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Water and Energy Commission Secretariat
Singha Durbar, Kathmandu
Nepal

Final Report
(Lumbini Province)

Energy Consumption and Supply Situation in Federal System of Nepal (Gandaki, Lumbini, Karnali and Sudurpashchim Province)

April 2024

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Acronyms

AEPC	Alternative Energy Promotion Center
ATF	Aviation Turbine Fuel
CBD	Convention on Biological Diversity
CBS	Central Bureau of Statistics
CCDR	Country Climate Development Report
DoF	Department of Forest
EoI	Embassy of India, Kathmandu, Nepal
FRA/DFRS	Forest Resource Assessment/ Department of Forest and Research and Survey
FEC	Final Energy Consumption
FY	Fiscal Year
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GJ	Giga Joule
GRID	Green Resilient Inclusive Development
GVA	Gross Value Added
HH	Household
HIH	High Economic Growth (Scenario)
ICS	(Mud) Improved Cook Stoves
INPS	Integrated Nepal Power System
IEA	International Energy Agency
IEA – ETSAP	International Energy Agency – Energy Technology Systems Assistance Program
IRENA	International Renewable Energy Agency
ISPS	Institutional Solar Photovoltaic System
IWM	Improved Water Mill
kL	Kilo liter
kW	Kilowatt
kWh	Kilowatt hour
LCEDS	Low Carbon Economic Development Strategy
LOW	Low Economic Growth (Scenario)
LTS	Long Term Strategies
MHP	Micro Hydro Project

MICS	Metallic Improved Cook Stoves
MJ	Mega Joule
MoALD	Ministry of Agriculture and Livestock Development
MOEWRI	Ministry for Energy, Water Resources, and Irrigation
MoF	Ministry of Finance
MOPE	Ministry of Population and Environment
MSW	Municipal Solid Waste
MT	metric tons
MW	Mega Watt
NACEUN	National Association of Community Electricity Users-Nepal
NDC	Nationally Determined Contributions
NEA	Nepal Electricity Authority
NECC	National Electric Cooking Campaign
NOC	Nepal Oil Corporation
NPC	National Planning Commission
NRB	Nepal Rastra Bank
NSIC	National Standard Industrial Classification
NSO	National Statistical Office
NPHC	National Population and Household Census
ODK	Open Data Kit
PSF	Primary Solid Biomass Fuels
PSU	Primary Sample Unit
REF	Reference Economic Growth (Scenario)
RET	Renewable Energy Technologies
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy for All
SEDS	Sustainable Energy Development Scenario
SHS	Solar Home System
SPVPS	Solar Photo Voltaic Pumping System
SREP	Scaling Up Renewable Energy Program
TJ	Tera Joule
ToE	Tons of Oil Equivalent
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme

UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
W2E	Waste to energy
WB	World Bank
WECS	Water and Energy Commission Secretariat
YOY	Year -Over -Year

Executive Summary

Global and National Energy Review

Energy is an essential requirement for any economy and the sustenance of its people. Developments in society and energy systems have a strong correlation in effect and influence. More than 2/3rd of global CO_2emissions is emitted from the energy sector. The adverse impacts of climate change have become severe leading to a strong global commitment to curtail GHG emissions to limit temperature rises to 1.5 ^{0}C by the end of twenty first century. Hence, most countries are on the pathway to transition their energy systems to cleaner energy developed from renewable sources.

The global energy sector has been moving towards renewable energy at a faster pace than ever. After the COVID - 19 pandemic and energy crises due to conflicts in some geographical regions, energy production from renewables is strongly moving forward. Renewable sources of energy such as wind and solar PV continued to grow rapidly, and electric vehicles set new sales records. World Energy Outlook 2023 (IEA, 2023) indicates that fossil fuel prices have declined from their 2022 peaks, but markets are tense and volatile due to continued fighting in Ukraine and escalation of new war in the Middle East. The global average surface temperature is already around 1.2^{0}C above pre-industrial levels causing wild forest fires, floods, rise in sea levels, heatwaves, and glacial flash floods across the globe. The energy sector accounts for the primary reason for the polluted air that more than 90% of the global population is forced to breathe, which causes more than 6 million premature deaths in the world. Against these climate - related catastrophic events and anthropogenic causes, the growing emergence of clean energy economy, bolstered by solar and electric vehicles, provides a strong hope for the way forward.

The 2022 edition of Tracking SDG 7: The Energy Progress Report highlights that at today's rate of energy access, the world is still not on track to achieve SDG 7 goals by 2030. The global electricity access rate increased remarkably between 2010 and 2020 – from 83% to 91% of the population. The number of unserved people declined from 1.2 billion in 2010 to 733 million in 2020. In the context of universal access to clean cooking, more than 65 countries have already included household or clean cooking-related goals in their NDCs, but population growth outpaced the technology and policy improvements. The number of people lacking access to clean cooking has dropped from 3 billion in 2010 to 2.4 billion in 2020. There are remarkable improvements in clean cooking access in Asian countries but in Sub-Sahara Africa, the access deficit to clean cooking rose by 50% since 2000, reaching 923 million people in 2020. There is still a strong hope and with the concerted efforts from the developed and the developing countries, the goals of Paris Agreement can be achieved through energy transitions to clean energy sources. As per the recent IEA's 2023 update on the roadmap for NZE by 2050, ramping up renewables, improving energy efficiency, and increasing electrification with technologies available today can deliver more than 80% reduction of emissions by 2030.

As per the Energy Synopsis Report of Nepal, Nepal's final energy consumption stands at 640 PJ in 2022out of which tradition biomass occupies 64%, commercial energy carriers occupy 28%, grid electricity 5% and renewables around 2.5% respectively (WECS 2023). Nepal's Second NDC and the Long-Term Strategies follow the Paris Agreement of 2015, the SDG7 and other goals, and the SE4ALL program targets 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. Solar home systems are taking a strong foothold in Nepal with the reduction of their global price per unit as well as readily available technology. However, the scope of solar energy is still limited to lighting. SDG7 targets set by the NPC in its roadmap to achieve SDGs by 2030 mention that 99% HHs will have access to electricity, shifting the use of fuelwood, and limiting the use of LPG by 2030. It requires an installed capacity of 15,000 MW by 2030. To fulfill the target the government has already started its strategic action plan focusing on the development of the energy and power sector. Nepal has prepared the implementation plan for the Second NDC to achieve the goals of hydropower development, energy access, and clean cooking. Nepal has also submitted the Long-term Strategy for Net-Zero Emissions by 2045 to the UNFCCC in 2021 before COP26 and the Nepal Government has reemphasized the pledge in 2023 at the UN as the Head of the Least-Developed Countries (LDCs).

Objective and Scope of Study

Objectives

The main objective of this study is to find the existing situation of energy consumption and supply situation of the energy resources of Gandaki, Lumbini, Karnali and Sudurpashchim Provinces as well as to forecast energy demand up to 2050 A.D. at different growth rates of techno-socio-economic parameters based on consultation with National Planning Commission (NPC). The outcomes of this study is presented in three physiographic regions (Hills, Mountains, and Terai). Following are the specific objectives of the survey work in each province:

- To determine the present status of energy consumption of all districts and supply situation in provincial level of economic sectors namely residential/domestic, industrial, transport, commercial/business, agricultural, construction and mining industries of each province including data analysis and presentation based on different physiographic regions.
- To prepare energy flow diagram (Sankey chart).
- To estimate the energy supply and demand of all type of energy up to 2050 AD at 5 years interval in all economic sectors (Residential, Industrial, Commercial, Transport, Agriculture, Construction and Mining sectors) of each Province at different physiographic regions and with different growth scenarios.
- Potential of all type of energy resources of each Province is identified on the basis of available secondary data/information.
- Prepare the most appropriate and relevant models for energy demand forecast.
- To identify the costs of all energy resources in each economic sector in each sample unit.
- To analyze and report per capita and per economic sector energy consumption for different economic sectors and physiographic regions based on different growth rates.

Scope of the Study

The scope of the work, but not limited to, was the following:

- Before conducting the survey on energy consumption, supply situation and demand projection, the existing plans, policies, rules, regulations, and guidelines related to energy were reviewed.
- Primary data was collected at physical and local unit (eg. bhari) at first and then converted into standard gigajoules (GJ) and Ton of Oil Equivalent (ToE) unit later during analysis.

- Methodology of energy demand analysis for each economic sector was developed by the consultant and was implemented after approval from the WECS.
- Total and Specific energy consumption of all districts of each province in all economic sectors by each fuel type, end uses, and energy technologies/devices used were provided.
- Energy supply and demand of each Province at different physiographic regions and with different growth scenarios in all economic sectors were determined.
- The potential of all type of energy resources of each province was determined based on the available secondary data/information.
- The study was carried out for all districts of each province including three physiographic regions (Hill, Mountain and Terai) for the sample survey.
- Major statistical information of the energy consumption in each economic sector at district and provincial level was assessed during the survey. Especially the average energy consumption, standard deviation/variation, coefficient of variation, standard error of the mean was found out for each type/form of energy consumption in all sectors as well as total energy consumption of the sectors.
- After collection and compilation of all the data, energy supply and demand of each province at different physiographic regions (Hill, Mountain and Terai) for all economic sectors and with different growth scenarios up to 2050 AD were forecasted by using freely available software/model
- All the energy resources available and used in the country were considered while surveying the energy consumption, demand, and supply status. All the energy resources used in all economic sectors for all purposes and end uses by all devices were identified during the survey.
- For determination of sample size, all existing data of each economic sector was collected from the latest reports of concerned authorities.
- A detailed survey questionnaire for each economic sector was prepared separately by the consultant and sample survey was carried out only after the questionnaire has been approved by the WECS. The questionnaire would also address the peak and the off-peak time of energy consumption.
- Before conducting the Energy Consumption, Supply and Demand survey, a training program for the enumerators, field supervisors and WECS staffs was organized.
- A letter certifying the work carried out from the concerned surveyed commercial, industrial, agricultural and construction and mining company/institution/firm etc. was submitted to the WECS along with the survey report based on the supply of these letters from the concerned organizations. The official authenticated letter included the name and contact number of the concerned person of the concerned institution shall be submitted to WECS after completion of the field work in Field/Interim report.

Lumbini Province

Lumbini Province shares an international border with India only in the south. Stretching from east to west, it borders Gandaki and Karnali Provinces to the north, Sudurpashchim Province to the west, and Uttar Province and Bihar states of India to the south. The province extends 150 km north to south and about 300 km east to west at its maximum width. It shares 413.14 km of border with India. This province is the sixth largest province by area while it is the fourth most populous among the seven provinces. Deukhuri is taken as the provincial capital in October 2020, replacing Butwal as the provisional capital. The population size of the province was 5.12 million as per the census 2021 over its geographical area of 22,288 square kilometers. The province encompasses 12 districts and a total of 109 local government units, which include 4 sub-metropolitan cities, 32 urban municipalities and 73 rural municipalities.

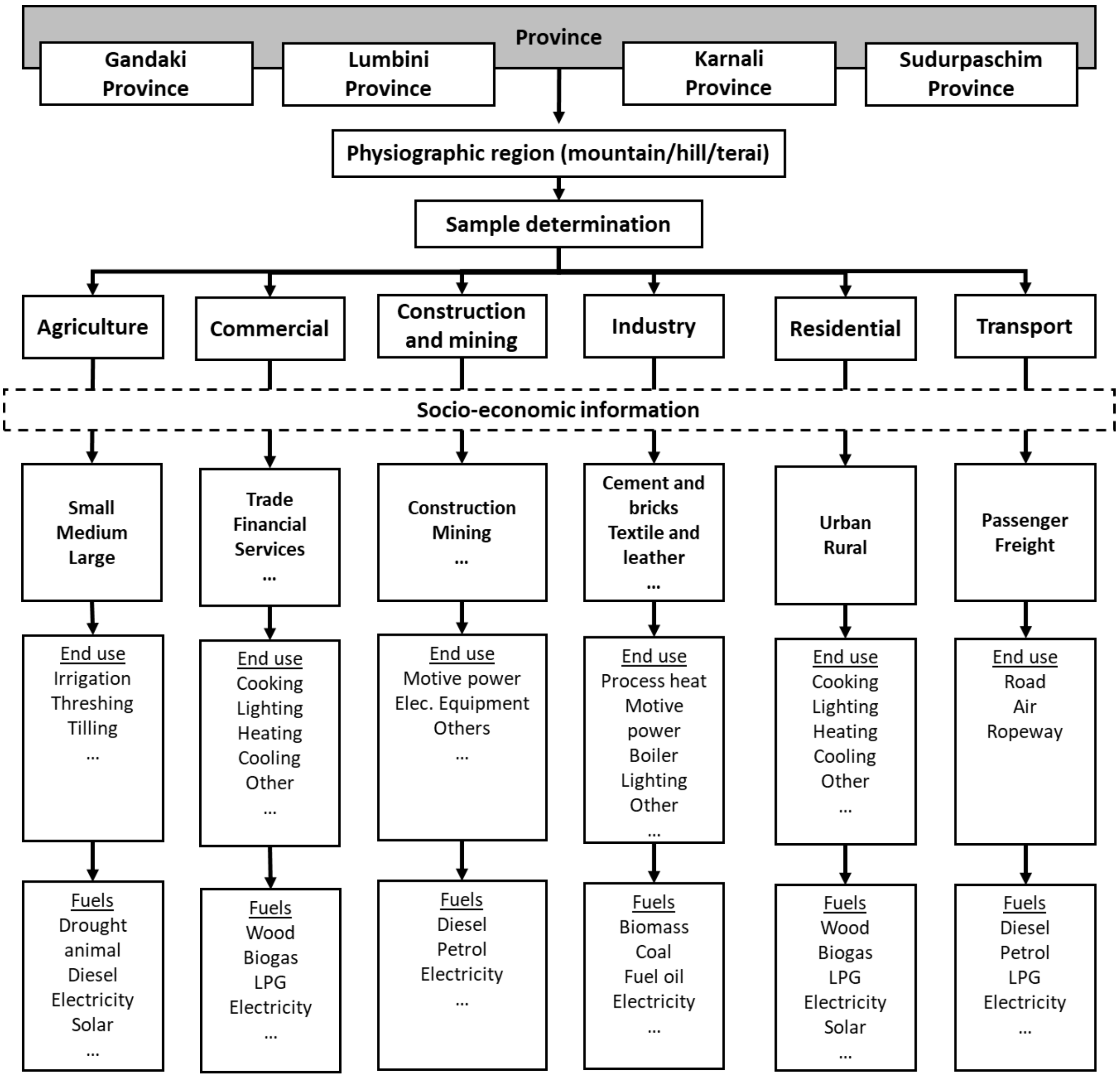
With five Terai districts, one Inner-TeraiTerai and 6 hill districts the province holds the potential for diversified agricultural production. The province has sizable arable land of good fertility and access to dependable irrigation. Out of 485,000 ha of agriculture land in the province, around 248,000 ha is irrigated. Similarly, there are various irrigation projects under construction, namely, the Bheri-Babai diversion, Babai Irrigation, and Sikta Irrigation Projects, and their completion will greatly expand the irrigation coverage in the province.

So far administrative and population situations are concerned, Lumbini Province covers 11.8% of the total area with 109 local levels. Local road network in this province has extended till now to 9,139 KM (14.1% of the national road network). The number of schools is 5,622 (16.4% of the national total). Rs. 171.1 billion has been invested in 94,138 industries in the province.

Methodology for Study

The methodological approach was conducted, systematically identifying the steps in collection, analysis, and synthesis of information from different sources. The basic disaggregation for the sample survey is bottom up for every sector for energy as well as socio- economic information. The categorization followed a framework like given in Box 1 for Lumbini Province. The survey covers all the economic sectors in the province – which are further disaggregated as per National Standard Industrial Classification so that all the sectors and subsectors are captured. In addition, all possible types of end-uses in each sector are considered for energy used in each form. The details of the categorization are given in the next section.

BOX 1: ENERGY SECTOR STRUCTURE



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 a sample survey of all the economic sectors of Lumbini Province.

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

The census population has been used to determine the sample size for survey in each economic sector. The questionnaire survey has been carried out in this province, using the approved survey design. It is focused on identifying occupants and building information, device and occupant behaviors, and their energy consumption based on the geographical and ecological division of the province.

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.

The energy system analysis was done from the bottom-up approach, i.e., all possible energy activities were considered at the end-use level for each sector. The base year was taken as 2022 for energy demand analysis. From here, energy scenarios have been developed until 2050, andshort term, medium term, and long-term targets have been devised. The initial data collected from the survey has 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, Model for Analysis of Energy Demand (MAED) is used for energy demand projection. Secondly the TIMES model has been used, that includes demand projection as well as the supply and emission analysis.

Energy Supply Situation in Lumbini Province

Lumbini Province of Nepal is blessed by nature with lots of forests in terai, dun valleys like Dang, mid-hills, and high hills. As compared to other provinces of Nepal, this province has more forest area per person. In addition, there is good sunlight, enough water in the watersheds of many small rivers, which originate in the province, and alluvial soils. Although deforested to some level, there are still very good forests in the province. But urbanization and agriculture have impacted good forests, and some of the good forests are changed into non-forests, especially in the Dang and terai districts. Similarly, human pressure for fuelwood in the past changed the forests into degraded ones. But, due to the better conditions for plant growth and past interventions of community forestry, Lumbini Province still has good potential for forest management and production. Thus, annual fuelwood from the whole Lumbini Provincewas 1,562,753 m^3 (This is a harvestable quantity) in 2021. It comes to be around 1.44 million tons of fuelwood. The availability of animal dung in Lumbini Province is 11 million tons which can be used for biogas production and making animal dung cakes. There is a potential energy of 285 PJ from waste to energy in the province. The potential of agriculture residue for energy was 48 PJ in 2021

Petroleum Products

There is no source of feasible petroleum products anywhere in Nepal. All the petroleum products consumed in the country are imported from India. The only company that deals with import and sales of petroleum products – that include diesel, petrol, kerosene and LPG and others **(Table 1).**

Table 1. Petroleum sales in 2077-78 in Lumbini Province (NOC)

Districts	MS	Diesel	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Arghakhanchi	1,866	7,177	580	-	-
Banke	14,743	64,743	984	4,173	40,232
Bardiya	5,292	17,604	296	-	-
Dang	13,257	52,479	599	-	-
Gulmi	1,769	7,272	2,367	-	-
Kapilvastu	10,711	44,128	172	-	-
Parasi	17,617	69,455	105	-	-
Palpa	3,257	7,711	-	-	-
Pyuthan	1,202	5,318	-	-	-
Rolpa	785	4,568	-	-	-
Rupandehi	35,583	138,256	628	1,908	76,777
Total	**106,082**	**418,711**	**5,731**	**6,080**	**117,009**

(NOC 2022)

LPG sales could not be properly ascertained from the NOC database as the Product Delivery Orders (PDO) are obtained by the LPG bottling plants and distributed from the several private LPG sales depots and most of the time there are sales crisscrossing different districts.

Electricity Supply

The electricity supply status as obtained from Nepal Electricity Authority for Lumbini Province showed the total electricity consumption of 1487 GWh in 2020/21.Most of the electricity is consumed in the industry sector (49%) as large area of industrial belt lies in this province, followed by the residential and commercial sectors with 37% and 12% respectively and remaining in agriculture and transport sector (NEA, 2022). The independent power purchasers are actively working in the province which have already developed 15 MW of installed capacity and 7 MW under construction phase and 1.5 MW is in planning phase and NEA installed capacity is 1 MW in 2023 as per Department of Electricity Development (DoED, 2023).Among the districts, Rupandehi and Parasi have the highest consumption of electricity, as there are many industries established in these districts.Lumbini has 98% of households who have access to electricity.

Modern Renewables

Alternative Energy Promotion Centre (AEPC) has been promoting renewable energy technologies in Nepal with the objective to raise the living standard of the rural people and protect the environment. As of 2021, Lumbini Province is generating 2.9 MW of electricity from mini and micro hydro projects. Talking about the modern renewables AEPC has installed 272 nos. of improved water mills, 152,268 nos. of solar home system units, 359 nos. of institutional solar PV Systems generating 571.9kWp, 421 solar irrigation systems, and 37 solar water pumping systems have been installed which covers 2.4%, 19.1 %, 10.7 %, 19.2% and 19.8% of the total country installation respectively in 2021. Similarly, AEPC has promoted 1,612,934 cleaner and improved cooking technologies including domestic biogas, mud ICS and metallic ICS in Nepal. Out of the total, around 17.7% of the installation has been done in Lumbini Province, i.e., 67,622 Nos. of domestic biogas plants, 211,442 mud ICS and 6,926 metallic ICS respectively(AEPC, 2022).

Energy Consumption in 2022

The total final energy consumption (FEC) in Lumbini Province was found to be 77,259TJ. Among the six sectors, the residential sector is the highest energy-consuming sector followed by industries. The highest share of energy consumed, although is still biomass (42%), the lower share of it in final energy consumption, compared to other provinces, shows that the use of modern energy has been increasing. With the increase in demand for energy in industrial and other economic sectors, the consumption of commercial energy has increased significantly, especially petroleum products - taking a share of 40% in final energy consumption.

Figure 1 and Figure 2 show the energy consumption as per fuel mix and consumption in different economic sectors. In Lumbini Province, the use of fuelwood is still prevalent. But the use of fuelwood for thermal purposes has shifted. Hence the consumption of diesel, furnace oil, and coal for thermal use is seeing an increase. Due to higher demand for thermal purposes such as heating and cooking, and due to electrification, the share of electricity is slightly higher than the national average.

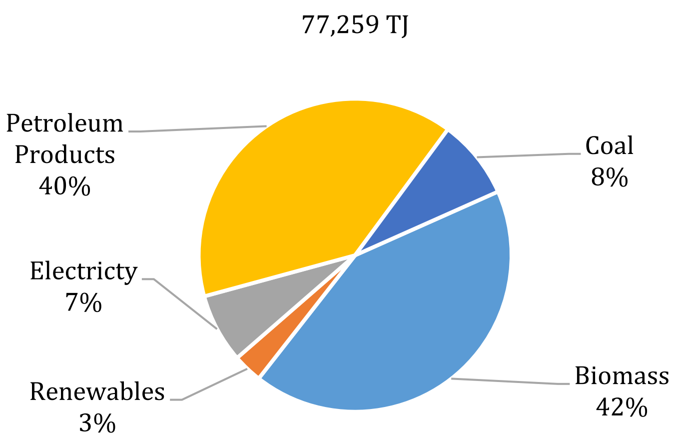


Figure 1. Energy Mix in Lumbini Province

Figure 2 also indicates the change in the consumption pattern in different economic sectors. With the residential and the industrial sectors being the highest energy-consuming sectors at 37%, the use of biomass and fossil fuels is prevalent in the energy mix. The transport sector is third at 8.79%. The agriculture and commercial sectors share the nearly same amount of energy. Thus, compared to other provinces, Lumbini also has significant agricultural activities and is more highly mechanized than in hilly regions.

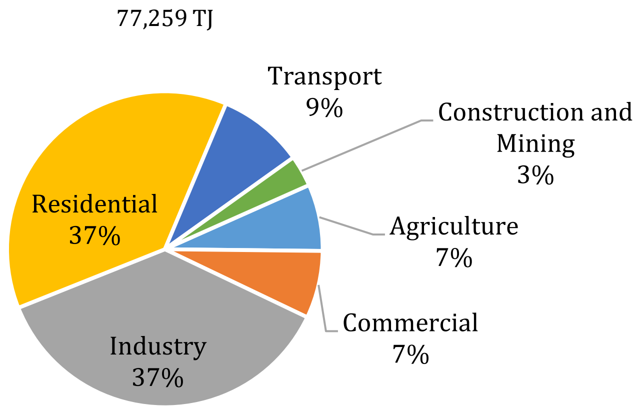


Figure 2. Sector-wise Energy in Lumbini Province

However, large amounts of agricultural residues are seen to be being used in industry for thermal purposes – mainly due to cheaper prices and local/regional availability. Due to the presence of larger industries in this province, the use of commercial energies like electricity and petroleum products is highest in the industrial sector. In addition to that, the industry also uses diesel for electricity generation using diesel generators. Meanwhile, due to higher mechanization in the agricultural sector, the use of diesel for agriculture is also significant in the Lumbini Province.

The Sankey diagram depicted in **Figure 3** visually illustrates the energy distribution from sources to consumption in the year 2022. It is clear from the diagram that most of the energy supply originates from biomass sources, including fuelwood, agricultural products, and animal waste. A significant portion of this biomass energy is directed towards the residential sector, with the industrial sector also receiving a substantial share. On the consumption side, the industrial sector stands out as the largest consumer of energy, whereas the agricultural sector appears to primarily rely on non-mechanical sources of power, such as animal and human labor.

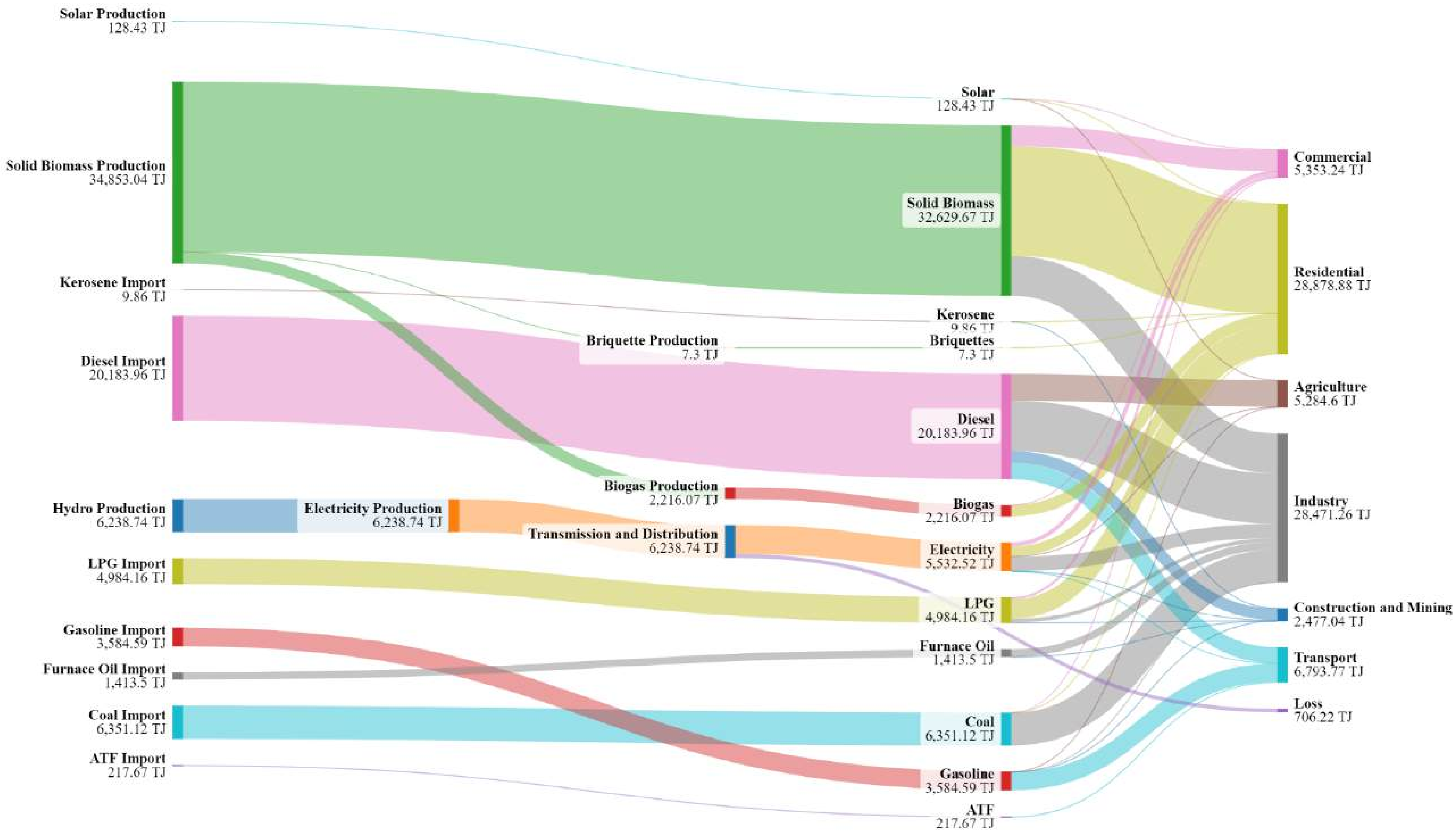


Figure 3. Sankey Diagram for Flow of Energy in Lumbini Province

Energy Scenario Analysis

A large-scale bottom-up partial-optimization modelling framework developed collaboratively by IEA-ETSAP program is used for energy scenario development in Nepal, based on the energy demand projections from the MAED model. It allows for a unique set of analytical capacities in energy markets, technology trends, policy strategies and investments across the energy sector that would be critical to achieve sustainable energy development and climate goals in the provinces of Nepal. It covers all sectors across the energy system with dedicated bottom-up modelling.

Further, this Integrated Energy – Economy - Climate (IEEC) Model is designed to analyze a diverse range of aspects of the energy system. The IEEC model uses a scenario approach to examine future energy trends. The IEEC Model is used to explore various scenarios, each of which is built on a different set of underlying assumptions about how the energy system might respond to the current global energy crisis and evolve thereafter based on the national energy and climate -related plans and programs, and Nepal's commitment and pledges to the international energy and climate related programs. Four different sets of possible future energy demand have considered for analysis such as Reference Economic Growth (REF) scenario at 6.96% GDP growth rate, Low Economic Growth (LOW) scenario at 6.18% GDP growth rate, High Economic Growth (HIH) scenario at 8.13% GDP growth rate, and a policy scenario – Sustainable Energy Development (SED) scenario. SED scenario is developed with policy intervention measures for attaining Nepal’s pledges to international programs such as SDGs, Paris Agreement, and other climate programs at the GDP growth rate same as the REF scenario. In the SED scenario, electrification, and use of carbon-neutral but domestically available fuels are emphasized in all economic sectors.

The final energy demand in the REF scenario is projected to grow from 77 PJ in 2022 to 309 PJ in 2050 – a demand increase of 400%. The share of solid biomass will decrease from 43% in 2022 to 33% of total final energy in 2050, whereas the share of petroleum products will slightly increase from 40% in 2022 to 43% in 2050. But, in absolute terms, demand for petroleum products will increase tremendously as a result of extensive use in industry sector. Electricity demand will increase to 13% of the total final energy demand in 2050 from 7% in 2022. Consequently, the installed powerplant capacity needs to increase to 5,604 MW in 2050 from 421 MW in 2022 in REF scenario.

The data presented in **Figure 4** clearly illustrates that in the absence of policies promoting clean and renewable energy sources, Koshi Province will continue to heavily rely on biomass energy sources. This scenario is anticipated to lead to a significant rise in the demand for fossil fuels by the year 2050. There are concerns regarding the sustainability of such a high demand for biomass energy, considering the available forest resources in Lumbini Province. Additionally, there is a question about whether province's economy can viably support the import of such substantial quantities of fossil fuels over the long term.

In the SED scenario with the various energy transition policy measures undertaken, the final energy demand in 2050 reaches 274 PJ. Solid biomass fuels will occupy 35% of the total final energy in 2050. Petroleum products will decline to 28% of the total final energy demand in 2050. But electricity is expected to reach 32% of the total energy due to energy transition measures- especially electrification in the economic sectors. The installed capacity of power plants required will be 11,530 MW in 2050. GDP energy intensity improves from 0.39 toe/US$1,000 in 2022 to 0.21 toe/US$1,000 in 2050. The current GDP energy intensity in the South Asia region is 0.3 toe/US$1,000, whereas in the emerging developing countries it is 0.28 toe/US$1,000. Due to energy transition envisaged in the SED scenario, GDP energy intensity has decreased by almost 50% by 2050 compared to 2022. Electricity intensity of GDP attains 6,165 kWh/ NR million in 2050 in the SED scenario, compared to 2,805 kWh/NR million in the REF scenario – electricity intensity increased by more than 2 times. It bodes well for the country from the angle of energy security and sustainability. GHG emissions per capita will decrease to 923 kg in 2050 in the SED scenario, which will be 1,781 kg in the REF scenario. Per capita GHG emissions are also decreased by 50% in the SED scenario.

