173.53
Sunsari	125.90	76.44	51.69	254.04
	353.88	**122.49**	**58.13**	**534.50**

Table 7.9. gives the energy consumption for each district by the fuel type in agricultural sector of Province 1. 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 7.9: District Wise Energy Consumption by Fuel Type in Agriculture Sector of Province 1 (TJ)

District	Gasoline	Diesel	Electricity	Solar	
Mountain	-	-	-	-	
Taplejung	-	-	-	-	-
Sankhuwasabha	-	-	-	-	-
Solukhumbu	-	-	-	-	-
Hill	**-**	**5.37**	**0.03**	0.00	**5.41**
Okhaldhunga	-	-	-	-	-
Khotang	-	-	-	-	-
Bhojpur	-	-	-	-	-
Dhankuta	-	-	-	-	-
Terhathum	-	-	-	-	-
Panchthar	-	-	-	-	-
Illam	-	3.08	-	0.00	**3.09**
Udayapur	-	2.29	0.03	-	**2.32**
Terai	**0.02**	**528.93**	**0.05**	**0.09**	**529.10**
Jhapa	0.01	101.43	0.04	0.04	**101.53**
Morang	0.01	173.50	0.00	0.02	**173.53**
Sunsari	-	254.00	0.01	0.03	**254.04**
	0.02	**534.30**	**0.08**	**0.093**	**534.50**

In overall, the agricultural sector still depends on petroleum fuels. However, the shift to solar power is a positive indication of clean and renewable energy usage in agriculture. There is still ample 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 1 is given in Annex IV.

7.3 Commercial sector

The commercial sector represents the major economic activity. **Table 7.10** highlights the energy consumption in commercial sector of Province 1. It is seen that out of 2,144 TJ consumed by commercial sector, the majority is commercial sources of energy. The highest amount of energy used in commercial sector is still wood (41%) followed by electricity and LPG, at nearly 30% each. By end use, the highest amount of energy is consumed for cooking in accommodation and food services due to higher activities of hospitability segment in urban areas. 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, although the share of wood is lesser in province 1, the use of LPG is very high, near as much as electricity.

Table 7.10: Energy Consumption in Commercial Sector in Province 1 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	
Firewood	884	0.00	0.45	-	-	-	0.12	**885**
Kerosene	0.16	-	-	-	-	-	-	**0.16**
LPG	614	1.4	10	-	-	-	16.5	**642**
Electricity	6.2	0.71	26	112	100	372	0.0	**617**
biogas	0.07	-	-	-	-	-	-	**0.07**
briquettes	0.02	-	0.01	-	-	-	-	**0.03**
Solar thermal	-	0.00	-	-	-	-	-	**0.00**
	1,504	**2**	**36**	**112**	**100**	**372**	**17**	**2,144**

(Survey 2019)

Figure 7.8 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 are less than 0.01%.

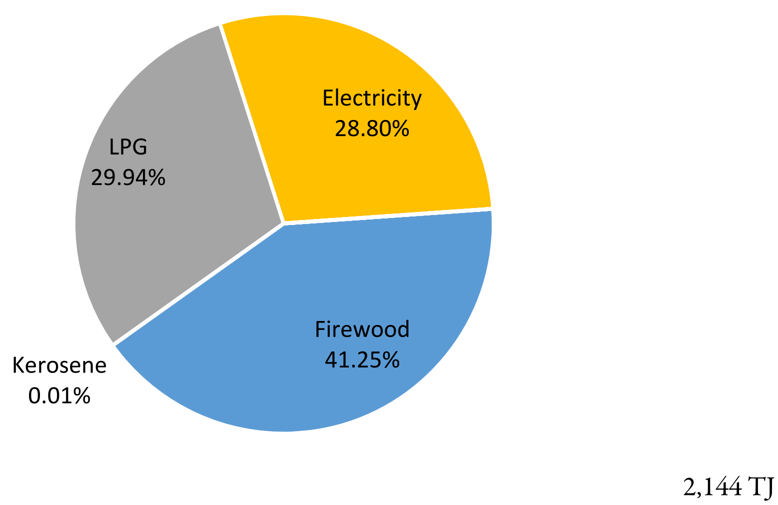


Figure 7.8: Energy Mix in Commercial Sector in Province 1

The energy consumption in commercial sector in physiographic region is as shown in Figure 7.9. It shows hilly region consumes comparatively higher share of energy in Province 1 followed by Terai and Mountainous region. Firewood, LPG and kerosene are the major the sources of energy in the region. Electricity consumption is comparatively lower in mountainous region due to poor access to electricity.

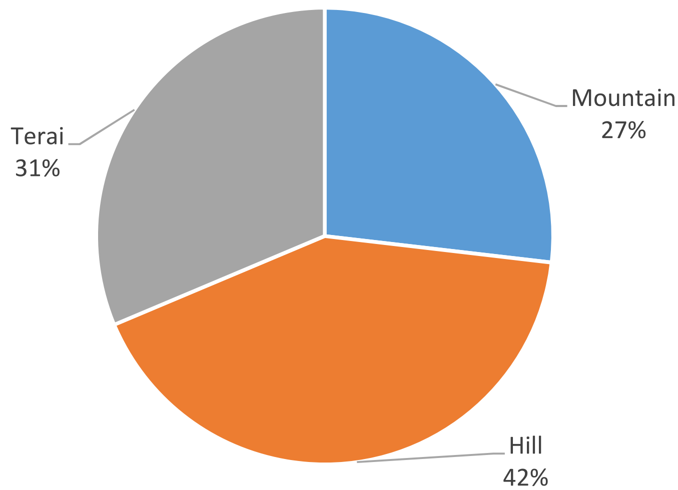


Figure 7.9: Energy Consumption in Commercial Sector by Physiographic Region Province 1

Table 7.11 shows the energy mix in each subsector. It indicates that largest amount of energy is consumed in accommodation and food services sector in Province 1, owing to their highest value presence in economic activities. The consumption of electricity is high in the trade and retails sector except for accommodation and food where LPG dominates the energy mix. But due to access to firewood and rural areas in hills and mountains there is also substantial amount of firewood used for heat energy.

Table 7.11: Energy Consumption for Each Subsector by Energy Types in Commercial Sector in Province 1 (TJ)

	Firewood	Animal waste	LPG	Electricity	biogas	briquettes	Solar thermal	
Trade and retails	330	0.16	121	194	0.06	0.03	0.00	645
Accommodation and food	455	-	320	145	-	-	0.00	921
Financial and real estate	-	-	12	81	-	-	-	94
Social services	13	-	108	94	0.01	-	0.00	215
Other services	86	-	80	104	-	-	0.00	270
	885	0.16	642	617	0.07	0.03	0.00	2,144

(Survey 2019)

Table 7.12 shows the energy mix by end- uses on each subsector of commercial sector in Province 1. It shows that accommodation and food service have the highest energy consumption, followed by trade and retails. Other service subsector has also energy consumption primarily on electrical appliances and subsequently, on cooking.

Table 7.12: Energy Consumptions for Each Subsector by End Use in Commercial Sector in Province 1 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	
Trade and retails	438	0.89	19	7.74	58	114	6.85	**645**
Accommodation and food	773	0.52	3.83	62	8.59	70	3.53	**921**
Financial and real estate	13	0.05	4.17	22	5.47	49	-	**94**
Social services	120	0.32	2.48	19	13	60	0.14	**215**
Other services	160	0.38	7.04	2.09	14	79	6.11	**270**
	1,504	**2**	**36**	**112**	**100**	**372**	**17**	**2,144**

(Survey 2019)

The energy intensities in commercial sector in province 1 is given in Table 7.13. It can be seen that, in Province 1, the most energy demanding sector is Accommodation and food. This subsector utilized high amount of energy for cooking purpose. Secondly, trade and retails, which comprises shops and repair centers, which also uses comparatively huge amount of energy for cooking purpose. The energy intensity in accommodation and food comes to 0.09 GJ per person, which is slightly less than that for developed countries like, USA and China, but is close to their adjusted range (SPL, 2019).

Table 7.13 Energy Intensities in Commercial Sector in Province 1.

	GJ per million NRs	GJ per person
Trade and retails	26.04	-
Accommodation and food	113.06	0.09
Financial and real estate	2.53	-
Social services	9.03	-
Other services	12.01	-

The district- wise energy mix in **Table 7.14** by end- uses shows significant energy consumption in the terai regions due to high economic activities. Meanwhile, in districts some hilly, due to comparatively lower commercial activities than other districts, the energy demand is exceptionally low. The hilly area shows higher demand for traditional fuels than commercial energy.

Table 7.14: District Wise Energy Consumptions by End Use in Commercial Sector of Province 1 (TJ)

District	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	
Mountain	545.1	0.6	7.1	0.1	1.3	5.8	15.7	576
Taplejung	102.6	0.3	5.1	0.0	0.2	0.1	0.0	108
Sankhuwasabha	107.6	0.1	0.1	0.1	0.5	4.2	0.5	113
Solukhumbu	334.9	0.2	1.9	-	0.5	1.6	15.2	354
Hill	660.2	1.5	29.1	5.9	33.3	165.5	0.8	896
Okhaldhunga	125.7	0.3	0.2	0.0	0.6	0.7	0.1	128
Khotang	185.0	0.1	0.6	0.0	9.3	81.8	0.2	277
Bhojpur	58.2	0.0	0.3	0.2	1.3	2.1	0.4	63
Dhankuta	63.4	0.4	18.7	5.1	15.0	52.5	-	155
Terhathum	37.9	0.1	2.2	0.0	1.2	4.0	-	45
Panchthar	84.7	0.2	0.1	0.0	1.2	2.2	-	89
Illam	62.1	0.3	1.0	0.4	3.4	15.1	-	82
Udayapur	43.1	0.1	6.1	0.1	1.2	7.1	-	58
Terai	299.0	0.1	0.1	106.5	65.5	200.8	0.1	672
Jhapa	71.1	0.1	0.0	67.1	3.5	65.9	-	208
Morang	193.5	0.0	0.1	28.3	60.2	22.8	0.1	305
Sunsari	34.4	0.0	0.0	11.1	1.8	112.2	-	159
	1,504	2	36	112	100	372	17	2,144

(Survey 2019)

Meanwhile, **Table 7.15** highlights the district- wise energy consumption by energy type and by ecological regions. It indicates that mountain region has the highest demand for firewood while is the lowest in consumption of electricity, while in other districts electricity consumption are comparatively higher –especially in Terai.

Table 7.15: District Wise Energy Consumptions by Fuel Type in Commercial Sector of Province 1 (TJ)

	Firewood	Kerosene	LPG	Electricity	biogas	briquettes	Solar thermal	
Mountains	**433.82**	**0.16**	**133.49**	**8.26**	**0.00**	**0.00**	**0.00**	**576**
Taplejung	80.58	-	27.37	0.37	-	-	-	**108**
Sankhuwasabha	74.37	0.16	33.59	4.95	-	0.00	0.00	**113**
Solukhumbu	278.86	-	72.53	2.94	-	-	0.00	**354**
Hills	**367.80**	**0.00**	**292.40**	**235.96**	**0.07**	**0.03**	**0.00**	**896**
Okhaldhunga	82.87	-	42.64	2.08	0.01	-	0.00	**128**
Khotang	166.88	-	18.92	91.33	-	-	0.00	**277**
Bhojpur	37.06	-	21.35	4.19	-	-	0.00	**63**
Dhankuta	4.02	-	58.47	92.70	-	0.01	0.00	**155**
Terhathum	18.25	-	19.80	7.22	0.06	-	-	**45**
Panchthar	37.06	-	47.74	3.69	-	0.02	-	**89**
Illam	13.82	-	48.09	20.33	-	-	0.00	**82**
Udayapur	7.84	-	35.39	14.43	-	-	-	**58**
Terai	**82.89**	**0.00**	**216.04**	**373.23**	**0.00**	**0.00**	**0.00**	**672**
Jhapa	6.89	-	64.36	136.52	-	-	-	**208**
Morang	62.22	-	131.05	111.65	-	-	-	**305**
Sunsari	13.78	-	20.63	125.06	-	-	0.00	**159**
	885	**0.16**	**642**	**617**	**0.07**	**0.03**	**0.00**	**2,144**

(Survey 2019)

In totality, commercial sector is the user of clean energy – electricity from hydropower and comparatively lesser clean energy carrier - LPG. Thus, it is essential to foresee the impact of cleaner energy in commercial sector boom while planning for electricity development and considering the growing dependence on petroleum imports.

7.4 Industrial Sector

The industrial sector consumed 32,961 TJ of energy in Province 1. Table 7.15. shows fuel wise energy consumption in fourteen districts of the province. Jhapa, Morang, Sunsari and Udayapur are the industrial hub of province 1 consuming comparatively higher energy than other districts of the province. The three districts of mountainous region consumed less than 1% of total energy consumed in this sector, eight districts of hilly region consumed 38% energy and remaining 62% is consumed in three districts of Terai region. Coal is consumed as a major source of energy in industry constituting a 47% share of the total energy consumed, followed by Agri residue 21%, diesel 13%, and electricity 9% respectively. It clearly shows that the industrial sector still depends heavily on the non-renewable energy sources.

Table 7.16: District Wise Energy Consumption in Industry Sector by Fuel Wise in TJ

	Firewood	Agri residue	Coal	kerosene	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Mountain	25	-	17	-	-	19	-	-	14	75
Taplejung	-	-	-	-	-	10	-	-	0	10
Sankhuwasabha	-	-	-	-	-	9	-	-	2	11
Solukhumbu	25	-	17	-	-	-	-	-	12	54
Hills	2,101	-	9,336	-	-	318	-	54	665	12,475
Okhaldhunga	-	-	-	-	-	93	-	-	2	95
Khotang	76	-	-	-	-	13	-	-	507	596
Bhojpur	-	-	-	-	-	57	-	-	1	58
Dhankuta	1,539	-	-	-	-	131	-	-	48	1,718
Terhathum	449	-	122	-	-	3	-	-	3	576
Panchthar	-	-	-	-	-	11	-	-	1	11
Ilam	37	-	46	-	-	10	-	-	99	192
Udayapur	-	-	9,168	-	-	-	-	54	6	9,228
Terai	173	6,915	6,268	-	4	3,799	-	1,108	2,144	20,412
Jhapa	34	-	3,148	-	-	154	-	-	623	3,959
Morang	63	1,662	2,118	-	-	1,769	-	-	724	6,336
Sunsari	76	5,253	1,001	-	4	1,877	-	1,108	797	10,117
Grand Total	2,300	6,915	15,620	-	4	4,136	-	1,162	2,823	32,961

(Survey 2019)

Energy mix in industrial sector is as shown in **Figure 7.10**. It shows that coal is the major source of fuel consuming 47% 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 28% of total energy consumed in the sector. 16% of energy comes from petroleum products and 9% 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 1, although coal has highest share of energy consumption in this sector, due to large usage of process heat and boiler, and accessibility of agricultural residue in compare to wood, its share has risen.

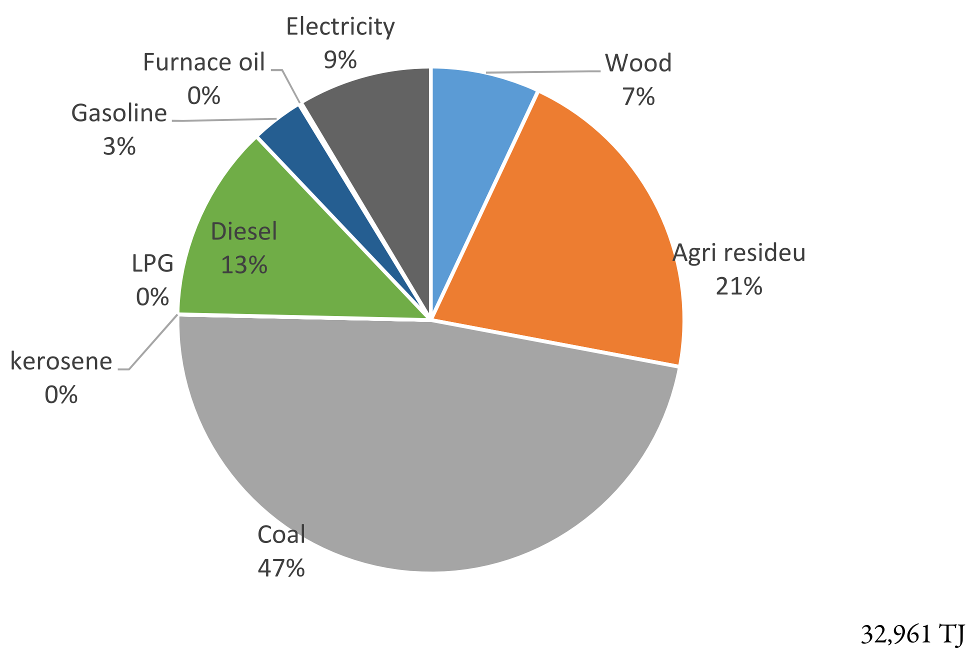


Figure 7.10: Energy Mix in Industrial Sector in Province 1

The energy consumption in physiographic region in industry sector is as shown in Figure 7.11 . Since most of the industries are in Terai region, energy consumption is higher in the region constituting 62% of total industrial sector consumption.