The Sankey diagram depicted in **Figure 5** illustrates a significant reduction in reliance on solid biomass and the minimal importation of fossil fuels by 2050, as demonstrated in the SED Scenario. Nepal's electricity generation has transitioned to cleaner, renewable sources, thereby bolstering energy security and sustainability within the province.

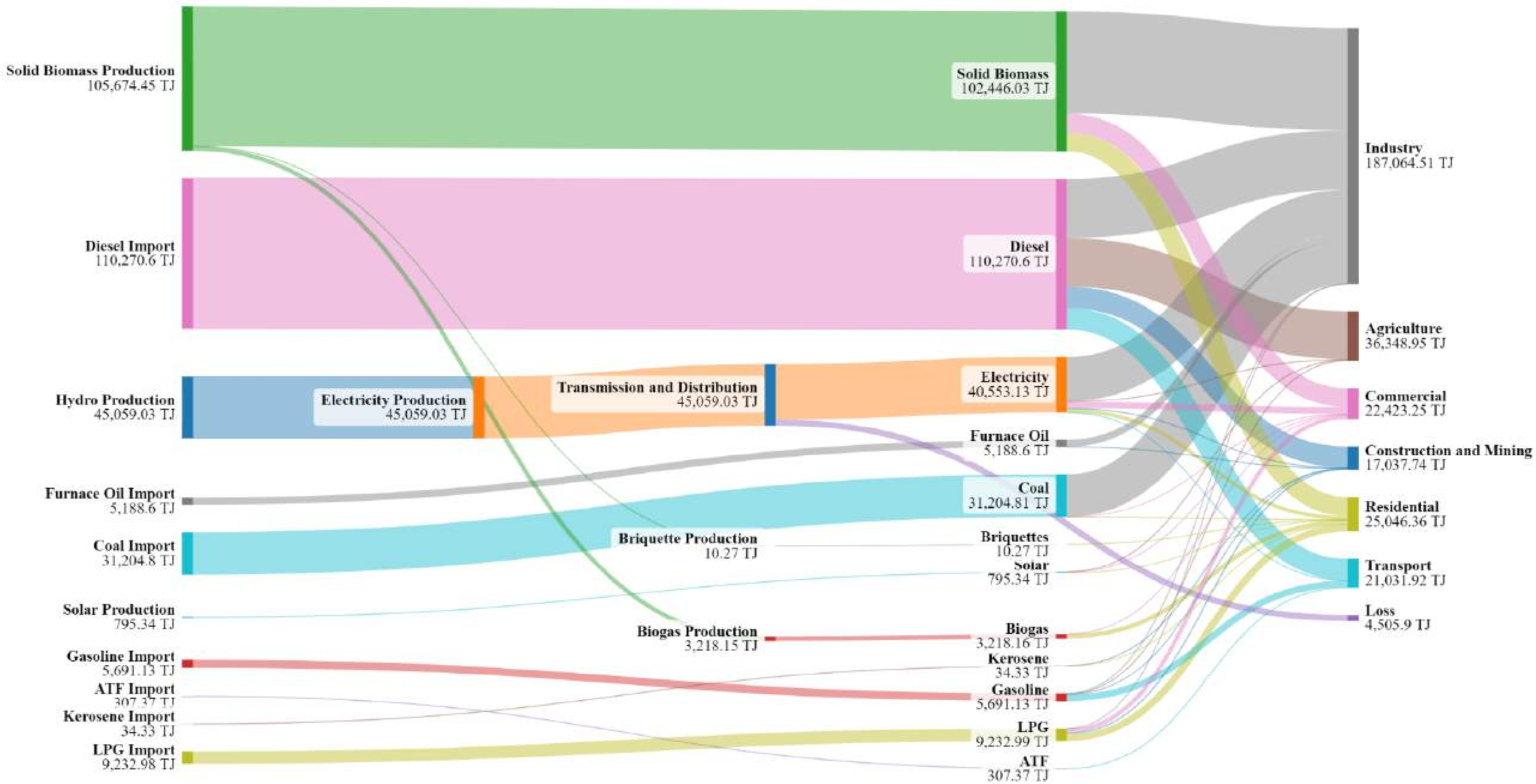


Figure 4. Sankey Diagram for Flow of Energy in Lumbini Province for the Reference Economic Growth Scenario in 2050 (PJ)

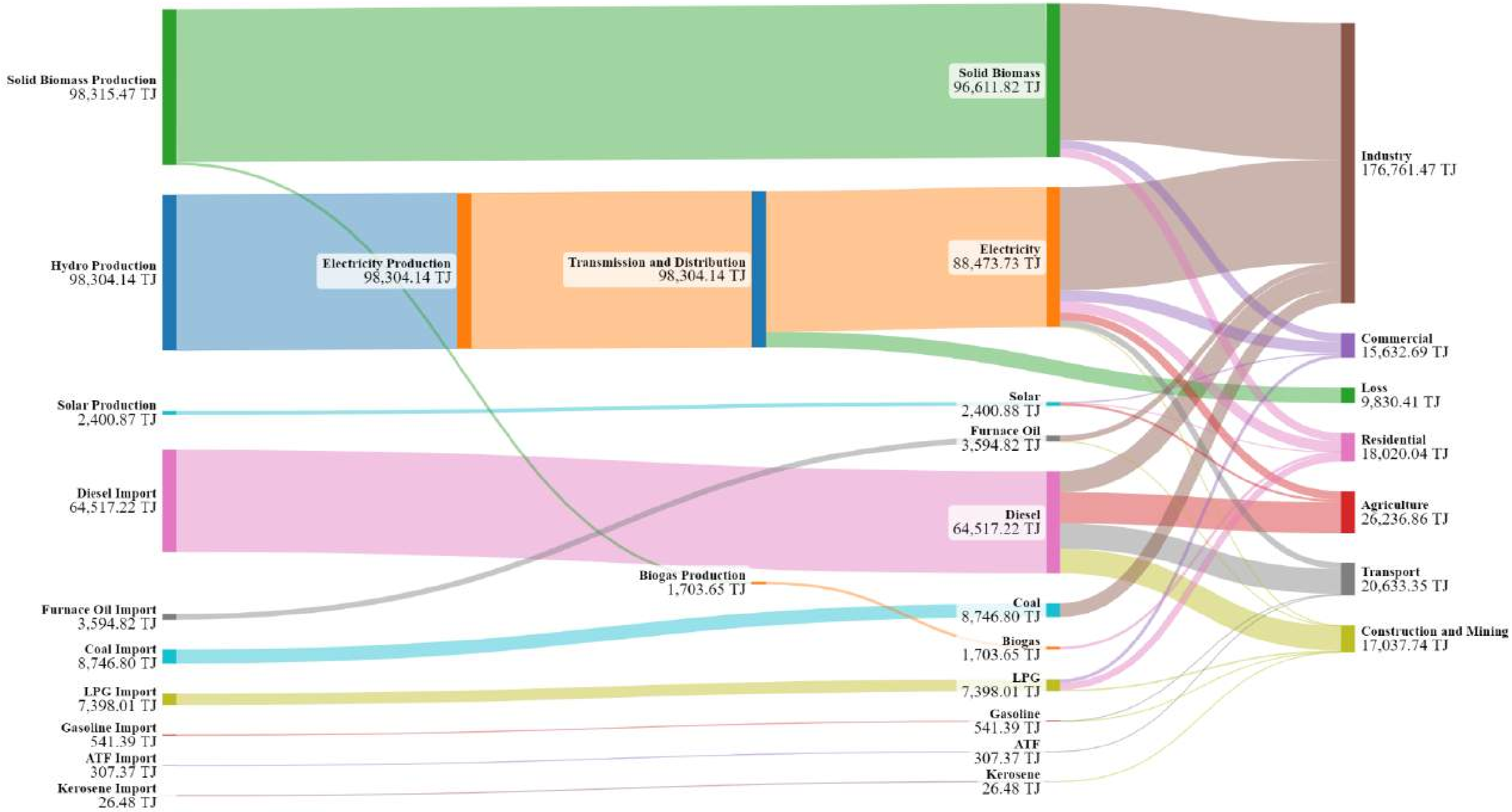


Figure 5. Sankey Diagram for Flow of Energy in Lumbini Province for the Sustainable Energy Development Scenario in 2050 (PJ)

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Lumbini Province indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and the sustainable energy development in the national context. This study also indicates that with the core focus on energy security, reliability, and sustainability, Lumbini Province/Nepal's energy development should be geared towards 5 energy transition 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.

1. Introduction

1.1. Background

Energy is the backbone of livelihood and the economy. Developments in society influence the energy systems in many ways, but, on the other hand, the energy systems have a strong effect on the development of society. The transformative change creating our present energy systems was the Industrial Revolution, first occurring around 1750 in England. Though fossil fuels were known before this time, the scale of their use massively increased in the nineteenth century. Before 1900 fuelwood remained the most important energy source – profusely used in cooking, which was paramount for subsistence of society. Around 1900, two major developments occurred – introduction of electricity supply through electricity grids and power plants fired by coal, oil and based on hydropower(Blok et al., 2021).In recent years, the adverse impacts of climate change havebecome severe and there is a strong commitment of nations to curtail GHG emissions to limit temperature rises to 1.5^0Cby the end of twenty first century.Hence, most of the countries are on the pathway to transition their energy systems to clean energy developed from renewable sources.

Water & Energy Commission Secretariat (WECS) has been the national government authority to collect, compile, and publish energy databases. The organization 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. The 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. The Agricultural Sector Energy consumption survey was also completed in 2000/01. Based on these primary surveys of the energy consumption-supply situation, WECS published the Energy Sector synopsis report regularly. Energy Consumption and Supply Situation of Nepal, 2011/12 is the latest national energy survey carried out by WECS.

With the country entering the federal system in 2015, the country has been administratively divided into 7 provinces. Following federalism, the WECS also initiated collecting data on energy consumption, and supply and is in the process of projecting energy demand for each province. For this purpose, WECS has already completed the project “Energy Consumption and Supply Situation in Federal System of Nepal (Koshi, Madhesh and Bagmati Provinces). The main objective of this project is to develop a database on Energy consumption, energy supply, and energy consumption of the remaining four provinces viz – Gandaki, Lumbini, Karnali, and Sudurpashchim Provinces. This study pertains to the energy consumption and supply situation of the Lumbini Province.

The current study at the provincial levels conducted by the WECS is very timely and appropriate as it provides many policy/planning inputs in the sustainable energy development at the local, provincial and the national levels as the whole world is undergoing an energy transition to clean energy based on renewable sources.

1.2. Global Outlook

The world saw a global pandemic at the end of 2019. As a result, global energy consumption declined sharply. In the wake after the COVID-19 pandemic, energy production from renewables took a leap forward. Renewable sources of energy such as wind and solar PV continued to grow rapidly, and electric vehicles set new sales records (IEA, 2021). The World Energy Outlook 2021 points out that the new energy economy will be more electrified, efficient, interconnected, and clean. However, the report also suggests that the speed of change in energy can be countered by another showing the stubbornness of the status quo – the main reason being uneven economic recovery from last year's Covid-induced recession. Besides, events of recent years have accentuated the cost to the global economy of an energy system highly dependent on fossil fuels. Oil, gas, and coal prices have soared to new highs due to global disturbances which has much more adverse impacts on oil importing developing countries like Nepal (IRENA, 2022). Current escalation of conflict in the Eastern Europe in the fourth quarter of 2022 drastically curtailed oil and gas deliveries from Russia to western Europe, China, and India, creating structural uncertainty in the petroleum and coal markets (IEA, 2022). As such, oil importing countries like Nepal which depends even on import of electricity from neighboring country in dry season are at a very precarious situation since most of the power plant in India and other countries are based on fossil fuels. These events forebode catastrophe in the world unless nations engage in accelerated energy transitional efforts to clean energy from renewable sources.

The 2022 edition of Tracking SDG 7: The Energy Progress Report highlights that at today's rate of energy access, the world is still not on track to achieve SDG 7 goals by 2030. There are remarkable signs of progress, but the pace is hampered by many troublesome events related to the health pandemic and geo-political issues in the world. The global electricity access rate increased remarkably between 2010 and 2020 – from 83% to 91% of the population. The number of unserved people declined from 1.2 billion in 2010 to 733 million in 2020. In the context of universal access to clean cooking, more than 65 countries have already included household or clean cooking-related goals in their NDCs, but population growth outpaced the technology and policy improvements. The number of people lacking access to clean cooking has dropped from 3 billion in 2010 to 2.4 billion in 2020. There are remarkable improvements in clean cooking access in Asian countries but in Sub-Sahara Africa, the access deficit to clean cooking rose by 50% since 2000, reaching 923 million people in 2020 (IEA et. al, 2022).

IRENA indicates that the energy transition is off-track. Despite some progress, significant gaps remain between the currently deployed energy transition technologies and the levels needed to achieve the goals of the 2015 Paris Agreement to limit global temperature rise within 1.5^0 C (IRENA, 2023). IEA projects that the share of fossil fuels predominantly occupies the global energy supply -80% of total global supply for decades- is starting to edge downwards and expected to reach 73% in 2030 (IEA, 2023a). There is still a strong hope and with the concerted efforts from the developed and the developing countries, the goals of Paris Agreement can be achieved through energy transitions to clean energy sources. As per the recent IEA's 2023 update on the roadmap for NZE by 2050, ramping up renewables, improving energy efficiency, and increasing electrification with technologies available today can deliver more than 80% reduction of emissions by 2030 (IEA, 2023b).

World Energy Outlook (IEA, 2018)[1] emphasized that energy is of paramount importance to human society and economic activity and Its 2022 version forebodes that the combination of the Covid pandemic and the energy crisis means that those people who have gained access to electricity may lose the ability to afford electricity and around 100 million people may no longer be able to cook on clean fuels (IEA,2022). The world has seen sharp price rises in natural gas, coal, and electricity markets. That the countries must act to provide modern energy services is a necessity for eradicating poverty and reducing the divide between rich and poor. Besides, several empirical studies have shown that non-renewable energy is a major source of air pollutions that cause severe health problems around the world, especially in developing countries like Nepal. The energy sector is responsible for almost three-quarters of the emissions. Hence, it is of utmost importance for solutions to climate change. Energy features have prominence in the United Nations Sustainable Development Goals (SDGs), agreed upon by almost 200 nations in 2015. Nepal, in its roadmap for achieving SDGs by 2030 (NPC, 2018) envisions a middle-income country in 2030 with vibrant, youthful middle-class people. 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(Lambrides, J.P. et. al, 2019)shows that nations need to focus their attention on low- carbon, low -cost and low- impact energy resources to limit global warming to 1.5^0 C by the end of the twenty-first century. These kinds of energy resources are solar, wind, and low -dam or low -impact hydropower storage plants for flexibility and meeting the intermittency caused by variable energy resources like solar and wind. It means that developing nations must discourage the usage of fossil fuels and concentrate on renewable energy and energy efficiency for meeting their rising energy demand. But unfortunately, Nepal is becoming too much dependent on imported fossil fuels - imports of petroleum products against goods and services exports of Nepal have jumped from 59% in 2014 to above 90% in 2022[2] which has reflected in Nepal's poor balance of payment situation. 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 into the national energy systems planning for sustainable energy development and energy security in the country.

1.3. National Energy Scenario

The national energy demand has been seeing growth along with growth in population and economy – it is a common feature of the developing country. However, Nepal’s overall energy mix is still dominated by non-commercial energy sources. Although, as a result of Covid, the energy consumption saw a dip, mainly in the manufacturing sector, the total energy consumption of Nepal stood at 606 PJ in 2020 with an annual average growth rate of 4% maintained over the last decade (MoF 2021). As per the Energy Synopsis Report of Nepal, 2023, Nepal’s final energy consumption stands at 640 PJ in 2022, out of which tradition biomass occupies 64%, commercial energy carriers occupy 28%, grid

[1] International Energy Agency, 2018. World Energy Outlook 2018.

[2] Ministry of Finance, 2023. Economic Survey 2079/80; NOC, 2023.

electricity 5% and renewables around 2.5% respectively (WECS, 2023). Nonetheless, it is very important to note that there is an evident shift in the commercial fuels – primarily petroleum products. The provincial energy consumption and supply situation analysis completed for Koshi, Madhesh and Bagmati Provinces conducted by WECS in 2020 and 2022 also supports the transition in energy mix patterns by sectors(WECS, 2021a, 2021b, 2022) .

Apart from the gradual energy transition, Nepal is actively working to increase access to clean energy options and increase the efficiency of energy use by taking strategic actions based on SDGs, LTS, and Second NDC. In addition to that, Nepal itself is setting its goal via slogan targets like “Electricity for all”, “Each house, one electric cooktop”, and others.

There are strong Nepal government’s commitments to the international programs for clean energy development, mitigation and adaptation to climate change, energy consumption patterns in Nepal are still not in the right pathway to energy transition to clean energy even though there are existing technology and economic efficiency in switching over to clean energy technology such cooking on electricity rather than on LPG and fuelwood Analysis of household energy economics in urban areas indicates that at present it is more than 50% cheaper to cook on electricity than on LPG in Nepal (Nakarmi, 2022 - updated on 01 September 2023).Due to rising prices in the international market, import costs of petroleum products increased to NR 300 billion in 2022 compared to above NR 150 billion in 2021 – almost double fold in one year (NOC, 2022). These statistics amply highlight the vulnerability of economics of Nepal and energy security of the country. Notwithstanding all these happenings, Nepal is already in the fifth year of National Electric Cooking Campaign (NECC) in 2024 under the AEPC and other campaign partners like NEA, NACEUN, development partners, and national NGOs. At the local levels such as Lalitpur and Terai districts, local level governments are also distributing induction cooktops in subsidy to households.

In the current context, however, the primary source of energy in the residential sector remains to be fuelwood, agriculture residue, animal waste, biogas, and other biomass energy resources. Hydro electricity and solar energy are substituting traditional energy in urban residential areas, mainly for cooking and lighting but the pace of transition is happening at a slower pace especially in cooking. The industrial sector consumes coal, fuelwood, diesel, and electricity as major sources of energy with a 63% share of non-renewable energy consumption. The transport sector consumed 99% of gasoline an 87% of diesel imported into the country. Diesel, petrol, and Aviation Turbine Fuel (ATF) are major fuel sources in the transport sector with minimal contribution from electricity in this sector. The National Survey of Energy Consumption and Supply Situation in Nepal, 2013 shows fuelwood, LPG, coal, and grid electricity as major fuel sources in the commercial sector with a 34% share of non-renewable energy consumption. The agriculture sector mainly uses fuel for water pumping and farm machinery that consumes diesel as a major fuel source.

Nepal’s Second NDC and the Long Term Strategies follow the Paris Agreement of 2015,the SDG7 and other goals, and the SE4ALL program targets 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 as per NPHC 2021, 54% of households (HHs) use solid biomass fuels for cooking, whereas 44% of households use LPG and only 0.5% of households use electricity for cooking (NSO, 2023). Access to electricity extends to 93% of HHs (NEA, 2021). However, the actual supply of electricity is inadequate, majorly due to lower capacity connection and reliability issues. Rural areas have access to 10% off-grid electricity that is used mainly for lighting and small electrical appliances.

There was still above 12% of the population without electrification in Nepal (Adhikari, 2019; NEA, 2019). By end of the fiscal year 2021/22, it is expected to reduce to 7% only (MoF, 2022).

Solar home systems are taking a strong foothold in Nepal with the reduction of their 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 fuelwood, and limiting the use of LPG by 2030 (NPC, 2018). It requires an installed capacity of 15,000 MW by 2030. To fulfill the target, the government has already started its strategic action plan focusing on the development of the energy and power sector. Nepal has prepared the implementation plan for the Second NDC to achieve the goals of hydropower development, energy access, and clean cooking.

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, supply, and resource potential. Based on those, appropriate energy plans are to be formulated to achieve sustainable development and energy security in the country.

1.4. Energy Supply and Demand Situation of Nepal

The overall energy consumption in Nepal reveals the dominance of the non-commercial energy sources. The total energy consumption of Nepal IN 2022 stood at 640 PJ with an annual average growth rate of 2.3% YOY.As per the energy synopsis report published by WECS, traditional energy consumption declined from 84% in 2010 to 64% in 2022 (WECS, 2023). However, the energy sources are still dominated by traditional sources (fuelwood, agricultural residues, and animal wastes). Nonetheless, there is a gradual shift to commercial energy sources (coal, petroleum products, and electricity) with an increase in the share of commercial energy from 15% in 2010 to 32% in 2021 at the national level, which recorded an increase of 12% growth per annum. There is a steady growth in renewable energy sources as well, with their share increasing from 1% in 2010 to 2% in 2021 (MoF 2022). Meanwhile, the consumption of electricity has also lately increased to 4% from 2% a decade ago. The energy consumption by fuel type in 2019/20 is shown in **Figure 1-1.**

The national energy supply and consumption survey carried out by WECS in 2011/12 shows the residential sector as dominating the energy-consuming sector. According to the survey, the residential sector accounts for the major share of energy consumption (80.4%) followed by industrial (7.9%), transport (7.1%), commercial (3.4%), and agriculture (1.2%) in 2011/12 (WECS, 2013).

The recent provincial energy consumption and supply situation analysis completed for Koshi, Madhesh and Bagmati Provinces by WECS showed a shift in energy consumption patterns by sector. The detailed energy survey shows that Koshi Province consumed 74PJ with the industrial sector accounting for 45% of the energy consumption followed by the residential sectors (41%) and the two sectors together are the energy-consuming sectors(WECS, 2021a). Solid fuels – fuelwood, biomass, and coal dominated the energy sources in use in Koshi Province. Similarly, Madhesh Province consumed 63PJ of energy with the residential sector consuming 62% of energy, mainly sourced from traditional biomass (55%) and non-renewable (36%)(WECS, 2021b). In Bagmati Province, out of total84 PJ consumed, the highest consumption is in residential sector (42%) followed by Industrial Sector (33%)(WECS, 2022). Contrastingly, in Bagmati Province, the transport sector has a large share in energy consumption of 15% which is primarily due to running of the International Airport in the country at largest. Fuelwise, the share of petroleum product is highest in the province, wherein consumption of electricity is also very good at 10%. These differences in the energy consumption pattern of the three provinces are attributable to various factors, but majorly due to the availability and accessibility of resources as well as differences in the population and economic growth in the three provinces.

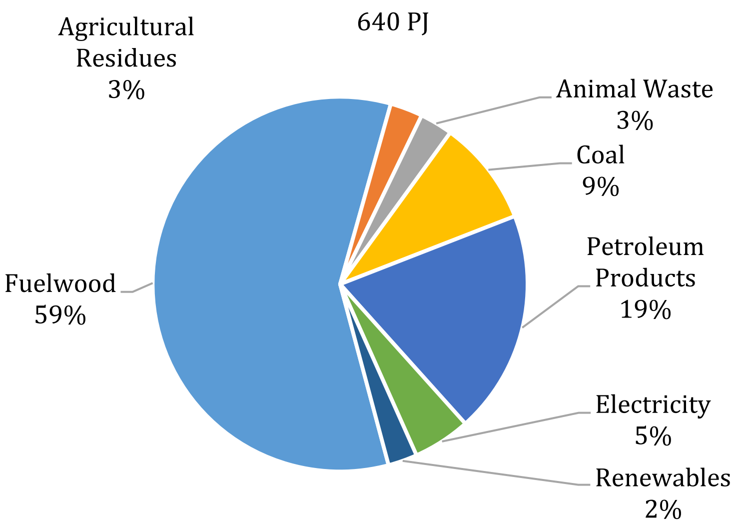
The major source of energy in the residential sector is fuelwood, agricultural residues, animal waste, biogas, and other biomass sources. Hydro and solar energy sources have the potential to substitute these traditional energy sources in urban and rural households that use traditional energy sources 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. Diesel, petrol, and ATF are the major fuel sources used in the transport sector with minimal use of electricity which is beginning to increase with the increase in the number of electric vehicles. The National Survey of Energy Consumption and Supply Situation in Nepal, 2013 shows fuelwood, LPG, coal, and grid electricity as the major fuel sources in the commercial sector with a 34% share of non-renewable energy. The agriculture sector mainly uses liquid fuel for water pumping and farm machinery operations, where diesel is the major fuel in use.

Apart from the gradual energy transition, Nepal is also actively working to increase access to clean energy options and increase the efficiency of energy use. The Sustainable Development Goal's target 7 (SDG-7) is directed to: i) achieving universal access to affordable, reliable, and modern energy services, ii) doubling the global rate of improvement in energy efficiency, and iii) increasing the share of renewable energy in the global energy mix by 2030 (UNDP, 2012). Nepal is also committed to achieving these targets. Currently, 75% of households (HHs) in the country use solid fuels, mainly fuelwood, as a primary source of energy for cooking while 18% use LPG. The access to electricity has risen to more than 90% HHs connected to the grid and off-grid supplies, though the actual supply of electricity is not reliable, particularly in the rural areas. Rural areas in the hills and mountains have access to primarily off-grid electricity used mainly for lighting and running small electric appliances at home. Solar home system is also gaining popularity in Nepal following a reduction in the price of solar PVs, storage batteries, and other accessories in the global market and readily available technology and supply chain of equipment and services developed across the country in recent years. However, the scope of small solar energy systems is still limited to lighting. Meanwhile, the new utility-scale solar plants are starting to integrate into the national grid. SDG7 targets to expand electricity access to 99% HHs and through this replace the dependence on fuelwoods for cooking and heating. The target is to replace the use of LPG with electricity by 2030. It would require an installed capacity of 15,000MW by 2030. To fulfill the target government has already started its strategic action plan, focusing on the development of the energy and power sector through periodic plans, and budget allocation as stated in Nationally Determined Contributions updated in December 2020.

The persisting impact of COVID-19 in Nepal over 2019-2020 led to a decline in energy consumption, mainly in production sectors. Petroleum products sales went down by 10% in 2019-20 compared to the value in 2018-19 while the electricity sale grew marginally by just 2% compared to the growth of 13% in 2018-19[3]. The growth in electricity use has risen again as COVID risk eased and industries begin to function to their capacity. Additionally, the increased access to electricity and the use of

[3] NOC,2020. Import and Sales Statistics of Nepal Oil Corporation Ltd.; NEA, 2020. Nepal Electricity Authority. A year in Review- Fiscal Year -2019/2020.

electric technologies have significantly increased the demand for electricity in the last 2 years (NEA, 2022).



(WECS, 2023)

Figure 1-1: Energy Consumption by Fuel Type in 2021/2022 in Nepal

1.5. Provincial Situation

Lumbini Province shares an international border with India only in the south. Stretching from east to west, it borders Gandaki and Karnali Provinces to the north, Sudurpashchim Province to the west, and Uttar Province and Bihar states of India to the south. The province extends 150 km north to south and about 300 km east to west at its maximum width. It shares 413.14 km of border with India. This province is the sixth largest province by area while it is the fourth most populous among the seven provinces. Deukhuri is taken as the Provincial capital in October 2020, replacing Butwal as the provisional capital. The population size of the province is 5.12 million as per the census 2021 over its geographical area of 22,288 square kilometers. The province encompasses 12 districts and a total of 109 local government units, which include 4 sub-metropolitan cities, 32 urban municipalities and 73 rural municipalities.

With five Terai districts, one Inner-TeraiTerai and 6 hill districts the province holds the potential for diversified agricultural production. The province has sizable arable land of good fertility and access to dependable irrigation. Out of 485,000 ha of agriculture land in the province, around 248,000 hais irrigated. Similarly, there are various irrigation projects under construction, namely, the Bheri-Babai diversion, Babai Irrigation, and Sikta Irrigation Projects, and their completion will greatly expand the irrigation coverage in the province.

So far administrative and population situations are concerned, Lumbini Province covers 11.8% of the total area with 109 local levels. Local road network in this province has extended till now to 9,139 KM (14.1% of the national road network). The number of schools is5,622 (16.4% of the national total). Rs. 171.1billion have been invested in 94,138 industries in the province (**Table 1-1**).

Table 1-1. Provincial Economic and Social Indicators of Lumbini Province

Indicators	Nepal	Lumbini	Share
Administrative and population situation[1]			
No. of local level	753	109	14.5
Population (%)	100	17.55	17.6
Area (%)	100	11.8	11.8
Economic and Social Sectors			
Economic growth at consumers' prices (%)[1]	5.84	5.36	91.8
Gross Domestic Production			
Provincial contribution to GVA (at consumers' prices)	100	14.1	14.1
Per capita GDP (in US $)[1]	1,372	1,103	80.4
No. of registered industries[2]	8,656	656	7.6
No. of cottage and small industries[2]	555,776	94,138	16.9
Investment in industry (in Rs. Billion)[2]	2512.1	171.1	6.8
No. of registered companies[3]	283,358	18,713	6.6
hydropower production (MW)[4]	2,023	31	1.5
Forest Area (%)[5]	100	14.74	14.7
Local road network (KM)[6]	64,617	9,139	14.1
No. of Schools[7]	34,368	5,622	16.4
Financial Sector[8]			
No. of branches of bank and financial institutions	11,349	2,186	19.3
Population per branch (no.)	2,572	2,344	91.1
Branch of Insurance companies (No.)[9]	2,905	421	14.5
provincial expenditure (inRs. 10 million)[10]	18,883	3,210	17.0
provincial revenue (inRs. 10 million)[10]	8,794	1,212	13.8

Sources: 1. Central Bureau of Statistics, 2022, 2. Ministry of Industry, Commerce and Supplies, 2022, 3. Company Registrar's office2022, 4.Ministry of Energy and Irrigation, 2022, 5. Ministry of Forest and Environment 2022, 6. Ministry of Federal Affairs and General Administration, 2022, 7. Ministry of Education, Science and Technology, 2022, 8. Nepal Rastra Bank, 2022. 9. Insurance Committee 2022, 10. Financial Comptroller General, 2022.

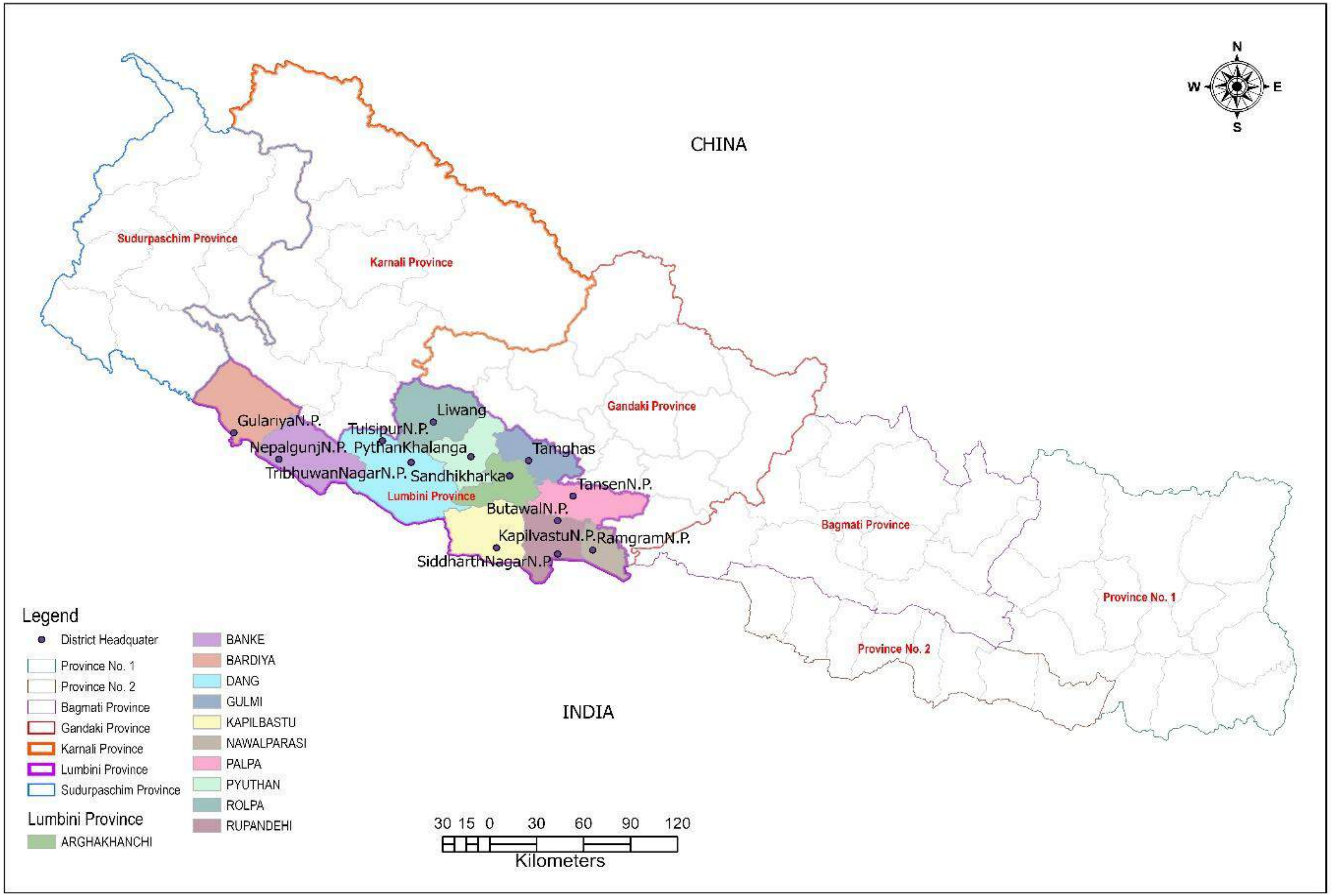


Figure 1-2: Lumbini Province

As much as 98% of the population has access to electricity in the province (NEA, 2023). Of the 12 districts in Lumbini Province, Parasi, Kapilvastu, and Bardiya have been electrified by more than 99 percent. Gulmi, Arghakhanchi, and Rupandehi have more than 95 percent electrification and Rukum East has the lowest electrification of 11.25 percent. Lumbini generates 31 MW of hydroelectricity (MoF, 2021). According to the NEA, the highest sales of electricity sale is in the industrial sector (57%) followed by the domestic sector (31%). The loss of electricity in the province was estimated to be8.5% for the year 2079/80. Butwal Solar PV Project is the country's first private grid-connected solar power plant, which was connected to the national grid in October 2020. Ridi Hydropower Company has constructed the power plant in Tilottama Municipality in Rupendehidistrict. With over 32,000 solar panels of 330 watts each, the plant can generate 8.5 MW of electricity.

1.6. Review Related to Plans, Policies, Regulations, and Guidelines Related to Energy

1.6.1. Policy and Strategy Overview

- **NDC Implementation Plan 2023**

Government of Nepal (GoN)submitted its second Nationally Determined Contribution (NDC) for the years 2021-2030 in December 2020. NDC 2020 has set the quantitative and policy-related mitigation targets along with the implementation priorities. This NDC implementation plan is developed to effectively implement the NDC targets in different sectoral and sub-sectoral areas with activity monitoring indicators, timelines, and required resources for the implementation.

In the energy sector, major focus is concentrated in energy transition to cooking in household and transport sectors for substituting fossil fuels to clean renewable energy sources available in the country. Financial resources required for the implementation of NDC targets in energy sector are expected to be US$ 22 billion till 2030. The huge financial resources cannot be arranged through internal sources only but must be sourced from international climate finance funds, domestic public, and private financial sources.

- **15th five-year Plan (2076/77-2080-81)**

The current fifteenth five-year plan (2076/77-2080/81) has emphasized rapid hydropower production ensuring energy security. It has aimed to ensure clean energy availability through the increase in the production of hydropower energy; to increase the consumption of electric energy in different sectors of life. It also intends to increase the regional trade of electric power by reducing the import of petroleum products. Additionally, the plan aims to enhance renewable energy production and use ensuring access to energy for all.

- **Nepal's Long-term Strategy (LTS) for Net-zero Emissions, 2021**

The Long-term Strategy for Net-zero emissions was formulated in 2021 by the Ministry of Forest and Environment and was recently submitted to the COP26 by Nepal Government. The major target is to reduce carbon emissions and achieve net-zero carbon emissions from both the energy and non-energy sectors by 2045. To move towards the path of carbon-neutrality, it has taken stringent mitigation measures which would require bold policymaking, social transformation, and technological advancements. Its high ambition-related actions necessitate significant conditional financial resources, and its realization requires huge investments from domestic and international funding institutions. The sectoral targets include electrification in all potential end-use services.

- **Second Nationally Determined Contribution, 2020**

The Government of Nepal – Ministry of Population and Environment, in December 2020, communicated its Second NDC to the UNFCCC as a national pledge to contribute to the promotion of renewable energy services across the country. In the recently submitted NDC, GoN emphasized clean energy generation as well as replacing conventional technologies with modern and environmentally friendly energy technologies. On energy generation fronts, an increase of national hydropower generation from the existing 1400 MW to 15,000 MW by 2030 has been emphasized of which 5-10% will be generated from renewable electricity generation options such as mini and micro-hydro, solar, wind, and bioenergy. Electrification in the transport sector and replacement of conventional stoves with electric and improved cook stoves in the residential sector are also highlighted. The climate change mitigations strategies and targets included in the INDC adhere to and also support existing policies and plans. To achieve electric cooking targets for Nepal's NDC, an assessment was carried out by Ministry of Forest and Environment (MoFE) in 2021 which shows that an average annual increment of 32% would be needed from 2020 to 2030 so that the percentage share of households using electric cook stoves as their primary mode of cooking increases from 6% in 2020 to 25% in 2030. Similarly, the electric mobility assessment by MoFE in 2021 shows that the ambitious e-mobility Scenario decreases fossil fuel dependency from the transportation sector by around 9% in 2025 and 28% in 2030.

- **Ministry for Electricity, Water Resources, and Irrigation (MOEWRI) White Paper 2075**

Ministry for Electricity, Water Resources, and Irrigation (MOEWRI) released a 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 the current 700kWh to 1500kWh in the coming ten years. It requires the penetration of electricity in all sectors, including electrification in residential, commercial, transport, industry, and agriculture. It plans to generate 3000 MW of hydropower by 2021 and upgrade the generation capacity by 5000MW in the coming five years and by 15,000MW in 10 years. It also envisages that domestic demand will increase to 10,000 MW in the coming ten years. The government plans to generate 200MW of solar power from Madhesh Province, where the hydropower potential is minimal. The white paper focuses on the optimum generation and utilization of clean energy resources, including efficiency improvement in the country.

- **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 tariffs, 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.

- **Nepal's Intended Nationally Determined Contribution (INDC)**

The Government of Nepal – Ministry of Population and Environment, 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 mitigation strategies and targets included in the INDC report adhere to the existing policies and plans. One of the key strategies includes the formulation of a Low-Carbon Economic Development Strategy (LCEDS) that provides the framework for the promotion of renewable energy across the country in all economic sectors.

- **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 graduating from the list of Least Developed Countries which requires rapid economic growth of at least 7% over the decades. It highlights significant issues and challenges along the route to meeting SDGs. It emphasizes three sectors mainly clean energy, agriculture, and tourism for the sustainable prosperity of the nation.

- **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 reducing national GHG emissions. The strategy provides a framework for achieving sustainable development, prioritizing the sector-specific implementation plans for low GHG emissions. The strategic sectors included in the report are energy, agriculture and livestock, industry, transportation, and commercial.

- **National Energy Strategy of Nepal, 2013**

The Energy Strategy of Nepal is based on and guided by a comprehensive policy framework, developed by the Water and Energy Commission Secretariat (WECS)with inputs from key stakeholders. This adopts a set of objectives and policy principles that provide the framework for energy development. In addition to mitigating several issues related to the energy sector such as access to energy technology, clean and modern energy options, generating hydropower, conserving the environment, and reducing health impact due to indoor air pollution, the top priority of the strategy is focused on the promotion of integrated energy development plan with two guiding principles-energy becoming instrumental for socio-economic transformation and contributing to environmental sustainability.

- **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 to meet energy demand sustainably. It envisions reducing the dependence on imported petroleum products by substituting them with indigenously available hydropower and other renewable energy resources. It identifies hydropower as the lead energy resource 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, the GDP share of the energy sector should approximately be 2.4%.

- **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 as well as implementations of rural renewable energy programs to make the local governance system environment friendly.

- **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 to the overall energy consumption in the country. The installed renewable capacity was 35 MW in 2015, and it targets to increase the installed capacity to 894MW by 2030. The share of renewable energy in total energy consumption was 2% in 2015 and the plan targets to increase the share to 15% by 2030. The contribution of small/micro hydropower was 1.7%, and 0.1% each from wind, solar, and biomass in 2015. The 20-year perspective plan targets to increase the share of small/micro hydropower to 9% and each of wind, solar, and biomass to 2% in 2030. The target for domestic biogas plant installation is 1.5 million plants from 0.3 million in 2015. Similarly, the target for improved cook stoves 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.

- **Other Supporting Plans, Policies, and Programs:**

Key Plans, Policies, programs	Features
National Energy Efficiency Strategy, 2018	• Lists out the main activities to be carried out along with specific goals, time period as well as responsible agencies. • Focuses on following strategies: • Generate awareness about energy efficiency. • Establish required policy, legal and institutional frameworks. • Develop national standards for energy efficiency. • Make services and production cost effective and competitive. • Reduce energy import by energy conservation
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

Key Plans, Policies, programs	**Features**
Biomass Energy Strategy (BES), 2017	• Increase production of sustainable biomass energy by utilizing agriculture, forest residues, and organic wastes. • Contribute to increased access to clean cooking technologies to all Nepalese households through the means of modern biomass energy. • Increase effectiveness and efficiency in the utilization and production of biomass energy. • Partially substitute the utilization of diesel and petrol with biodiesel and bioethanol.
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
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
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.

Key Plans, Policies, programs	Features
Nepal Energy Efficiency Program	• Demonstration of energy efficiency in household and industries • Advocacy and pilot audit projects in energy-intensive industries. • Establishment and capacity development of the Energy Efficiency Center
Nepal Rural and Renewable Energy Program	• Single program modality for the effectiveness of RE projects and activities. • Targets for various RETs
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.
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
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.
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
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 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 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.

The GoN has taken back the Electricity Bill -2077 recently, which was under consideration at the National Assembly[4]. The government is in the process of revising the law to allow the private sector in the power trade through an amendment to the Electricity Act[5].There is huge pressure from the private

[4]https://english.nepalpress.com/2022/09/16/government-takes-back-electricity-bill-2077/

[5]https://kathmandupost.com/money/2022/05/21/government-revising-law-to-allow-private-sector-to-engage-in-power-trade

hydropower developers as there is surplus power during the rainy season for allowing private sector involvement in open access through power trade inside the country and across the border. Currently, Electricity Bill 2080 is under consideration in the parliament.

1.7. 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 policies 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 clean accessible energy for all. The future energy supply plan will be based on current energy consumption as analyzed by the study itself, taking consideration of supply potential of each province first and national potential to supply energy as well as the cost effectiveness.

2. Methodology

The methodological approach, systematically identifying the steps in collection, analysis, and synthesis of information from different sources is illustrated in**Figure 2-1.**

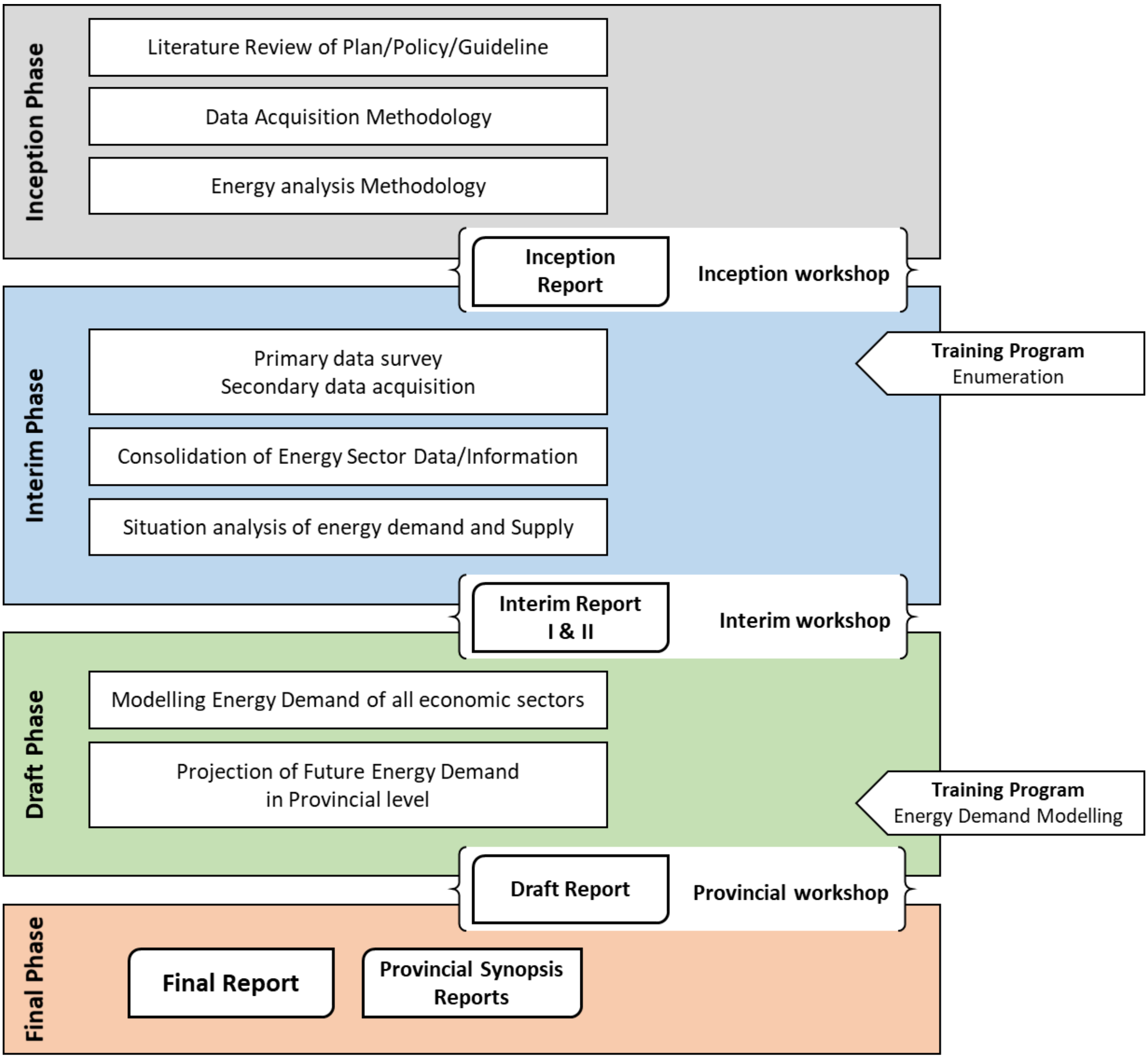


Figure 2-1: Methodological Framework

Specific to energy sectors, the need of data/information has been identified as presented in Box-1 below:

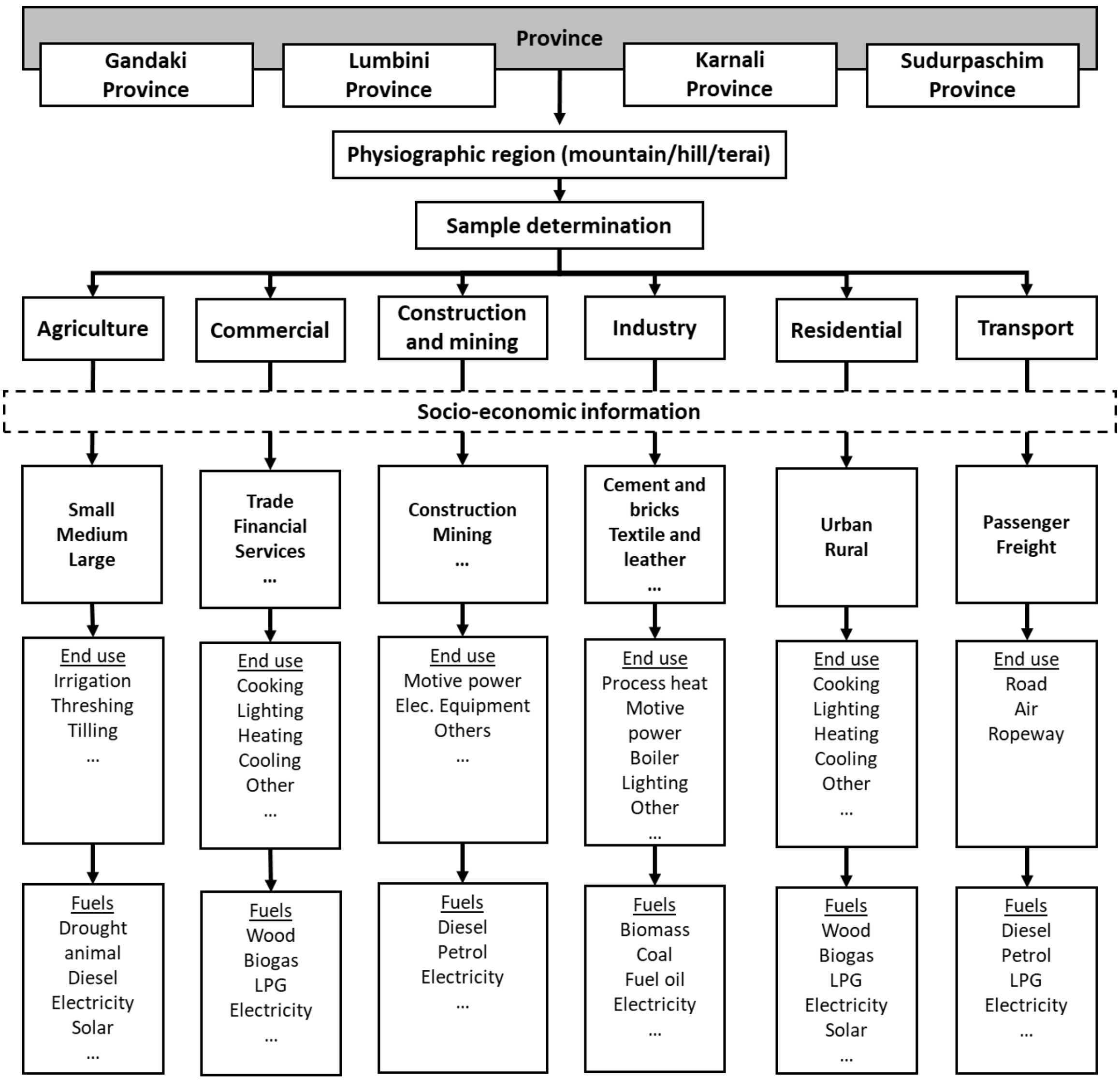
BOX 1: ENERGY SECTOR AND RESOURCES
State of Current Energy Demand and Changes Over Time by Sectors of Energy Uses: *a.* Residential (Household) Sector *b.* Industrial/Production Sector *c.* Commercial/ Service Sector *d.* Agricultural sector *e.* Transport Sector *f.* Construction and Mining Sector Supply of Energy and Changes in Energy Supply by Source: *a.* Renewable *b.* Conventional renewable *c.* Modern Renewable *d.* Non-renewable *e.* Coals *f.* Petroleum *g.* Natural Gas Energy Sector Development Projects, including those undertaken in the past, relating to: *a.* Hydropower *b.* Micro-Hydro *c.* Petroleum, Gas and Mineral Coal Exploration *d.* Biomass Energy *e.* Solar Energy f. Biogas g. Integrated Energy System

Required data/information was collected using six sets of semi-structured questionnaires as follows:

- Household energy survey questionnaire
- Industrial energy survey questionnaire
- Construction and mining energy survey questionnaire
- Commercial & services energy survey questionnaire
- Agricultural energy survey questionnaire
- Transportation energy survey questionnaire

The basic disaggregation for the sample survey was bottom up for every sector for energy as well as socio- economic information. The categorization followed a framework like given in Box 2 for Lumbini Province. The survey covers all the economic sectors in the province – which are further disaggregated as per National Standard Industrial Classification so that all the sectors and subsectors are captured. In addition to that, all possible types of end-uses in each sector are considered for energy used in each form. The details of the categorization are given in the next section.

BOX 2: ENERGY SECTOR STRUCTURE



2.1. Data Collection Methodology

Population and Households for each province are based on census 2021. **Table 2-1** shows the census population used as the population to determine the sample size for the survey.

Table 2-1: District Wise Population and Household Status

	Household	Rural Population	Urban Population	Total Population
Hills				
Arghakhanchi	49,073	67,801	108,733	176,534
Gulmi	66,721	186,120	60,438	246,558
Palpa	64,258	148,860	90,660	239,520
Pyuthan	56,960	156,413	74,221	230,634
Rolpa	52,989	199,387	35,644	235,031
Rukum East	13,163	57,540	-	57,540
Terai				
Banke	131,920	335,119	266,547	601,666
Bardiya	106,429	85,798	373,124	458,922
Dang	165,742	232,375	440,697	673,072
Kapilvastu	122,689	199,147	485,455	684,602
Parasi	83,878	172,666	211,788	384,454
Rupandehi	241,432	458,276	659,391	1,117,667
Total	**1,155,254**	**2,299,502**	**2,806,698**	**5,106,200**

This study adopted a combination of quantitative and qualitative approaches. Data was collected mainly from primary sources while some information was collected from secondary sources as per available related reports or published documents. Primary data was collected through the survey.

For sample size estimation the following formula was adopted with 95% confidence level 5% marginal error.

$$n = \frac{\chi^2 Np(1-p)}{e^2(N-1) + \chi^2 p(1-p)}$$

Equation 1

Where,

P = Proportion of population (0.5)

χ^2 = chi-square of degree of freedom1 and confidence level (95%) = 3.841

N = Population size

e = Assumed Marginal error =0.05

n = Sample size

Data collection methodology of six sectors was adopted as follows.

After the survey, the response rates in each sector are as follows:

	Total Samples	Response rate
Agriculture	4,668	102%
Commercial	4,594	107%
Industrial	183	112%
Residential	4,899	107%
Transport	1,105	96%
Construction and Mining	84	104%

- **Residential Sector:**

For this study in the residential sector, each district was considered as the ultimate population area for estimation and household of each district was considered as the primary sample unit (PSU). Population size was considered as the total household of the district on the basis of the Nepal census 2021. Multistage stratified sampling was adopted to collect to make more representative information.

For this, each district was classified into two strata Rural and Urban and for sampling one rural municipality and one rural municipality were selected during the selection of municipality population density and energy consumption. Within rural and urban areas, further households were sub-stratified into roof type house type as thatch/straw, galvanized iron/tiles and slates, RCC, and wood/plank/mud.

To estimate the sample size determination 95% level of confidence, 5% marginal error, and 5% non-response rate were considered. The total sample size was distributed proportionately to the population density of rural and urban areas and within this further distributed proportionately to the roof type of building.

Energy demand was calculated from a bottom-up approach. The energy data is 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 the approximation of energy in the 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.

- **Industrial Sector:**

For this study in the industrial sector, a single factory with a particular product is taken as the sample unit of industrial energy consumption. Districts were the ultimate location for the estimation of sample size Industrial Energy Consumption Survey covers both the traditional/cottage and modern industries. The population of the industry for sampling was further stratified (i.e. Food, Beverage and tobacco, Textile, Metallurgy, Mechanical engineering, Electrical and electronic products etc.) defined by the National Census of Manufacturing Establishments by the Central bureau of statistics and the Department of Industry. **Table 2-2** shows the categorization for each industry type.

Table 2-2: Industrial Sector Categorization

S.N.	Category	NSIC category
1	Food, beverages, and tobacco	Food, Beverage, Tobacco
2	Textiles, Apparels, and leather products	Textiles, Apparels, Leather Products
3	Chemical, Rubber and Plastics	Chemical Industry, Pharmaceutical / Botanical product, Rubber Industry/ Plastic Industry
4	Mechanical Engineering and Metallurgy	Machinery and equipment, Metal products, Motor/Transport vehicles
5	Electrical Engineering Products	Electrical equipment, electronic equipment
6	Wood Products and Paper	Wood Products/Furniture, Paper/Printing Industry
7	Cement, Bricks & Clay Products	Cement Industry, Non-metallic Products, Brick Industry, Clay Products

For population size up to 750, 33% threshold was used for the determination of sample size and population size more than 750, then the estimation of the sample size shall be determined with 95% level of confidence, 5% margin error and at 5% non-response rate.

Energy consumption for the industry sector was also calculated from the bottom-up approach. The energy data are collected with the information of what energy is used for what purpose. Such energy was 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 the approximation of energy in industry sector is

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

Equation 3

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.

- **Transport Sector:**

For this survey a vehicle is considered as the primary sample unit in this sector. The sample units are motorcycle, jeep, car, bus, truck, airplane, helicopter/train, boat, cable car etc. All transport sectors are broadly divided into Road Transport (Passenger and Freight), Air transport and Ropeway, Navigation and Railways sub sector. Road, Air and Ropeway transport which is further be divided into public, private, corporate and government transport and others. The transport sector is classified as Transport Sector **Table 2-3**.

Table 2-3: Transport Sector Categorization.

Sub-sector	Modes of transport
Public Passenger	Bus
	Microbus
	Minibus
	Tempo
	E rickshaw
Private Passenger	Car
	Jeep
	Van
	Motorcycle
Freight	Truck
	Mini Truck
	Tractor
	Pickup
	Cargo van

The main uses of the transport sector are passenger services, goods carrier services. In this sector buses, cars, jeeps, vans, motorcycles, and cable cars are used for passenger services and trucks, lorries, and pickups could be the load carrier services. Similar categories can be made in the air transport sector.

For population size zone data is the ultimate population for sample determination. The estimation of the sample size is determined with 95% level of confidence, 5% margin error and 5% non-response rate.

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

- **Commercial Sector:**

The commercial sectors represent service providing institutions either in the form of goods or other services. For this study the basic sample unit for this sector shall be a commercial entity. 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.

Since energy consumption patterns vary by commercial sector wise. The NSIC also classifies the commercial sector into different groups by the type of goods or service provided. To make representative all sectors during the survey, the commercial sector is classified as in **Table 2-4.**

Table 2-4: Commercial Sector Categorization

Category	Inclusions/description
Trade and retails	Wholesale and retail shops, Repair centers and others
Accommodation and food	Hotel and restaurants, Hostels, catering services
Financial service	Financial Institutions, Real estate service
Social Services	Health, Education/Social work
Other Services	Technical/Professional/Administrative, Entertainments and others

The district is the ultimate location for the estimation of sample size.

A complete list of the commercial entities by district and province is identified from the government registration office. Thesenumbers are considered as the population for sample size calculation. The determining sample size is proportionally distributed according to the population of different types of commercial entities as classified by National Standard Industrial Classification (NSIC).

Energy consumption for the commercial sector is also calculated from a bottom-up approach. The energy data is 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 the district, subsequently giving the total energy of the province. The general formula for the approximation of energy in the 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.

- **Agriculture Sector:**

In this sector a farm is the sample unit for the energy consumption survey. For the population of agriculture sector, land holding as defined by CBS has been taken. The land holdings are separated into three groups as per National Sample Census of Agriculture 2011/12. The general criteria given by the document and the categorization adopted are given in **Table 2-5.**

Table 2-5: Categorization of Farm Size

Category	Terai			Hills	For study purpose
	Bigha	Ha	Ropani	Ha	Ha
Small	1	Up to 0.68	10	0.51	0.6
Medium	1 to 3	0.68 to 2.03	10 to 30	0.51 to 1.53	0.5 to 2
Large	3 above	2.03 above	30 above	1.53above	2* and above

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

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

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

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.

- **Construction and Mining Sector:**

In this sector, 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.) are the sample unit for the energy consumption survey. District is the ultimate location for the estimation of sample size. For population size up to 750, a 33% threshold is used for the determination of sample size and for population size more than 750, then the estimation of the sample size is determined with a 95% level of confidence, 5% margin error, and at 5% non-response rate.

The database of heavy equipment used in the construction and mining sector is also registered in the 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 was used to calculate the total energy demand of the construction and mining industry using the formula.

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

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

2.2. Data Collection Tool

Data has been collected using semi-structured questionnaires. 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 the project sites district. Having received feedback on pre-testing, adjustments have been made to the tools before field mobilization.

Six 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. 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 wome’'s hospital UNOCHA, UNHCR, UNDP, WFP and many more.

2.2.1. 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 have been deployed in Enumerator’s Android mobile and Tablets.
- The list of the sample HHs was provided with the address to the Enumerators in advance. GPS coordinates tracked the enumerators during the household survey through an online data survey system.
- Two–day data collection training was 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 at the Nepal AdministrativeStaff College, Jawalakhel, Lalitpur, in May 2022.

- Enumerators were informed to transfer collected data daily to the "Server" using their Android mobile/tabs.
- Data collections at the field were continuously monitored by the core team for quality assurance.

2.2.2. Data Quality Assurance

The following measures were applied to ensure data quality.

- Questionnaires finalization using the expertise of the study team as well as the suggestions from the WECS experts.
- Two days of data collection training were conducted, including a mockery and a pre-test for enumerators to make them familiar with data collection tools as well as the digital data collection procedures.
- Data collection in the field is monitored by the core team for quality assurance.
- Day-to-day feedback collected from the enumerators by the team member to assure data quality.

2.2.3. Data Analysis

After completing data collection, the final data sets were transferred into Excel and then it was exported in SPSS software for analysis. The report was prepared using SPSS, MS-Word, and EXCEL software.

2.2.4. Workflow of Data Collection

The workflow of data collection is as shown in**Figure 2-2.** The template was designed at first. The final questionnaire was uploaded to the cloud server. Enumerators downloaded the template using the server. The survey was carried out on mobile using the application developed for the survey. After completing the survey, the enumerators uploaded the data into the cloud survey to be received by the statistician for analysis.

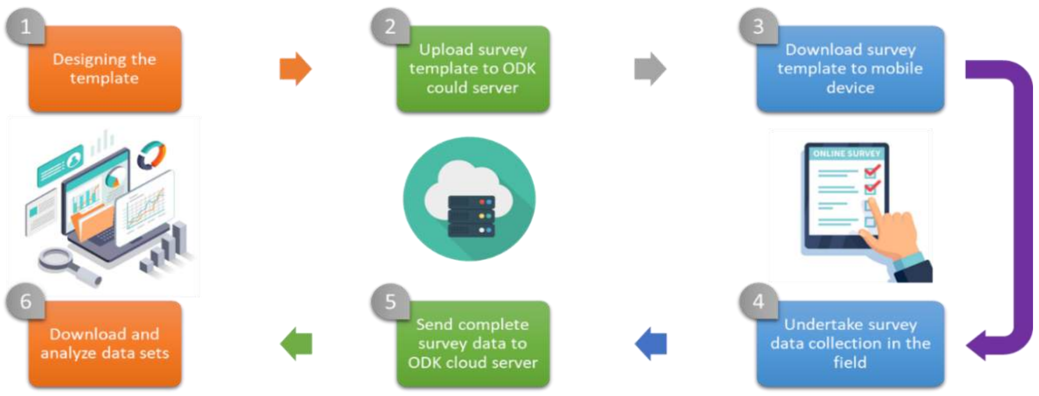


Figure 2-2: Workflow of Survey Design and Data Collection

Questionnaires and district-wise sample sizes are given in the Annex II and IV.

3. Macroeconomic Analysis

Nepal has achieved significant development progress and its GDP growth rate averaged 4.9% in the decade from 2009 to 2019 and it has attained lower-middle-income status in 2020. The multidimensional poverty has declined to 17.4% in 2019. But these development gains are at risk due to climate change as Nepal is highly vulnerable to climate and disaster risks. Though Nepal's contribution to GHG emissions to the emissions space is significantly negligible but it ranks as the 10th most affected country in the world due to climate change according to the Climate Risk Index. Heavy Monsoon floods and landslides caused several hundreds of deaths in 2020 and displaced thousands of people. As Nepal's agriculture and power sectors are heavily dependent on river waters and climate variability will have huge impact on national economy(WB, 2022), Nepal should focus on Green Resilient Inclusive Development (GRID) with one of the priority transitions on harnessing hydropower opportunity and energy transition.