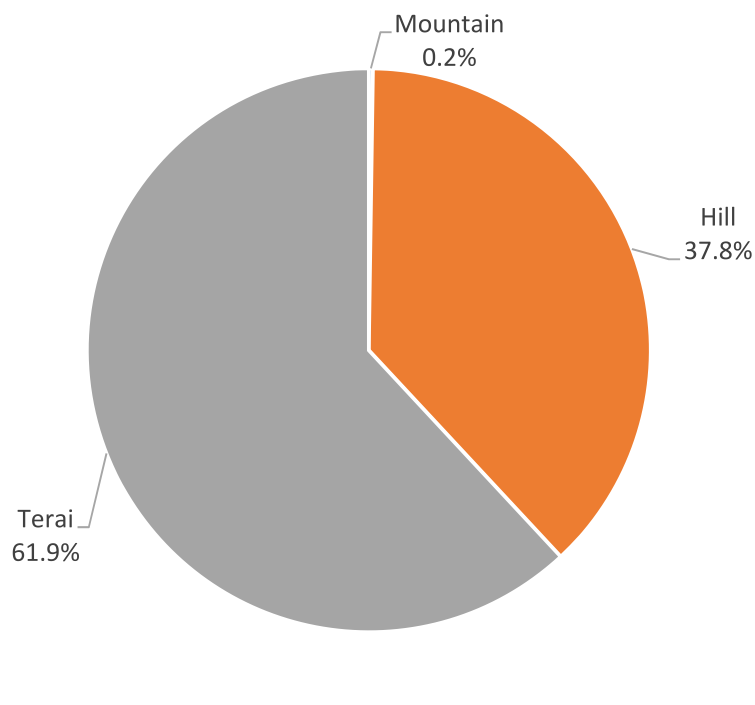


Figure 7.11: Energy Consumption in Industry Sector by Physiographic Region in Province 1

Table 7.17 shows the total energy consumed in the industry by its end-use services. It shows that process heat consumes 21,672 TJ of energy which is 66% of total energy consumed in the sector. Motive power and Boiler consumed 14% and 20% of total industrial energy respectively.

Table 7.17: District Wise Energy Consumption in Industry Sector by End-Use Service in TJ

District	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Mountain	0.44	0.52	26.23	29.49	18.35	75.03
Taplejung	0.28	-	-	10.16	-	10.45
Sankhuwasabha	0.04	-	-	10.01	0.78	10.82
Solukhumbu	0.12	0.52	26.23	9.32	17.58	53.76
Hills	8.48	90.91	11,456.23	898.33	20.74	12,474.69
Okhaldhunga	0.74	-	0.31	93.84	-	94.88
Khotang	1.45	-	77.78	516.39	-	595.62
Bhojpur	0.33	-	-	57.89	-	58.22
Dhankuta	3.60	-	1,575.25	118.79	20.13	1,717.77
Terhathum	1.98	-	570.78	3.48	0.15	576.40
Panchthar	0.09	1.57	3.97	5.63	0.22	11.49
Ilam	0.28	89.33	-	102.32	-	191.94
Udayapur	0.01	-	9,228.13	-	0.24	9,228.37
Terai	17.93	6,426.34	10,189.13	3,695.13	82.96	20,411.50
Jhapa	2.93	-	3,321.20	633.83	1.09	3,959.06
Morang	7.27	862.56	3,400.24	2,065.55	0.29	6,335.91
Sunsari	7.73	5,563.78	3,467.69	995.75	81.58	10,116.54
Grand Total	26.85	6,517.77	21,671.59	4,622.96	122.06	32,961.22

(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 7.18**. Industrial cement and Nonmetallic Products, and bricks and structural clay products consumed comparatively higher energy consuming11,872 TJ and 6,928 TJ respectively. These two industries consumed 57% of the total energy consumed in the sector. It consumed coal and diesel as the major sources of energy. Textile and leather industries consumed 19%, chemical rubber and plastic industry (7%), wood products and paper industries (6%), mechanical engineering and manufacturing industries (5%), food beverage and tobacco consumed3% of total energy.

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

	Firewood	Agricultural residue	Coal	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Industrial Food Beverage and Tobacco	119.5	71.9	16.8	4.4	485.5	-	-	300.5	999
Industrial Textile and Leather Goods	-	4,966.7	-	-	890.1	-	-	312.5	6,169
Industrial Chemical Rubber and Plastic	-	425.8	-	-	1,338.9	-	-	450.4	2,215
Industrial Mechanical Engineering and Manufacturing	-	-	11.9	-	533.2	-	1,107.9	89.8	1,743
Industrial Electrical Engineering Products	-	-	-	-	22.1	-	-	260.0	282
Industrial Wood Products and Paper	74.4	1,004.2	-	-	415.0	-	-	484.6	1,978
Industrial Bricks & Structural Clay Products	121.7	-	6,051.9	-	245.9	-	-	508.0	6,928
Industrial Cement & Nonmetallic Products	1,942.4	-	9,493.7	-	26.9	-	54.5	354.1	11,872
Industrial Construction and Mining	-	-	-	-	-	-	-	-	-
Industrial Other Manufacturing	41.7	446.3	46.1	-	178.6	-	-	63.3	776
Total	2,299.7	6,914.8	15,620.4	4.4	4,136.2	-	1,162.4	2,823.3	32,961

(Survey 2019)

Table 7.19 shows energy consumption in the industrial subsector by its end-use services. It shows that the process heat consumed high energy (66%) of total energy due to energy intensive equipment used in the industry. Industrial cement and non-metallic products and industrial bricks and structural clay products used 82% energy used in process heat. Food beverage and tobacco, textile and leather goods, chemical rubber and plastic and wood products and paper industries consumed most of the energy consumed in boilers.

Table 7.19: 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	4.73	320.68	294.96	358.36	19.83	998.56
Textile and Leather Goods	3.75	3,793.57	1,176.49	1,195.20	0.26	6,169.27
Chemical Rubber and Plastic	3.04	739.63	1,250.55	221.70	0.20	2,215.11
Mechanical Engineering and Manufacturing	0.73	-	1,121.53	620.09	0.38	1,742.74
Electrical Engineering Products	1.90	80.11	39.33	160.79	-	282.12
Wood Products and Paper	1.43	1,029.09	-	866.08	81.62	1,978.23
Bricks & Structural Clay Products	2.25	-	6,231.72	693.59	-	6,927.56
Cement and Non-metallic Products	8.30	-	11,496.19	366.65	0.44	11,871.57
	-	-	-	-	-	-
Other Manufacturing	0.71	554.70	60.83	140.50	19.33	776.07
Total	26.85	6,517.77	21,671.59	4,622.96	122.06	32,961.22

(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 purposes – while electricity being generated from hydropower plants in the country, replacing the need of decentralized generators operating on imported fossil fuels.

The detailed district wise energy consumption in Industrial Sector in Province 1 is given in Annex IV.

7.5 Residential Sector

The residential sector is second most energy consuming sector in the province. The province 1 consumed about 30,163 TJ of energy in residential sector **Table 7.19.** It is seen that firewood is still the predominant energy source. Nearly 80% of the energy comes from firewood. The high use of firewood is primarily for cooking and animal feed preparation. The consumption of LPG for cooking is on increasing pattern due to increase in accessibility while electricity consumption is used in household electrical appliances as well as space cooling and lighting.

Table 7.20: Energy Consumptions in Residential Sector of Province 1 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Animal feed preparation	Agro and food processing	Social events	
Firewood	13,832.65	10.25	4.17	-	-	-	9,700.37	332.89	380.42	**24,260.75**
Agri residue	26.97	0.02	-	-	-	-	13.15	1.90	-	**42.04**
Animal waste	550.84	0.12	-	-	-	-	275.08	-	-	**826.04**
Coal	3.80	-	-	-	-	-	-	-	-	**3.80**
kerosene	0.86	-	-	-	39.54	-	-	-	-	**40.40**
LPG	2,856.25	3.13	0.89	-	-	-	42.94	4.09	220.03	**3,127.31**
Diesel	-	-	-	-	-	-	-	-	-	**-**
Gasoline	-	-	-	-	-	-	-	-	-	**-**
Electricity	62.85	5.70	3.16	535.00	225.94	958.82	0.00	0.03	0.16	**1,791.66**
biogas	47.44	1.85	-	-	-	-	0.86	-	10.05	**60.20**
briquettes	0.43	-	-	-	-	-	-	-	-	**0.43**
Solar thermal	-	0.00	-	-	-	-	-	-	-	**0.00**
Solar PV	-	-	-	-	9.88	-	-	-	-	**9.88**
	17,382.09	**21.07**	**8.21**	**535.00**	**275.36**	**958.82**	**10,032.41**	**338.90**	**610.66**	**30,162.52**

Energy mix in residential sector is as shown in **Figure 7.12**. It shows that wood is the major source of fuel in this sector consuming 80% of total energy consumed followed by LPG. There is consumption of 10% LPG fuel and 6% 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 1 at current situation, the consumption of wood is still high, but the share of other biomass has decreased and is replaced by use of electricity and LPG. In contrast to that, it is also seen that the agricultural residue has been largely used in industries, thus affecting use in residential sector.

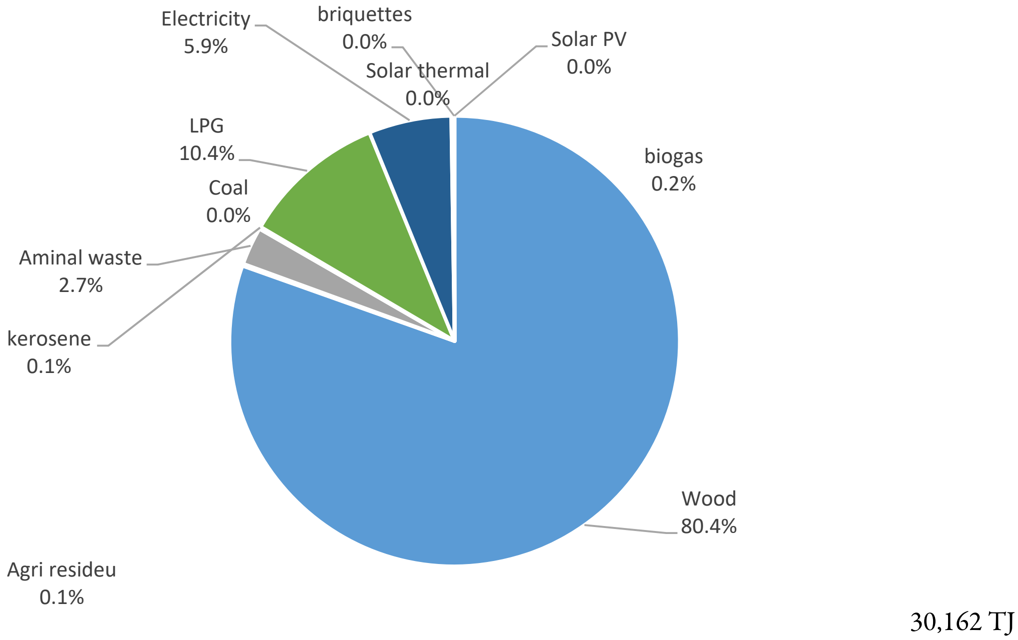


Figure 7.12: Energy Mix in Residential Sector in Province 1

Energy consumption in residential sector by its physiographic region is as shown in Figure 7.13 . In residential sector, hilly region consumed more energy compared to other two regions. Most of the energy is consumed in cooking and animal feed preparation.

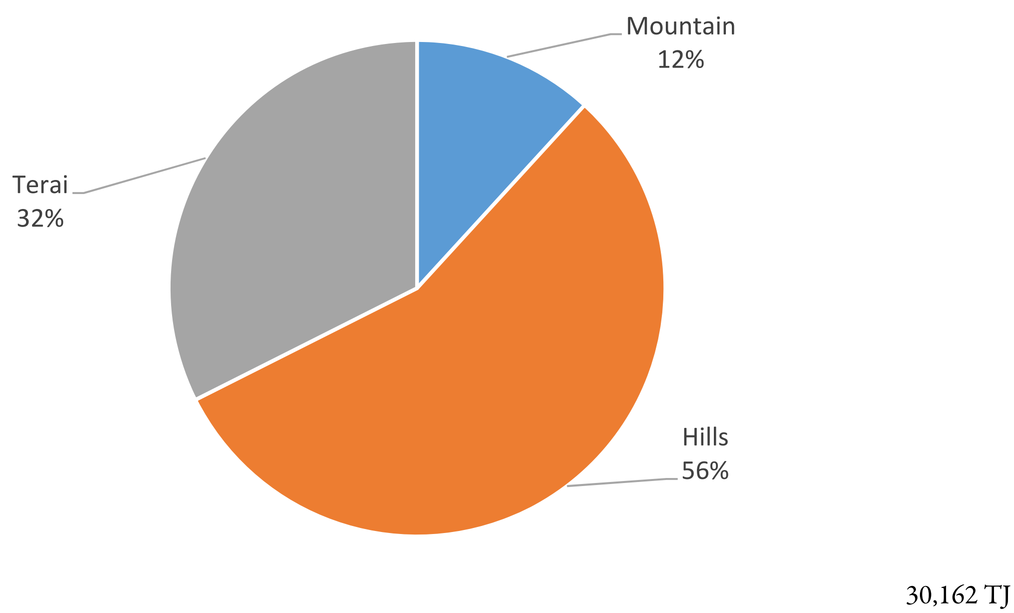


Figure 7.13: Energy Consumption in Residential Sector by Physiographic Region in Province 1

Residential sector in province 1 can be broadly subdivided into 2 subcategories – urban and rural areas as per administrative boundaries.

Table 7.20 and **Table 7.21.** show the energy consumption in each of the subsectors of residential sector. Urban sector consumed about 44% of total residential energy demand in province 1. Among this, the share of biomass is still highest here with firewood at about 67%, and the share of commercial energy sources are growing with LPG at 17% and electricity at 9%. By end use, cooking is still the mist energy consuming activity with 60% energy consumed in it alone.

Table 7.21: Energy Consumptions in Urban -Residential Sector of Province 1 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Animal feed preparation	Agro and food processing	Social events	
Firewood	5,119	7	4	-	-	-	3,447	131	161	**8,869**
Agricultural residue	1	0	-	-	-	-	-	2	-	**3**
Animal waste	488	0	-	-	-	-	275	-	-	**763**
Coal	0	-	-	-	-	-	-	-	-	**0**
kerosene	1	-	-	-	14	-	-	-	-	**15**
LPG	2,063	3	1	-	-	-	43	4	202	**2,316**
Diesel	-	-	-	-	-	-	-	-	-	**-**
Gasoline	-	-	-	-	-	-	-	-	-	**-**
Electricity	48	0	2	419	124	689	0	0	0	**1,281**
biogas	19	0	-	-	-	-	1	-	5	**25.3**
briquettes	0	-	-	-	-	-	-	-	-	**0.4**
Solar thermal	-	0	-	-	-	-	-	-	-	**0**
Solar PV	-	-	-	-	5	-	-	-	-	**5.0**
	7,741	**10.7**	**7**	**419**	**142**	**689**	**3,765**	**137.2**	**367**	**13,278**

(Survey 2019)

The rural sector also presents similar energy mix. However, the shares of biomass are higher than in urban sector with firewood at 91%. The use of commercial energy is still lower in rural sector with LPG demand at 4.8% and electricity at 3%. By end uses, cooking is still the most energy consuming activity with 57% energy consumed in it followed by animal feed preparation (37%). Unlike urban sector, the consumption for space heating and space cooling is lower in rural population.

Table 7.22: Energy Consumptions in Rural - Residential Sector of Province 1 (TJ)

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Animal feed preparation	Agro and food processing	Social events	
Firewood	8,714	2.91	-	-	-	-	6,254	202	220	**15,392**
Agri residue	26	0.02	-	-	-	-	13	-	-	**39**
Animal waste	63	-	-	-	-	-	-	-	-	**63**
Coal	3.59	-	-	-	-	-	-	-	-	**3.59**
kerosene	-	-	-	-	26	-	-	-	-	**26**
LPG	793	0.16	-	-	-	-	-	-	18	**811**
Diesel	-	-	-	-	-	-	-	-	-	**-**
Gasoline	-	-	-	-	-	-	-	-	-	**-**
Electricity	15	6	1.56	116	102	270	-	0.02	0.08	**510**
biogas	28	1.66	-	-	-	-	-	-	5.20	**35**
briquettes	-	-	-	-	-	-	-	-	-	**-**
Solar thermal	-	0.00	-	-	-	-	-	-	-	**0.00**
Solar PV	-	-	-	-	5	-	-	-	-	**4.9**
	9,642	**10.3**	**1.56**	**116**	**133**	**270**	**6,267**	**202**	**243**	**16,885**

(Survey 2019)

The residential sector shows two peculiar features – first, they still tend to prefer traditional biomass for fuel – significantly 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 clean electricity seems to be inevitable in near future due to its availability in abundance in the country and its economic efficiency.

7.6 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 crossings are still in use in many parts of Nepal. In this energy consumption survey, for Province 1, road transport is emphasized due to its major share in overall transportation. For this purpose, road transport is disaggregated into following categories (**Table 7.23).**

Table 7.23: 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
Gasoline	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 in **Table 7.24.** Approximately 27% of total registered vehicles are registered in Province 1.