3.1. Economic Status

The pandemic COVID-19 left unexpected severe adverse effects on the economy at both the national and the provincial levels in FY 2019/20 and in its succeeding fiscal years: FY 2020/21 and FY 2021/22 but at a decreasing trend. **Figure 3-1** shows that in the fiscal year 2021/22 the estimated GDP at consumers' prices was provisioned to Rs. 4,851,625 million, out of which, Lumbini Province had contributed Rs. 684,877 million (14.1%) to national GDP. As the result of the pandemic COVID -19, the estimated economic growth rate was expected to 5.84% in the country whereas; the estimated annual growth rate of Lumbini Province was provisioned to 5.36% in the same fiscal year while considering GDP at consumers' prices. GDP at constant prices is required to be considered for tracing the actual trend.

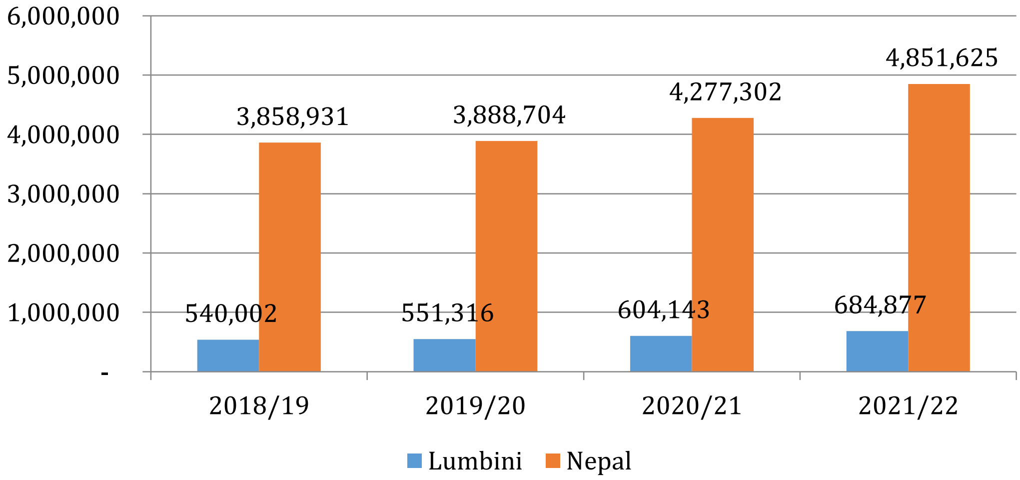


Figure 3-1: GDP at Consumer'' Prices of Lumbini Province and Nepal (in NR million)

The annual GDP growth rate of the country in FY 2019/20 was reduced to -2.37%. In the same fiscal year, the annual GDP growth rate of Lumbini Province fell to -0.84%. The annual GDP growth rate of the country in 2020/21 and 2021/22 were both positive and were 4.25% and 5.84% respectively. Similarly, those of Lumbini Province were also positive and at the increasing trend, i.e., 4.06% and 5.36% respectively in these two consecutive years, 2020/21 and 2021/22. This increasing effect post COVID-19 on economic activities of both levels in FY 2021/22 supported to increase in the economic growth rates of all provinces relatively compared to last FY2020/21.

Figure 3-2 demonstrates that the covid-19 affected adversely on secondary, tertiary sectors and on the primary sector. The annual growth of secondary and tertiary sectors in 2019/20 fell to -5.5% and -3.8% respectively, whereas that of primary sector fell down but remained positive as this sector is mostly nature dominated. The primary sector has not returned to the previous level even in the last FY 2021/22. The annual growth rates of all broad sectors succeeding fiscal years 2020/21 and 2021/22 were improved and secondary sector was in relatively better positions.

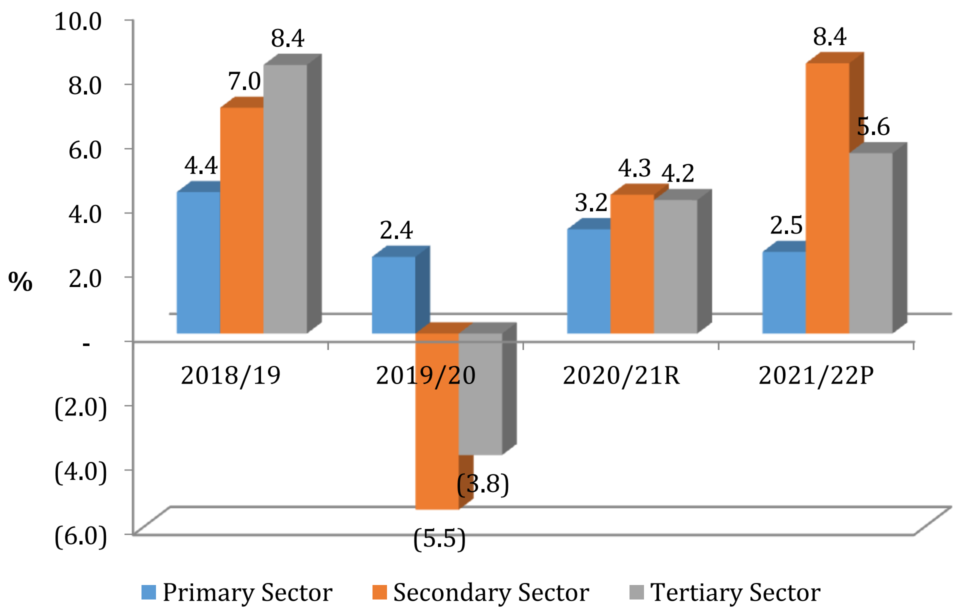


Figure 3-2: Annual Broad Sectoral Growth Rates in Lumbini Province During (2018/19-2021/22)

Figure 3-3 shows that the largest share of the provincial GDP was covered with tertiary sector covering 54.5% and secondary sector covered the least share i.e., 15.4%. The contribution of primary sector to provincial GDP was 30.1%. The trend of the GDP composition shows that the tertiary sector is increasing at the cost of primary and secondary sectors.

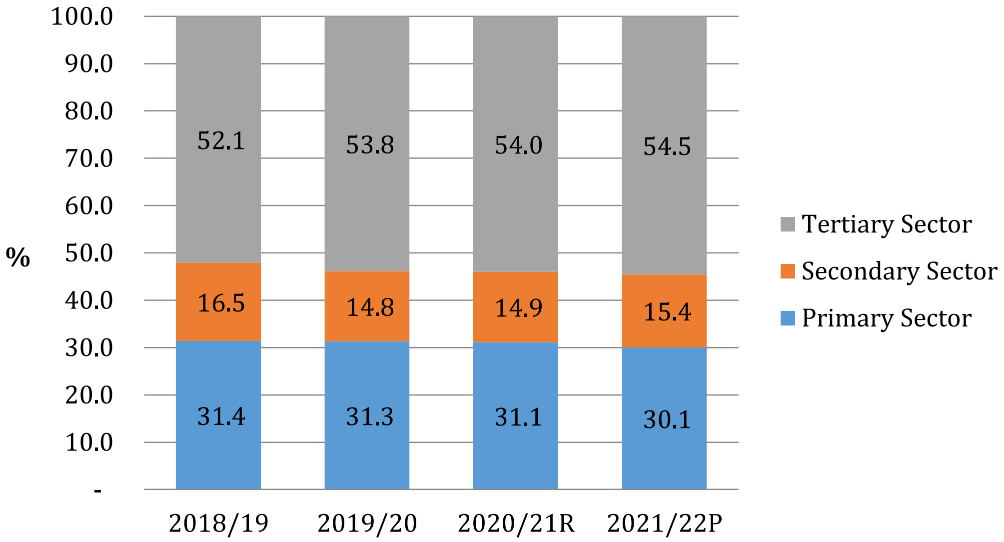


Figure 3-3: Composition of GDP at Basic Prices in Lumbini Province

As shown in **Figure 3-4**, the contribution of Lumbini Province to national GDP at current basic prices is found around 14%. The primary sector contributes around 17%, the secondary sector 16% and the tertiary sector 12% to their respective national sectoral GDP. The contribution of the tertiary sector is mildly increasing, whereas the contribution of secondary sector is decreasing.(**Figure 3-4).**

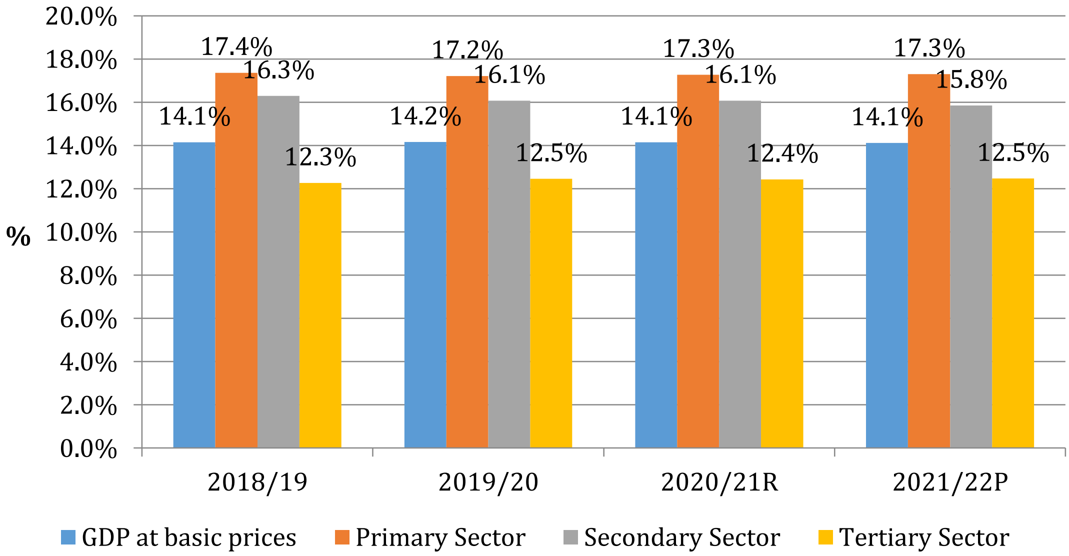


Figure 3-4: Contribution of Lumbini Province to National GDP at Current Basic Prices by Sector

Per capita income in Lumbini Province was estimated lesser (US$ 1103) than the national per capita income (US$ 1372) in FY 2021/22.

3.2. Public Finance

Revenue and expenditure of Lumbini Province as a percentage of its provincial GDP were 2.01% and 5.31% respectively in FY 2020/21, which were lesser than those of the country, i.e., 2.7% and 7.63% respectively.

Table 3-1 shows that both the national and the provincial total expenditures increased at a faster rate. Total expenditure of Lumbini Province was Rs. 17,034 million in FY 2018/19 and increased to Rs. 32,103 million in 2020/21, which is 1.88 times higher in two years. The weight or provincial share of national total expenditure was also increasing from 15.0% in FY 2018/19 to 17.0% in 2020/21. The ratio of capital expenditure in Lumbini Province was lower than the national ratio of capital expenditure and it was decreasing in this province while it was increasing in the national level.

Table 3-1: Capital Expenditure Pattern of Provincial Government of Lumbini Province

					in million Rs.
FY	Total expenditure	Weight	Ratio of capital expenses	National total expenditure	Ratio of capital expenses
2018/19	17,034	0.150	59.7	112,090	54.42
2019/20	25,407	0.160	57.9	156,114	57.21
2020/21	32,103	0.170	57.6	188,829	59.34

Source: Financial Comptroller General, 2022

Table 3-2 demonstrates that total expenditure of government of Lumbini Province was Rs. 32,103 million (i.e., 17.0% of national total expenditure) in FY 2020/21. The total receipt of the province was Rs. 12,118 million (i.e., 13.8% of national total revenue) in the same year. 82.0% of the total receipt was utilized as total expenditure but revenue contributed only 30.9% to total receipt. Total expenditure was covered only 37.7% by revenue in this province. Grants contributed 44.4% to total receipt. Thus, the major source of total receipt was grants as in the country.

Table 3-2: Expenditure and Revenue of Lumbini Province in FY 2020/21

				In Rs. Million	
				Utilization of Funds	
Description	Lumbini	Nepal	Share of Lumbini (%)	Lumbini	Nepal
Provincial expenditure	32,103	188,829	17.00	82.0	71.2
Revenue	12,118	87,944	13.78	30.9	33.2
Tax	9,842	77,009	12.78	25.1	29.0
Others	2,276	10,936	20.82	5.8	4.1
Other receipt including irregularities	9,663	66,410	14.55	24.7	25.0
Grants	17,377	110,348	15.75	44.4	41.6
Repayment of loan and investment	-	541	-	-	0.2
Total receipt	39,158	265,243	14.76	100.0	100.0
Provincial reserved funds (surplus +/loss-)	(7,055)	(76,415)			

Source: Financial Comptroller General, 2022

The provincial government of Lumbini Province spent Rs. 10,822 million, out of which 50.1% as recurrent expenditure and 49.9 % as capital expenditure in FY 2021/22. The expenditure weight for this province was 16.6%.

Table 3-3: Expenditure Pattern of Provincial Government in Lumbini Province in 2021/22

		in Rs. Million		
Province	**Lumbini**	**Nepal**	**Lumbini**	**Nepal**
Recurrent expenditure	5,427	35,449	50.1	54.5
Capital expenditure	5,395	28,591	49.9	44.0
Financing	-	100.0	-	1.5
Total Expenditure	10,822	65,041		
expenditure weight	16.6%	100.0%		

Source: Financial Comptroller General, 2022

The total number of branches of banks and financial institutions in Lumbini Province in 2021/22 (till 2078 Falgun) was 2,186, which was 11.3% of the national total branches, 11,349. Persons per branch numbered 2,344 in the same year. Thus, financial access in Lumbini Province was relatively better compared to that in the nation, as persons per branch in this province was lesser than that in the country (2,572)**Table 3-4.**

Table 3-4: Number of Branches of Bank and Financial Institutions in Lumbini Province (till 2078 Falgun)

Province	Lumbini	Nepal
Commercial Bank	730	4,930
Development bank	250	1,086
Financial companies	43	257
Micro finance	1,163	5,076
Total	2,186	11,349
Share (%)	19.3	100.0
Population** (persons /branch)	2,344	2,572

Source: Nepal Rastra Bank, 2022

3.3. Macroeconomic Modelling

A macroeconomic model has been developed with 65 variables consisting of 11 policy variables and other exogenous variables and 54 endogenous variables. The model has been built with 25 behavior equations and 29 identities. The model has been simulated based on the historical reference period from 1974/75 to 2021/22. 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, private sector, external sector, monetary and price sectors, and employment. Lastly it ends with the projection of major macroeconomic indicators / variables.

3.4. Economic Growth

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, a relatively higher economic growth rate was achieved till the start of domestic conflict and turmoil in Nepal during the last decade of the twentieth century.

The first decade of the twenty-first century was found discouraging in the economic activities due to the Maoist problem and political instability in the country. Maoist conflict and political instability was prolonged till the peace treaty between the government and Maoist Party in 2005/06. Both industry and services sectors were badly influenced by the strikes, Nepal general strike and political conflicts caused by political turmoil and political instability during these decades. Many industries and organizations were forced to shut up their operations. Load shedding was another major cause of slowing down the economic activities in the country. Another serious problem is the massive out flow of Nepalese youths for overseas employment since the start of domestic political conflict and turmoilin the country.

A shortage of agricultural labour force was felt in each village, even in remote areas. Policy discontinuity due to frequent change of government stood as an obstacle in creating an investment environment. The growth rate of services value added was also not encouraging although it had the highest contribution to the GDP. Even after the peace treaty between them the political transition phase in the country was continued till the proclamation of Nepalese Constitution in 2072 and thus it was expected that political instability had ended with the formation of two-third majority government of NCP elected under the new constitution of 2072. That's why the average annual growth rate of GDP at basic price was about 4.0 percent during the first and half decade of twenty-first century. More than 6 percent annual growth rate of GDP at basic price was achieved in the last two fiscal years 2016/2017 and 2017/18 due to political stability, improvement in electricity supply, and favorable climate for agriculture. Mechanization has been initiated in the agriculture sector and it has made the farmers happy due to the cost effective and time saving practice.

At the end of 2019 the COVID-19 pandemic was started at first in China and later extended worldwide. It had badly affected the world up to January 2023 and it has not yet been completely controlled. According to WHO, the confirmed cumulative cases of corona virus in the world till date are 768,237,788 and cumulative deaths from corona virus are 6,951,677. Nepal could not escape from this pandemic. The total confirmed cases were 978,989 and number of deaths was 11,952 in Nepal. The Nepalese economy was badly affected for the last three fiscal years.

If the gloomy situation as shown in the Low Growth Scenario continues in the coming twenty-eight years ahead, it will be difficult to achieve the desired goals and targets fixed in the running 1^{5t}h five years plan and SDGs. However, the increasing domestic electricity generation will improve the trade deficit replacing the imported fossil fuels in future. The recent power trade agreement with India agreeing to export 1000MW in coming 10 Years will support to improve the trade deficit with India.

3.5. Variables

The lists of policy variables and other exogenous variables as well as of endogenous variables, used in the model, are presented in **Table 3-5 and 3-6.** These variables have a direct impact on national output and the GDP.

Table 3-5: List of Policy Variables and Other Exogenous Variables

1. ACMFERT1	Chemical Fertilizers
2. ATCA1	Total Cultivated Land Areas
3. CDIAG1	Cumulative gross fixed capital formation in agriculture sector
4. CDIIND1	Cumulative gross fixed capital formation in Industry sector
5. CDISERV1	Cumulative gross fixed capital formation in Service sector
6. EXGRATE1	Foreign exchange rate in terms of US Dollar
7. FXGS1	Export of goods and services in external sector
8. GFGRANT1	Foreign grants to government sector
9. GFI_N1	Government net financial investment
10. INDCPI1	Indian consumer price index
11. POP1	Population in number

Table 3-6: List of Endogenous Variables

12. CPI	Consumer Price Index
13. DCG	Government Consumption Expenditures
14. DCP	Private Consumption Expenditures
15. DCST	Change In Stocks
16. DCTOT	Total Consumption Expenditures
17. DGFCF	Gross Fixed Capital Formation
18. DGFCFG	Government Gross Fixed Capital Formation
19. DGFCFP	Private Gross Fixed Capital Formation
20. DMGS	Imports Of Goods and Services in Real Sector
21. DTINV	Gross Capital Formation
22. DXGS	Exports Of Goods and Services in Real Sector
23. FCAB	Current Account Balance
24. FGSB	Balance on Goods and Services
25. FKFAB	Capital And Financial Account Balance
26. FMGS	Imports Of Goods and Services in External Sector
27. FOB	Overall, Balance in External Sector
28. FTRB	Current Transfers Net
29. FYB	Primary Income Net
30. GCASHBAL	Budgetary Cash Balance
31. GDBOR	Domestic Borrowing
32. GDTX	Direct Taxes
33. GFAID	Foreign Aids
34. GFISCBAL	Budgetary Fiscal Balance
35. GFLOAN	Government Foreign Loans
36. GGEXP	Total Government Expenditure
37. GGOVRECI	Total Government Receipts
38. GGREV	Government Revenue
39. GINDTX	Indirect Taxes
40. GKEXP	Government Capital Expenditures
41. GNTXREV	Non-Tax Revenue
42. GOVSAV	Government Saving
43. GPR	Principal And Interest Repayment
44. GREXP	Government Regular Expenditures
45. GTRAF	Government Transfers (Government Subsidies)

46. GTXREV	Tax Revenue
47. LAG	Employment in Agriculture Sector
48. LIND	Employment in Industry Sector
49. LSERV	Employment in Service Sector
50. LTOT	Total National Employment
51. MM2	Broad Money Supply (M2)
52. PSAV	Private Savings
53. PY	Implicit GDP Deflator
54. Y	Gross National Income
55. YAG	Value Added in Agriculture Sector
56. YBP	Gross Domestic Product at Basic Prices
57. YDI	Gross National Disposable Income
58. YDIP$	Per Capita Gross National Disposable Income in US Dollar
59. YDSAV	Gross Domestic Saving
60. YIND	Value Added in Industry Sector
61. YINDTXN	Indirect Tax (Net) (Tax Less Subsidies on Products)
62. YNSAV	Gross National Saving
63. YP$	Per Capita Gross National Income in US Dollar
64. YPP	Gross Domestic Product at Producers' Prices
65. YSERV	Value Added in Services Sector

3.6. Model Simulation

The macro econometric model has been simulated based on the historical data of the period 1974/75 to 2021/22. This model has projected required macroeconomic variables for coming 28 fiscal years of period (2022/23 to 2049/50) for study on "Energy Consumption and Supply Situation in Federal System of Nepal (Provinces, namely, Gandaki, Lumbini, Karnali and Sudurpashchim Provinces)" using the ordinary least square estimates.

3.6.1. Sources of Data and Use of Software

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 publications of government authorities especially, MOF, CBS, NRB, and NPC and others governmental organizations as well as of the World Bank, Asian Development Bank and International Monetary Funds.

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 changed since the fiscal year 2000/01. The economy has been classified into 15 sectors against the traditional classifications of 9 sectors and recently has further increased to 18 sectors along with the compilation of annual GVA of seven provinces by the CBS since implementation of federal republic political system in the country. Similarly, CBS has updated the GDP by expenditure category too. Public income and expenditure pattern and balance of payment pattern have already improved. These frequent changes in compilation pattern of data have made it more complicated.

For this modeling exercise, these classifications have been rearranged into three broad sectors, namely, agriculture, industry, and services 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 principal 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 structure of the government finance has further changed with the implementation of fiscal federalism in the budgetary system. 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 subheading 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 the period of 1974/75 to 2021/22 have been estimated based on its annual control totals published by CBS. Sectoral and national ICOR used in some last midterm Plans published by the National Planning Commission (NPC) 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 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.

The employment database is also 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 2071, 2081, 2091, 2001, 2011 and 2021 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 the 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

eViewscomputer 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.

3.6.2. 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 Low Growth Scenario.They are considered as the policy variables in the model for other alternative scenarios. That's why they are exogenously assumed in these alternative scenarios to achieve the expected economic growth rates. In addition to them, some other exogenous variables such as: exchange rate, Indian consumer price index, foreign grants, 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 Low Growth Scenario and exogenously fixed for alternative scenarios wherever required.

Low Growth 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 Low Growth Scenario most of these policy variables have been projected using the trend method and the 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 3-7: Projected Average Annual Growth Rates of Policy/Exogenous Variables in Low Growth Scenario

In Percent

Indicators	2011-2020	2021-2030	2031-2040	2041-2050	2023-2050
ACMFERT1	40.7	(4.0)	2.5	1.7	1.7
ATCA1	(0.9)	0.6	0.4	0.3	0.4
CDIAG1	3.0	2.8	2.1	1.8	2.1
CDIIND1	12.2	9.4	9.5	9.4	9.5
CDISERV1	7.2	6.7	6.9	7.0	6.9

In the above table, trend projections of average annual percentage growth rate of cumulative gross fixed capital formation in agriculture and industry sectors are at declining trend whereas that in services sector has a mild rising trend. The use of chemical fertilizers is 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. The projected average annual growth rate of ATC1 has also been gradually declining as the tendency of Nepalese youths including agriculture laborers for foreign employment is increasing.

Other Exogenous Variables:

In the Low Growth Scenario, it is assumed that all other exogenous variables (including EXGRATE1, FXGS1, POP1, GFGRANT1, GFI_N1 and INDCPI1) have been projected based on the trend method. The projected average annual growth rates of other exogenous variables are presented in the following tables.

Table 3-8: Projected Average Annual Growth Rates of Other Exogenous Variables in Low Growth Scenario

In Percent

Indicators	2011-2020	2021-2030	2031-2040	2041-2050	2023-2050
EXGRATE1	4.7	1.9	1.8	1.5	1.7
FXGS1	2.1	4.1	1.4	1.2	1.6
GFGRANT1	(12.0)	6.7	1.9	1.0	2.7
GFI_N1	14.3	1.2	2.3	2.0	2.2
INDCPI1	6.2	5.6	4.6	4.2	4.7
POP1	1.0	1.1	1.1	1.0	1.1

Reference Scenario

It is assumed that the country's economic situation will gradually be improved in future. 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.

The government has decided to develop the agriculture sector encouraging and mobilizing the returnees from overseas employment by providing them economic incentives and skill training to be self-employed in agriculture sector. Some of them have returned with skills and technical know-how too. They have invested and operate their agriculture farms. The load shedding problem has also been almost completely solved. The 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), industry (electricity, mining, manufacturing and construction) and tertiary or service sectors (wholesale and retail trade, hotels and restaurants, transport, storage and communications, financial intermediation, real estate, renting and business activities, public administration and defense, education, health and social works, and other community, social and personal services) are expected to go up and will increase the productions as well as will generate employment opportunities to solve the rising national 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. The present government has recently signed in the Nepal- India power exporting agreement of 10,000MW electricity to India in 10 years (EoI, 2024). The expanding economic activities will also demand production and productivity of services sector too in consistent way. Investment has to be increased for higher growth to achieve the abovementioned goals. Sustainable development goals have to be also achieved. That's why the investments for these broad economic sectors are projected exogenously. ATCA1 and ACMFERT1 are expected to be increased. The projected average annual growth rates of rest other policy/exogenous variables are taken the same as those in the Low Growth Scenario. These projected average annual growth rates of these policy/exogenous variables for Reference Scenario are presented as below:

Table 3-9: Projected Average Annual Growth Rates of Policy/Exogenous Variables for Reference Scenario

In percent

Indicators	2011-2020	2021-2030	2031-2040	2041-2050	2023-2050
ACMFERT1_1	40.7	(1.0)	3.8	4.6	4.3
ATCA1_1	(0.9)	0.7	0.7	0.8	0.7
CDIAG1_1	3.0	3.8	4.9	5.8	4.9
CDIIND1_1	12.2	9.6	10.8	11.8	10.8
CDISERV1_1	7.2	6.7	7.5	8.5	7.7

High Growth Scenario

It is assumed in the High growth scenario that all policy /exogenous variables namely, CDIAG1, CDIIND1, and CDISERV1 are exogenously projected with further higher increment to achieve higher growth rates of sectoral as well as national GDP growth rates. The agriculture sector has increased slightly only as the productivity of capital in this sector is relatively low whereas, that of services sector is relatively moderate and high in industry sector. That's why; CDIIND1 and CDISERV1 have increased higher rate for higher GDP growth. The country has achieved political stability after facing a longer period of economic recession due to nearly two decades long political turmoil and political transition.

The country has also faced serious economic hardships for nearly two years due to the worldwide outbreak of the COVID-19 pandemic at the end of the year 2019. So, in order to revive the economy faster, the country will need a higher economic growth to compensate the economic losses to resume its normal growth in future. That's why; it is targeted to have 7.1 and 8.0 percent average annual growth rate of GDP at producers' prices for coming 28 years in medium and high GDP growth scenarios and accordingly, average annual growth rates of these policy/exogenous variables ACMFERT1, ATCA1, CDIAG1, CDIIND1, and CDISERV1 have been projected at the higher side to achieve the targeted growth rate. Other exogenous variables have been projected using the trend method as in Low Growth Scenario. The projected average annual growth rates of these policy/exogenous variables are presented in the table below.

Table 3-10:Projected Annual Growth Rates of Policy/Exogenous Variables for High Growth Scenario.

In percent

Indicators	2011-2020	2021-2030	2031-2040	2041-2050	2023-2050
ACMFERT1_2	40.7	(1.0)	4.3	5.3	4.6
ATCA1_2	(0.9)	0.7	0.7	0.8	0.7
CDIAG1_2	3.0	4.1	5.4	6.9	5.6
CDIIND1_2	12.2	10.2	11.6	13.0	11.8
CDISERV1_2	7.2	7.5	8.8	9.8	8.8

3.7. Projection of Provincial Gross Value Added by Industrial Division

CBS has started to publish the provincial Gross Value Added by industrial division for seven provinces since fiscal year 2018/19 and continued to date. Based on the single year provincial data of Gross Value Added at producer's prices by industrial division for FY 2021/22 and three projected scenarios of national GDP at producer's prices, Gross value added by industrial division for four provinces, namely, Gandaki Province, Lumbini Province, Karnali Province and Sudurpashchim Province have been projected assuming that the structure of provincial gross value added of these provinces in FY 2021/22 will continue for all the FY years of the projected period due to inadequate provincial time series data for tracing their structural trends. Three projected scenarios of national GDP at Producer's Prices have been shown in following **Table 3-11.** The detailed GVA are given in ANNEX.

Table 3-11:Growth Scenarios of GDP at Producer's Prices

Industrial Classification	**2022– 2025**	**2025– 2030**	**2030– 2035**	**2035– 2040**	**2040– 2045**	**2045– 2050**
Low Growth Scenario	4.37%	5.70%	6.16%	6.55%	6.96%	7.37%
Reference Scenario	4.49%	5.88%	6.57%	7.36%	8.25%	9.23%
High Growth Scenario	5.04%	6.72%	7.70%	8.68%	9.75%	10.89%

Three scenarios of provincial gross values added by industrial division for each concerned province have been forecasted based on the abovementioned three growth scenarios of national GDP at producer's prices. Thus, each province has three growth scenarios.

4. Energy Scenario Development

4.1. 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 a 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).

4.2. Major Assumptions/Options for Demand/Supply analysis

4.2.1. 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, in the residential sector, waste outputs are assumed to be dependent on population. The transport sector, on the 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 4-1.** 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 were calculated based on the macro-economic activities in the provinces as detailed in Chapter 3. 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 4-1. Assumptions and Sectoral Categorization

<table>
<tr><td colspan="2">Particulars</td><td>References</td></tr>
<tr><td rowspan="2">GDP*</td><td>Low economic growth
High economic growth</td><td rowspan="3">(MoF, 2016; NPC, 2014; NPC, 2017; CBS, 2012; CBS, 2014; ADB, 2015) and other recent documents as published by authorized agencies.</td></tr>
<tr><td>Reference economic growth</td></tr>
<tr><td>Demography</td><td>Population</td></tr>
</table>

* Details are given in Chapter 3.

4.2.2. 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 4-2** shows the basic assumptions taken for scenario development of each of the energy sectors.

Table 4-2. 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. Meanwhilethe transport sector, which is responsible for the 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.

4.3. 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 4-1**. The energysystem analysis was done from the bottom-up approach, i.e., all possible energy activities were considered at the end-use level for each sector. The base year was taken as 2022 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 the 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, MAED is 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 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 4-1.** The 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.

[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.

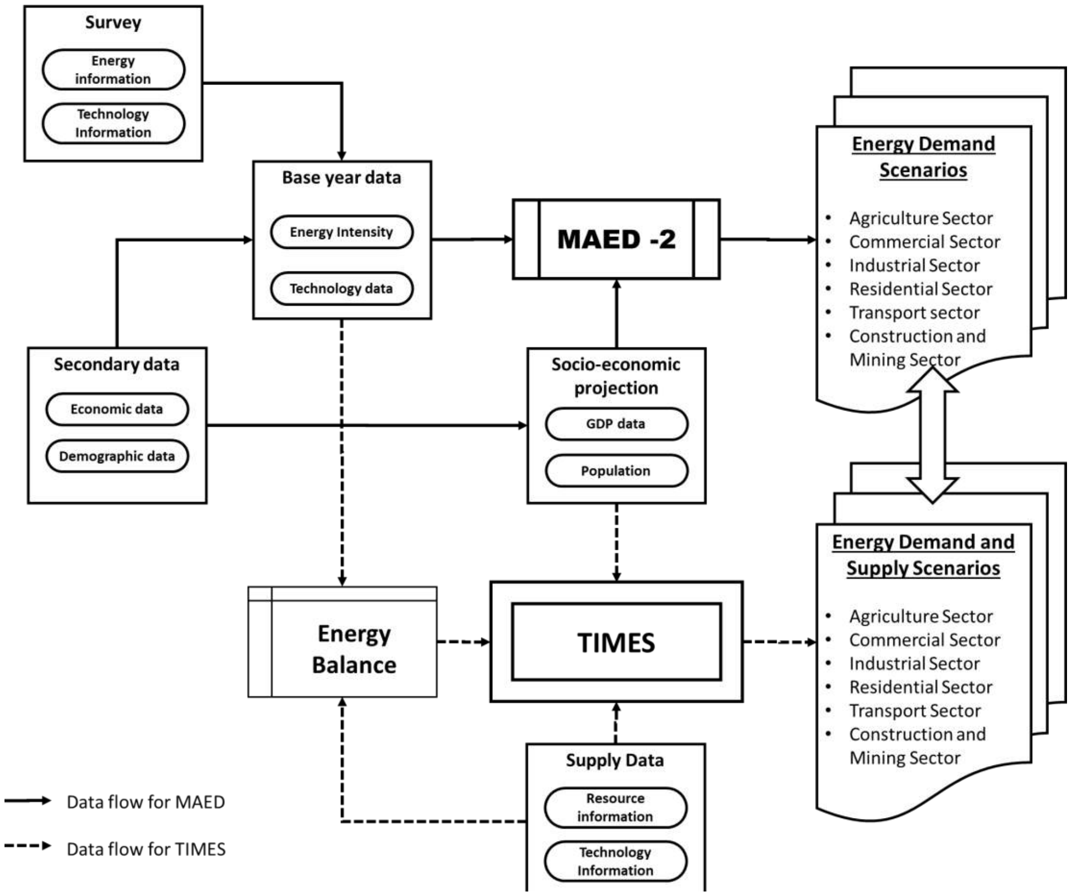


Figure 4-1: Methodological Framework of Projection in MAED and TIMES

4.3.1. 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.

The TIMES model has been used for developing least-cost optimization scenarios. However, the energy demand projections were 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 as these modeling frameworks are widely used in other developed and developing countries.

4.4. 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 4-2)**

- 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.

4.4.1. Model for Analysis of Energy Demand (MAED)

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

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

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

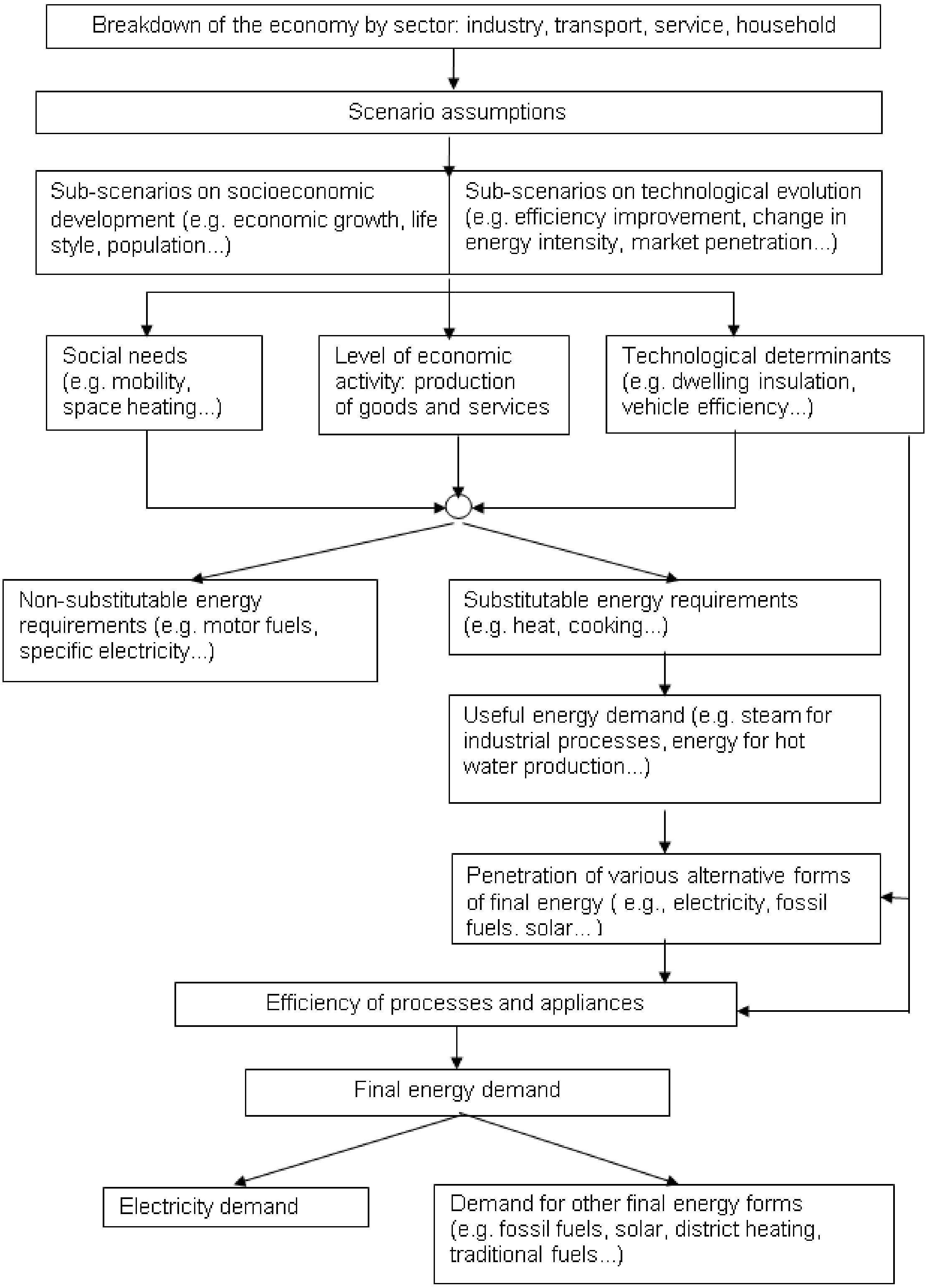


Figure 4-2: Scheme used to Project Useful and Final Energy Demand in Module 1 of MAED

4.5. Energy Supply Analysis

With limitation of MAED only being able to project the energy on demand basis only. The 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.

4.5.1. 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 4-3)**

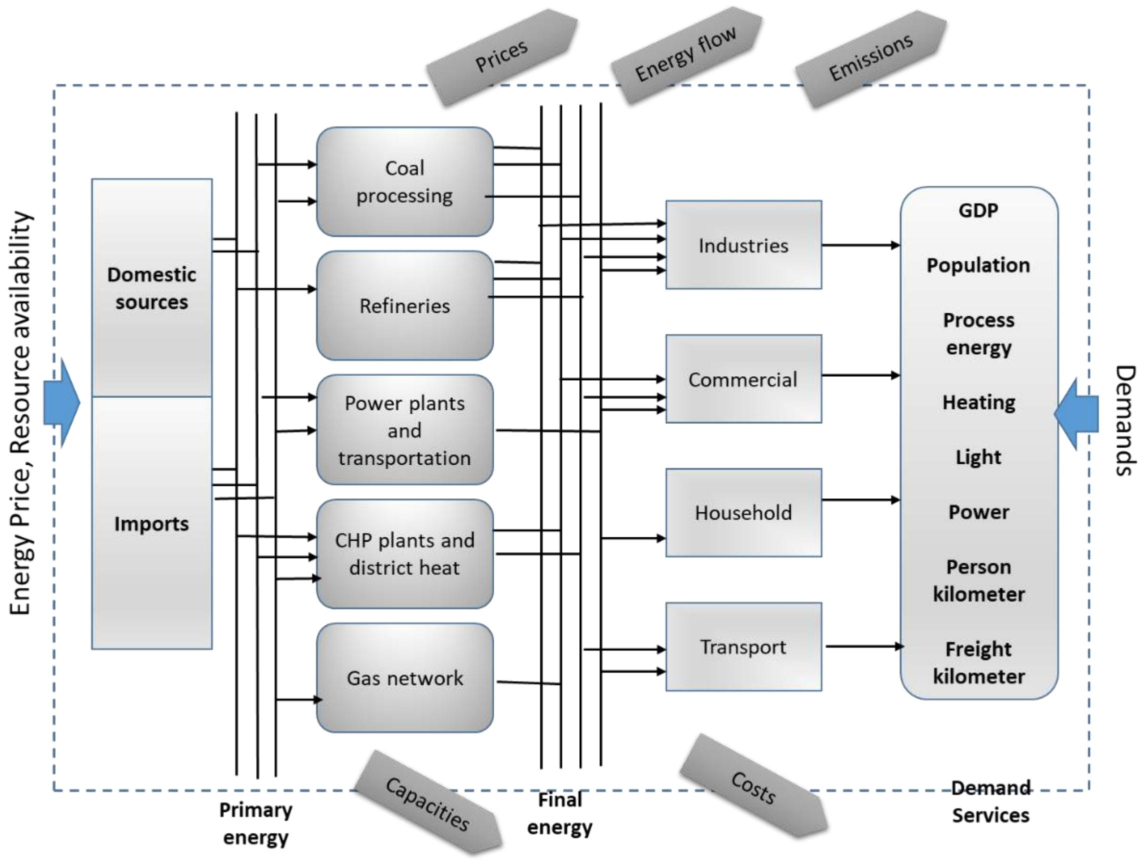


Figure 4-3: Structure of TIMES Framework

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

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

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

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

Equation 4.1

Where, X = vector of all decision variables

I = number of demand categories

CAP = capacities of end-use technologies

DM = exogenous demands to be satisfied

B = coefficient of other constraints

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

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

5. 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 the new renewable category includes solar energy, wind energy, solar-wind hybrid system, geothermal energy, hydrogen fuel, hydropower, etc. Traditional biomass means fuelwood, agricultural residues, and animal dung whereas modern biomass includes both liquid and non-liquid biofuels. Biogas from animal and human excreta and other waste biomass, ethanol, and biodiesels are some examples of liquid biofuels whereas non-liquid biofuel means bio-briquettes, charcoal, etc. Non-renewable energy resources primarily include fossil fuels that cover petroleum fuel, natural gas, and coal. The categorization of energy resources is given in **Figure 5-1.**

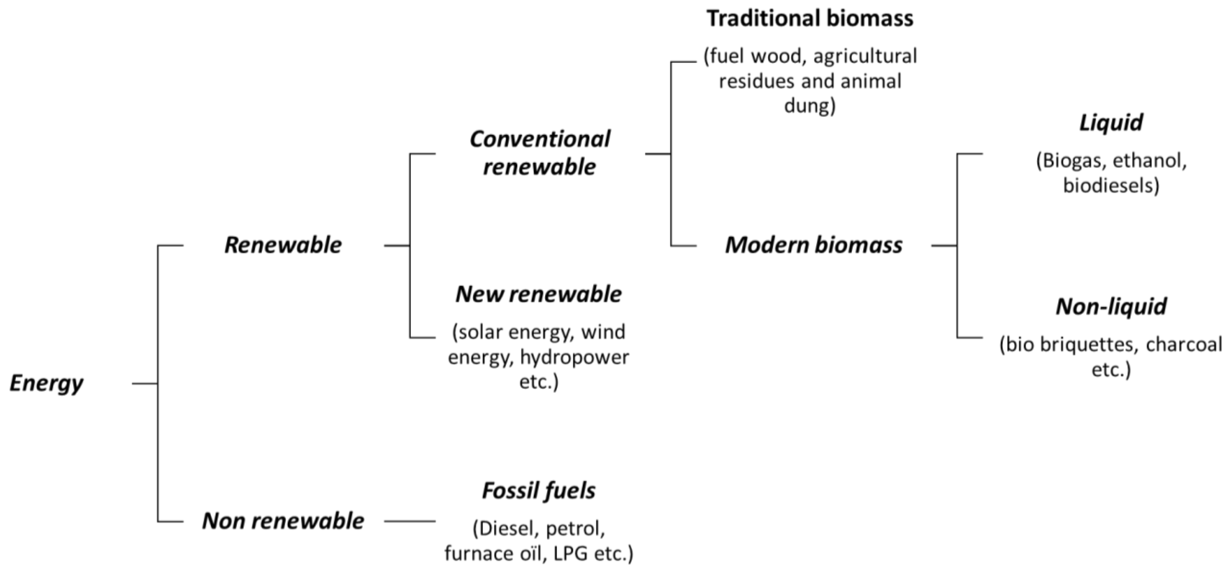


Figure 5-1. Energy Classification for Nepal

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

5.1. Solid Biomass

Lumbini Province of Nepal is blessed by nature with lots of forests in terai, dun valleys like Dang, mid-hills, and high hills. As compared to other provinces of Nepal, this province has more forest area per person. In addition, there is good sunlight, enough water in the watersheds of many small rivers, which originate in the province, and alluvial soils. Although deforested to some level, there are still very good forests in the province. But urbanization and agriculture have impacted good forests, and some of the good forests are changed into non-forests, especially in the Dang and terai districts. Similarly, human pressure for fuelwood in the past changed the forests into degraded ones. But, due to the better conditions for plant growth and past interventions of community forestry, Lumbini Province still has good potential for forest management and production. Therefore, from the perspective of energy these forests have very high potential. On the other hand, most of the people in the province are poor; therefore, they still depend upon bioenergy as a cheap source of energy, which is very important for them.

5.1.1. Forest in Lumbini Province

Terai forests predominantly composed of Sal (*Shorearobusta*), followed by *Terminalia-Anogeissus* and *Acacia catechu* and *Dalbergiasissoo* forest along stream banks and riverbeds. The other species generally grown there are haldu, harro, barro, simal, kadam, jamun, kusum, etc. In the Terai region, growth rate of these species is higher in comparison to mountainous species. Species like sal, asna, kadametc are good construction timber. Sisoo is very good for furniture and khayar fletches high cost due to52imala content in wood, which is main ingredient of panparag. Most of the above tree species are also good as fuelwood. Small stems and branches of these species are used as fuelwood and large size branches are also used as timber.

Subtropical broad-leaved forests occur mainly between 1,000 meters and 2,000 meters above sea level and are dominated by *Schimawallichii* and *Castanopsisindica*. Riverine forests of Cedrelatoona are common along river valley sides, while *Alnusnepalensis* is widespread along streams and exposed sites and moist places. Subtropical conifer forests primarily consist of *Pinusroxburghii* 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. *Castanopsistribuloides*, *Castanopsishystrix*and *Quercusmalayana* are the main tree species in these forests.

Upper temperate forests are found in drier south-facing slopes between 2,200-3,000 meters. Blue pine,malayana cedar are major conifer species and Quercus is the main broad leaf species.

Subalpine forestsoccur between 3,000 – 4,100 meters and are mainly comprised of small and generally ill-formed trees of *Abiesspectabilis*, *Piceasmithiana*, *Betulautilis*, and *Rhododendron spp.* Alpine scrub vegetation occurs between the treeline (around 4,000 meters) and the snowline (around 5,500 meters). **Table 5-1** showsthe forest area and major species of Lumbini Province.

Table 5-1. Summary of Physio Graphic Zone of theLumbini Province

S.No	Physiographic zone	Altitude (m)	Districts	Forest area (ha)	Major species	Stem total total stem volume (m3)	Growth rate %
1.	Terai	500	Banke, Bardia, Dang, Kapilbastu, Parasi,Rupandehi	44,8238	sal, sisoo, khair, asna	75,044,006	medium
2.	Middle mountain	500-3000	Arghakhanchi, Gulmi, Palpa, Pyuthan, Rolpa, Rukum E	420,059	chima-castanopsis, pinus, oak, alnus	52,196,531	medium

Forest resources are very important for ecosystem balance and people's livelihood in Nepal, and it is true also for Lumbini Province. Reliable and up-to-date information on forest resources isessential for supporting policy formulation, strategic planning, and sustainable forest management. Such information can ultimately guide wise decision-making aiming at supporting livelihoods, sustainable development and poverty reduction as stipulated in major policy documents (GoN, 2014; GoN, 2015; NPC, 2013N). 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, 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).

5.1.2. Forest Management in Lumbini Province

Banke and Bardiya National Parks are two protected areas in the province, which are managed for biodiversity conservation. Almost all remaining forests are managed for production which includes timber, fuelwood, and non-timber forest products. The most prominent forest management in the terai part of Lumbini Province is community forest, although there isa significant number of Collaborative Forest Management and block forests managed by the government.

The area of forests in Lumbini Province under community forest management is given below. The table shows that 379,005 ha area is handed over to 4055 forest user groups (DoF, 2019). This figure is low as compared to the community forests are handed over in other hill districts (**Table 5-2**).

Table 5-2. Community Forests and Areas in Lumbini Province

SN	Districts	No of UG	Area Managed (ha)
1	Banke	106	19,059
2	Bardiya	288	20,313
3	Dang	513	105,546
4	Kapilvastu	105	13,296
5	Parasi	123	15,707
6	Rupandehi	92	11,654
7	Arghakhanchi	438	30,487
8	Gulmi	385	15,283
9	Palpa	645	34,826
10	Pyuthan	387	46,668
11	Rolpa	503	38,365
12	Rukumeast	470	27,801
	Total	**4,055**	**379,005**

(DFO, 2071, 2074, 2075; DoF, 2061,2075)

5.1.3. Wood as Fuel

Biomass, the total of non-fossil organic material derived from biological sources, is the most important source of renewable energy in the world. It accounts for 35 % of primary energy consumption in developing countries and 14 % of the final energy consumption, globally (Parrika 2004; Demirbas et al. 2009; Panwar et al. 2011). Fuelwood is the main source of energy in rural Nepal as well. It accounted for 70% and biomass for 92% of Nepa''s total energy consumption. The main use of Nepal's forests is to provide biomass to satisfy the needs of domestic fuel. Fuelwood is used for several purposes like cooking, heating, and other thermal purposes in several processes in domestic, commercial as well as industrial use. Historically, Nepal's rural populations have been meeting the energy needs from the traditional sources liked fuel-wood and other bio-mass resources (AEPC, 2000). Most of the fuelwood has been reported to be derived from forests with some trees outside forest and tree growing on homeland and agricultural areas. Forests provide about 81 percent of the total fuel requirements of Nepal. However, the average annual production of fuelwood constitutes only 31 percent of demand. Agricultural residues contribute about 51 percent and cattle dung account for the rest (18 percent) (WECS, 1996). Following its national policy, Nepal gives emphasis to alternative and other renewable energy sources that aim at reducing dependence on forest products and animal dung (FAO, 2019). The demand for fuelwood in the country has rapidly increased due to population growth in the past andhas resulted tremendous pressure on existing forests. Local communities bring hundreds of cycle loads offuelwood to their villages from forests in rural area. But, due to migration of population into towns and employment abroad, rural population has decreased in recent years, and thereisa transition to LPG in cooking as well with the result of burgeoning double-digit growth in imports of LPG in the country.

5.1.4. Effect of Fuelwood Collection onForest

In past decades, because of the increasing population, the areas under agriculture expanded and forests shrunk. The forest areas in the Terai 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. In Banke and Bardia districts, the government of Nepal had initiated a settlement program in the past, and forests are cut for the cultivation of cotton. The average 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 areas (FRA/DFRS 2014).In this province also the land under cultivation increased at the 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.The fuelwood is practically free if people can afford time for collection from forest as well as those swept by river as seen in lower terai belts. Large quantity of fuelwood is being collected from community managed and government managed forest by the local people**(Table 5-3)**.

Table 5-3. Forest Area and Actual Fuelwood Produced in Current

Districts	Area inha	Fuelwood produced inchatta
Banke	115,776	401
Bardia	31,729	451
Dang	193,450	1521
Kapilvastu	60,448	145
Parasi	21,859	150
Rupandehi	25,976	185.39
Arghakhanchi	73,235	7219
Gulmi	46,098	98
Palpa	82,296	108
Pyuthan	64,218	5428
Rolpa	98,896	34
Rukum E	55,316	40
Total	**869,297**	**15,780**

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

(DFO, 2071, 2074, 2075; DoF, 2061,2075)

5.1.5. National Demand and Supply Situation

Assessing the true state of fuelwood resources in Nepal is a difficult task (Thompson and Warburton 1985) because the distribution of forest and vegetation in the forest is diverse and is an integral part of the subsistence economy. Presently fuelwood comes from government forests, community forests and private forests and other source like leasehold forests, garden, and orchards in the province.

The demand for fuelwood depends upon the household number which uses fuelwood and their consumption patterns like food cooked, use of fuel for heating, etc. Mathematically fuelwood demand is the function of households, their fuelwood uses, and per capita consumption.

Fuelwood from Community Based Forests

Most of the forest products in Lumbini Province come either from community forests or government forests or private forests. Their government forests are mostly matured and degraded. Therefore, these forests have small growing stock. In the past, although forest management plans were made, forests are not managed on a sustained basis. Felling of trees in government forests is often limited to the clearing of the sites for different projects like road, resettlement of villagers, transmission lines, irrigation channels, industrial states etc. Lately, management has initiated community forests and collaborative forests as pilot programs. Results of these forest management are highly positive, therefore, in the future managed forest area will be increased and this will produce more forest products like timber and fuelwood.

5.1.6. Potential Increment

If carefully implemented, sustainable management of forests in Nepal could not only increase and stabilize the supply of forest products, but it would also help in contributing to the livelihood of the people involved in 19, 919 community forests which mean 2,546,760 households are involved in community forest management (DoF, 2019) and collaborative forest management (**Table 5-4**). The demand and supply of forest products depend not only on biophysical factors inherent in different ecological regions of Nepal but also on the policy regimes perused and implemented by the Government of Nepal (MFSC, 2013).

Table 5-4. Forest Area and potential Fuelwood Production in the currentsituation

	Forest Area ha	Accessible forest area ha	Fuelwood Production/year m^3	Fuelwood Production/year kilo ton
Banke	115,776	104,198	329,561	224.18
Bardia	31,729	28,556	90,318	61.43
Dang	193,450	174,105	550,664	374.59
Kapilvastu	60,448	54,403	172,068	117.05
Nawal P W	21,859	19,673	62,223	42.32
Rupandehi	25,976	23,378	71,095	50.29
Arghakhanchi	73,235	65,911	50,006	105.30
Gulmi	46,098	41,488	31,477	66.27
Palpa	82,296	74,066	56,193	118.32
Pyuthan	64,218	57,796	43,849	92.33
Rolpa	98,896	89,006	67,528	142.19
Rukum E	55,316	49,784	37,771	79.53
Total	**869,297**	**782,367**	**1,562,753**	**1437.84**

(DFO, 2071, 2074, 2075; DoF, 2061,2075)

Thus, annual fuelwood from the whole Lumbini Province is 1,562,753 m^3 (This is a harvestable quantity). This volume accounts for 11 categories, 10 defined species, and 1 other (miscellaneous).And to classify fuelwood production as per each species, the proportion of stem volume of each species is multiplied to1,562,753m^3. Thus, obtained value is converted to the kilogram and or tone using wood density (average 1 m^3 =711 kg) and totaled to final fuelwood 1,437.84 kilo tons.

5.2. Biogas in Lumbini Province

- **Livestock in the Lumbini Province**

The number of livestock and the collectable dung play a major role in determining the biogas production potential. The number of livestock in different districts of Lumbini Province is given in **Table 5-5**.

Table 5-5. Numbers of Livestock in Lumbini Province (Fiscal Year 2077/78)

District	Cattle	Buffaloes	Sheep	Goat	Pigs	Fowl	Duck
Arghakhanchi	40,046	98,517	1,242	134,161	2,808	493,214	1,070
Banke	221,297	185,337	9,700	322,897	75,639	1,146,410	2,621
Bardiya	123,245	132,936	11,247	214,749	38,296	487,445	2,381
Dang	141,678	138,450	34,386	301,104	92,161	3,180,939	14,800
Gulmi	44,524	49,863	6,586	151,259	11,456	255,081	516
Kapilvastu	164,820	145,480	12,645	270,350	23,719	720,915	8,095
Parasi	78,484	69,935	2,860	100,493	39,715	549,013	21,642
Palpa	76,262	89,241	2,864	220,986	28,203	762,240	2,458
Pyuthan	75,211	74,532	14,273	179,638	10,998	324,099	1,060
Rolpa	102,641	55,312	14,525	202,015	36,506	498,287	558
Rukum east	18,191	17,452	22,355	62,125	10,265	128,789	275
Rupandehi	98,423	151,128	4,445	260,111	17,349	1,361,151	23,615
Total	**1,184,822**	**1,208,183**	**137,128**	**2,419,888**	**387,115**	**9,907,583**	**79,091**

(Source: Ministry of Agriculture and Livestock Development, 2022)

For production of biogas, dung from cattle and buffaloes are considered collectable dung while other livestock are considered as not collectable because these animals are not put in shade but grazed in forests and other communal lands. Considering production of dung as 10 kg/day from cattle and 15 kg per day from buffalo (WECS, 2010), dung production for Lumbini Province can be estimated as shown in **Table 5-6.**

Table 5-6. Dung Production in Lumbini Province

District	Cattle	Buffaloes	Dung produced from cattle tons/ year	Dung produced from buffalo tons/ year	Total dung production tons/Year
Arghakhanchi	40,046	98,517	146,168	539,381	685,548
Banke	221,297	185,337	807,734	1,014,720	1,822,454
Bardiya	123,245	132,936	449,844	727,825	1,177,669
Dang	141,678	138,450	517,125	758,014	1,275,138
Gulmi	44,524	49,863	162,513	273,000	435,513
Kapilvastu	164,820	145,480	601,593	796,503	1,398,096
Parasi	78,484	69,935	286,467	382,894	669,361
Palpa	76,262	89,241	278,356	488,594	766,951
Pyuthan	75,211	74,532	274,520	408,063	682,583
Rolpa	102,641	55,312	374,640	302,833	677,473
RukumEast	18,191	17,452	66,397	95,550	161,947
Rupandehi	98,423	151,128	359,244	827,426	1,186,670
Total	**1,184,822**	**1,208,183**	**4,324,600**	**6,614,802**	**10,939,402**

5.2.1. Potential of Biogas Production Per Year

The estimation of potential biogas production in Lumbini Province is done 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 2020/2021 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 (Vaid, V. and Garg, S., 2013),**Table 5-7**shows the potential energy production from biogas.

Table 5-7. Potential of Biogas in Current

District	Total dung production “000” tons/Year	Biogas in “000” cubic meter	Energy in “000” GJ per year	Potential percentage	Potential in 000 GJ
Arghakhanchi	686	24.680	493.59	0.75	370.20
Banke	1,822	65.608	1,312.17	1	1,312.17
Bardiya	1,178	42.396	847.92	1	847.92
Dang	1,275	45.905	918.10	1	918.10
Gulmi	436	15.678	313.57	0.75	235.18
Kapilvastu	1,398	50.331	1,006.63	1	1,006.63
Parasi	669	24.097	481.94	1	481.94
Palpa	767	27.610	552.20	0.75	414.15
Pyuthan	683	24.573	491.46	0.75	368.59
Rolpa	677	24.389	487.78	0.75	365.84
Rukum east	162	5.830	116.60	0.75	87.45
Rupandehi	1,187	42.720	854.40	1	854.40
Total	**10,939**	**393.818**	**7,876.37**		**7,262.57**

Potential of biogas production is considered 75% for 6 mid hill districts and 100 % for 6 Terai districts and the production of biogas for Lumbini Province is 7,263 thousand GJ.

The use of dung for making dung cakes and dung sticks to be used as a cooking fuel in poor families can decrease potential generation of biogas in specific Terai regions of Lumbini Province.

5.2.2. Waste-to-Energy Potential from Commercial and Municipal Waste in Lumbini Province

The estimated potential of waste to energy potential from commercial/ industrial and municipal solid waste for various districts of Lumbini Province based on the secondary data from the study reports from AEPC is presented in **Table 5-8.**

Table 5-8. Potential of Waste to Energy Production per year in Lumbini Province

District	District Population (2078)	Total commercial/Industrial Waste (tons/day)	Total Organic Municipal Waste (tons/day)	Total Organic Waste Production (tons/day)	Total Biogas Yield (cum/day)	Total Organic Waste Production "000" tons/Year	Biogas in "000" cubic meter	Energy in "000" GJ per year
Arghakhanchi *	177,200	19.04	7.01	26.06	1,330.80	9.51	485.74	9,714.81
Banke **	603,393	143.07	6.80	149.87	8,202.40	54.70	2,993.88	59,877.52
Bardiya *	460,831	49.52	18.24	67.76	3,460.89	24.73	1,263.23	25,264.52
Dang *	676,277	72.67	26.77	99.44	5,078.92	36.30	1,853.81	37,076.12
Gulmi *	246,836	26.53	9.77	36.30	1,853.76	13.25	676.62	13,532.48
Kapilvastu **	686,739	7.72	18.70	26.42	1,054.90	9.64	385.04	7,700.77
Parasi **	385,515	28.05	30.80	58.85	3,289.80	21.48	1,200.78	24,015.54
Palpa *	242,423	26.05	9.60	35.65	1,820.62	13.01	664.53	13,290.55
Pyuthan *	231,848	24.91	9.18	34.09	1,741.20	12.44	635.54	12,710.79
Rolpa *	236,226	25.39	9.35	34.74	1,774.08	12.68	647.54	12,950.81
Rukum east *	57,962	6.23	2.29	8.52	435.30	3.11	158.88	3,177.68
Rupandehi **	1,118,975	121.67	44.70	166.37	8,939.60	60.73	3,262.95	65,259.08
Total	**5,124,225**	**550.85**	**193.22**	**744.07**	**38,982.28**	**271.59**	**14,228.53**	**284,570.65**

(Source: AEPC Study Report, 2019, and CBS, 2021)

**Source data from of AEPC field study report.

*Projected and calculated based on the AEPC field study report

The estimated potential of waste generation for commercial/ industrial waste consisted of data from the cow farms, buffalo farms, poultry farms, pig farms, sugar industry, liquor industry, vegetable market, slaughterhouse, hospitals, and residential schools.

Organic municipal waste is the segregated part of the total municipal waste which excludes nonorganic dumping waste.

The W2E potential for Arghakhanchi, Bardiya, Dang, Gulmi, Palpa, Pyuthan, Rolpa and Rukum East districts has been calculated based on the proportionating population density with reference to other districts since no field studies have been conducted in these districts so far and no secondary data are available.

Since technically feasible and financially viable W2E projects demand uninterruptable and sizable quantity of waste economically available for operation of large-scale biogas, the potential sites are in the city areas with high population density, thus, while calculating the potential commercial and municipal waste availability, only the urban population within the respective districts are taken. Based on the Preliminary Report of National Population Census 2021 and Statistical Information on Nepalese Agriculture 2077/78 (2020/21), 66.08% of the population of each district has been considered to live in the city area.

From the table given above, it is seen that East Rukum, Arghakhanchi and Kapilvastu districts have the least W2E potential and Rupandehi and Bankedistricts have high potential within the province. The total W2E potential energy is found to be 284,570 thousand GJ per year.

5.3. Agriculture Residues

Agriculture waste is also the main source of fuel because it is already available at home during the harvest of agriculture crops. Area used for farming different crops is shown in **Table 5-9**

Table 5-9. Area of Different Crop in Districts

	Area cultivated in Ha					
	Paddy	**Maize**	**Wheat**	**buckwheat**	**Oil seed**	**Millet**
Palpa	8,254	21,479	5,864	425	1,355	2,541
Gulmi	9,458	25,443	6,820	217	599	2,904
Arghakhachi	7,620	17,536	5,340	259	1,512	501
Rupandehi	21,175	4,466	7,616	85	3,932	225
Kapilvastu	65,882	2,678	25,934	0	6,757	45
Rolpa	68,154	2,551	24,565	0	4,850	0
Pyuthan	36,065	24,843	12,100	19	19,089	15
Dang	34,550	9,034	17,850	0	9,187	0
Banke	47,329	2,657	18,800	0	9,422	0
Bardia	1,781	8,652	5,573	0	373	460
Rukum	5,981	12,603	8,577	12	724	1,993
Parasi	4,629	13,434	8,582	115	404	1,017

	Area cultivated in Ha					
	Paddy	**Maize**	**Wheat**	**buckwheat**	**Oil seed**	**Millet**
Total	**310,878**	**145,376**	**147,621**	**1132**	**58,204**	**9,701**

After collecting cultivated area of different crops, we can come to estimate residues produced as below in **Table 5-10**

Table 5-10. Energy from Agriculture Waste /Year

	Residues of crops in tons							
Districts	**Paddy**	**Maize**	**Wheat**	**Buckwheat**	**Oil seed**	**Millet**	**Total residue in tons**	**Energy produced in GJ**
Palpa	48,698	117,060	19,761	637	1,734	4,827	192,720	2,890,809
Gulmi	55,802	138,664	22,983	325	766	5,517	224,059	3,360,896
Arghakhachi	44,958	95,571	17,995	388	1,935	951	161,800	2,427,011
Rupandehi	12,932	24,339	25,665	127	5,032	427	180,526	2,707,891
Kapilvastu	388,703	14,595	87,397	0	8,648	85	499,430	7,491,464
Rolpa	402,108	13,902	82,784	0	6,208	0	505,003	757,505
Pyuthan	212,783	135,394	40,777	28	24,433	28	413,445	6,201,686
Dang	203,845	49,235	60,154	0	11,759	0	324,994	4,874,912
Banke	279,241	14,480	63,356	0	12,060	0	369,137	5,537,068
Bardia	10,507	47,153	18,781	0	477	874	77,793	1,166,906
Rukum	35,287	68,686	28,904	18	926	3,786	132,069	2,061,152
Parasi	27,311	73,215	28,921	172	517	1,932	132,069	1,981,044
Total	**1,834,180**	**792,299**	**497,482**	**1,698**	**74,501**	**18,431**	**3,218,593**	**48,278,897**

Table 5-10provides an estimate of the total agricultural residue produced from different crops and the energy produced from these agricultural residues. Total potential energy produced from such waste is 48,279TJ. More than half of this energy comes from paddy and maize straw.