Table 7.24: Provincial Vehicle Registration in 2074-75

	Bus	Minibus/Mini Truck	Crane/Dozer/Roller/ Excavator/Loader/Grl	Car / Jeep/Van	Pickup	Micro Bus	Tempo	Motorcycle	Tractor/Power Trailer	E-Rickshaw	Others	FY Total	Total
Mechi	209	30	249	657	470	7	1,516	5,397	624	224	8	9,391	93,935
Koshi	339	61	672	744	443	7	4,025	22,799	1,224	1,566	19	31,899	328,927
Total	**548**	**91**	**921**	**1,401**	**913**	**14**	**5,541**	**28,196**	**1,848**	**1,790**	**27**	**41,290**	**422,862**

Aviation

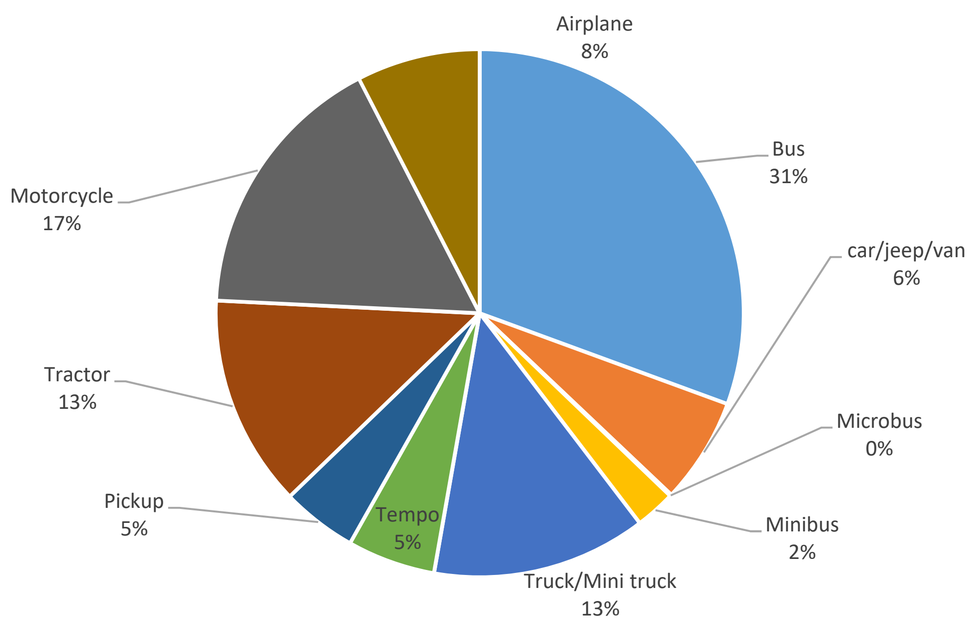
There are total ten airports in operations, where only domestic flights take place. The data regarding aircraft are published by Civil Aviation Authority of Nepal (CAAN). The data shows the total aircraft movement, passenger movement and cargo movement as given in Table 7.25.

Table 7.25: Aviation Sector Activity (CAAN, 2020; CAAN, 2020a)

	Aircraft movement	Passenger movement	Cargo movement (in kg)
Biratnagar	11,626	652,225	591,985
Bhadrapur/Chandragadhi	3,072	174,921	125,913
Phaplu	2,749	10,278	944,736
Taplejung	435	2,097	-
Lukla	19,680	129,481	2,272,055
Tumlingtar	1,872	35,303	41,952
Bhojpur	436	5,991	713
Thamkharka	116	1,110	-
Lamidanda	70	480	-
Rumjatar	184	779	-
Province 1	40,240	1,012,665	3,977,355

7.6.1 Transport Sector Energy Consumption by Fuel Types

The modal mix based on energy consumption is as shown in **Figure 7.14.** 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 30% of total energy consumed in this sector. Private car/jeep/van together consumed 6% of the energy.



7,448 TJ

Figure 7.14: Energy Mix in Transport Sector in Province 1

(Survey 2019)

Total energy consumption in the transport sector is as shown in **Table 7.25.** Total energy consumption in the transport sector is 7,448 TJ. 67% of total energy is consumed by diesel vehicles, 25% by gasoline vehicles and 8% by air jet. Less than 1% of energy is consumed by electric vehicles. 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 1 as well, while there is increasing trend for consumption of gasoline. The average fuel economy and average distance traveled per year are obtained from the field survey. According to Nepal oil corporation, sales data, and fuel consumption survey results 66% of gasoline sales in Province 1 is used for the transport sector, whereas only 54% of diesel sales are used in this sector.

Table 7.26: Total Transport Sector Energy Consumption by Fuel Types

Diesel				
Row Labels	**Average Distance Travelled (km)**	**Km/lt**	**TJ**	**lt**
Bus	49,982	4.6	2,275	62,171,251
Car	34,750	13.0	183	5,007,819
Cargo van	22,500	12.0	23	641,288
Jeep	30,973	9.7	58	1,572,451
Microbus	56,733	13.2	7	194,901
Minibus	52,615	5.0	183	5,008,858
MiniTruck	20,403	4.9	48	1,314,683
Pickup	11,332	6.7	320	8,736,101
Tempo	-	0.0	-	-
Tractor	7,641	3.3	965	26,380,766
Truck	16,434	1.9	930	25,411,874
Van	40,000	14.0	24	669,082
Total			**5,017**	**137,109,075**
Gasoline				
Row Labels	**Average Distance Travelled**	**Km/lt**	**TJ**	**lt**
Car	22,220	16.5	178	5,361,129
Cargo van		0.0	-	-
Jeep	5,000	15.0	12	350,184
Microbus	-		-	-
Motorcycle	7,593	37.8	1,240	37,380,371
Tempo	17,100	16.2	402	12,108,587
Van	23,047	14.0	27	820,093
Total			**1,858**	**56,020,364**
Electric				
Electric	**Average Distance Travelled**	**Km/kWh**	**TJ**	**kWh**
E rickshaw	19,587	20	10	5,593,545
Jet fuel				
Electric	**Average Distance Travelled**	**Km/kWh**	**TJ**	
Aviation			563	
Grand Total			**7,448**	

The energy consumption in transport by subsectors and fuel types is as shown in **Table 7.26.** The energy consumption by public passenger vehicle is 39%, that of private passenger vehicle is 23%, freight vehicle is 31% and remaining 8% by air transport. Public passenger consumed 49% of total diesel and 22% of total petrol consumed in the sector. In contrast public passenger vehicle consumed 5% of total diesel and 78% of total petrol consumed in this sector. Freight consumed approximately 46% of total diesel consumed in the sector.

Table 7.27: Total Transport Sector Energy Consumption by Subsector and Fuel Types (TJ)

Sub-sector		Diesel	Gasoline	ATF	Electric	
Public Passenger	Bus	2,275				2,275
	Microbus	7	-			7
	Minibus	183				183
	Tempo	-	402			402
	E rickshaw				10	10
Total		**2,465**	**402**		**10**	**2,877**
Private Passenger	Car	183	178			361
	Jeep	58	12			69
	Van	24	27			52
	Motorcycle		1,240			1,240
Total		**265**	**1,456**	-	-	**1,721**
Freight	Truck	930				930
	Mini Truck	48				48
	Tractor	965				965
	Pickup	320				320
	Cargo van	23	-			23
Total		**2,286**	-	-	-	**2,286**
Aviation				563		
Grand Total		**5,017**	**1,858**	**563**	**10**	**7,448**[9]

(Survey 2019)

The transport sector being heavily dependent on imported petroleum products, there is a huge opportunity to switch to electric mobility. The use of e-rickshaw is getting popular, but it is essential that this trend is not so good affecting the fuel-efficient passenger carriers such as buses in one hand and on the hand, it seems better that e-rickshaws are also affecting fuel-inefficient vehicles – i.e. motorcycles and cars. The detailed energy consumption in the transport sector in province 1 is given in Annex IV.

7.7 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 activities like in road construction. Thus, total energy consumed in construction and mining sector totals to be around 585 TJ with highest consumption of diesel followed by kerosene (**Table 7.28**).

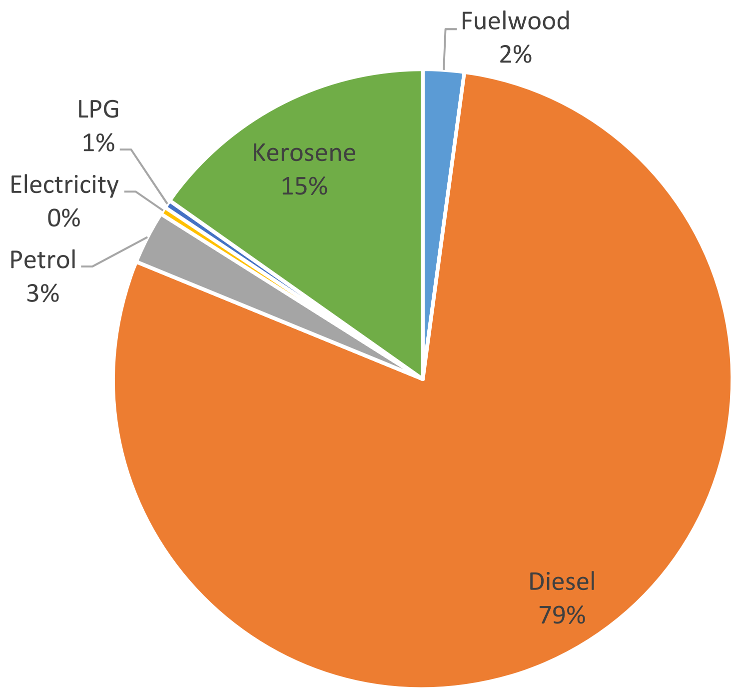
Table 7.28: Energy Consumptions in Construction and Mining Sector in Province 1 (TJ)

Firewood	12.57
Diesel	462.38
Gasoline	16.20
Electricity	2.32
LPG	2.46
Kerosene	89.07
Total	585.02

(Survey 2019)

Figure 7.15 shows the energy mix in construction and mining sector in province 1 which depicts that the most of the energy is used for motive power and thermal use.

[9] Values may slightly differ due to rounding up.



585 TJ

Figure 7.15: Energy mix in Construction and Mining Sector in Province 1 (TJ)

8 Socio-economic and Technical Analysis

8.1 Socio-economic Status

Province 1ranges from low Terai to highest peak in the world. Due to this, there is a large variation in socio-economic characteristics. As shown in **Figure 8.1,**the majority of respondents that belongs to Mountain, Hill and Terai regions. Large shares of respondents belong to Hill janjati in both the Mountain and Hill regions, whereas in Terai region, Brahmin/Chhetri are the major ethnic groups and they are seconded by Terai Janjati. Overall, Hill janjati are major respondents and secondly Hill Brahim/Chhetri in province-1. However, the respondents also include other ethnic groups ranging to Hill Janajati and Hill Dalit groups as well.

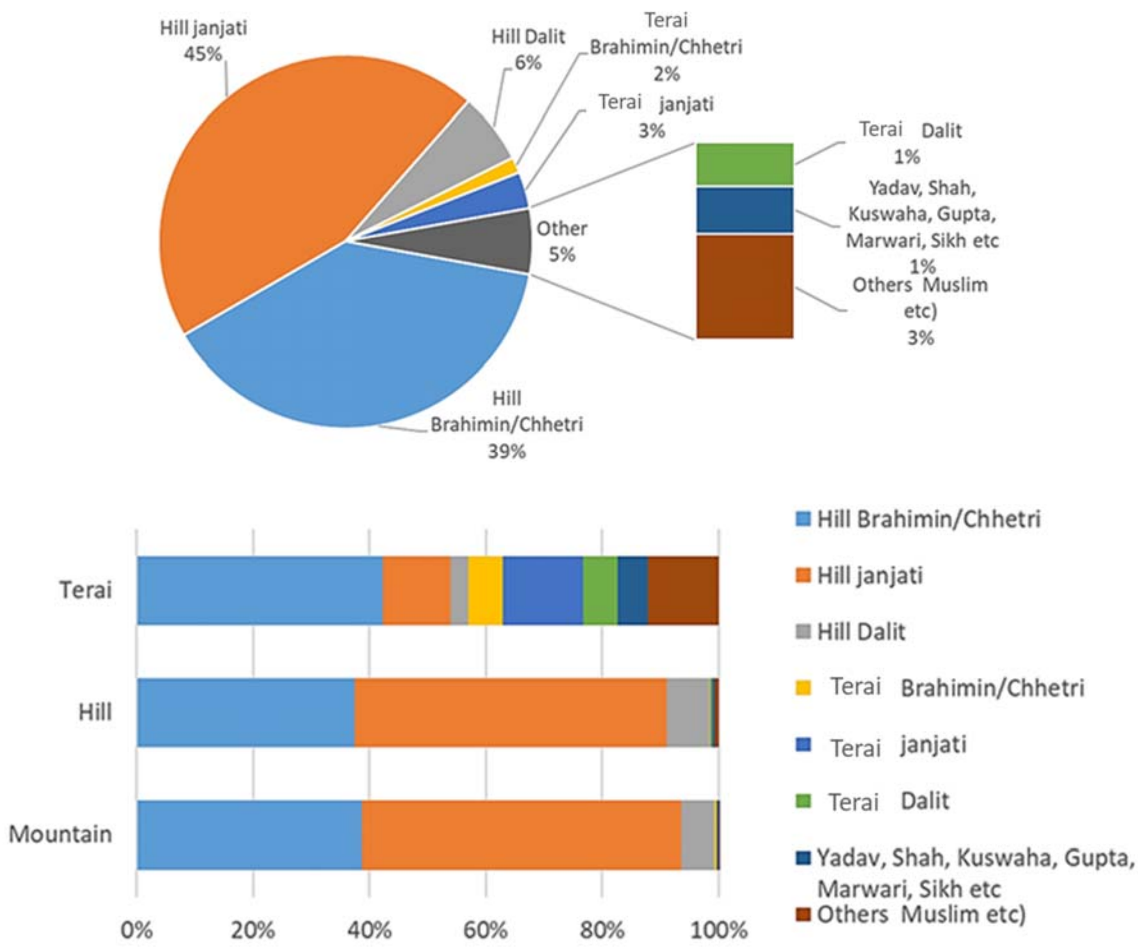


Figure 8.1: Mix of Respondents by Ethnic Group in Province 1 (top) and Ecological Regions (bottom)

It is evident that education level has influence on decision making. Thus, looking at the education level of household heads in province 1, it was seen that substantial household heads have no formal education followed by partially literate. Nearly 50% of household's heads do not have formal education (**Figure 8.2**). And the impact can be seen in the energy mix–firewood and other biomass still being predominant in the energy mix. Ecologically, Terai region have highest proportion of population with no formal education and education level seems higher in the Terai region.

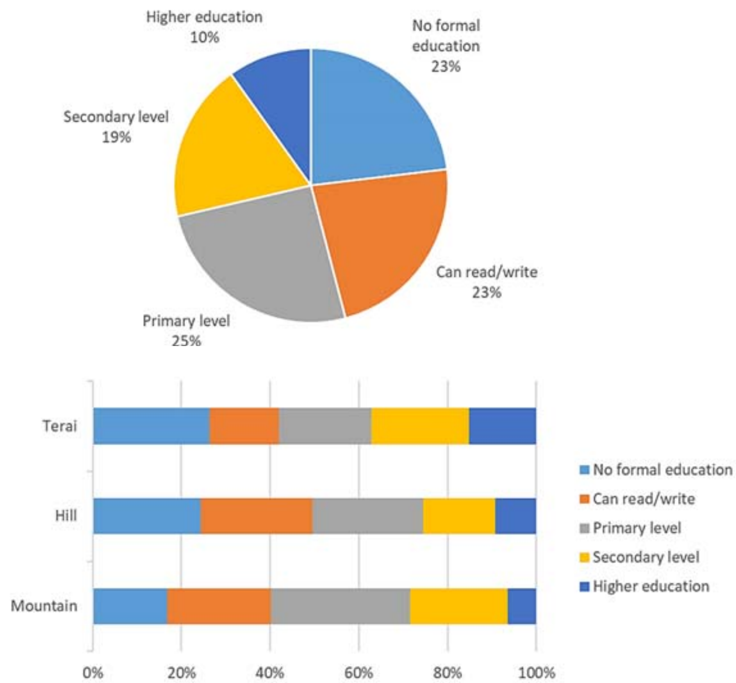


Figure 8.2: Mix of Respondents by Education Level of Household Head in Province 1 (top) and Ecological Regions (bottom)

Another important aspect of socio-economic behavior is sources and level of income. The major source of income of the respondents is agriculture followed by family business and services. Only low share of people independent on income from pension and house rent but the income from remittance and other jobs including wages is also substantial as shown in **Figure 8.3.**

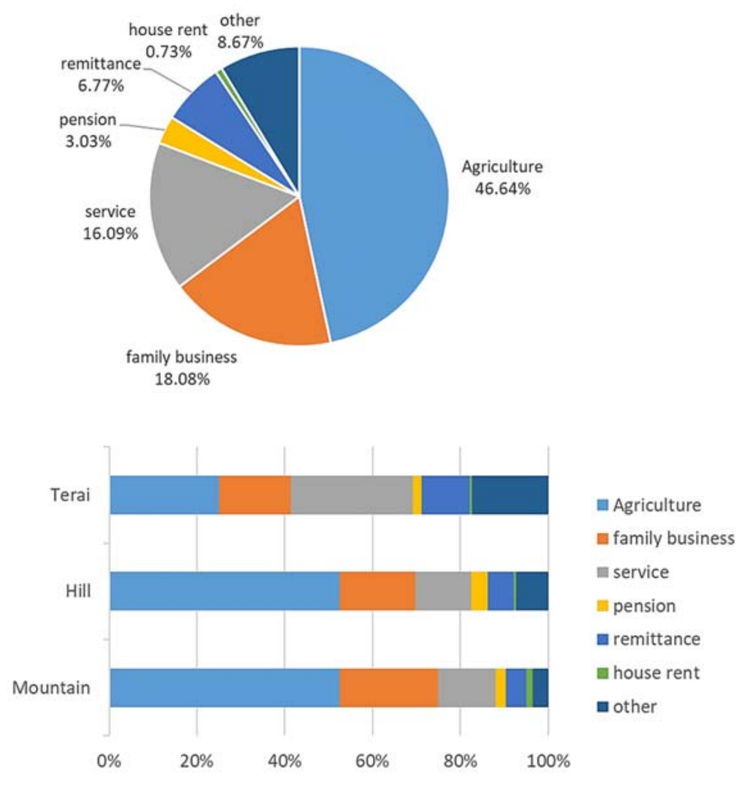


Figure 8.3: Mix of Respondents by Major Source of Income in Province 1 (top) and ecological regions (bottom)

The average monthly family income level ranges from as low as 8,000 per month to highest of 28,000 (at average). This comes to an average of NRs 230,000 annual income per household in Province 1. This income level is near to par with reference to the income level as per National Living Standards survey (CBS, 2011).Comparing ecologically, the income level is higher in average in Terai then hills than mountain. This is mostly due to higher economic activity in terai region due to easy access to economic centers – even to neighboring country. However, there is a huge variance from mean level of income in most of the cases which is evident from **Figure 8.4.**

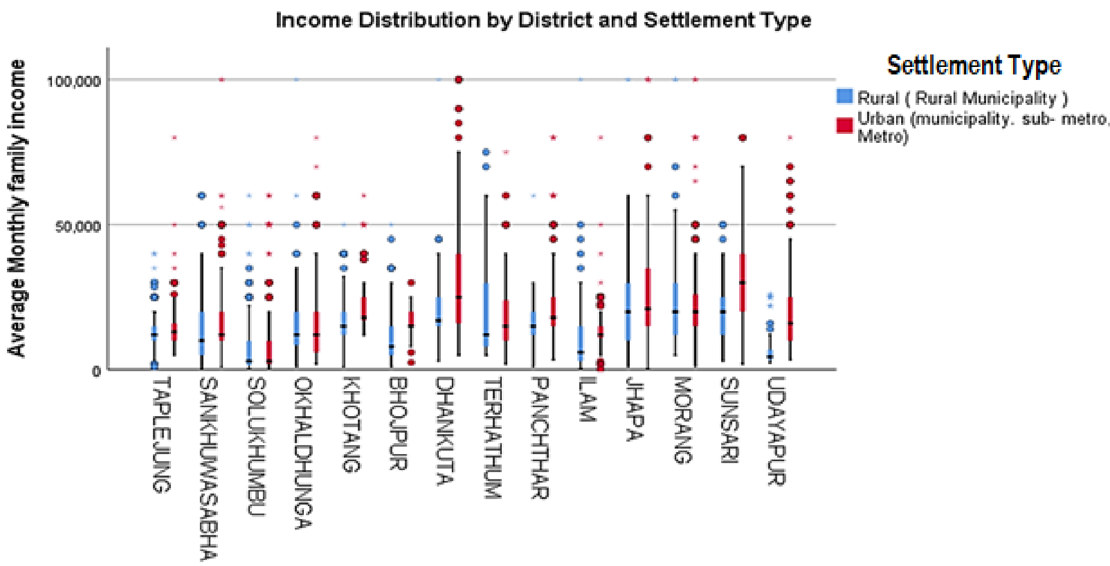


Figure 8.4: Average Monthly Income of Households in Province 1

In Province 1, more than 50% of the surveyed households found are made of mud mortar with brick or stone, followed by RCC frame with cement mortar, and the remaining are from bamboo or wood respectively **(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.