5.4. Petroleum Products

Petroleum drilling is being explored under the Department of Mines and Geology, GoN, but proven reserve of feasible petroleum products is yet to be found out in Nepal. All the petroleum products consumed in the country are imported from India. The only company that deals with import and sales of petroleum products – that include diesel, petrol, kerosene, and LPG and others. The furnace oils and other oil residues are imported by the industries themselves. Thus, the supply of petroleum products is obtained from the regional offices of Nepal Oil Corporation. District-wise sales data for 2077-78 is shown in **Table 5-11**. All the units for MS, Diesel and SKO are in liters except for LPG in metric ton (MT). These sales data represent the sales to depots in 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. The sales data from NOC depot shows that approximately 18-25% total national sales of diesel, gasoline and kerosene are consumed in Lumbini Province, besides individual imports from other provinces.

Table 5-11. Petroleum Sales in 2077-78 in Lumbini Province

Districts	MS	Diesel	SKO	ATF	LPG
	kL	kL	kL	kL	tons
Arghakhanchi	1,866	7,177	580	-	-
Banke	14,743	64,743	984	4,173	40,232
Bardiya	5,292	17,604	296	-	-
Dang	13,257	52,479	599	-	-
Gulmi	1,769	7,272	2,367	-	-
Kapilvastu	10,711	44,128	172	-	-
Parasi	17,617	69,455	105	-	-
Palpa	3,257	7,711	-	-	-
Pyuthan	1,202	5,318	-	-	-
Rolpa	785	4,568	-	-	-
Rupandehi	35,583	138,256	628	1,908	76,777
Total	**106,082**	**418,711**	**5,731**	**6,080**	**117,009**

(NOC 2022)

LPG sales could not be properly ascertained from the NOC database as the Product Delivery Orders (PDO) are obtained by the LPG bottling plants and distributed from the several private LPG sales depots and most of the time there are sales crisscrossing different districts.

5.5. Electricity

5.5.1. Hydropower Potential

Nepal's theoretical hydropower potential has been estimated at about 83,000 MW and its technically and economically feasible potential of about 45,000 MW and 42,000 MW respectively (Shrestha, 1966). A study by Bajracharya (2015) shows the total theoretical estimation at annual mean flow to be 103,341 MW. The recent study carried out by WECS in 2019 for the estimation of hydropower potential shows the gross hydropower potential of 72,544 MW from three river basins: Koshi, Gandaki, and Karnali basin which covers 94% of the total gross potential of the country(WECS, 2019). Gross hydropower potential distributions in provinces based on the major three river basins are as shown in **Table5-12**. KoshiProvince which includes most of the Koshi basin incorporates the highest hydropower potential (22,619 MW)- which is 31% of total hydropower potential. Madhesh Province incorporates the lowest hydropower potential (275 MW)-which is 0.4% of total potential. Similarly, Bagmati, Gandaki, Lumbini, Karnali, and SudurpashchimProvince incorporate 14.6%, 20.7%, 3.7%, 18.9%, and 10.6% of the total potential respectively.

Table 5-12. Distribution of Gross Hydropower Potential Among Different Provinces Based on 3 Major River Basins

SN	Province	Power Potential (MW)	% of Basin Potential (MW)
1	Koshi	22,619	31.2
2	Madhesh	275	0.4
3	Bagmati	10,568	14.6
4	Gandaki	14,981	20.7
5	Lumbini	2,677	3.7
6	Karnali	13,702	18.9
7	Sudurpashchim	7,722	10.6
Total		**72,544**	**100**

(WECS, 2019)

Nepal Electricity Authority is the sole organization responsible for the operation and distribution of electricity supply in the country. The total installed capacity of NEA is 627.03 MW (20 hydro and 2 thermal) out of total 2,189.91 MW in Integrated Nepal Power System (INPS). The annual energy generation from NEA power plants under Generation Directorate is 3,242.483 GWh, which is about 29.29% of the total energy generation in Nepal (NEA Hydropower Stations, Subsidiary Companies and IPPs) (NEA 2022).

The province wise NEA and IPP developed, under construction and planned hydropower plants projects greater than 1MW areas shown in **Table 5-13.**

Table 5-13. NEA Developed, Under Construction and Planned Hydropower Plants

S.No.	Power Stations	District	Total Installed Capacity (MW)	FY 2077/78 (MWh)
NEA developed HPP				
Lumbini Province				
1	Lumbini	Parasi	1.02	

(DoED, 2023)

The IPPs operated, under construction and planned projects greater than 1MW is as shown in **Table 5-14**

Table 5-14. IPPs Developed, Under Construction and Planned Hydropower Plants

	In operation	Under construction	Planned Projects
	Installed capacity MW	Installed capacity MW	capacity
Lumbini	14.9	7.19	1.5

(DoED, 2023)

5.5.2. Electricity Supply

The district-wise electricity supply status as obtained from Nepal Electricity Authority for Lumbini Province is shown in **Table 5-15**along with its use in economic sectors. It shows Rupandehi and Parasi have a comparatively high consumption of electricity due mainly to the number of industries located in the districts.

Table 5-15. Electricity Sales in 2077-78 in Lumbini Province

	Agriculture	Commercial	Industry	Residential	Transport	in TJ
Arghakhachi	0.63	10.27	75.08	32.07	-	118.05
Banke	11.31	125.74	220.59	339.28	-	696.92
Bardiya	10.05	23.42	34.05	145.53	-	213.04
Dang	6.38	105.47	404.99	187.64	0.01	704.49
Gulmi	-	35.11	2.35	24.08	-	61.55
Kapilvastu	3.36	41.20	181.60	223.78	-	449.94
Parasi	2.78	27.03	560.47	177.62	-	767.91
Palpa	0.87	31.57	6.27	37.86	-	76.58
Pyuthan	0.07	6.81	2.26	21.26	-	30.40
Rolpa	0.07	4.04	6.12	15.03	-	25.26
Rukum East	-	0.47	0.13	0.71	-	1.31
Rupandehi	8.23	255.37	1,166.99	777.61	0.01	2,208.22
Total	**43.74**	**666.51**	**2,660.92**	**1,982.47**	**0.02**	**5,353.66**

(NEA, 2022)

5.6. Modern Renewable Energy Sources- Solar &Other Renewables

- **Current Energy Consumption Status**

As of 2021, AEPC has been able to implement 1851 nos. of mini and micro hydro projects generating 34.47 MW of electricity among which, 142 nos. of projects are implemented in Lumbini Province generating 2.89 MW of electricity benefitting 30,370 nos. of rural households. Rolpa and Eastern Rukum have comparatively more beneficiary households covering 33.3% and 33.4% of total provincial beneficiaries respectively, while Banke, Bardiya, Dang, Kapilvastu, Parasi and Rupandehi had not benefitted at all due to lowland geography. According to AEPC, 272 nos. of improved water mills, 152,268 nos. of solar home system units, 359 nos. of institutional solar PV System generating 571.9 kWp, 421 solar irrigation systems, and 37 solar water pumping systems has been installed which covers 2.4%, 19.1 %, 10.7 %, 19.2% and 19.8% of the total country installation respectively in 2021.

Addressing the need for modern renewable energy and cleaner cooking technologies to reduce household air pollution and improve the health conditions of the rural population, AEPC has promoted more than 1,612,934 cleaner and improved cooking technologies including domestic biogas, mud ICS and metallic ICS in Nepal. Out of the total, around 17.7% of the installation has been done in Lumbini Province, i.e, 67,622 Nos. of domestic biogas plants, 211,442 mud ICS and 6,926 metallic ICS respectively (**Table 516**).

Table 5-16. Modern Renewable Energy Technologies Installed in Lumbini Province

Technologies	Solar Irrigation System	Solar Water Pumping System	Domestic Biogas	Large Biogas Plant	Mud ICS and Metallic ICS	
District	**Numbers**	**Numbers**	**Numbers**	**Numbers**	**Mud ICS**	**Metallic ICS**
Arghakhanchi	12	2	952	-	30,094	433
Banke	107	-	6,791	4	1,329	987
Bardia	43	-	13,627	1	1,342	1,171
Dang	21	1	13,725	4	18,632	735
Gulmi	33	1	1,765	-	43,418	1,781
Kapilvastu	100	-	5,687	-	31,534	76
Parasi	42	-	6,026	3	1,848	293
Palpa	-	10	8,509	3	22,987	121
Pyuthan	18		1,825	1	32,572	58
Rolpa	12	19	313	-	12,314	558
Eastern Rukum	-	4	34	-	4,884	165
Rupandehi	33	-	8,368	4	10,489	548
Grand Total	**420.5**	**37**	**67,622**	**20**	**211,443**	**6,926**

Technologies	Micro Hydro Projects			Improved Water Mill	Solar Home System	Institutional Solar Photovoltaic System	
District	**No. Projects**	**kW**	**HHs**	**Numbers**	**Numbers**	**Numbers**	**Wp**
Arghakhanchi	2	9.5	146	-	9,517	37	68,000
Banke	-	-	-	-	13,874	18	41,500
Bardia	-	-	-	-	5,459	3	6,000
Dang	-	-	-	-	13,330	20	38,000
Gulmi	21	398.7	4311	-	13,632	43	91,000
Kapilvastu	-	-	-	-	278	4	17,400
Parasi	-	-	-	-	5,057	10	25,500
Palpa	36	338.5	3,571	1	10,279	18	37,000
Pyuthan	12	187	2,083	78	11,682	22	32,000
Rolpa	41	965.1	10,102	131	48,951	88	157,000
Eastern Rukum	30	993.5	10,157	62	20,146	87	19,700
Rupandehi	-	-	-	-	63	9	38,800
Grand Total	**142**	**2892.3**	**30,370**	**272**	**152,268**	**359**	**571,900**

(AEPC, 2021)

5.7. Household Energy Production

Traditional energy, particularly agri-residue and animal waste are produced at household level. Fuelwood energy supply is generally mixed from bothproductions from own garden as well bought from the nearest market. The household energy production obtained from the survey shows that in Lumbini Province there is sufficient supply of agri-residue and animal waste to meet its demand for household purposes. However, in case of fuelwood, approximately 40% is met by own production and remaining demand of fuelwood is supplied from the market. Similarly, for the modern energy supply, biogas and solar are two prominent sources. Biogas plants of various sizes are installed in different districts supplying enough biogas energy which is predominantly used for cooking proposes in residential sector. Regarding solar energy, the small and institutional solar home system installed at household level also supplied adequate energy which is used for lighting purposes at household level (**Table 5-17**). Details of household energy production of each district are given in annex.

Table 5-17. Household Energy Production

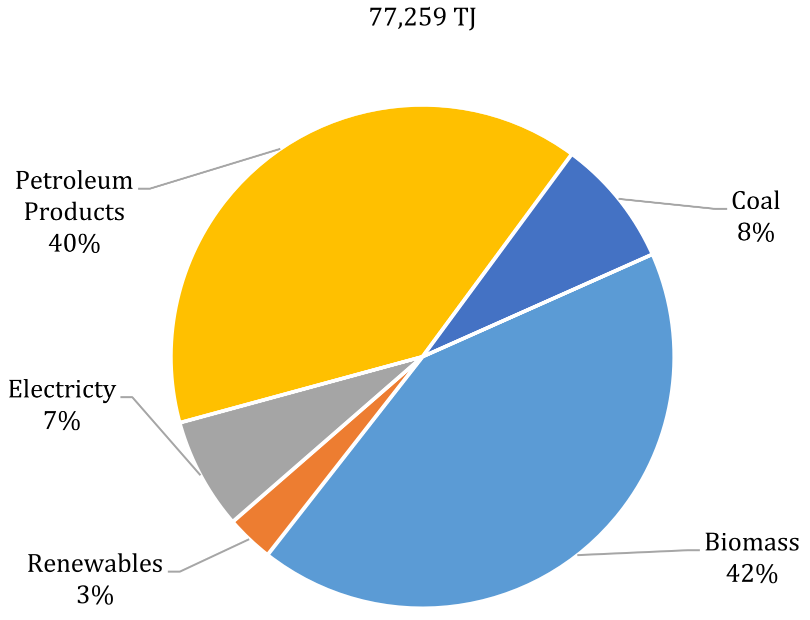
Fuel sources	TJ
Fuelwood	**8,558.76**
Agri-residue	**198.25**
Animal waste	**132.10**
Biogas	**2,621.23**
Solar PV	**18.52**

(Calculated from survey data, 2022)

6. Energy Consumption in 2021/2022

The total final energy consumption (FEC) in Lumbini Province was found to be 77,259TJ. Among the six sectors, the residential sector is the highest energy-consuming sector followed by industries. However, the amount of energy they consume is nearly equal. These results are an indication of energy efficiency improvement as well as the use of energy in productive uses. This can be seen in the energy mix as well. The highest share of energy consumed, although is still biomass (42%), the lower share of it in FEC shows that the use of modern energy has been increasing. With the increase in demand for energy in industrial and other economic sectors, the consumption of petroleum products has increased significantly, taking a share of 40% in FEC. The primary reason behind this change in energy pattern is seemingly due to energy transition and energy efficiency improvement, as indicated by IEA (2018) in developing countries.

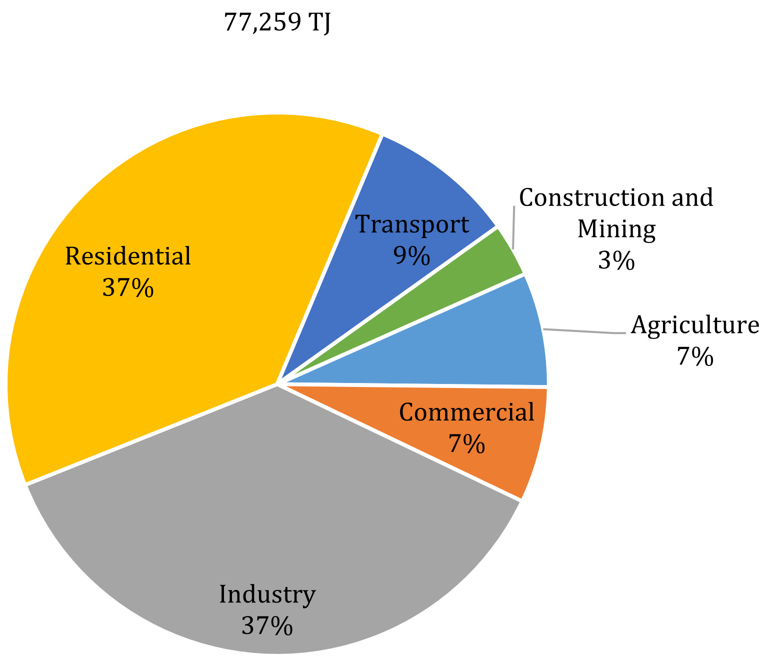
In Lumbini Province, the use of fuelwood is still prevalent among biomass (**Figure 6-1).** But the use of fuelwood for thermal purpose has shifted. Hence the consumption of diesel, furnace oil, and coal for thermal use is seeing an increase. Due to higher demand for thermal purposes such as heating and cooking, and due to electrification, the share of electricity is slightly higher than the national average. The use of animal waste as fuel has largely reduced as well while for biogas – although increasing in number, the actual use is very little. This can be mainly attributed to reaching LPG, decreasing livestock farming as well as peoples' reluctance due to work needed to operate residential biogas plants. In addition to that, the use of biogas is limited to residential and very limited commercial usage.



(Survey, 2022)

Figure 6-1. Energy Mix in Lumbini Province

Figure 6-2alsoindicates the change in the consumption pattern in different economic sectors. With the residential and the industrial sectors being the highest energy-consuming sectors, the use of biomass and fossil fuels is prevalent in the energy mix. The transport sector is third at 9%. The agriculture and commercial sectors share the nearly same amount of energy. Thus,compared to other provinces, Lumbini also has significant agricultural activities and is more highly mechanized than in hilly regions.



(Survey, 2022)

Figure 6-2. Sector-wise Energy in Lumbini Province

The energy mix by fuel type in different sectors can be seen in **Table 6-1**. The major portion of the traditional biomass is consumed in the residential sector. Meanwhile, the use of agricultural residue and animal waste are very low – firstly due to the availability of commercial fuels, and secondly, animal wastes go for biogas as well as manure making. However, large amounts of agricultural residues are seen to be being used in industry for thermal purposes – mainly due to cheaper prices and local/regional availability. Due to the presence of larger industries in this province, the use of commercial energies like electricity and petroleum products is highest in the industrial sector. In addition to that, the industry also uses diesel for electricity generation using diesel generators. Meanwhile, due to higher mechanization in the agricultural sector, the use of diesel for agriculture is also significant in the Lumbini Province. Due to the large number of transportation vehicles in the province being intercity, they tend to refuel in other regions as well, thus reducing the quantity of fuel sales within the province compared to other sectors.

Table 6-1. Annual Energy Consumption in Lumbini Province by Sector and Fuel Type

in TJ

	Renewables							Nonrenewable							Total
	Conventional renewable					New Renewables									
	Traditional biomass			Modern biomass											
	Fuelwood	**Agricultural Residue**	**Animal dung**	**Biogas**	**Bio briquettes**	**Solar**	**Grid Electricity**	**Petrol**	**Diesel**	**Kerosene**	**Furnace Oil**	**Aviation turbine fuel**	**LPG**	**Coal**	
Agriculture	-	-	-	-	-	0.56	49.50	105.36	5,129.18	-	-	-	-	-	5,284.61
Commercial	3,602.55	247.87	146.03	3.28	-	108.64	785.58	-	-	-	-	-	445.67	13.62	5,353.25
Industry	4,706.35	2,879.38	-	-	-	-	2,760.54	4.89	9,675.11	-	1,413.47	-	717.52	6,314.01	28,471.27
Residential	20,748.83	178.13	120.53	2,212.79	7.30	19.23	1,881.42	-	-	6.01	-	-	3,681.15	23.49	28,878.88
Transport	-	-	-	-		-	0.23	3,468.43	3,107.44	-	-	217.67	-	-	6,793.78
Construction and mining	-	-	-	-		-	55.23	5.90	2,272.23	3.85	0.03	-	139.80	-	2,477.04
Total	**29,057.73**	**3,305.38**	**266.56**	**2,216.07**	**7.30**	**128.43**	**5,532.51**	**3,584.59**	**20,183.96**	**9.86**	**1,413.50**	**217.67**	**4,984.16**	**6,351.12**	**77,258.83**

(Survey, 2022)

Table 6-2shows the energy consumption indicators which highlight the status of energy consumption in Lumbini Province. The total final energy consumption per capita of 15 GJ is near to the previous national average. This is due to the usage of inefficient technologies on the one hand and the high amount of energy consumed in the industrial sector on the other. The electricity demand per capita is nearly the national average, due to larger industrial consumption. However, the residential electricity consumption per household lies in tier 3 of the multi-tier framework and is way behind the tier-5 level of 3,000 kWh in 2030(World Bank/ESMAP, 2015).

Table 6-2. Energy Consumption Indicators

Parameter	Unit (per annum)	Value
Energy per capita	GJ per capita	15.08
Energy per GVA	GJ per million NRs	130
Share of modern and new renewable energy		10.2%
Electricity Consumption (Total)	kWh per capita	307
Electricity Consumption (Residential)	kWh per HH	480

(Survey, 2022)

The energy consumptions at the district levels are provided in Annex.

Figure 6-3 illustrate sthe flow of energy in Lumbini Province. It is quite visible that the largest share of energy is from primary solid biomass followed by petroleum products in 2022 and mostly are consumed by residential and industry sectors.

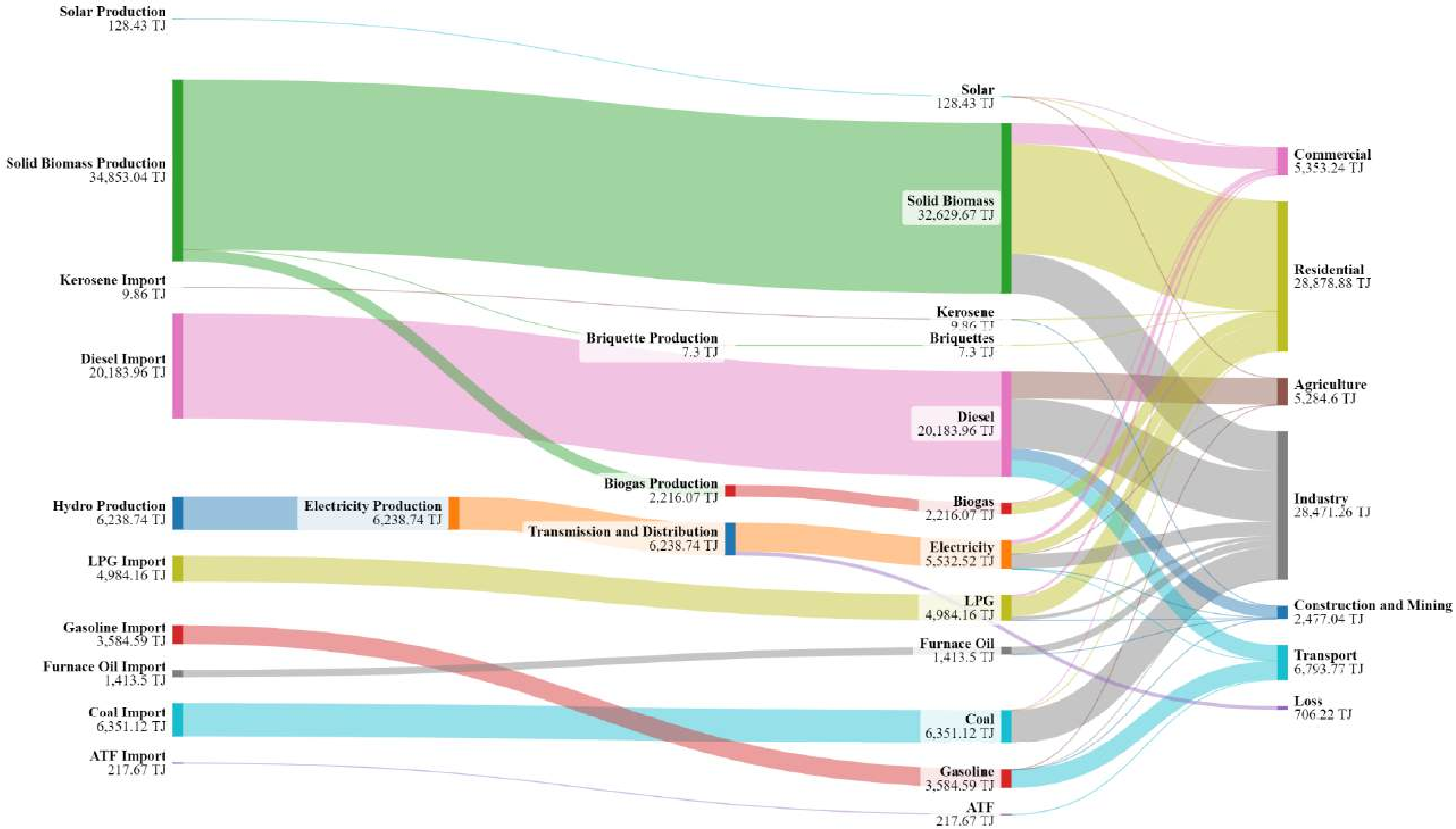


Figure 6-3. Energy Flow in Lumbini Province (Sankey Diagram)

6.1. Energy Consumption in Lumbini Province by Ecological Regions

The ecological distribution of energy consumption is affected by population, as well as energy access. As seen from T**able 6-3,** the hilly region has the least amount of energy consumed – primarily due to the least population. On the contrary, the populated and industrially developed terai region, where economic activities are higher, has the highest energy consumption in the province. In terms of energy types, the use of traditional Biomass is comparatively not too far off in the two regions. Meanwhile, commercial energy carriers such as Petroleum and electricity are high in terai. Fuels used for thermal purposes such as coal, agricultural residue, and diesel are significantly high in the terai region. Sector-wise also, energy consumption is yet again impacted by population and the presence of economic activity. Due to easier access and higher mechanization, energy consumption in the agriculture sector is also higher in the terai region. The hilly region is primarily dependent upon ground water and rainwater for irrigation, and drought animals for farming activities.

Table 6-3. Annual Energy Consumptions by Ecological Regions and Sectors in 2022 (TJ)

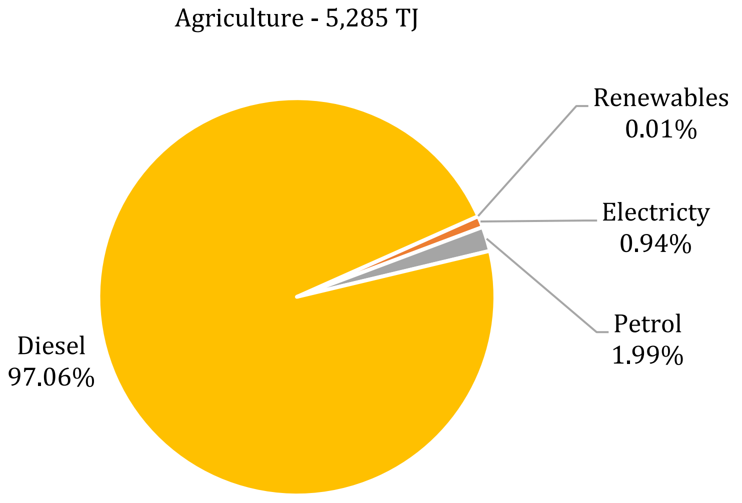
In TJ

	Fuelwood	**Agriculture residue**	**Animal waste**	**Coal**	**Kerosene**	**LPG**	**Diesel**	**Gasoline**	**ATF**	**Furnace oil**	**Electricity**	**biogas**	**briquettes**	**Solar thermal**	**Solar PV**	**Total**
Hills	**12,313.44**	**380.49**	**147.41**	**277.33**	**1.03**	**880.11**	**2,009.94**	**6.56**	**-**	**573.00**	**259.09**	**519.12**	**-**	**0.05**	**113.41**	**17,480.98**
Agriculture	-	-	-	-	-	-	905.42	1.67	-	-	2.03	-	-	-	0.09	909.22
Commercial	2,136.59	240.96	143.19	12.33	-	235.73	-	-	-	-	102.44	3.28	-	0.03	98.91	2,973.46
Industrial	7.78	1.31	-	264.54	-	1.58	1,104.52	4.89	-	573.00	18.60	-	-	-	-	1,976.21
Residential	10,169.07	138.23	4.22	0.46	1.03	642.80	-	-	-	-	136.02	515.84	-	0.02	14.41	11,622.10
Terai	**16,744.29**	**2,924.89**	**119.15**	**6,073.79**	**4.98**	**3,964.24**	**12,794.36**	**103.69**	**-**	**840.47**	**5,217.96**	**1,696.95**	**7.30**	**0.00**	**14.97**	**50,507.03**
Agriculture	-	-	-	-	-	-	4,223.76	103.69	-	-	47.47	-	-	-	0.47	4,375.39
Commercial	1,465.96	6.91	2.84	1.29	-	209.95	-	-	-	-	683.14	-	-	0.00	9.70	2,379.79
Industrial	4,698.57	2,878.07		6,049.47	-	715.94	8,570.59	-	-	840.47	2,741.95	-	-	-	-	26,495.07
Residential	10,579.76	39.91	116.31	23.03	4.98	3,038.35	-	-	-	-	1,745.40	1,696.95	7.30	-	4.80	17,256.79
Mountain																
Transport	-	-	-	-	-	-	3,107.44	3,468.43	217.67	-	0.23	-	-	-	-	6,793.78
Construction and mining	-	-	-	-	3.85	139.80	2,272.23	5.90	-	0.03	55.23	-	-	-	-	2,477.04
Grand total	**29,057.73**	**3,305.38**	**266.56**	**6,351.12**	**9.86**	**4,984.16**	**20,183.96**	**3,584.59**	**217.67**	**1,413.50**	**5,532.51**	**2,216.07**	**7.30**	**0.06**	**128.38**	**77,258.83**

(Survey, 2022)

6.2. Agriculture Sector

The agriculture sector in Lumbini Province consumes about 5,285TJ and among this, the use of diesel for farm machinery is very high compared to consumption of petrol and electricity (**Figure 6-4**). Although the penetration of solar pumping systems for irrigation is gaining popularity, its use has been limited.



(Survey, 2022)

Figure 6-4. Energy Mix in Agriculture Sector

Table 6-4,most of the diesel is used for farm machinery. Meanwhile, electricity is mostly used for water pumping and very less for other farming machinery. Solar is limited to irrigation purposes only. The largest amount of energy is used for tillage, which is also aided by using draught animals, mostly in hilly regions, but in terai, they have been mechanized significantly.

Table 6-4. Energy Consumptions in Agriculture Sector

In TJ

	Water pumping	Tilling	Threshing	Total
Petrol	51.84	-	53.52	105.36
Diesel	1,391.82	2,972.33	765.04	5,129.18
Electricity	49.50	0.00	0.00	49.50
Solar	0.56	-	-	0.56
	1,493.72	**2,972.33**	**818.56**	**5,284.61**

Ecologically, the largest amount of energy is consumed in the terai region for all purposes (**Table 6-5**). In contrast to hills, irrigation is largely done by diesel pumps. Meanwhile, the upper regions, being more dependent upon rainwater, use less energy for irrigation. Tillage is equally important and thus is done by diesel tractors in both hilly and terai regions, but due to the larger area, energy use is still high in terai lands. Due to higher yields of crops, the energy used for threshing is also higher.

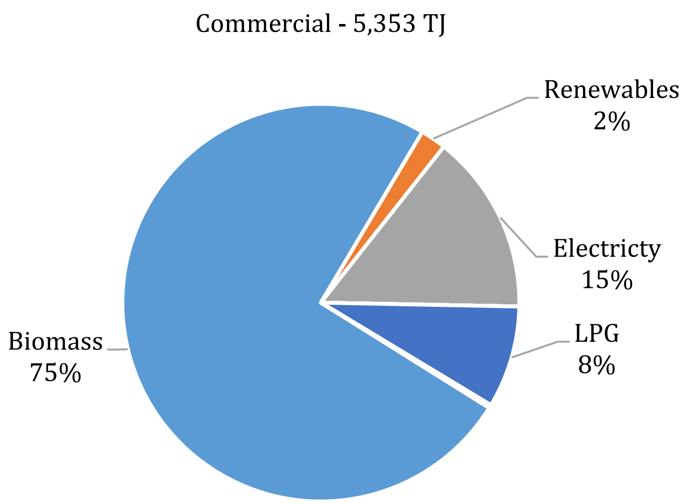
Table 6-5. Energy Consumption by End Uses in Agriculture Sector by Ecological Region

In TJ

	Water pumping	Tilling	Threshing	Total
Hills	7.15	830.36	71.71	909.22
Terai	1,486.57	2,141.97	746.85	4,375.39
Total	**1,493.72**	**2,972.33**	**818.56**	**5,284.61**

6.3. Commercial Sector

The commercial sector is the fourth most energy-consuming sector, at 5,353TJ. Although the commercial sector is expected to use commercial forms of energy, theuse of biomass is still prevailing in this sector in Lumbini Province (**Figure 6-5**). This is used primarily in hotels, restaurants as well as small shops for cooking purposes. Some portions of biomass are used for space heating in colder seasons as well. The energy for space cooling is as much as that for space heating due to the hot seasons in the terai region of Lumbini Province. The electricity is used for electrical appliances and lighting as well as space cooling purposes.