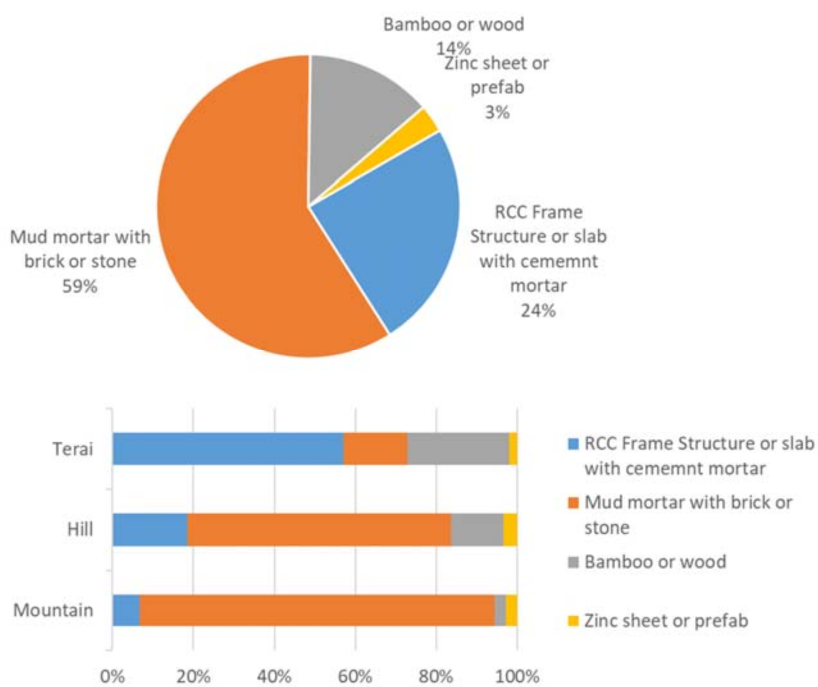


Figure 8.5: Mix of Respondent Household by Build Type

Meanwhile, for roof structure, 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**).

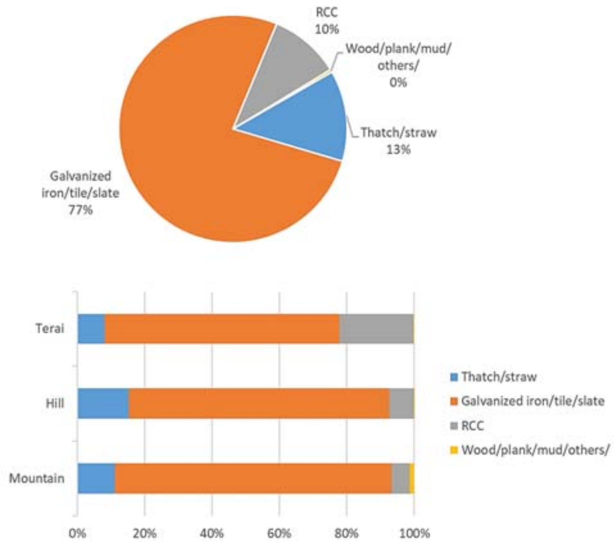


Figure 8.6: Mix of Respondent Households by Roof Type in Province 1 (top) and Ecological Regions (bottom)

8.2 Society and Energy Technology

Figure 8.7 shows the penetration of energy types in the province 1. Over 95% of population has access to electricity. Second to that is the use of firewood, where nearly 85% of the respondents still use firewood as source of energy. Following is the LPG at nearly 54%. This energy mix shows that the society in province 1 is still at phase of energy transition from traditional to modern fuels. Even though reach of electricity is higher than firewood but in energy terms, use of firewood 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 firewood collection is not considered. Thus, people tend to use these sources more often. **Figure 8.7** highlights fuel stacking in Province 1 and it is normal practice in developing countries as consumers cannot depend on one source of energy due to affordability, fuel security, and traditional practices. The district wise penetration of energy sources is given in Annex VI.

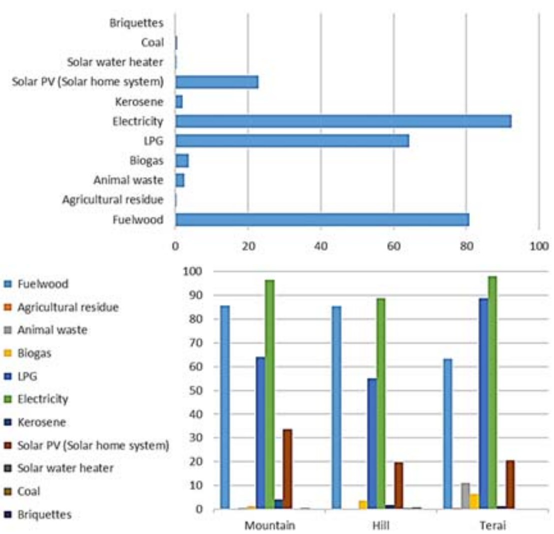


Figure 8.7: Penetration of Energy Types in Province 1 in Province 1 (top) and Ecological Regions (bottom)

Table 8.1 shows how much people paid for the commercially traded energy sources. At current times, even firewood is being traded at an average rate of NRs. 403 per bhari (around 40 kg) on average, with the highest in Terai while the lowest in mountains. Meanwhile the LPG in province 1 costs at around NR 1,565 per cylinder, with transportation cost. It is seen that LPG is available at marked prices in Terai, however due to transport cost, it is much higher in costs in hills and in mountain regions. These account for nearly NRs 1 per MJ of energy for firewood, while more than NR 2.5 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 in Province 1

			Ecology		
	unit	Province 1	Mountain	Hill	Terai
Firewood	(40 kg)	403	344	428	437
Bio-Briquettes	Kg	4	4	-	-
kerosene	Liter	167	151	194	119
LPG	cylinder	1,565	1,774	1,571	1,404
Coal	kg	55	48	57	-

		Districts													
	Unit	Taplejung	Sankhuwasabha	Solukhumbu	Okhaldhunga	Khotang	Bhojpur	Dhankuta	Terhathum	Panchthar	Ilam	Jhapa	Morang	Sunsari	Udayapur
Firewood	(40 kg)	245	311	541	348	331	-	702	390	353	231	449	478	408	326
Bio-Briquettes	Kg	4	-	-	-	-	-	-	-	-	-	-	-	-	-
kerosene	Liter	94	162	105	243	120	-	111	118	85	180	120	119	120	-
LPG	cylinder	1,682	1,809	1,851	1,856	1,617	2,079	1,469	1,619	1,584	1,539	1,409	1,393	1,411	1,415
Coal	kg	80	27	-	-	-	-	44	26	250	35	-	-	-	-

Figure 8.8 shows that share of electricity connection as per ampere capacity of households who have electricity. It was observed in survey that over 90% of the households lies within minimal amperage capacity of 5A **(See Annex VI).** 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 1.

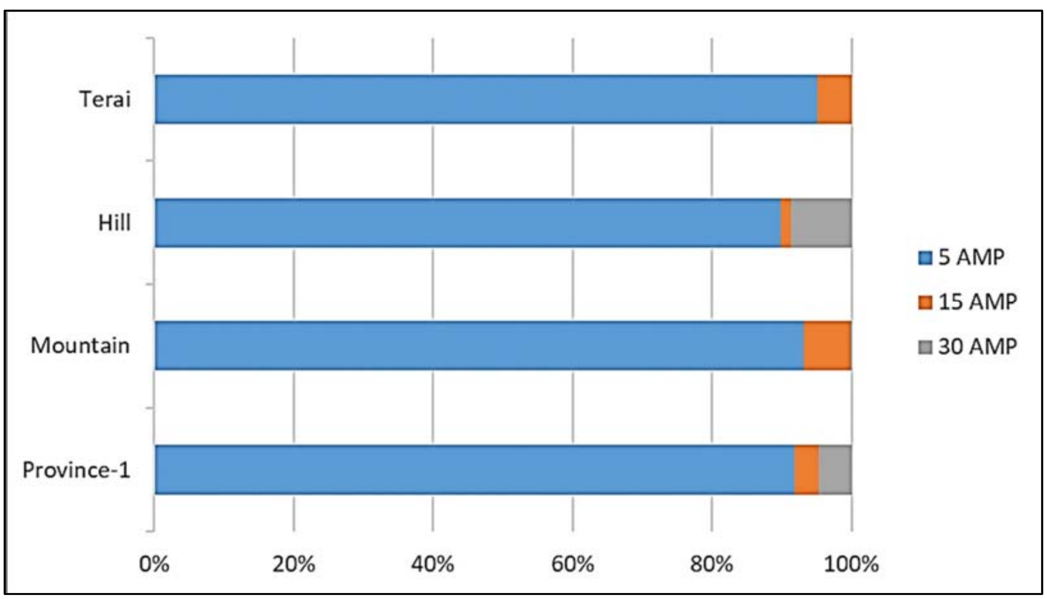


Figure 8.8: Mix of Ampere Capacity of Households with Electricity Access

9 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.
- Because of the prolonged lockdown due to COVID -19, some additional data collection was marred initially in the commercial sector and in some other sectors. However, we became successful in collecting enough representative data afterwards through further deployment of enumerators in Bhadra 2077.
- 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 were 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. This sector either are not locally based and/or bring the equipment form other region when necessary for the limited time as per requirement. Thus, their energy demand had to be based on overall yearly energy demand than by each end-use activity.

10 Energy Scenario Analysis

10.1 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 10.1.4. .

10.1.1 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 be same as in the base year

The **Table 10.1.** 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 1 is expected to grow from current level of 74 PJ in 2019 to 105 PJ in 2030 and 298 PJ in year 2050 which accounts for almost four folds of increase. The average annual growth rate of energy demand is 4.6% for the reference case. Per capita energy demand is expected to grow from 15 GJ in 2019 to 39 GJ in 2050 in this scenario.

Table 10.1: Fuel Demand in Reference Economic Growth Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	35.24	35.76	39.7	45.87	54.15	65.41	80.87	102.39
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.09
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
			Grid Electricity	5.24	5.32	6.17	7.72	9.91	13.05	17.51	23.92
Non-renewable			Petrol	1.87	1.92	2.05	2.2	2.36	2.54	2.73	2.94
			Diesel	10.15	10.33	12.12	15.48	20.26	27.17	37.07	51.31
			Kerosene	0.13	0.13	0.15	0.19	0.25	0.34	0.46	0.63
			Furnace Oil	1.16	1.18	1.44	1.93	2.64	3.69	5.2	7.39
			ATF**	0.56	0.57	0.61	0.65	0.7	0.75	0.8	0.85
			LPG	3.78	3.83	4.19	4.69	5.34	6.18	7.3	8.82
			Coal	15.62	15.9	19.29	25.91	35.54	49.6	69.91	99.35
Total				73.83	75.02	85.83	104.76	131.23	168.83	221.96	297.73

*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 and growing at an annual rate of 3.5%. Petroleum and coal demand are expected to grow at the rate of 5% and 6% respectively whereas electricity demand would grow at 5% per annum **Figure 10.1**. The share of electricity would increase by nearly 1.4 times in 2030 and four-fold in 2050.

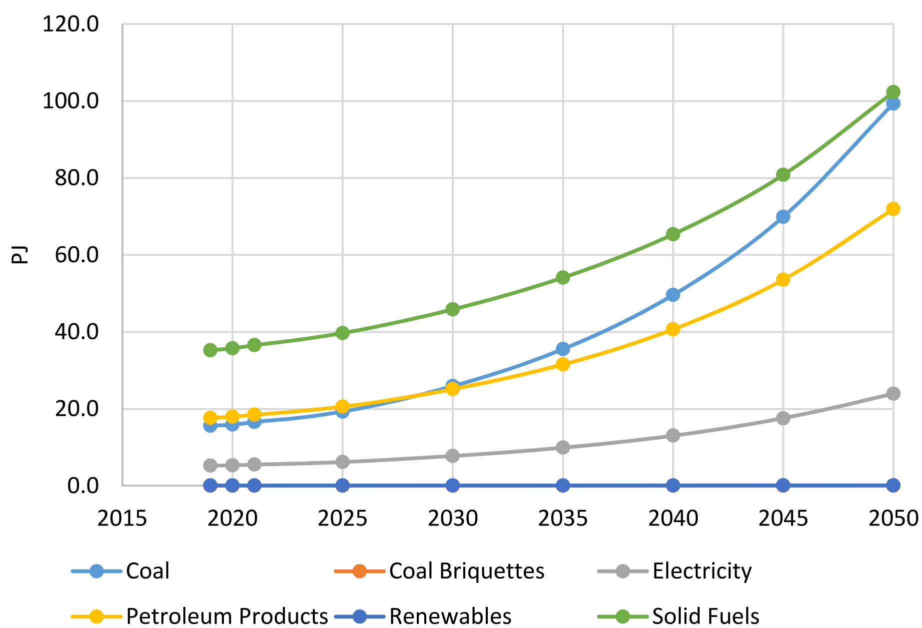
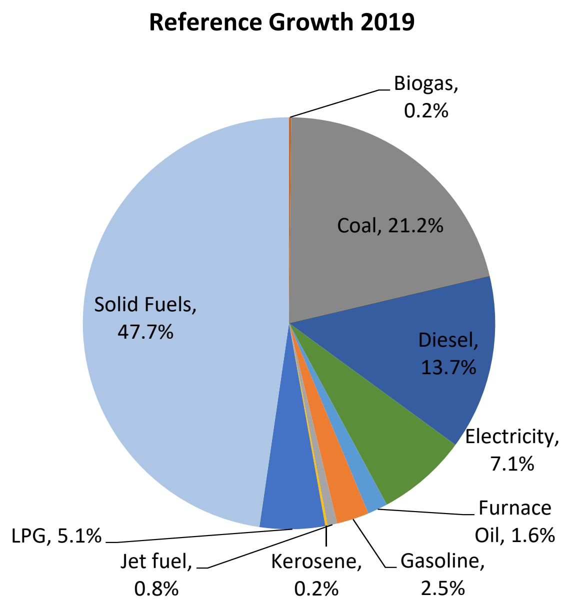
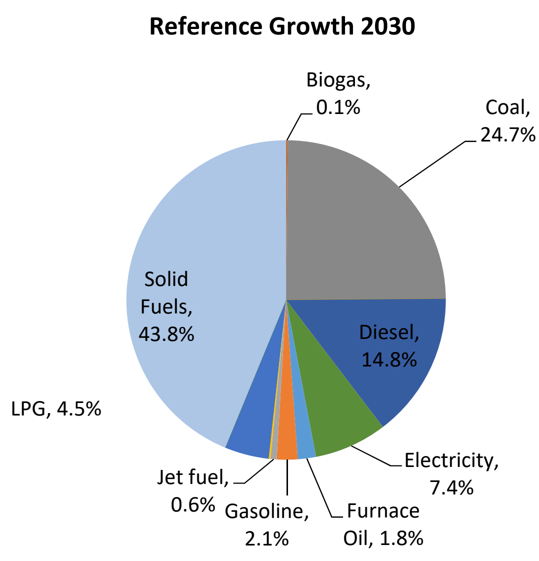


Figure 10.1: Fuel Demand Trend at Reference Economic Growth Scenario

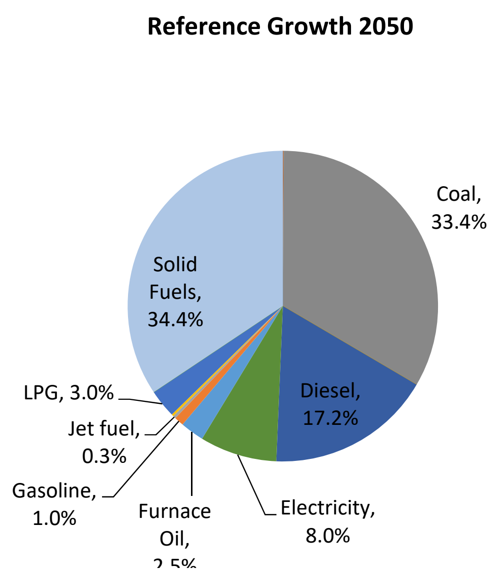
The **Figure 10.2** show the energy mix in the total fuel demand for 2019, 2030 and 2050 years. The demand of fuelwood is expected to decrease to 44% in 2030 and 34% in year 2050 respectively. Compared to 2019, the demand of coal and diesel would grow by 66% and 52% respectively in 2030. The electricity demand share would be 7% in 2030 and 8% in 2050 respectively.



(a) Total Final Energy Demand = 74 PJ



(b) Total Final Energy Demand = 105 PJ



(c) Total Final Energy Demand = 298 PJ

Figure 10.2: Fuel mix at Reference Economic Growth Scenario

Table 10.2. shows the sectoral energy demand in this scenario. The share of residential sector decreases to 15% in 2050 from 41% in 2019. Meanwhile, industrial sector share of energy demand will increase to 52% in 2030 and 70% in 2050. Whereas the share of Energy demands in the commercial sector will increase more than 6 folds in 2050 from its base year value. There will be 32% growth of energy demand in transport sector in 2030 and demand will be 3 times in 2050.

Table 10.2: Sectoral demand at Reference Economic Growth Scenario (PJ)

	2019	2020	2025	2030	2035	2040	2045	2050
Agriculture	0.53	0.54	0.66	0.88	1.21	1.69	2.38	3.38
Commercial	2.14	2.18	2.62	3.47	4.71	6.51	9.12	12.88
Construction and Mining	0.59	0.60	0.72	0.97	1.33	1.86	2.62	3.72
Industry	32.96	33.55	40.70	54.68	74.99	104.66	147.52	209.64
Residential	30.16	30.57	32.69	34.95	37.38	39.97	42.74	45.71
Transport	7.45	7.58	8.44	9.80	11.63	14.13	17.58	22.40
Total	73.83	75.02	85.83	104.76	131.25	168.30	221.96	297.73

Sub sectoral energy demand projections are given in annex VIII.

Figure 10.3 shows the power plant capacity required for the study period. The required peak power plant in 2019 was 310 MW. The future power requirement would be 742 MW in 2030 and 2,299 MW in 2050. The electricity demand per capita is seen to be growing by over two folds during the study horizon from current value of 287 kWh in 2019 to 863 kWh by 2050.

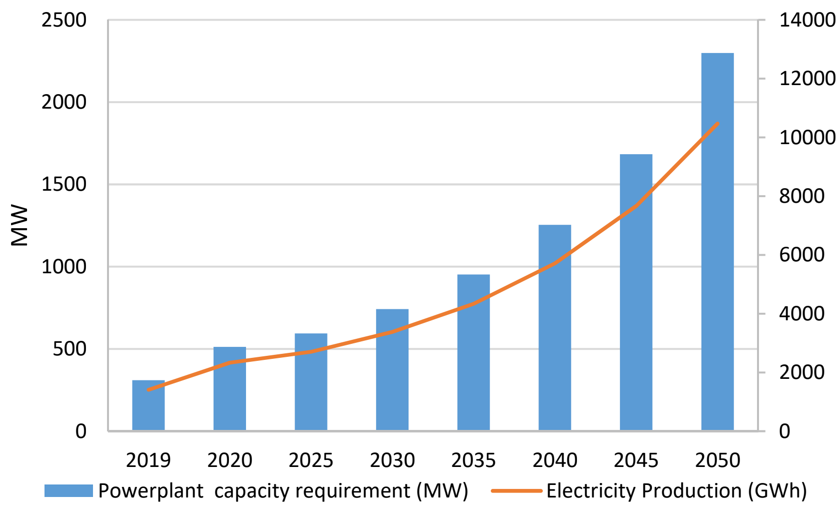


Figure 10.3: Installed Power Plant Capacity at Reference Economic Growth Scenario

GHG emissions trend in Reference Economic Growth Scenario is as shown in **Figure 10.4.** GHG emissions would increase from 2,969 kt in 2019 to 4,542 kt in 2030 and is reaching 15,156 kt in 2050. The GHG emissions would grow at an average growth rate of 5% during 2019-2050. There will be 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 1.

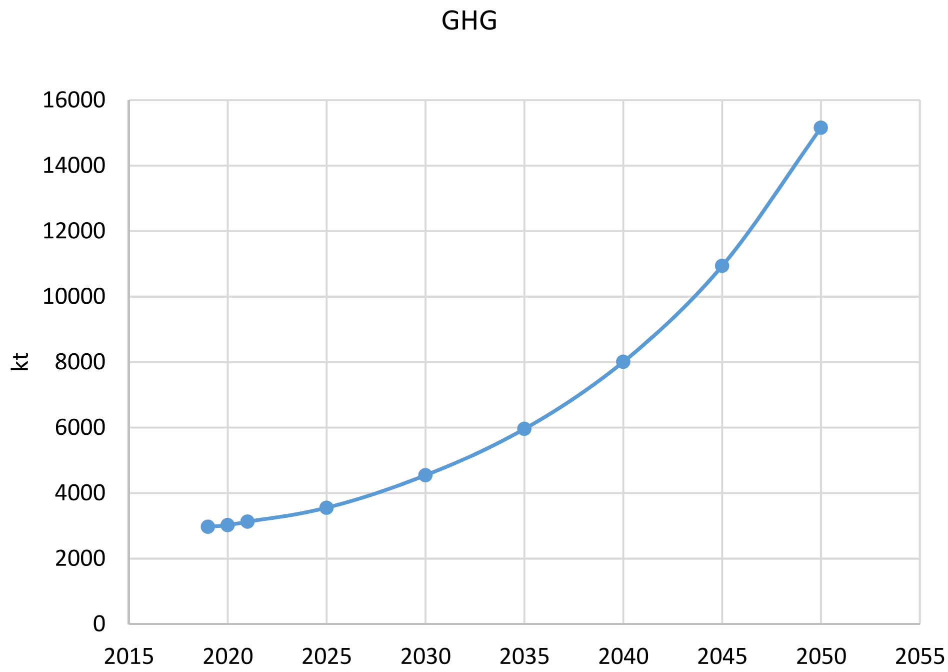


Figure 10.4: GHG emissions at Reference Economic Growth Scenario

10.1.1.1 Energy Indicators in the Reference Economic Growth Scenario

Table 10.3 gives the energy indicators for Reference Economic Growth Scenario which shows that under normal circumstances, with no policy intervention in energy sector, the energy demand would increase such that per capita energy demand would nearly triple in 2050 with respect to current demand. 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 58% in 2050 from 45% in 2019, all due to increase in carbon-based energy demand and the conventional demand technologies. This being said, the imported carbon-based fuels and their uses are also going to impact per capita GHG emissions reaching almost four times by 2050 from the current baseline values.

Table 10.3: Energy Indicators in Reference Economic Growth Scenario

Energy Indicators									
		2019	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Final energy demand/capita	GJ/capita	14.52	14.56	15.57	17.78	20.83	25.05	30.80	38.64
Final electricity demand	kWh/capita	287	288	312	365	437	538	676	863
Final energy demand	GJ/million NRS	1,825	1,822	1,719	1,562	1,427	1,315	1,226	1,157
Final Electricity Demand	kWh/million NRS	36,068	35,985	34,416	32,023	29,965	28,254	26,900	25,853
Total Electricity Used/household	kWh/HH	654	655	655	655	655	655	655	655
share of non-carbon energy in primary supply	per cent	7.11%	7.11%	7.21%	7.38%	7.56%	7.74%	7.90%	8.04%
Share of renewable energy in final total energy demand	per cent	7.20%	7.19%	7.28%	7.45%	7.62%	7.78%	7.94%	8.07%
the ratio of net import to total primary energy supply	per cent	45.07%	45.13%	46.43%	48.74%	51.12%	53.47%	55.63%	57.53%
GHG emission	GHG in Kg/capita	584	586	644	771	946	1,188	1,518	1,967

10.1.2 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 10.4. below 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 1 is expected to grow from the current level of 74 PJ in 2019 to 101 PJ in 2030 to 252 PJ in 2050 which accounts for more than two folds of increase. The average annual growth rate of energy demand is 4% in this scenario.

Table 10.4: Fuel Demand in Low Economic Growth Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	35.24	35.76	39.48	44.96	52.0	61.121	73.54	90.39
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.09
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
			Grid Electricity	5.24	5.32	6.10	7.41	9.21	11.68	15.12	20.00
Non renewable			Petrol	1.87	1.92	2.05	2.2	2.36	2.53	2.72	2.93
			Diesel	10.15	10.33	11.95	14.79	18.69	24.1	31.69	42.51
			Kerosene	0.13	0.13	0.15	0.19	0.23	0.3	0.39	0.52
			Furnace Oil	1.16	1.18	1.41	1.82	2.4	3.21	4.36	6.01
			ATF**	0.56	0.57	0.61	0.65	0.7	0.75	0.8	0.85
			LPG	3.78	3.83	4.17	4.64	5.2	5.92	6.84	8.06
			Coal	15.62	15.9	18.92	24.47	32.22	43.12	58.59	80.8
Total				73.83	75.02	84.93	101.2	123.11	152.91	194.15	252.19

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

**ATF : Aviation Turbine Fuel

The energy demand in low growth scenario is expected to grow linear at the rate of 4% with the highest share in throughout the years from solid biomass. The demand of coal is expected to grow at the rate of 5% per annum during the study period surpassing the demand of petroleum products 2035 onwards. The petroleum products and grid electricity are seen to be increasing at the rate of 4% per annum. In the meantime, solid fuels and renewables would grow at the rate of 3% and 1.6% per annum respectively. The fuel demand trend in this scenario is as shown in **Figure 10.5.**

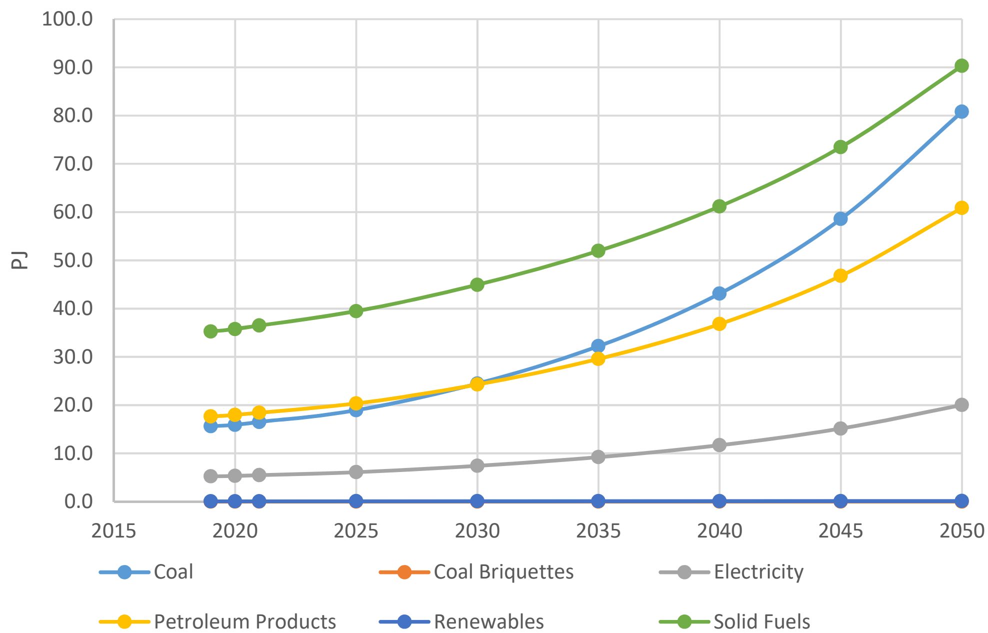
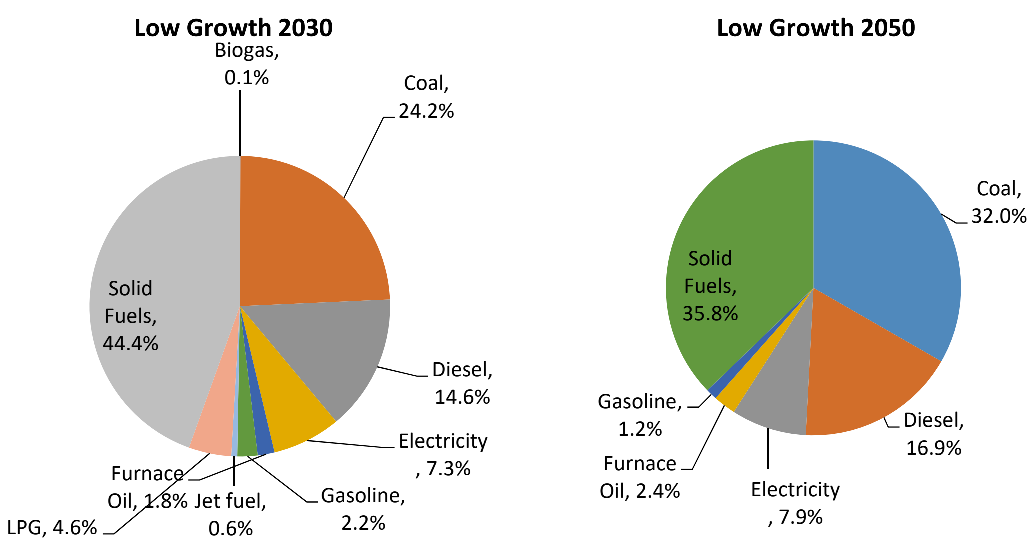


Figure 10.5: Fuel Demand Trend at Low Economic Growth Scenario

The **Figure 10.6** show the energy mix in the total fuel demands for 2030 and 2050 years. The share of solid biomass is expected to decrease to 44 % in 2030 and 36 % in 2050 respectively, whereas quantities of fossil fuels such as diesel and coal are expected to grow by almost 3 times in between 2030 and 2050. The share of electricity will be increased to 7% and 8 % in 2030 and in 2050, respectively.



(a) Total Final Energy Demand = 101 PJ (b) Total Final Energy Demand = 252 PJ

Figure 10.6: Fuel Mix at Low Economic Growth Scenario

Table 10.5. shows the sectoral energy demand in this scenario. The energy demand in industrial sector would be highest in this scenario and demand in 2050 would be almost 5 times than the demand in the base year. Transport is expected to grow by almost 3 times in 2050 from the base year values, whereas residential energy demand is expected to grow by 52% by 2050 whereas agriculture, and commercial sectors demands are also expected to increase by 5 fold by 2050 from their base year values, even though their demands are comparatively lower than those in the industrial and residential sectors.

Table 10.5: Sectoral Demand at Low Economic Growth Scenario

	2019	2020	2025	2030	2035	2040	2045	2050
Agriculture	0.53	0.54	0.64	0.83	1.10	1.47	1.99	2.75
Commercial	2.14	2.18	2.57	3.29	4.29	5.69	7.67	10.52
Construction and Mining	0.59	0.60	0.71	0.92	1.21	1.61	2.19	3.03
Industry	32.96	33.55	39.93	51.62	67.99	90.98	123.62	170.50
Residential	30.16	30.57	32.69	34.95	37.38	39.97	42.74	45.71
Transport	7.45	7.58	8.39	9.59	11.14	13.18	15.92	19.68
Total	73.83	75.02	84.93	101.2	123.11	152.91	194.15	252.19

Sub sectoral energy demand projections are given in annex VIII.

The power plant capacity required for the study period is as shown in **Figure 10.7.** The demand for grid electricity is expected to increase at the average annual rate of 6%. The installed power plants requirement in 2019 was 310 MW. The future power requirement would be 713 MW in 2030 and 1,923 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 287 kWh to 722 kWh in 2050.

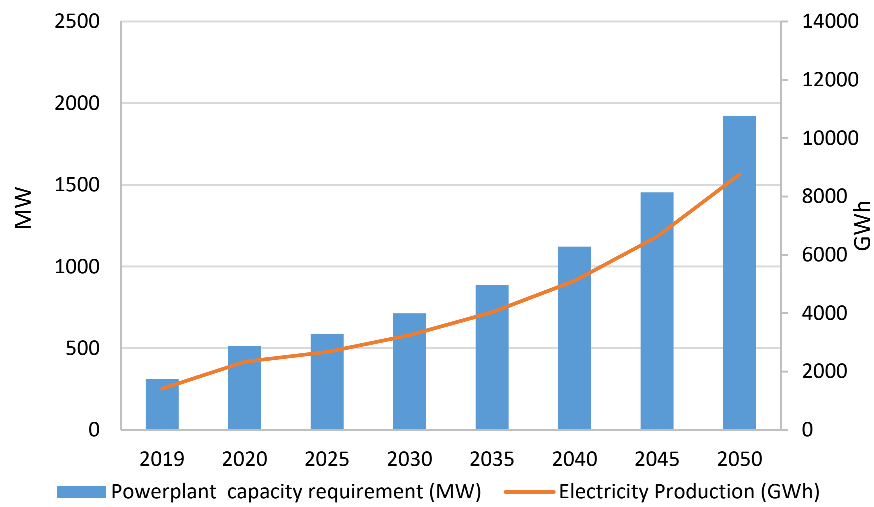


Figure 10.7: Installed Power Plant Capacity at Low Economic Growth Scenario

GHG emissions trend in low economic growth scenario is as shown in **Figure 10.8**. GHG emissions would increase from 2,969 kt in 2019 to 4,338 kt in 2030 and to 12,545 kt in 2050 respectively. The GHG emissions would grow at the average growth rate of 5% during 2019-2050.