(Survey, 2022)

Figure 6-5. Energy Mix in Commercial Sector

Table 6-6 indicates the consumption of energy types for different purposes. It is evident that due to the use of traditional biomass in an inefficient way, the amount of energy consumed is very high for cooking. No significant amount of use of kerosene was found, and the use of solar PV for lighting is present but due to the availability of grid connection, its use is comparably lower than in hilly regions of the country.

Table 6-6. Energy Consumption in Commercial Sector

In TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	Other use	Total
Wood	3,356.05	175.87	44.23	-	-	-	26.40	-	**3,602.55**
Agri residue	247.87	-	-	-	-	-	-	-	**247.87**
Animal waste	146.03	-	-	-	-	-	-	-	**146.03**
Coal	13.62	-	-	-	-	-	-	-	**13.62**
LPG	361.13	59.22	1.41	-	-	-	23.91	-	**445.67**
Electricity	17.43	42.40	16.45	62.76	92.72	553.83	-	0.00	**785.58**
Biogas	-	3.28	-	-	-	-	-	-	**3.28**
Solar thermal	-	0.04	-	-	-	-	-	-	**0.04**
Solar PV	-	-	-	-	13.14	95.47	-	-	**108.61**
	4,142.13	**280.82**	**62.08**	**62.76**	**105.86**	**649.29**	**50.32**	**0.00**	**5,353.25**

Subsector-wise, the highest amount of energy is used in the accommodation and food service sector which comprisesmostly hotels and restaurants. In addition to that, trade and retail also use a similar amount of energy. They are highly reliant on biomass for energy even though the use of LPG is also significant (**Table 6-7**). The financial and real estate sector uses the least amount of energy as their primary demand is lighting and other electrical equipment.

Table 6-7. Energy Consumption for Each Subsector by Energy Types in Commercial Sector

In TJ

	Trade and Retail	Accommodation	Financial	Social	Others	Total
Wood	1,280.37	1,478.00	-	767.78	76.40	**3,602.55**
Agriresidue	142.44	102.30	-	1.55	1.58	**247.87**
Animal waste	87.64	56.47	-	0.65	1.26	**146.03**
Coal	5.16	8.15	-	-	0.31	**13.62**
LPG	130.27	233.54	3.64	50.07	28.16	**445.67**
Electricity	324.14	196.38	17.97	135.27	111.82	**785.58**
Biogas	3.28	-	-	-	-	**3.28**
Solar thermal	0.01	0.02	-	0.01	0.00	**0.04**
Solar PV	0.97	0.50	0.04	107.06	0.03	**108.61**
	1,974.29	**2,075.36**	**21.65**	**1,062.39**	**219.56**	**5,353.25**

As for energy-using activities in sub-sectors, the highest amount of energy is used for cooking (**Table 6-8**), which is majorly in biomass as seen in**Table 6-9 to 6-10.**Space heating is mostly used by accommodation service institutions and retail businesses.

Table 6-8. Energy Consumptions for Each Subsector by End Use in Commercial Sector

In TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	Other use	Total
Trade and Retail	1,462.75	146.17	24.77	19.70	37.79	257.34	25.77	0.00	**1,974.29**
Accommodation	1,753.30	113.36	30.07	8.71	28.41	123.05	18.45	-	**2,075.36**
Financial	3.52	0.16	0.30	0.66	3.89	13.13	-	-	**21.65**
Social	805.87	18.26	3.38	22.25	27.08	179.46	6.10	-	**1,062.39**
Others	116.69	2.87	3.56	11.43	8.69	76.32	-	0.00	**219.56**
	4,142.13	**280.82**	**62.08**	**62.76**	**105.86**	**649.29**	**50.32**	**0.00**	**5,353.25**

Ecologically, the hills consume a larger portion of energy in the commercial sector due to the presence of a larger number of sales and service-oriented institutions (**Table 6-9 and 6-10**).Similarly, the energy for space heating is mostly used in the hilly region while that for space cooling is high in the terai region.

Table 6-9. Energy Consumptions by End Use in Commercial Sector by Ecological Regions

In TJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Social events	Other use	Total
Hills	2,470.15	223.23	46.94	2.31	20.62	170.14	40.09	0.00	**2,973.46**
Terai	1,671.98	57.59	15.15	60.45	85.24	479.16	10.23	-	**2,379.79**
	4,142.13	**280.82**	**62.08**	**62.76**	**105.86**	**649.29**	**50.32**	**0.00**	**5,353.25**

Fuel wise also, a higher amount of energy is used in the hilly region (**Table 6-10**). The use of solar thermal for water heating is found in hilly regions. The use of biogas is found in the hilly region, but no significant use of biogas is seen in teraifor commercial uses.

Table 6-10. Energy Consumptions by Energy Type in Commercial Sector by Ecological Regions

In TJ

	Wood	Agri residue	Animal waste	Coal	LPG	Electricity	Biogas	Solar thermal	Solar PV	Total
Hills	2,136.59	240.96	143.19	12.33	235.73	102.44	3.28	0.03	98.91	**2,973.46**
Terai	1,465.96	6.91	2.84	1.29	209.95	683.14	-	0.00	9.70	**2,379.79**
	3,602.55	**247.87**	**146.03**	**13.62**	**445.67**	**785.58**	**3.28**	**0.04**	**108.61**	**5,353.25**

6.4. ResidentialSector

The residential sector is the highest energy-consuming sector in the Lumbini Province with a total of 28,879TJ. In the energy mix, the use of biomass is dominant in this province followed by LPG and renewables **(Figure 6-6)**. The use of biogas is predominant as the terai region is a hotter region, and the production of biogas is significant. The use of electricity is not able to take a higher share, majorly due to the problem of power supply reliability.

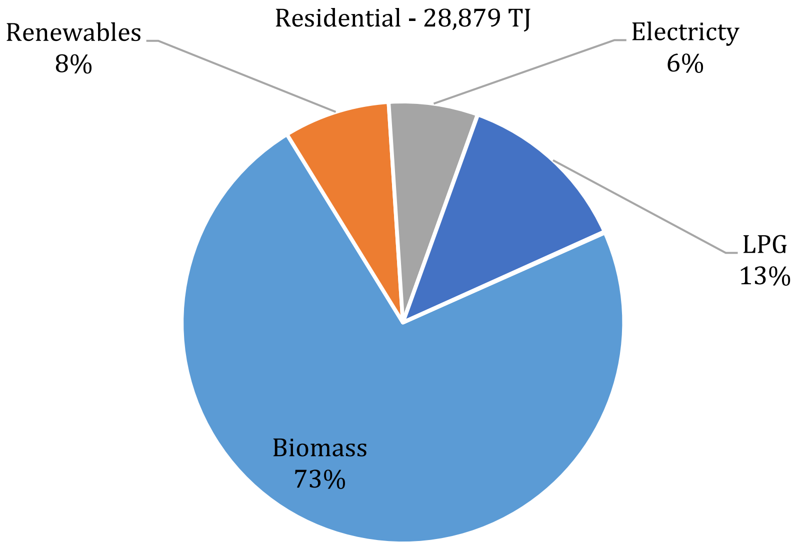


Figure 6-6. Energy Mix in Residential Sector

Table 6-11 gives the energy mix for various end-use activities in the residential sector. It can be observed that biomass is primarily consumed for cooking and water heating purposes. LPG is also mostly used for cooking purposes. A significant amount of electricity is seen to be used for cooking purposes, which is a positive sign towards electrification and clean energy transition. However, the current use of traditional biomass and LPG shows significant efforts required for energy transition to clean energy sources.

Table 6-11. Energy Consumptions in Residential Sector

InTJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Wood	18,622.04	740.45	153.97	-	-	-	1,232.38	**20,748.83**
Agriresidue	169.55	8.58	-	-	-	-	-	**178.13**
Animal waste	120.53	-	-	-	-	-	-	**120.53**
Coal	23.03	-	-	-	-	-	0.46	**23.49**
Kerosene	3.96	-	-	-	-	-	2.05	**6.01**
LPG	3,416.75	176.09	2.76	-	-	-	85.56	**3,681.15**
Electricity	109.58	-	0.04	232.86	362.77	1,170.14	6.04	**1,881.42**
Biogas	2,200.82	9.76	-	-	2.05	-	0.17	**2,212.79**
Briquettes	7.27	-	-	-	-	-	0.03	**7.30**
Solarthermal	-	0.02	-	-	-	-	-	**0.02**
SolarPV	-	-	-	-	19.21	-	-	**19.21**
	24,673.52	**934.89**	**156.77**	**232.86**	**384.03**	**1,170.14**	**1,326.68**	**28,878.88**

Although they have a similar population in both rural and urban areas, the amount of energy used is higher in rural areas with the share of 60% of total residential energy consumption (**Table 6-12**). The share of biomass is predominant in rural region with the share of 84%, followed by 8% share of biogas, 6% share of LPG, and 2% share of electricity in rural energy consumption.

Table 6-12. Energy Consumptions in Rural -Residential Sector

InTJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Wood	12,219.54	713.70	99.26	-	-	-	1,148.37	**14,180.88**
Agriresidue	136.77	8.58	-	-	-	-	-	**145.35**
Animal waste	70.10	-	-	-	-	-	-	**70.10**
Coal	-	-	-	-	-	-	0.44	**0.44**
Kerosene	0.38	-	-	-	-	-	0.45	**0.83**
LPG	942.88	99.78	-	-	-	-	66.48	**1,109.15**
Electricity	39.29	-	0.00	73.68	102.23	127.97	0.70	**343.86**
Biogas	1,438.23	9.76	-	-	2.05	-	0.17	**1,450.21**
Briquettes	-	-	-	-	-	-	0.02	**0.02**
Solar thermal	-	0.00	-	-	-	-	-	**0.00**
Solar	-	-	-	-	19.21	-	-	**19.21**
	14,847.19	**831.82**	**99.26**	**73.68**	**123.48**	**127.97**	**1,216.63**	**17,320.04**

In comparison to rural areas, the urban area is highly dependent upon commercial forms of energy. Although the share of biomass is predominant (58%) in urban regions, the consumption of LPG (22%) and electricity (13%) is significant. The use of biogas (7%) inurban area is primarily because of changes of administrative divisions and establishments of new urban municipalities from rural ones.

Table 6-13. Energy Consumptions in Urban -Residential Sector

InTJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Others	Total
Wood	6,402.49	26.75	54.71	-	-	-	84.00	**6,567.95**
Agri residue	32.78	-	-	-	-	-	-	**32.78**
Animal waste	50.43	-	-	-	-	-	-	**50.43**
Coal	23.03	-	-	-	-	-	0.02	**23.05**
Kerosene	3.59	-	-	-	-	-	1.60	**5.18**
LPG	2,473.87	76.30	2.76	-	-	-	19.08	**2,572.01**
Electricity	70.29	-	0.03	159.18	260.54	1,042.17	5.34	**1,537.56**
Biogas	762.58	-	-	-	-	-	-	**762.58**
Briquettes	7.27	-	-	-	-	-	0.01	**7.28**
Solarthermal	-	0.02	-	-	-	-	-	**0.02**
	9,826.33	**103.07**	**57.51**	**159.18**	**260.54**	**1,042.17**	**110.05**	**11,558.84**

Ecological distribution of energy consumption in the residential sector is highly influenced by the population distribution as well as forms of energy used as seen in **Table 6-14 and Table 6-15**. Access and reliability of electricity are better in terai regions.

Table 6-14. Energy Consumptions by end use in Residential Sector by Ecological Regions in TJ

InTJ

	Cooking	Water boiling	Space heating	Space Cooling	Lighting	Electrical Appliances	Other uses	Total
Hills	9,593.64	595.34	93.91	1.59	55.56	50.81	1,231.23	**11,622.10**
Terai	15,079.88	339.55	62.85	231.27	328.46	1,119.32	95.45	**17,256.79**
	24,673.52	**934.89**	**156.77**	**232.86**	**384.03**	**1,170.14**	**1,326.68**	**28,878.88**

In terms of energy type, it is observed that terai region predominantly use sall forms of energy except agriculture residue, which is higher in the hilly region. The use of biogas is also better in hotter terai plains. Meanwhile, solar PV is higher in hilly regions where access to the grid is difficult in some areas.

Table 6-15. Energy Consumptions by Energy Type in Residential Sector by Ecological Regions

InTJ

	Fuelwood	Agri residue	Animal wastes	Coal	Kerosene	LPG	Electricity	Biogas	Briquettes	Solar thermal	Solar PV	Total
Hills	10,169.07	138.23	4.22	0.46	1.03	642.80	136.02	515.84	-	0.02	14.41	**11,622.10**
Terai	10,579.76	39.91	116.31	23.03	4.98	3,038.35	1,745.40	1,696.95	7.30	-	4.80	**17,256.79**
	20,748.83	**178.13**	**120.53**	**23.49**	**6.01**	**3,681.15**	**1,881.42**	**2,212.79**	**7.30**	**0.02**	**19.21**	**28,878.88**

6.5. Industrial Sector

The energy mix in the industrial sector is shown in **Figure 6-7**with a total of 28,471 TJ**.** Diesel is the major source of fuel consuming 35% of total energy consumed in the sector. The higher amount of diesel consumption in industry is mainly due to the use of diesel generators for electricity as well as for motive power. On the other hand, agri-residue and fuelwood are mainly used in boilers and process heat for heating purposes in the bricks and clay industries, and wood products and paper industries. Some industries also use furnace oil for heating in the food and beverage industries. Coal is mainly consumed at large in the brick and cement industries. With the gradual shift to clean energy, electricity usage has increased to some extent in industries reaching its share to 10%.

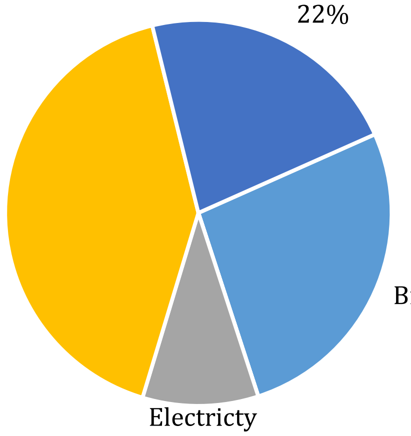


Figure 6-7. EnergyMixinIndustrySector

Table 6-16 shows the consumption of energy types for different end uses. It clearly indicates the higher use of energy for thermal purposes for which traditional biomass, coal, and diesel are the major sources. Diesel is also used for motive power as well as for other uses, particularly for electricity generation. The increase in electricity consumption comes mainly from the shift to electric motor equipment.

Table 6-16. Energy Consumption in Industry Sector

InTJ

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Fuelwood	-	4,298.05	395.05	-	13.26	**4,706.35**
Agri residue	-	1,316.64	1,536.90	-	25.83	**2,879.38**
Coal	-	1,052.53	3,985.80	-	1,275.68	**6,314.01**
LPG	-	222.98	8.15	-	486.40	**717.52**
Diesel	-	2,950.65	824.40	3,100.47	2,799.58	**9,675.11**
Gasoline	-	-	-	4.89	-	**4.89**
Furnace oil	-	-	1,322.94	-	90.53	**1,413.47**
Electricity	173.49	67.24	15.87	2,462.39	41.56	**2,760.54**
Total	**173.49**	**9,908.09**	**8,089.10**	**5,567.75**	**4,732.84**	**28,471.27**

(Survey2022)

All the manufacturing industries mentioned in Nepal Standard Industrial Classification are further grouped into 9 sub-sectors based on their energy intensity and type. The energy consumption based on its sub-sectors is shown in **Table 6-17**. Brick and structural clay products, food, and beverage industries, cement and non-metallic industries, and wood products and paper industries consumed comparatively higher energy consuming in Lumbini Province. These four types of industries consumed 81% of the total energy consumed in the sector. It consumed coal. diesel, furnace oil, fuelwood, and agri-residue as the major sources of energy.

Table 6-17. Energy Consumption for Each Subsector by Energy Types in Industry Sector

InTJ

	Fuelwood	Agricultural residue	Coal	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
FoodBeverageandTobacco	1,223.62	80.80	54.52	399.23	3,517.33	4.89	-	670.72	**5,951.11**
TextileandLeatherGoods	-	-	-	-	20.48	-	-	49.44	**69.91**
ChemicalRubberandPlastic	-	103.33	261.00	222.66	948.61	-	573.00	161.78	**2,270.39**
MechanicalEngineeringandManufacturing	-	-	-	89.06	947.43	-	740.54	248.89	**2,025.92**
ElectricalEngineeringProducts	-	-	-	-	42.02	-	-	154.38	**196.40**
WoodProductsandPaper	2,822.51	1,131.20	-	-	189.39	-	-	273.08	**4,416.18**
Bricks&StructuralClayProducts	659.73	1,564.04	4,771.23	6.57	2,385.64	-	90.53	59.51	**9,537.25**
Cement&Non-metallicProducts	0.49	-	1,227.27	-	795.72	-	9.40	1,021.74	**3,054.61**
OtherManufacturing	-	-	-	-	828.50	-	-	121.00	**949.50**
Total	**4,706.35**	**2,879.38**	**6,314.01**	**717.52**	**9,675.11**	**4.89**	**1,413.47**	**2,760.54**	**28,471.27**

(Survey2022)

Table 6-18 shows energy consumption in the industrial subsectors by its end-use services. It shows that other uses, which are mainly electricity generation from diesel generators used almost 43% of total energy consumption in the sector, followed by process heating and boilers. The major energy consuming industries in Lumbini Province are bricks and clay products and food and beverage industries.

Table 6-18. Energy Consumption for Each Subsector by End Use in Industry Sector

InTJ

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Food Beverage and Tobacco	8.32	3,603.62	277.57	842.91	1,218.68	**5,951.11**
Textile and Leather Goods	26.94	-	-	21.84	21.13	**69.91**
Chemical Rubber and Plastic	4.96	326.49	1,277.66	598.47	62.79	**2,270.39**
Mechanical Engineering and Manufacturing	4.37	-	745.05	252.23	1,024.28	**2,025.92**
Electrical Engineering Products	4.05	-	-	184.45	7.89	**196.40**
Wood Products and Paper	101.15	3,948.83	3.50	251.67	111.03	**4,416.18**
Bricks & Structural Clay Products	3.90	1,512.01	4,536.63	2,030.56	1,454.15	**9,537.25**
Cement & Non-metallic Products	13.94	5.22	1,235.88	1,261.57	538.00	**3,054.61**
Other Manufacturing	5.84	511.92	12.80	124.05	294.89	**949.50**
Total	**173.49**	**9,908.09**	**8,089.10**	**5,567.75**	**4,732.84**	**28,471.27**

(Survey2022)

There are 6 districts each in hilly region and terai region. But hilly regions consist of a lower number of industries thus consuming only 7% of total sectoral energy whereas the terai belt consists of large number of industries consuming almost 93% of the sectoral energy (**Table 6-19**).Most of the energy is consumed for thermal purposes in boilers and process heating in the terai region. In hilly areas, most of the consumption is for process heating. It also indicates that boiler and process heat consumed around 35% and 28% respectively of the total energy consumed in the sector. Motive power and other uses consumed 20% and 17% respectively of the total energy consumption in the sector. Other uses include electricity generation from diesel generators.

Table 6-19. Energy Consumption by End Use in Industry Sector by Ecological Region

InTJ

	Lighting	Boiler	Process Heat	Motive Power	Other uses	Total
Hills	1.61	21.26	1,204.50	461.92	286.91	**1,976.21**
Terai	171.88	9,886.82	6,884.60	5,105.83	4,445.93	**26,495.07**
Total	**173.49**	**9,908.09**	**8,089.10**	**5,567.75**	**4,732.84**	**28,471.27**

(Survey2022)

Fuel wise, traditional energy, coal, diesel, and electricity are mostly consumed in the terai region. Since most of the energy intensive industries are interai region, it consumed large share of total final energy. On the other hand, hilly region, where limited numbers of industries are located, consumed lower amount of energy.(**Table 6-20**).

Table 6-20. Energy Consumption by Energy types in Industry Sector by Ecological Region

InTJ

	Fuelwood	Agriresidue	Coal	LPG	Diesel	Gasoline	Furnace oil	Electricity	Total
Hills	7.78	1.31	264.54	1.58	1,104.52	4.89	573.00	18.60	**1,976.21**
Terai	4,698.57	2,878.07	6,049.47	715.94	8,570.59	-	840.47	2,741.95	**26,495.07**
Total	**4,706.35**	**2,879.38**	**6,314.01**	**717.52**	**9,675.11**	**4.89**	**1,413.47**	**2,760.54**	**28,471.27**

(Survey2022)

A huge amount of heat energy is obtained from fossil fuels – primarily from diesel, coal, and furnace oil. Diesel generator for electricity still consumes a large quantity of diesel usage in the industry as the electricity supply is not fully reliable. The batch production in industries required a significantly reliable electricity supply from grid. Diesel is also used for thermal uses in addition to uses in motive power. The grid electricity consumption share, however, is 10% in the Lumbini Province. Other major uses of energy in the industry sector are for thermal purposes – be it in direct heat or for boilers. 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.

There are palpable signs of energy transition to clean energy even in the industrial sector which were not there a couple of years ago. Electricity generation has increased to 2,200 MW in 2022 and Nepal has started exporting electricity to India since April 2021. NEA is planning to expand transmission and distribution infrastructure in a massive way in five years.

During the supervisory visit to industries in Rupendehi District, Lumbini Province, of the WECS officials and the study team members in August 2022, more than 75% of the industries visited showed enthusiasm in transitioning to electricity from fossil fuels and informed their increases in the industrial outputs, economic savings in the energy consumption and their economic benefits just after recent upgradation of power substation nearby - Manhaiya Substation.

6.6. 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. Roadtransport
b. Airtransport
c. Watertransport
d. Cabletransport

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 Lumbini

Province, road transport is emphasized due to its major share in overall transportation. For this purpose, road transport is disaggregated into the following categories (**Table 6-21**).

Table 6-21. 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, minibuses, etc.	Passenger/Freight
Gasoline	car, jeep, van, motorcycles, ,etc.	Passenger/Freight
LPG	Tempo	Passenger
Electric	Rickshaw	Passenger

Aviation

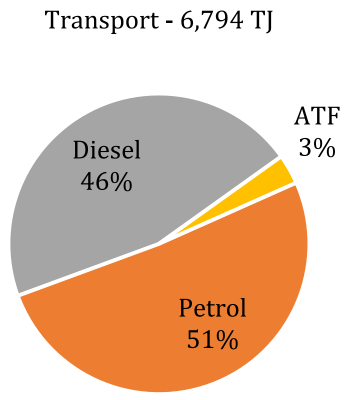
There are two airports in operation, where only domestic flights take place. The data regarding aircraft are published by Civil Aviation Authority of Nepal (CAAN). The data shows the total aircraft movement, passenger movement and cargo movement as given in **Table 6-22**.

Table 6-22. AviationSectorActivity

	Aircraftmovement	Passengermovement	Cargomovement(inkg)
GautamBuddha Airport	7,736	388,378	278,865
Total Lumbini Province	**7,736**	**388,378**	**278,865**

(CAAN, 2020; CAAN, 2020a)

The transport sector consumed 6,794TJ energy. The energy mix in the transport sector is shown in **Figure 6-8**. It shows more than 50% fuel share as petrol as the petrol operated private vehicles are significantly higher in number particularly motorcycle in the Lumbini Province. Consequently, about 20% of total diesel and 99% of total petrol sales in the province is solely used for transport activities. Most of the public passenger vehicles and all the freight vehicles are diesel operated, so diesel consumption is also significantly higher in the province.



(Survey 2022)

Figure 6-8. Energy Mix in Transport Sector

The energy consumption in transport by subsectors and fuel types is shown in **Table 6-23**.The energy consumption by public passenger vehicles is 19%, that of private passenger vehicles is 57%, freight vehicle is 31%, and the remaining 3% by air transport. Public passengers consumed 19% of the total diesel consumed in the sector. In contrast, private passenger vehicles consumed 100% of total petrol consumed in this sector and only 13% of diesel. Freight consumed approximately 68% of the total diesel consumed in the sector.

The fuel mix shows highest consumption of petrol with 51% share in the total transport energy mix followed by diesel (46%), ATF 3% and less than 1% electricity. The increasing numbers of private vehicles, particularly motorcycle considerably increased petrol consumption in the province.

Table 6-23. Transport Sector Energy Consumption by Subsector and Fuel Types

InTJ

Sub-sector		Diesel	Petrol	ATF	Electric	Total
Public Passenger	Bus	468.07	-	-	-	**468.07**
	Minibus	38.67	-	-	-	**38.67**
	Microbus	47.34	-	-	-	**47.34**
	Tempo	51.01	-	-	-	**51.01**
	E-rickshaw	-	-	-	0.19	**0.19**
Total		**605.10**	**-**		**0.19**	**605.29**
Private Passenger	Car	229.03	377.50	-	-	**606.53**
	Jeep	137.81	238.87	-	-	**376.68**
	Van	29.76	52.40	-	-	**82.16**
	Motorcycle		2,799.67	-	-	**2,799.67**
Total		**396.60**	**3,468.43**		**-**	**3,865.03**
Freight	Truck	1,209.82	-	-	-	**1,209.82**
	Mini Truck	26.83	-	-	-	**26.83**
	Pickup	771.58	-	-	-	**771.58**
	Tractor	82.95	-	-	-	**82.95**
	Cargo Van	14.56	-	-	-	**14.56**
Total		**2,105.75**	**-**		**-**	**2,105.75**
Aviation			-	217.67	-	**217.67**
GrandTotal		**3,107.44**	**3,468.43**	**217.67**	**0.19**	**6,793.74**

(Survey2022)

The transport sector is heavily dependent on imported petroleum products, so 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 fuel-efficient passenger carriers such as E-buses on the one hand and on the hand, it seems better that e-rickshaws are also substituting fuel-inefficient vehicles – i.e. motorcycles and cars.

6.7. Construction and Mining Sector

The construction and mining sector in Lumbini used the least amount of energy among the six sectors at 2,477TJ (**Figure 6-9**). Among these, the highest amount of energy is used in the form of diesel – mostly for heavy equipment. Diesel is also used for thermal purposes in addition to some kerosene and LPG. The LPG is also used by on-site workers for cooking and heating purposes of bitumen for mixing with asphalt. There may be an overlapping with energy consumption in the freight transport subsector as dumper trucks are widely used in the construction sector.

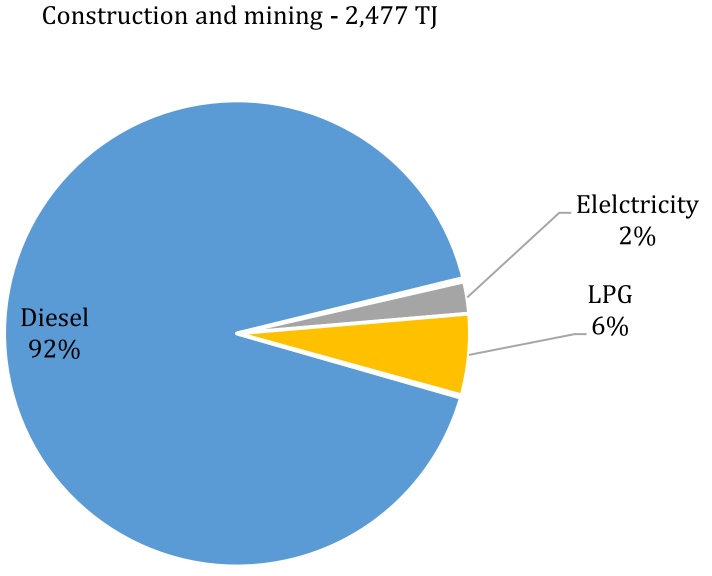


Figure 6-9. Energy Mix in Construction and Mining Sector

6.8. Fuel Demand by Time of Day

Fuel consumption/energy demand is dynamic in nature. When people are most active, like during the day, we use more energy, so we need more fuel to generate electricity. At night or when people are less active, we use less energy, and the need for fuel goes down. Thus, the fuel demand throughout the day depends on how much energy we need, which can be shown by the load/demand distribution curve. This curve reflects the ups and downs in energy usage during the 24 hours. Finding the right balance helps make sure we use fuel efficiently and take care of the environment while meeting our energy needs. Therefore, the energy usage pattern has been studied for major energy types – fuelwood, LPG, and electricity, with peak usage normalized to 1.

In the residential sector, it can be seen in **Figure 6-10** that the usage of fuelwood starts as early as 5 AM and peaks between 7 to 8 AM. Its usage is low during daytime. However, it again peaks between 6PM to 8 PM. These morning and evening peaks correspond to the cooking time for morning and evening meals. The daytime usage is for other purposes such as food processing, animal feed preparation and other life habits.

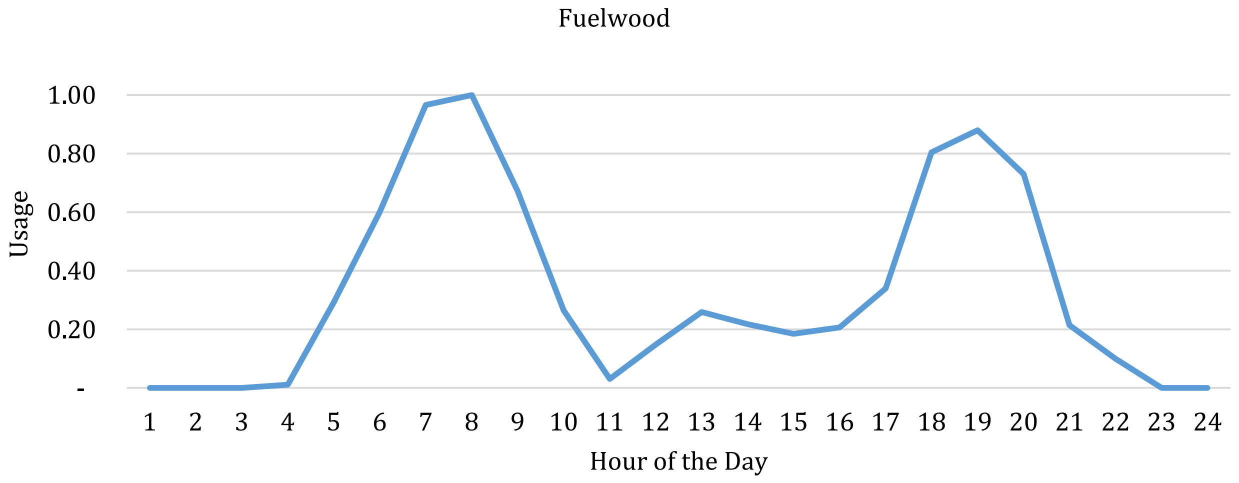


Figure 6-10. Energy Usage/Load Distribution Curve for Fuelwood in Residential Sector

It can be seen in **Figure 6-11** that the usage of LPG starts as early as 5 AM and peaks between 7 to 9 AM. The second peak is between 6PM to 8 PM. These morning and evening peaks correspond to the cooking time for morning and evening meals. The usage of LPG varies than for fuelwood as these being easy to use, as well as due to lifestyle habits. The usage pf LPG during daytime is usually for preparation of afternoon snacks.