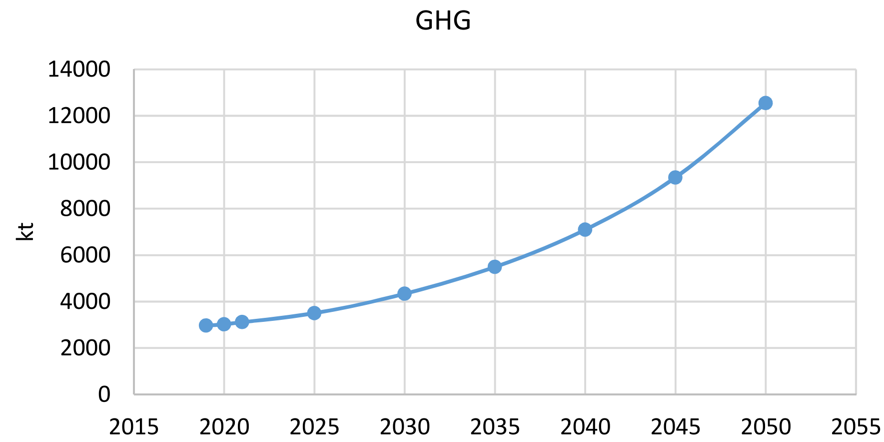


Figure 10.8: GHG emissions at Low Economic Growth scenario

10.1.3 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 in the base year

Table 10.6 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 1 is expected to grow from current level of 74PJ in 2019 to 106 PJ in 2030 to 329 PJ in 2050 respectively which accounts for more than four folds of increase. The average annual growth rate of energy demand is 4.9% in this scenario.

Table 10.6: Fuel Demand in High Economic Growth Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	35.24	35.76	39.78	46.10	54.73	66.91	84.68	110.567
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
		Modern biomass	Biogas	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.09
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
			Grid Electricity	5.24	5.24	5.32	6.19	7.78	10.10	13.53	18.76
Non-renewable			Petrol	1.87	1.92	2.05	2.2	2.36	2.54	2.74	2.96
			Diesel	10.15	10.33	12.17	15.62	20.69	28.27	39.87	57.38
			Kerosene	0.13	0.13	0.15	0.2	0.26	0.35	0.49	0.7
			Furnace Oil	1.16	1.18	1.44	1.95	2.71	3.86	5.64	8.34
			ATF**	0.56	0.57	0.61	0.65	0.7	0.75	0.8	0.85
			LPG	3.78	3.83	4.19	4.71	5.38	6.28	7.54	9.34
			Coal	15.62	15.9	19.37	26.22	36.44	51.92	75.81	112.14
Total				73.83	75.02	86.04	105.51	133.46	174.51	236.44	329.13

*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 - coal demand even surpassing solid biomass fuels in 2050. Since Coal and petroleum products are the major source of fuels in industry, their demand naturally 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 their base year values. Electricity requirement is expected to grow by fivefold in this scenario, mostly due to growth in economic activities in commercial and industrial sectors. Since Residential sector is a major sector consuming solid biomass fuels, the growth in fuel demand in this sector is affected mostly by the demographic drivers. Solid biomass and electricity demand is growing at the rate of 4% and 5% respectively during the study period. The fuel demand trend in this scenario is as shown in **Figure 10.9.**

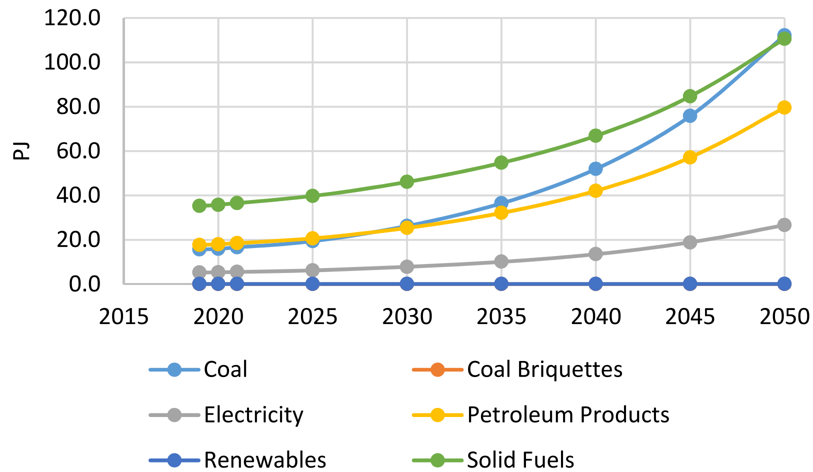
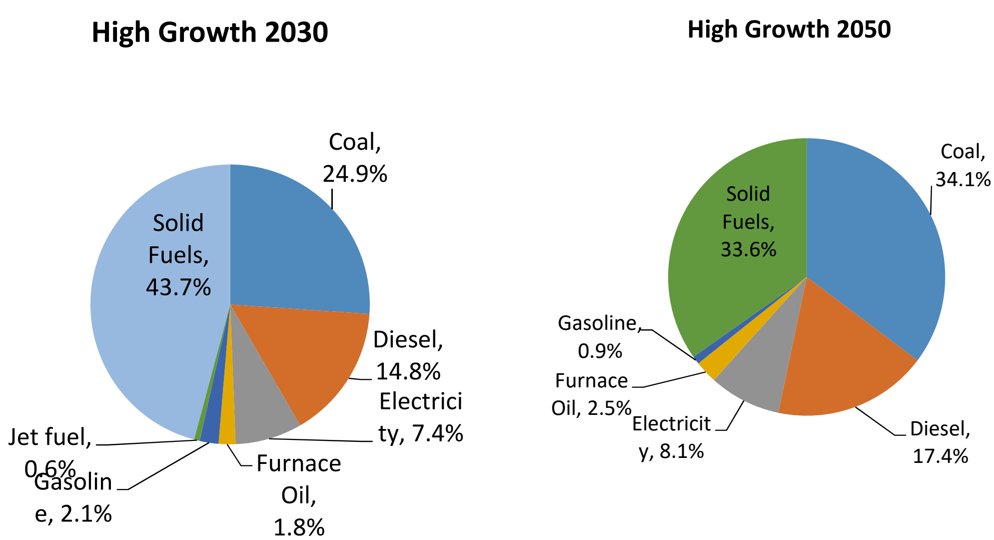


Figure 10.9: Fuel Demand Trend at High Economic Growth Scenario

Figure 10.10 shows the energy mix in the total fuel demands for 2030 and 2050 respectively. The demand for solid biomass fuels is expected to decrease from4 8% in 2019 to 44% in 2030 and 34% in 2050 respectively. In this scenario, the share of fossil fuels like diesel and coal are expected to grow by more than 5 folds. The share of electricity will increase to 7% and 8 % in in 2030 and 2050 respectively.



(a) Total Final Energy Demand = 106 PJ (b) Total Final Energy Demand = 329 PJ

Figure 10.10: Fuel Mix at High Economic Growth Scenario

Table 10.7. shows the sectoral energy demand in this scenario. The share of residential sector decreases to 14% in 2050 from 41 % in 2019. Meanwhile, industrial sector share of energy demand will increase to 52% in 2030 and 72% in 2050, respectively. Whereas the share of energy demands in the commercial sector, agriculture sector and transport sectors will be 4.4%, 1.2% and 7.4% respectively in 2050.

Table 10.7: Sectoral demand at High Economic Growth Scenario (PJ)

	2019	2020	2025	2030	2035	2040	2045	2050
Agriculture	0.53	0.54	0.66	0.89	1.24	1.77	2.58	3.82
Commercial	2.14	2.18	2.63	3.51	4.83	6.81	9.87	14.51
Construction and Mining	0.59	0.60	0.73	0.98	1.36	1.94	2.84	4.20
Industry	32.96	33.55	40.88	55.32	76.89	109.55	159.96	236.63
Residential	30.16	30.57	32.69	34.95	37.38	39.97	42.74	45.71
Transport	7.45	7.58	8.46	9.85	11.76	14.47	18.44	24.27
Total	73.83	75.02	86.04	105.51	133.46	174.51	236.44	329.13

Sub sectoral energy demand projections are given in annex VIII.

The power plant capacity required for the study period is as shown in **Figure 10.11.** The demand for grid electricity is expected to increase at the average annual rate of 6%. The required peak power plant in 2019 was 310 MW. The future power requirement would be 749 MW in 2030 and 2,559 MW in 2050.The electricity demand per capita is seen to be growing by over two folds during the study horizon from current value of 287 kWh to 961 kWh in 2050.

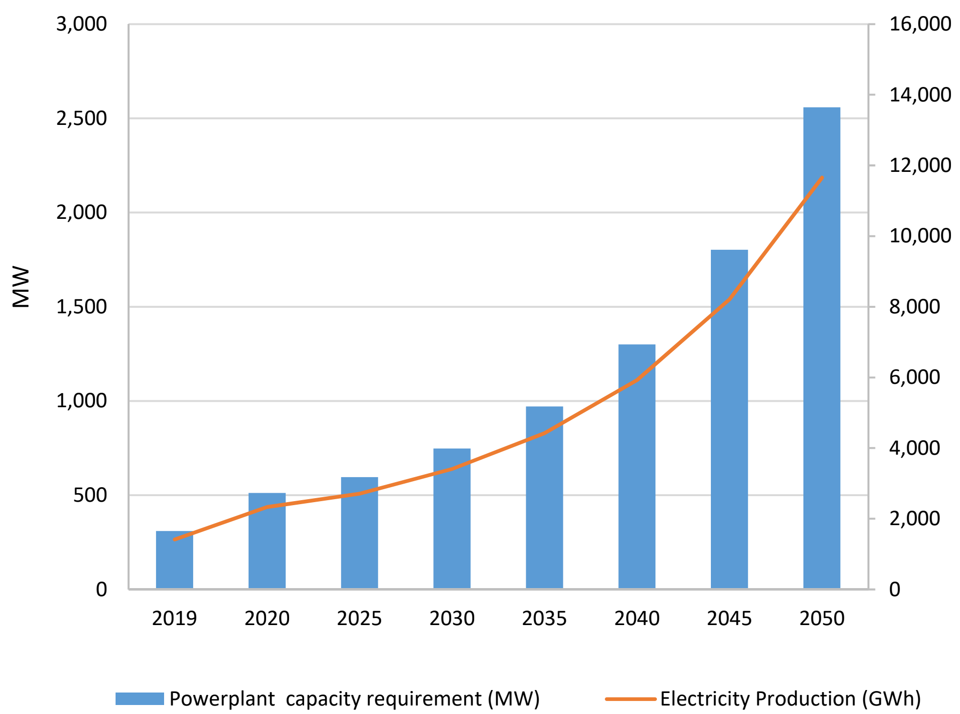


Figure 10.11: Power Plant Capacity Requirement at High Economic Growth Scenario

GHG emissions trend in high economic growth scenario is as shown in **Figure 10.12**. GHG emissions would increase from 2,969 kt in 2019 to 4,585 kt in 2030 and to 16,957 kt in 2050. The GHG emissions would grow at the average growth rate of 6% during 2019-2050. GHG emissions will be growing exponentially between the period 2030 to 2050 because of high GDP growth and higher demand for fossil fuels in the Province 1.

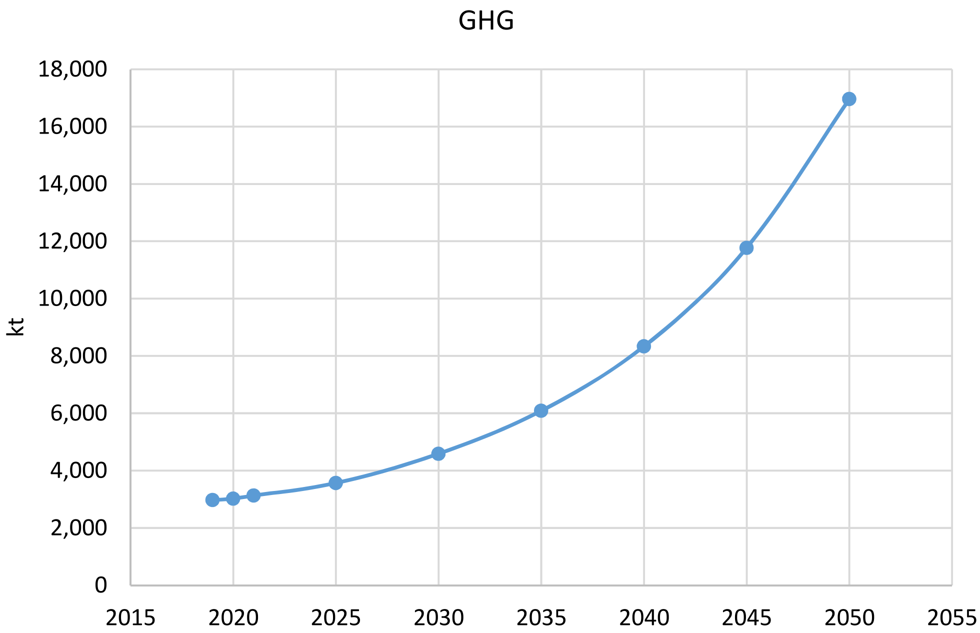


Figure 10.12: GHG Emissions at High Economic Growth Scenario

10.1.4 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:90% Electric, 10% solid biomass 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:90% Electric, 10% solid biomass by 2050
- Urban others: 100% electrification by 2050

The final demands of various fuels in this scenario have been given in **Table 10.8.** The total energy demand in 2030 and 2050 is expected to be 95 PJ and 256 PJ respectively. Per capita energy demand is expected to be 33 GJ in 2050 in the Sustainable Energy Development Scenario (SEDS), whereas it would be 39 GJ in the Reference Economic Growth Scenario.

Table 10.8: Fuel Demand Sustainable Energy Development Scenario (PJ)

				2019	2020	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	35.24	34.84	33.60	33.20	32.88	32.65	32.123	31.23
			Charcoal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Modern biomass	Biogas	0.06	0.09	0.23	0.40	0.59	0.81	1.05	1.32
			Bio briquettes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.01	0.01	0.02	0.05	0.08	0.14	0.24	0.39
			Grid Electricity	5.24	6.14	12.27	22.26	38.00	63.08	102.83	165.85
Non renewable			Petrol	1.87	1.92	1.8	1.67	1.5	1.31	1.1	0.85
			Diesel	10.15	10.19	10.84	12.33	14.1	16.08	18	19.4
			Kerosene	0.13	0.13	0.15	0.18	0.23	0.3	0.41	0.57
			Furnace Oil	1.16	1.16	1.24	1.44	1.68	1.92	2.1	2.14
			ATF**	0.56	0.57	0.61	0.65	0.7	0.75	0.8	0.85
			LPG	3.78	3.72	3.46	3.19	2.84	2.36	1.66	0.62
			Coal	15.62	15.56	16.8	19.79	23.32	27.22	30.85	33.17
Total				73.83	74.32	81.04	95.16	115.93	146.61	191.28	256.40

*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 4% per annum whereas electricity demand grows at an average rate of 12% per annum during 2019-2050. Compared to other energy carriers, electricity demand will be surpassing other demands by 2035. The primary solid biomass (wood, agri -residue and animal dung) demand is expected to be reduced at the rate of 0.4% 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 1% per annum during the analysis period. The energy demand trends are highlighted in **Figure 10.13.**

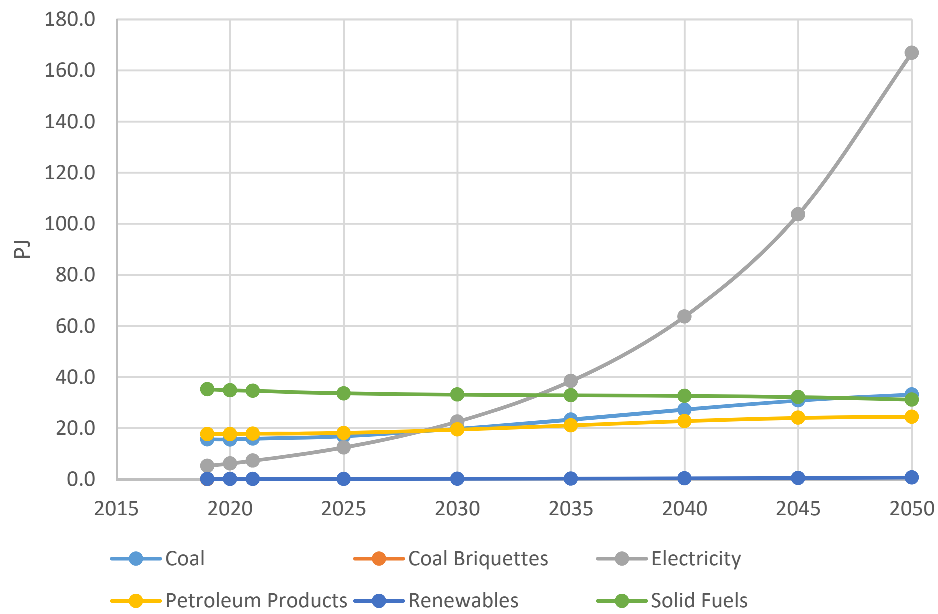
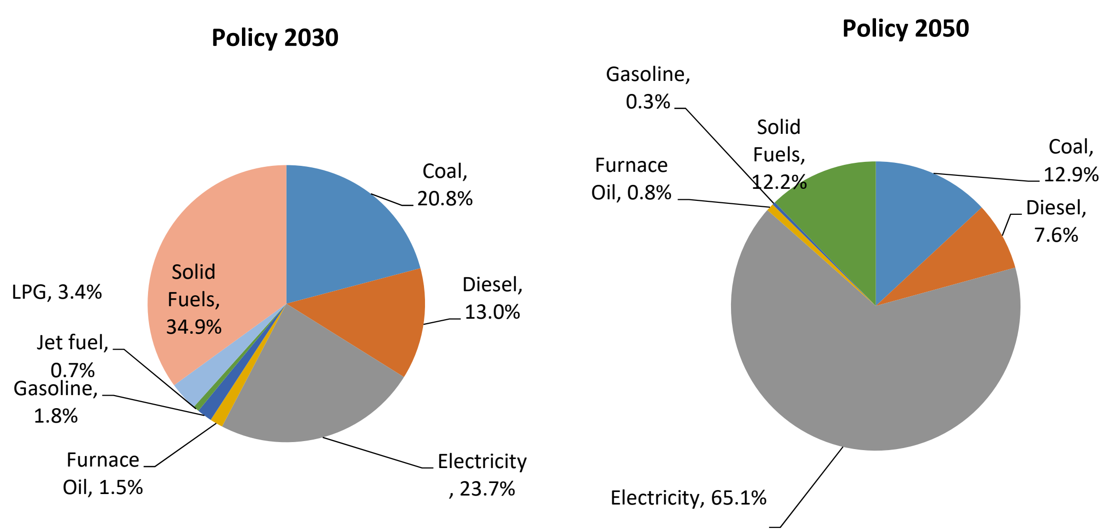


Figure 10.13: Fuel demand trend at Sustainable Energy Development Scenario (SEDS)

The **Figure 10.14** 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 35% in 2030 and 12% in 2050 respectively. The electricity demand would be 24% in 2030 and 65% in 2050 respectively.



(a) Total Final Energy Demand = 116 PJ (b) Total Final Energy Demand = 256 PJ

Figure 10.14: Fuel mix at Sustainable Energy Development Scenario (SEDS)

The **Table 10.9.** shows the sectoral energy demand in this scenario. The share of residential sector decreases to 6% in 2050 from 41 % in 2019. Meanwhile, industrial sector share of energy demand will increase to 58% in 2030 and 83% in 2050 respectively, whereas the share of energy demands in the commercial, agriculture, and transport sectors will be 3%, 1% and 7% respectively in 2050.

Table 10.9: Sectoral Demand at Sustainable Energy Development Scenario (SEDS) (PJ)

	2019	2020	2025	2030	2035	2040	2045	2050
Agriculture	0.53	0.53	0.60	0.74	0.92	1.16	1.46	1.82
Commercial	2.14	2.15	2.40	2.94	3.65	4.57	5.73	7.14
Construction and Mining	0.59	0.60	0.72	0.97	1.33	1.86	2.62	3.72
Industry	32.96	33.57	40.77	54.86	75.35	105.32	148.67	211.59
Residential	30.16	29.90	28.38	26.50	24.23	21.52	18.31	14.56
Transport	7.45	7.58	8.17	9.16	10.45	12.18	14.49	17.57
Total	73.83	74.32	81.04	95.16	115.93	146.61	191.28	256.40

The power plant capacity requirement in this scenario is as shown in **Figure 10.15.** The base year power requirement is 310 MW in Province 1. The power plant requirement for 2030 will be 2,205 MW, and it will be 16,572 MW by 2050. This is almost 7 times the requirement in the reference case in 2050. Industrial sector occupies the highest energy demand quantitatively compared to energy demands in other economic sectors from 2035 onwards.

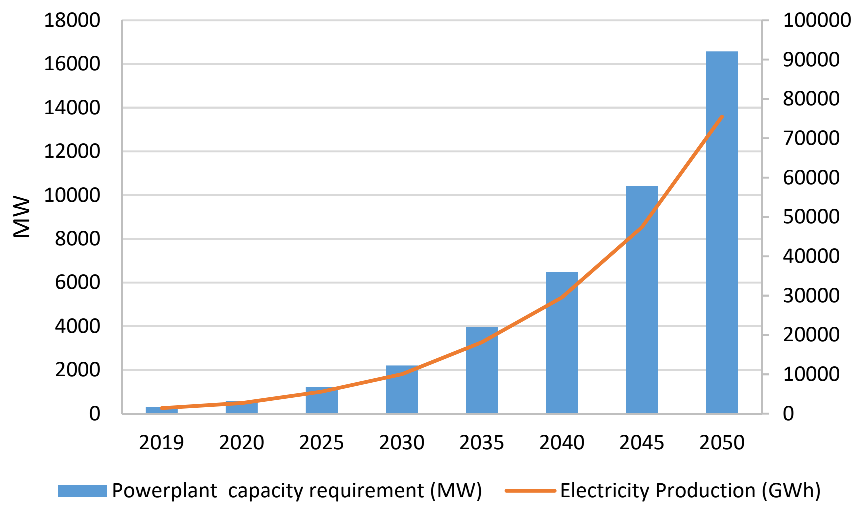


Figure 10.15: Power Plant Capacity in Sustainable Energy Development Scenario (SEDS)

GHG emissions trend in Sustainable Energy Development Scenario (SEDS) is shown in **Figure 10.16.** GHG emissions would increase from 2,969kt in 2019 to 3,475 kt in 2030 and to 5,065 kt in 2050. The GHG emissions would grow at the average rate of 2% during 2019-2050. Compared to the Reference Economic Growth Scenario, GHG emissions in SEDS would be reduced by 23% in 2030 and by 67% in 2050 respectively. Province 1 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).

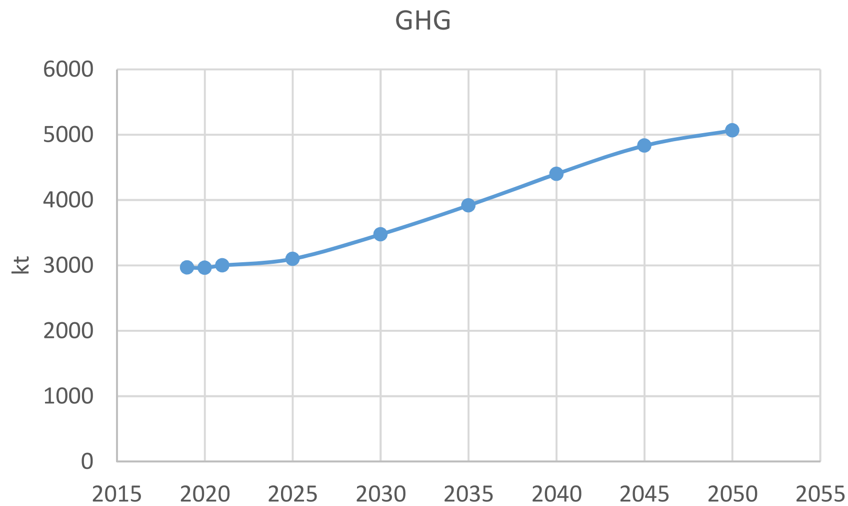


Figure 10.16: GHG Emissions at Sustainable Energy Development Scenario (SEDS)

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

Table 10.10 shows the energy indicator for policy scenario ie 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 to over 6,000 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 decreases to 41% of total energy from 49% in reference scenario in 2030 and to 22% in 2050. On other hand, use of national resources increases with increase in use of renewables to 65% in 2050 as compared to only 8% in the Reference Economic Growth Scenario.

Table 10.10: Energy Indicators in Sustainable Energy Development Scenario (SEDS)

Energy Indicators									
		2019	2020	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	14.52	14.42	14.70	16.15	18.40	21.76	26.54	33.27
Final electricity demand	kWh/capita	287	331	620	1,051	1,678	2,606	3,973	5,993
Final energy demand	GJ/million NRS	1,825	1,805	1,623	1,419	1,260	1,142	1,056	997
Final Electricity Demand	kWh/million NRS	36,068	41,481	68,406	92,353	114,972	136,728	158,134	179,492
Total Electricity Used/household	kWh/HH	654	701	934	1,167	1,400	1,633	1,865	2,098
share of non-carbon energy in primary supply	per cent	7.11%	8.28%	15.18%	23.44%	32.84%	43.12%	53.89%	64.84%
Share of renewable energy in final total energy demand	per cent	7.20%	8.39%	15.47%	23.86%	33.36%	43.67%	54.44%	65.35%
the ratio of net import to total primary energy supply	per cent	45.07%	44.73%	43.06%	41.25%	38.27%	34.06%	28.71%	22.47%
GHG emission	GHG in Kg/capita	584	575	563	590	622	653	671	658

10.2 Comparative Analysis

Figure 10.17 shows the final energy demand for the reference and policy (SEDS) 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 9% in 2030 to nearly 14% energy savings in 2050.

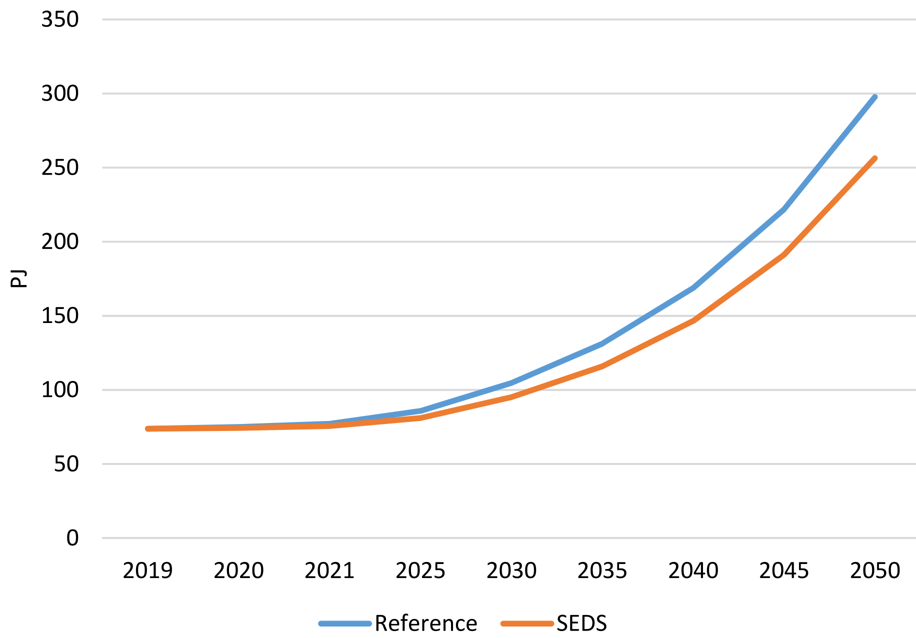


Figure 10.17: Total Final Energy Demand in Province 1

Per capita energy demand in **Figure 10.18** also shows similar pattern as above, but 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.

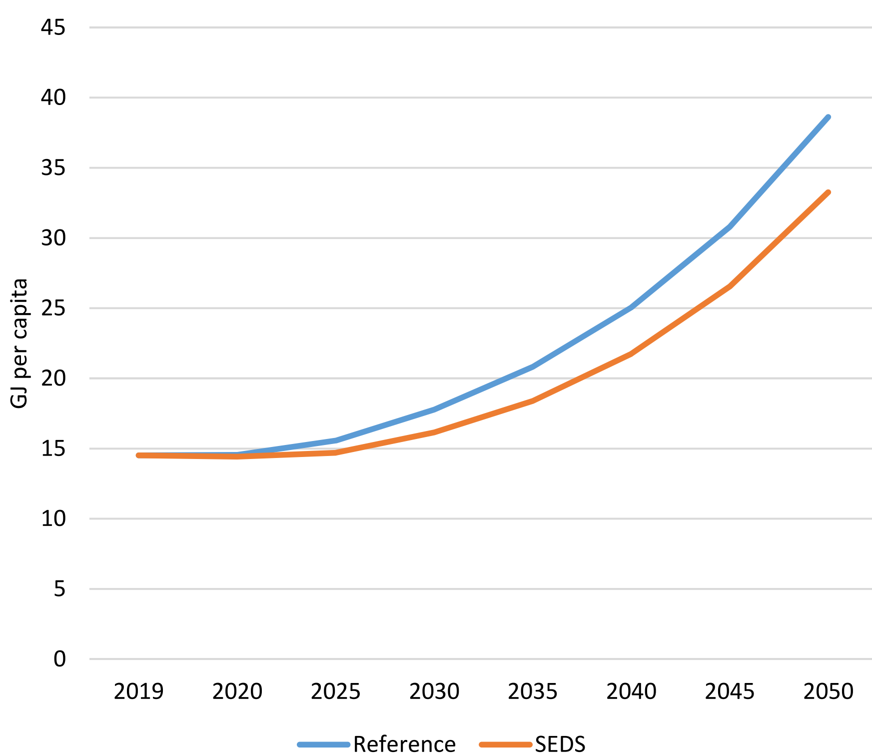


Figure 10.18: Final Energy Demand Per Capita in Province 1

Figure 10.19 depicts the electricity demand in compared scenarios which shows that in the SEDS, the household electricity demand reaches 2,100 kWh/HH indicating transition 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.

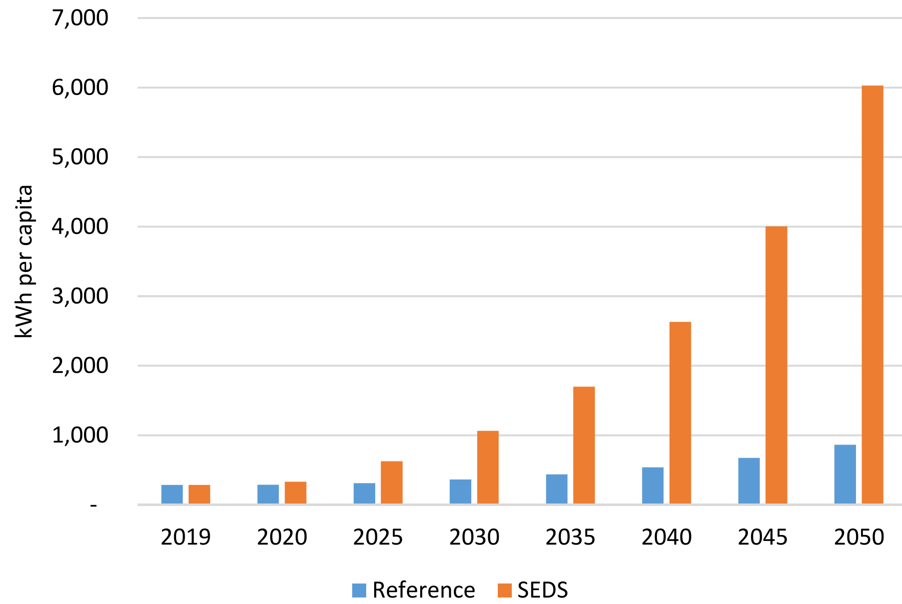


Figure 10.19: Electricity Demand Per Capita in Province 1

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 10.20. the share of clean renewable energy would increase from less than 10% in 2019 to more than 65% in 2050, provided that enough hydropower and power from solar PV are developed provincially and nationally.

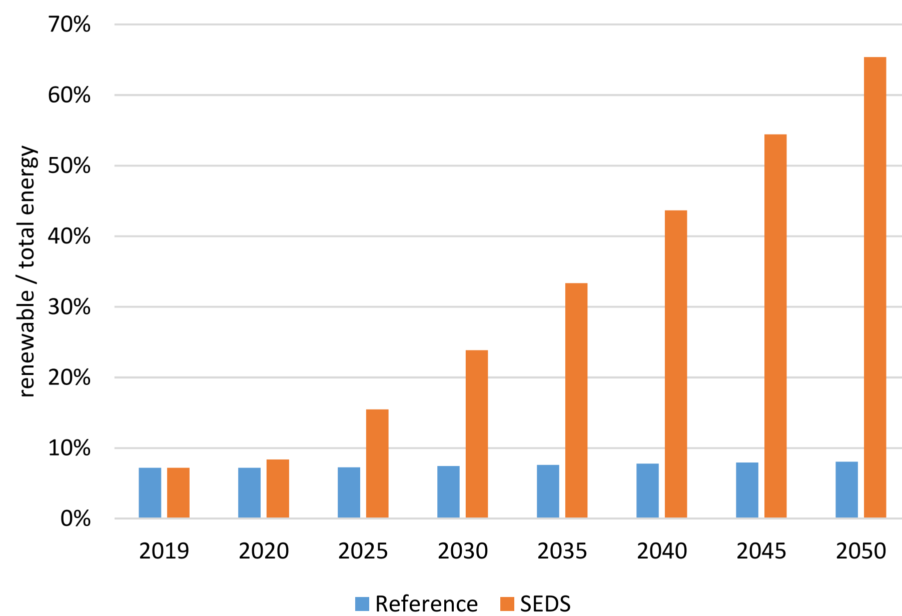


Figure 10.20: Renewable Energy to Total Energy Demand Ratio in Province 1

The effect of energy development and production from indigenous resources reduces the pressure on fuel dependency which is depicted in Figure 10.21. The net fuel import ratio of 58% in the Reference scenario would come down to 22% 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 1 and the country.

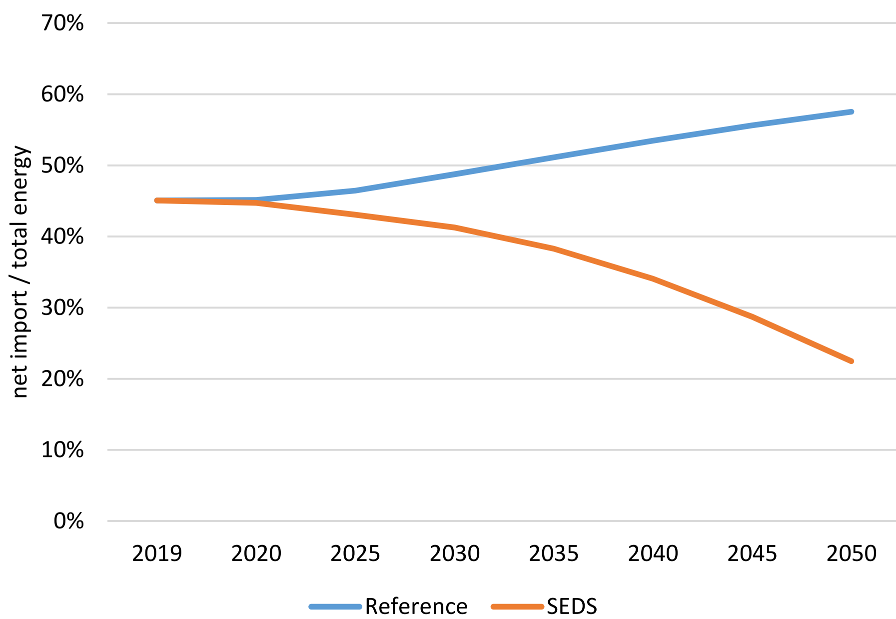


Figure 10.21: Petroleum Import to Total Energy Ratio in Province 1

Figure 10.22 shows the impact in GHG emissions dues to policy interventions of clean energy. Emissions which was growing at the rate of 5.4% in the Reference Economic Growth Scenario would increase at the rate of only 1.7% resulting in the GHG emission reduction of 24% in year 2030 and up to 67% 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.

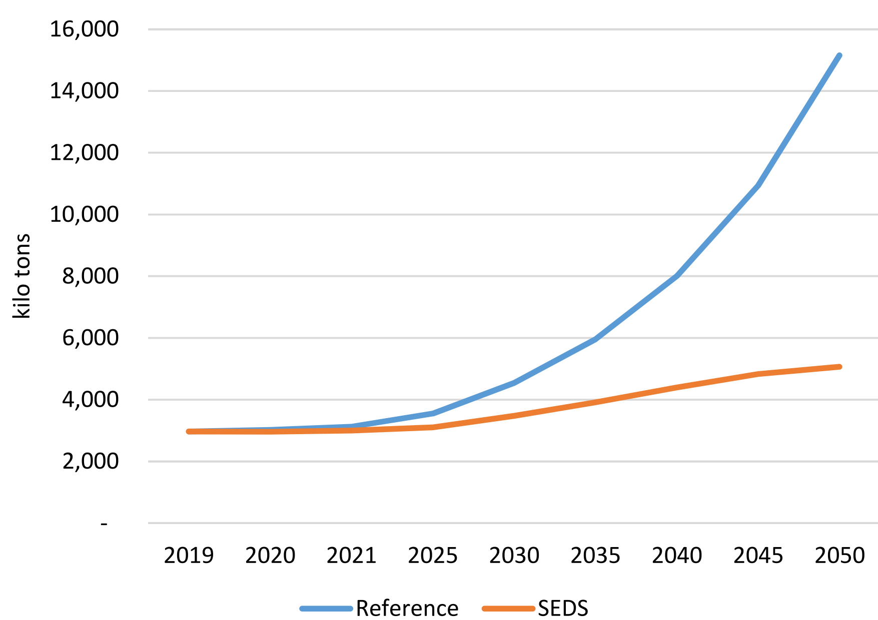


Figure 10.22: GHG Emission in Province 1

To meet the larger share of the energy requirements in the SEDS and to achieve the development goals described above, the development of hydropower plants is essential. With respect to reference case, the hydro power plant capacity requirement in the SEDS would be 90% more in 2030 and up to 170% additional power plant capacity is required in 2050 as shown in **Figure 10.23.**

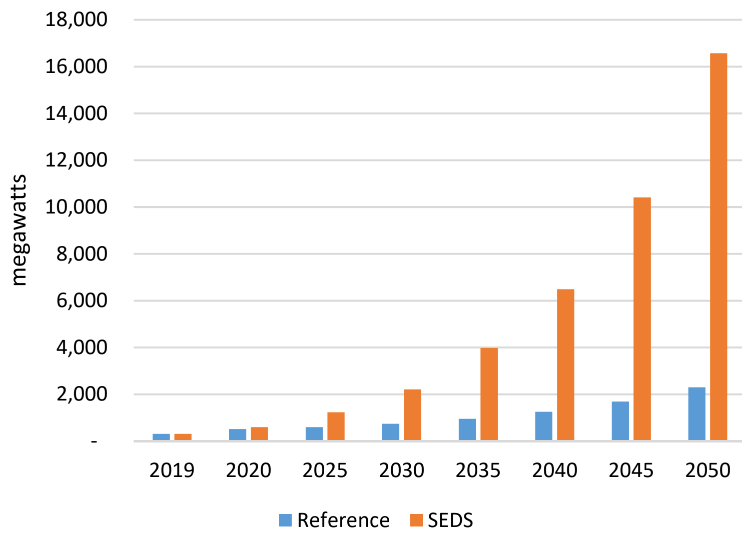


Figure 10.23: Hydro Power Plant Capacity Requirement in Province 1

11 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 1. Table 6-1 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 the reference scenario.

11.1 Capital Investment

In the REF scenario, the gross investment share in supply technologies is around 3 % 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 1% of GDP to 9% by 2030 and 17.6% 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. These figures can be accounted for the large-scale investment required in the hydropower development and industrial capital costs (Table 11.1).

In the case of Province 1, which have huge resources and feasibility for development of hydropower plants, the province needs to invest on hydropower development. Thus, the capital investment as given in Table 11.1, would be required to develop the power plants in the province. In addition to this, the province can build up solar power plants (off grid and utility) within the region for daytime supply at peak solar insolation hours of the day.

Table 11.1: Total Technology Cost for different scenarios

	2020	2025	2030	2035	2040	2045	2050
REF	10.82	16.03	24.26	34.55	48.08	66.26	92.22
Capital Investment as % of GDP	2.19%	2.68%	3.02%	3.14%	3.13%	3.06%	2.99%
SEDS	13.53	35.59	70.77	124.17	207.31	337.27	542.45
Capital Investment as % of GDP	2.75%	5.95%	8.81%	11.27%	13.49%	15.57%	17.62%

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.

11.2 The Marginal Abatement Cost

GHG emissions for reference scenario and SEDS scenario is shown in Figure 11.1. 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 23%, and 66% in 2050. This considerable reduction of GHG emission accounts to efficient and modern technology.

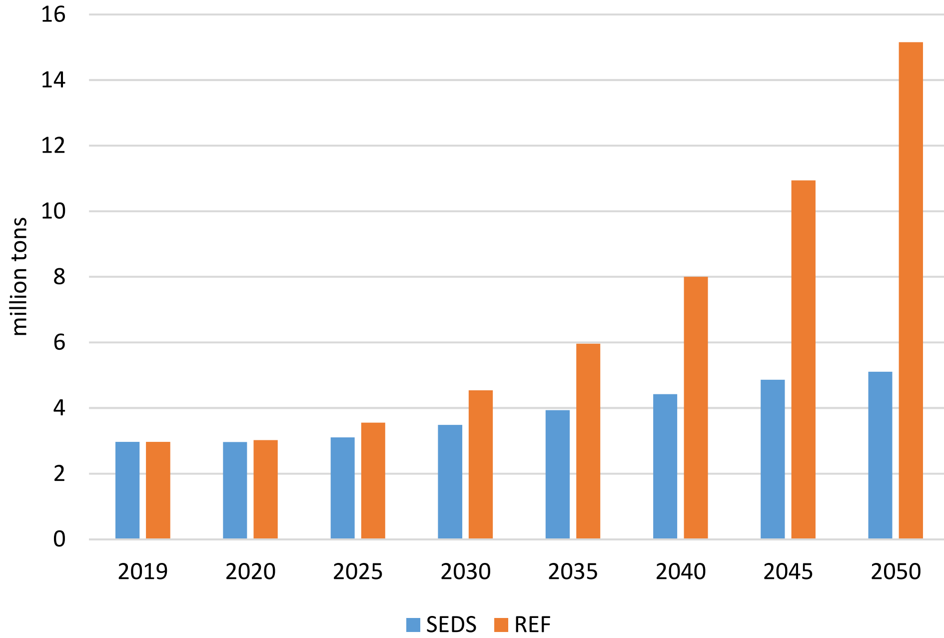


Figure 11.1: GHG Emission for Different Scenarios

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 11.2 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 11.2: MAC ("000 NRs. Per tons of CO2e)

	2020	2025	2030	2035	2040	2045	2050
Incremental Investments	2.72	19.55	46.51	89.62	159.22	271.01	450.23
GHG abated	58.04	450.98	1,056	2,026	3,583	6,073	10,052
MAC ('000 NPR/ton of CO2e)	46.83	43.36	44.04	44.25	44.44	44.62	44.79

11.3 Net Fuel Import Cost

Figure 11.2 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 23 billion NRs in 2030 and 417 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 33% investment required in 2030 for clean power plant development, while in 2050 the saving can contribute nearly 77% of the investment required. This indicates significant reduction in dependency on imported fuel. 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.

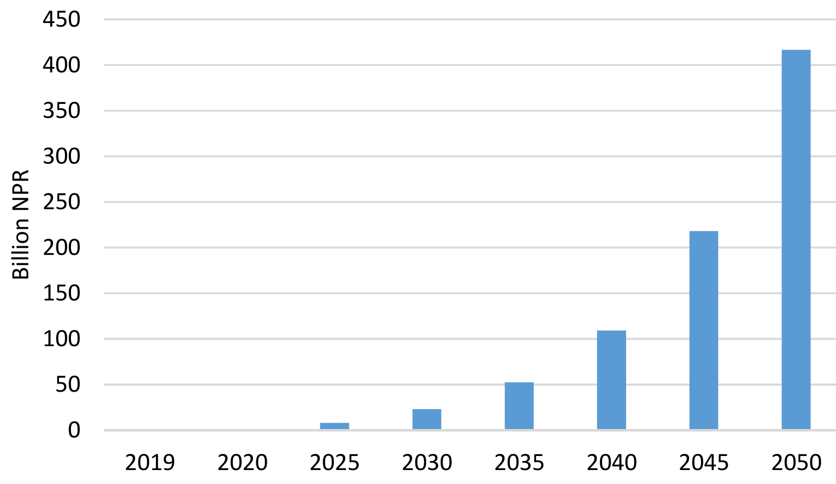


Figure 11.2: Net Fuel Import Cost Savings

11.4 Carbon trading

In addition to savings form import of fuel and the value addition to national economy by trading of electricity produced 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 11.3.

Table 11.3: Carbon Trading Benefits (billion Rs.)

	2020	2025	2030	2035	2040	2045	2050
Carbon trading benefits (billion Rs)	0.07	0.69	2.07	4.41	11.71	25.63	54.75

In the period 2020-2050, incremental supply costs are higher than the savings from fuel imports and carbon trading if the Province 1 makes investments in hydropower development. The benefits from net fuel savings and carbon trading will surpass the net supply investments in energy sector after 2050 onwards even if other environmental externalities and health benefits are not considered.

12 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.

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 firewood production in current status show potential production of 1,309 kilo tons in Province 1. 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 7,095TJ of energy from Biogas in Province 1 while the total potential energy produced from agricultural waste is 59,752TJ. Almost half of this energy comes from paddy straw, and about 38% comes from maize. As for the supply of petroleum products, the province depends entirely on the import of petroleum products. There was supply of 85million liters of gasoline, 254million liters of diesel, around 4million liters of kerosene and 82,176MT of LPG in Province 1 respectively. Meanwhile, the total sales of electricity in Province 1 is 1,011 GWh. In renewable energy sector, approximately 1,440kWp from SHS, 243kWp from SSHS, and 311kWpfrom ISPS have been installed in Province 1. Most of the biogas plants are sized 4 cubic meters in the province. There are 358 kW of micro-hydro plants installed in Province 1.

In year 2018/2019, it is seen that the total final energy demand of the Province 1 was 73,835 TJ which accounts for 14.5 GJ per capita. This energy demand per capita seems to be in line with the national averages from previous studies. The shares of energy consumptions in economic sectors of the Province 1 indicate some differences from the national level energy consumption pattern. Industrial sector is the most energy consuming sector with 45% of total energy consumption. However, different from the previous national average, the share of residential sector is about 41% while that of transport sector demand is 10% and commercial 3% respectively. This is primarily because Province 1 is an economic hub for industry. Thus, it is obvious that the demand for economic sectors would be higher. As for energy demand by fuel types, the use of biomass is still prevalent at around 48%. Petroleum products are 24% of the total energy consumed in the Province, and coal is 21% and new renewables including electricity is 7%.

As per ecological regions, Terai region has the highest consumption with 43% of the total consumption in the province, which is followed by hilly region at 41% and mountain region at 6% respectively. Hilly region consumes firewood significantly at almost 24% of the total energy consumed in the province, while fossil fuels and electricity consumptions in the Terai region are high with 24% of the total which is understandable with the concentration of industries in the region. Fossil fuel consumption in the mountain region is virtually non-significant. LPG consumption in Terai region is around 3% of the total, followed by 1.7% in the hilly region, respectively.

Yet, there is also difference in energy mix compared to the national mix due to reasons like 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 significant leap forward towards the renewable energy by intervention of solar water pumps. Industry has a large demand for electricity which would require dedicated large hydropower capacities as the country is expected to grow with higher demand for clean energy as per the government's plans and programs undertaken, even though there may be slight slowdown due to the aftermath of effect of COVID-19 for a short period. Post COVID-19, it is hoped that the country will take strong economic drive forward.

Therefore, the total energy demand in Province 1 shows an energy transition and a huge amount of energy being used for industrial sector. The impact of energy efficiency can be seen due to shift to modern form of energy and energy accessibility. However, there is still a huge potential of intervention of more energy efficient technologies along with inclusion of indigenous modern renewable clean energy technologies.

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 1 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 Reference Economic Growth Scenario, the total final energy demand reaches 105,000 TJ in 2030 increasing to 298,000 TJ in 2050 respectively. Similarly, in the Low Economic Growth Scenario, the total final energy demand attains 101,000 TJ in 2030 and it reaches to 252,000 TJ in 2050. In the context of High Economic Growth case, the final energy demand is expected to reach 106,000 TJ and reaching 329,000 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 95,000 TJ in 2030 and 256,000 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 65% in 2050 respectively. The power plant requirements reach 2,205 MW in 2030 and will be attaining 16,572 MW in 2050. In the SEDS, per capita electricity demand will reach 6,000 kWh in 2050 and the electricity demand per household reaches 2,100 kWh which is in transition 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 very high as a consequence, even in 2030, per capita electricity consumption will be 1,100 kWh which comes close to the target of 1,500 kWh per capita set by the National Planning Commission of Nepal in its roadmap for achieving SDGs in Nepal.

Comparative analysis of the SEDS with the Reference Scenario shows that energy demand in SEDS is reduced by 9% in 2030 and the reduction reaches 14% in 2050. In the SEDS, net fuel import ratio comes down to 22% compared to the Reference case of 58% in 2050 which no doubt indicates positive impact in the balance of payment condition and enhances energy security in the Province 1 and in the country. GHG emissions are reduced by 24% in 2030 – a reduction 1,100 ktons of CO2 equivalent from the value in the Reference Scenario. The reduction attains 67% in 2050 compared to the Reference case value of 15,200 ktons of CO_2 equivalent. Furthermore, energy intensity in the SEDS improves to 996 GJ/NRS millions of GDP in 2050, which is 45% less than the base year value of 1,825 GJ/NRS million GDP. GHG emissions per capita is 657 kg CO_2 equivalent in 2050 in the SEDS, whereas in the Reference Economic Growth Scenario GHG emissions per capita will be almost 2,000 kg/capita – a massive reduction of 65% in GHG emissions in 2050, which is in line with the low carbon emissions target of the international guidelines.

Overall, the energy consumption analysis in the base year 2019 and the policy measures taken in the future energy development in the Province 1 indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and integratedly, the sustainable energy development in the national context. This study also indicates that with the core focus on energy security, reliability, and sustainability, Province 1/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.

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.

CAAN, 2020a. *Domestic Hub.* [Online] Available at: http://caanepal.gov.np/aerodromes/domestic-hub/ [Accessed February 2020].

CAAN, 2020. *Domestic Airports.* [Online] Available at: http://caanepal.gov.np/aerodromes/domestic-airports [Accessed February 2020].

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. □□□□ □□□□□□□□ □□□□□□□□□□ □□ □□□□□□□□□□ □□□□□ □□□□□ □□□□/□□ □□□□ □□□□/□□, □□□□ □□□□□□ □□ □□□□□□□□. s.l.:District Forestry Office.

DFO Dhanusa, 2075. □□□□□ □□□□□□□□ □□□□□□□□□□ □□ □□□□□□□□□□ □□□□□ □□□□□ □□□□/□□ □□□□ □□□□/□□, □□□□□ □□□□□□ □□ □□□□□□□□. s.l.:District Forestry Office, Dhanusha.

DFO Parsa, 2069. □□□□□ □□□□□□□□ □□□□□□□□□□ □□ □□□□□□□□□□ □□□□□ □□□□□ □□□□/□□ □□□□ □□□□/□□, □□□□□ □□□□□□ □□ □□□□□□□□□. s.l.:District Forestry Office.

DFO Rauthat, 2074. □□□□□ □□□□□□□□ □□□□□□□□□□ □□ □□□□□□□□□□ □□□□□ □□□□□ □□□□/□□ □□□□ □□□□/□□, □□□□□ □□□□□□ □□ □□□□□□□□. s.l.:District Forestry Office.

DFO Saptari, 2075. □□□□□□ □□□□□□□□ □□□□□□□□□□ □□ □□□□□□□□□□ □□□□□ □□□□□ □□□□/□□ □□□□ □□□□/□□, □□□□□□ □□□□□□ □□ □□□□□□□□. s.l.:District Forestry Office.

DFO Siraha, 2075. □□□□□ □□□□□□□□ □□□□□□□□□□ □□ □□□□□□□□□□ □□□□□ □□□□□ □□□□/□□ □□□□ □□□□/□□, □□□□□ □□□□□□ □□ □□□□□□□□. 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.

Kandel, K., 2018. *A Comprehensive Study of Hydropower Potential of Nepal.* Kathmandu: s.n.

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.

NPC, 2018. *Universalizing Clean Energy in Nepal: Sustainable Distributed Generation and Grid Access to All (SUDIGGAA) by 2022,* Kathmandu, Nepal: National Planning Commission, Government of Nepal.

NRB, 2018. *Economic, social and financial status of Nepal 2075,* s.l.: Nepal Rastra Bank.

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, 2000. *Detailed Energy Consumption Survey in Trasport Sector of Nepal,* Kathmandu, Nepal: Water and Energy Commission Secreteriate.

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. *National Survey of Energy Consumption and Supply Situation in Nepal,* Kathmandu, Nepal: Water and Energy Commission Secretariate.

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

World Bank/ESMAP, 2015. *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.