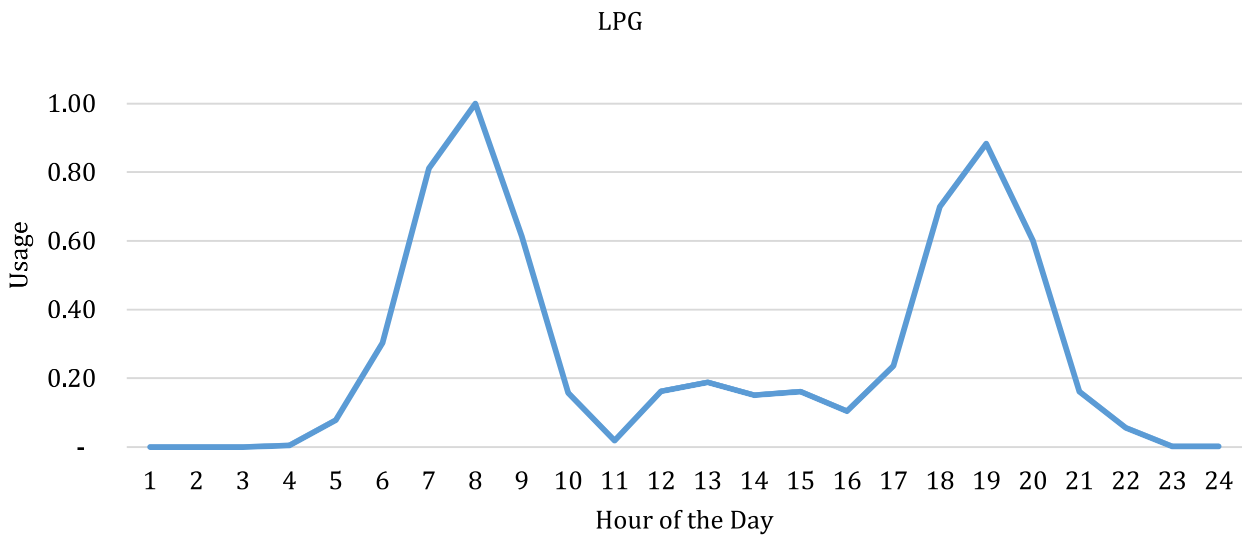


Figure 6-11. Energy Usage/Load Distribution Curve for LPG in Residential Sector.

In the residential sector, it can be seen in **Figure 6-12** that the usage of electricity starts as early as 4 AM and peaks between 5 to 7 AM. Although usage is comparatively lower during daytime, due to usage of cooling equipment like fans and coolers, the electricity usage is still substantial. It again peaks between 6 PM to 9 PM. These morning and evening peaks correspond active time during morning and evening for working people at residence. The daytime usage is for other electrical appliances used either due to all day running appliance like refrigerator or by people residing at home during daytime as well.

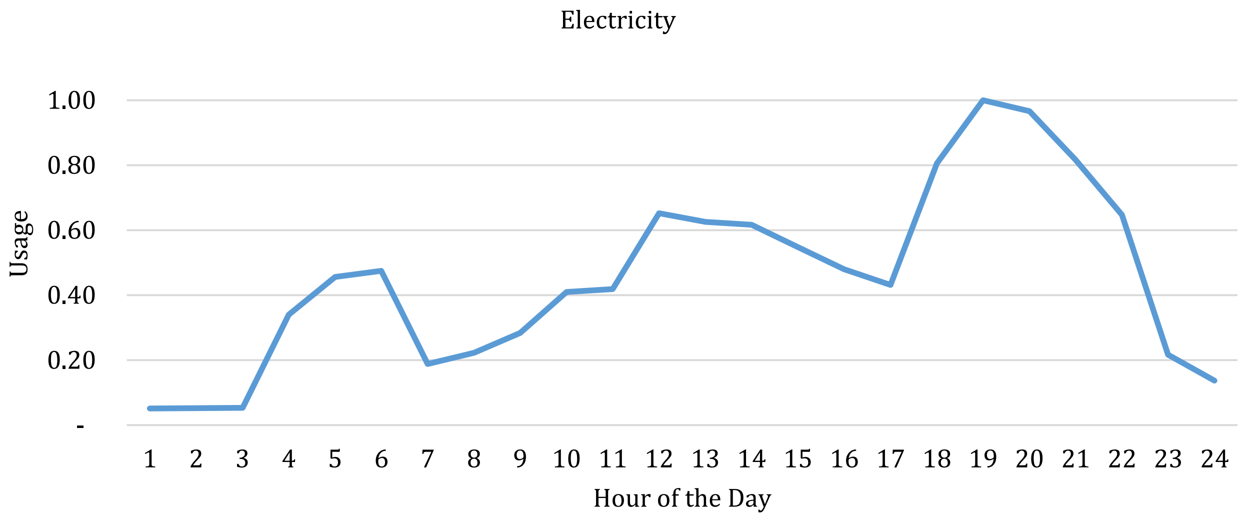


Figure 6-12. Energy Usage/Load Distribution Curve for Electricity in Residential Sector

The commercial sector has bit different characteristics than the residential sector. In the commercial sector, as seen in **Figure 6-13** that the usage of fuelwood starts as early as 5 AM and peaks at 8 AM. Its usage is low during daytime, but peaks at 1PM, during afternoon snacks. It again peaks between 6PM to 8 PM. These morning and evening peaks correspond to the cooking time for morning and evening meals. However, in comparison to the residential sector, the daytime usage is still higher as the commercial sector runs during the daytime as well.

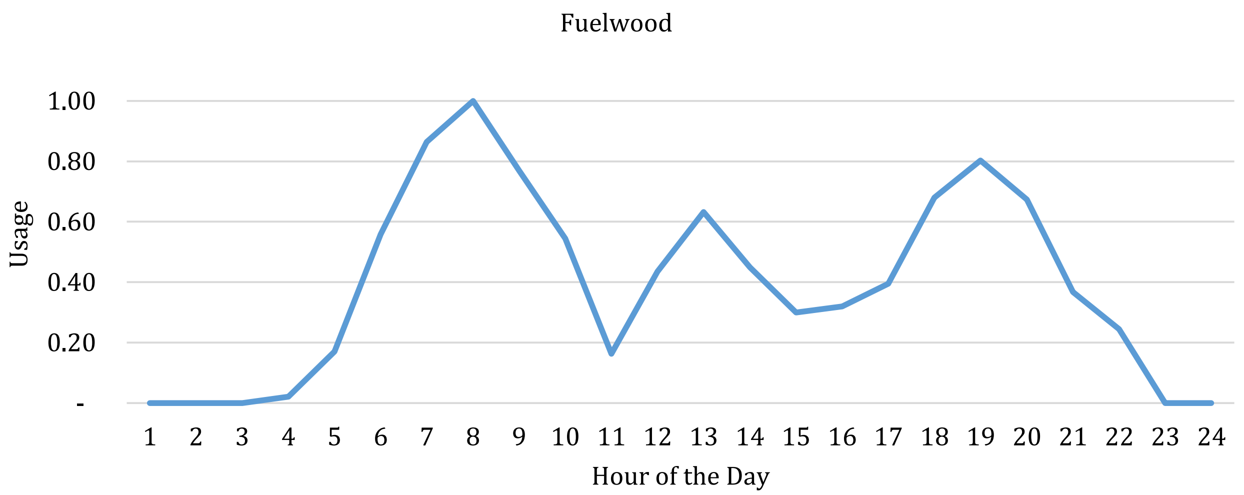


Figure 6-13. Energy Usage/Load Distribution Curve for Fuelwood in Commercial Sector

It can be seen in **Figure 6-**14 that the usage of LPG also peaks at three spots of daytime. The LPG usage starts at 5 AM and first peaks at 8AM. Its usage again peaks during daytime, corresponding to afternoon snacks between 12 PM to 3 PM. Finally, it again peaks between 6PM to 8 PM. These morning and evening peaks correspond to the cooking time for morning and evening meals at hotels, schools, hospitals. Like fuelwood, the usage of LPG remains high even in daytime, as these are constantly being used although the day.

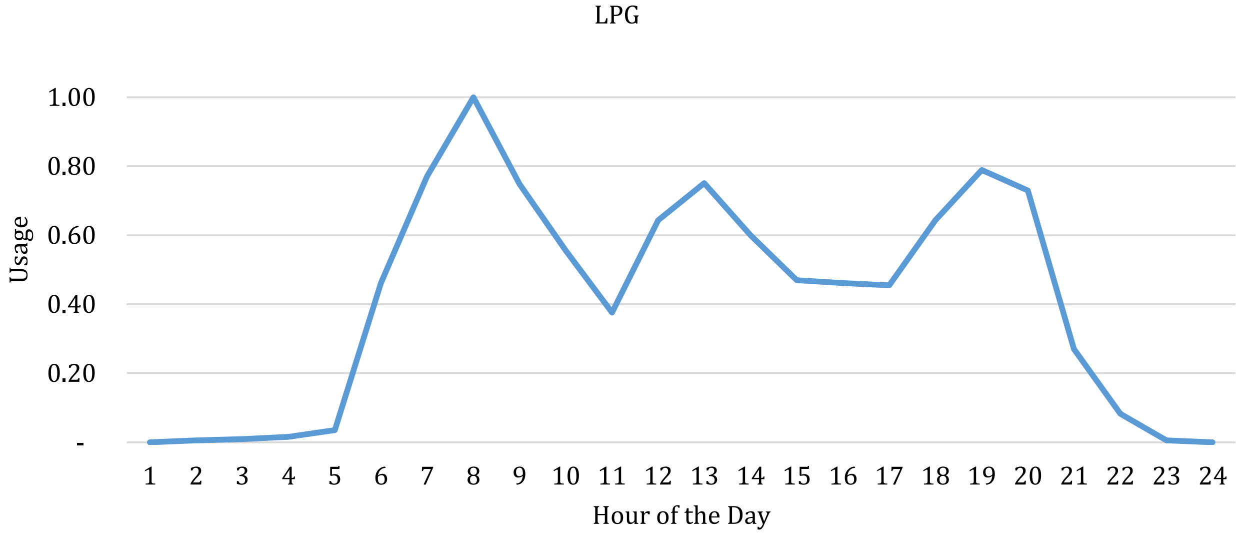


Figure 6-14. Energy Usage/Load Distribution Curve for LPG in Commercial Sector

The electricity uses in commercial sector starts at 4AM, as seen from **Figure 6-15**, when the service activities slowly start such as in schools or hospitals then it begins to rise up till the middle of the day when the activities are still going on including office activities and other commercial services and peaks at 10 and remains nearly constant time 6PM. The high use of equipment like fan, air conditioners and coolers used in hot zones of this province demand constant supply of electricity throughout the day.

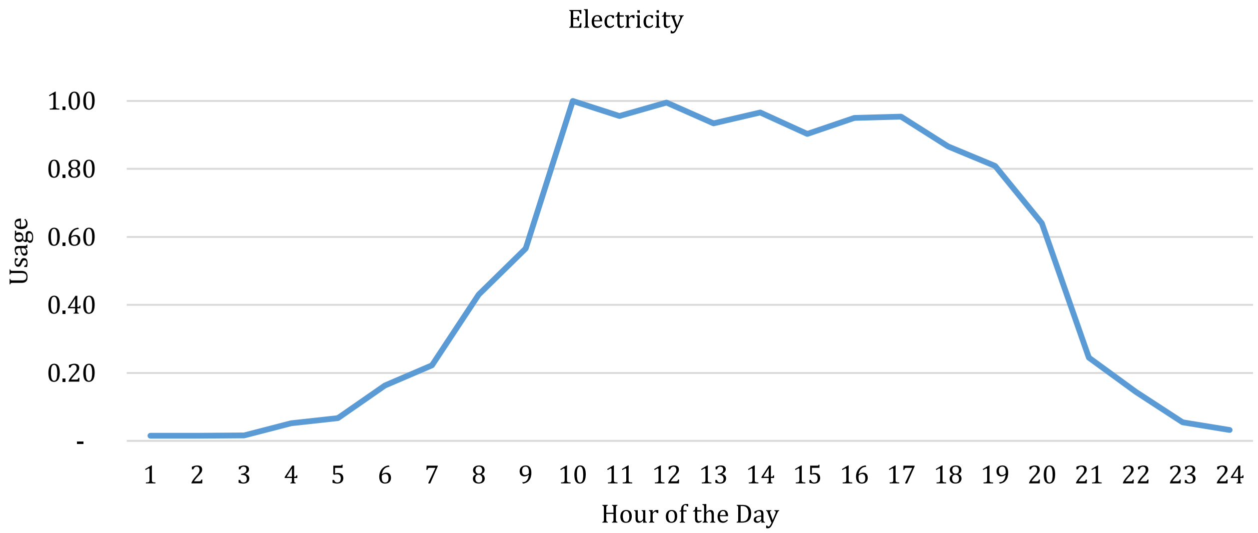


Figure 6-15. Energy Usage/Load Distribution Curve for Electricity in Commercial Sector

7. Socio-economicandTechnicalAnalysis

Lumbini Province ranges from low Terai to Hill regions. Due to this, there is a large variation in socio-economic characteristics. As shown in **Figure 7-1,** most of the respondents belong to Hill and Terai regions. Large shares of respondents belong to Hill janjati, and Hill Brahimin/Chhetri in both the Hill regions and Terai regions. Brahmin/Chhetri are the major ethnic groups, and they are seconded by TeraiJanjati. Overall, Hill janjatis are major respondents, and are seconded Hill Brahims/Chhetris in Lumbini Province. However, the respondents also include other ethnic groups ranging from Hill Janajati and Hill Dalit groups as well.

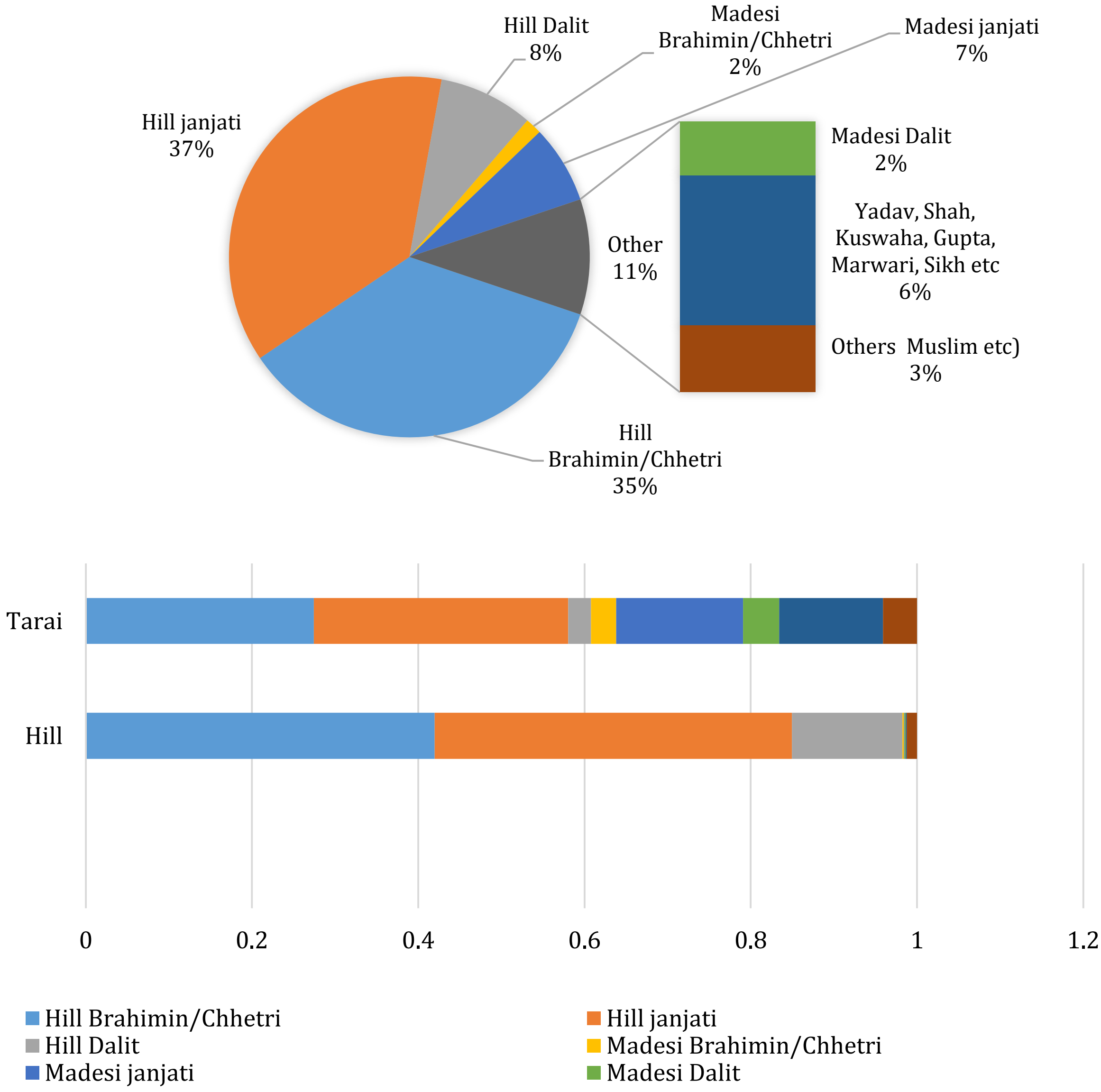


Figure 7-1: Mix of Respondents by Ethnic Group in Lumbini Province (top) and Ecological Regions (bottom)

Education level influences decision-making. Thus, looking at the education level of household heads in Lumbini Province, it was seen that substantial household heads have no formal education followed by partially literate. Nearly 45% of household heads do not have formal education **(Figure 7-2).** And the impact can be seen in the energy mix as well–fuelwood and other biomass are still being predominantly used. Ecologically, Terai region has the highest proportion of the population with formal education, and the education level seems higher in the Terai region than in the Hill region.

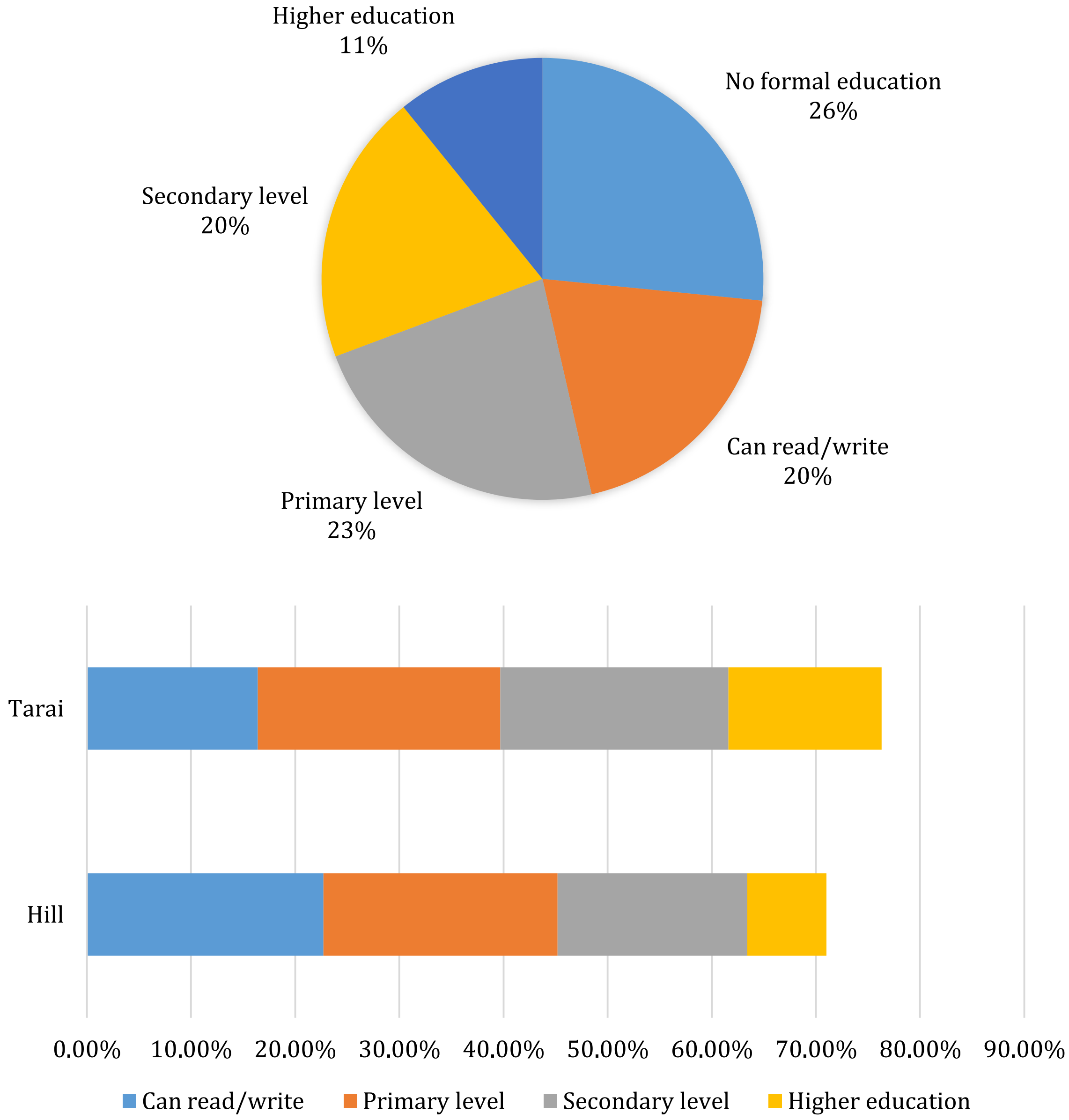
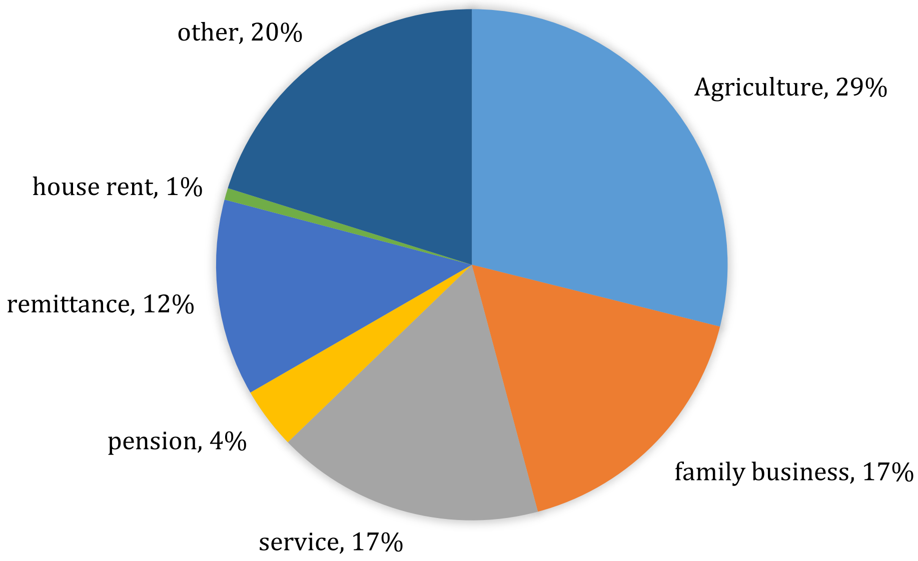


Figure 7-2: Mix of Respondents by Education Level of Household Head in Lumbini Province (top) and Ecological Regions (bottom)

Another important aspect of socioeconomic behavior are the sources and level of income. The major source of income of the respondents is agriculture followed by family business and services. Only a low share of people is 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 7-3.**



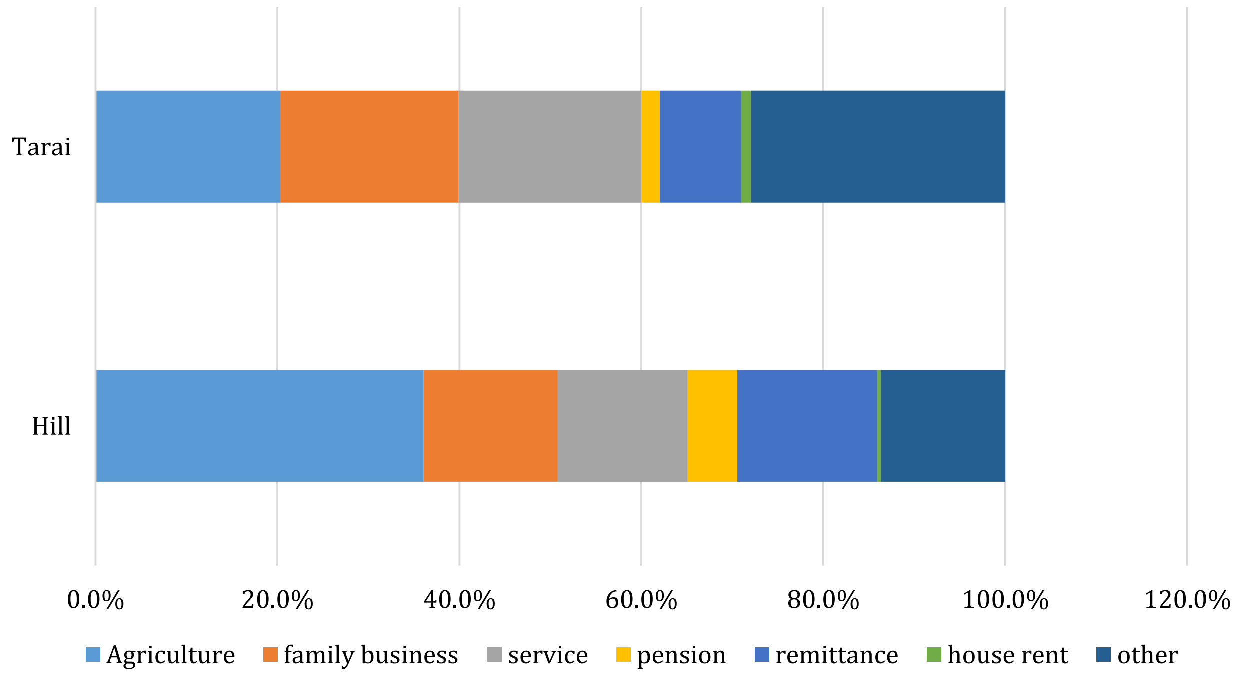


Figure 7-3: Mix of Respondents by Major Source of Income in Lumbini Province (top) and Ecological Regions (bottom)

The average monthly family income level ranges from as low as 26,631 per month to the highest NRs 31,9572.00 annual income per household in Lumbini Province as per the sample survey. This income level is near par with reference to the income level as per the National Living Standards survey Rs 30,121.00 (Fifth Household Budget Survey Nepal Rastra Bank 2014-2015). Comparing ecologically, the income level is higher on average in Terai than in hills. This is mostly due to higher economic activity in terai region due to easy access to economic centers – even to a neighboring country. However, there is a huge variance from the mean level of income in most of the cases which is evident from **Figure 7-4.**

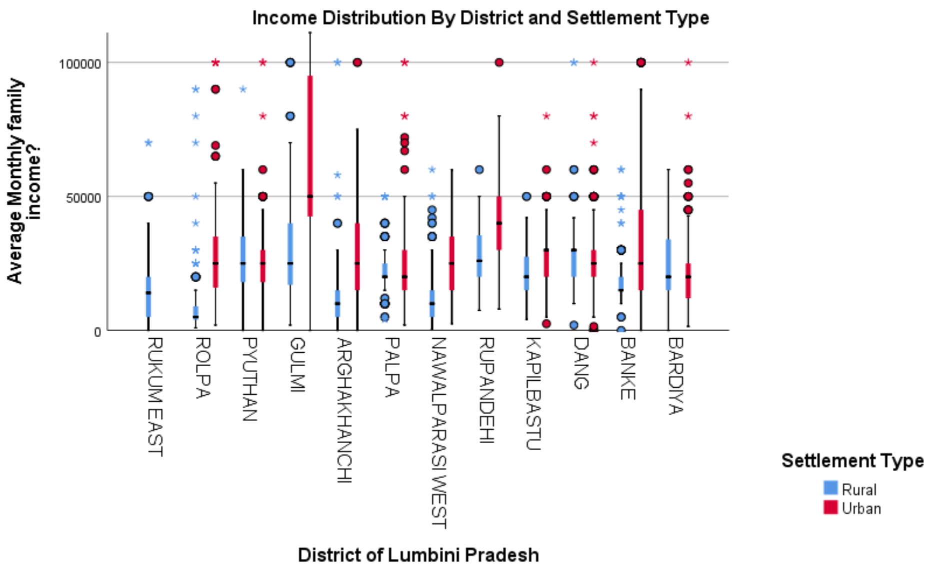


Figure 7-4: Average Monthly Income of Households in Lumbini Province

In Lumbini Province, 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 fuelwood respectively **(Figure 7-5).** However, the share of RCC frame with cement mortar is seen to be in around 65% in Terai region and Hill region mud mortar with brick or stone is of higher percentage around 80%.

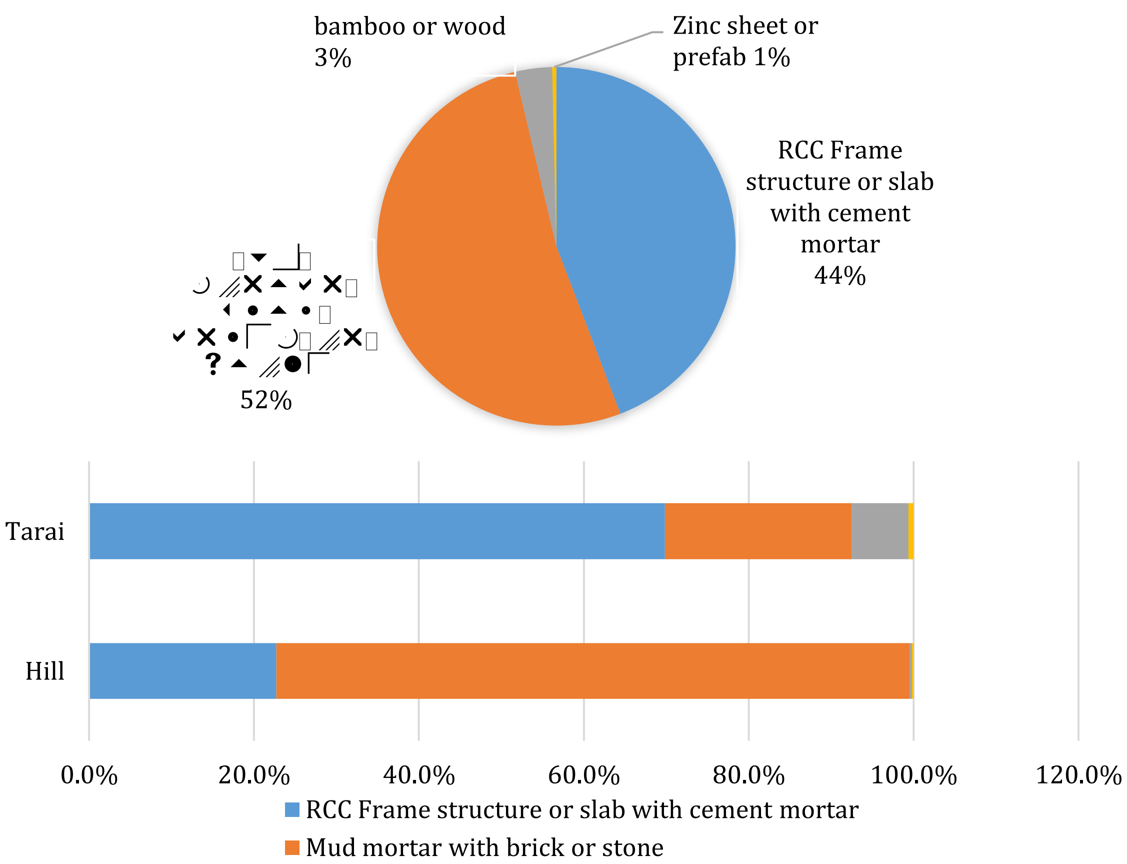


Figure 7-5: Mix of Respondent Household by Build Type in Lumbini Province (top) and Ecological Regions (bottom)

Meanwhile, for the roof structure, the majority of the households (55%) still used galvanized iron sheets or tile, or slate followed by RCC and then thatched roofs in older houses. Whereas in the Hill region, galvanized iron sheet is dominant at around 75%, whereas in the Terai region RCC is dominant at around 45% **(Figure 7-6).**

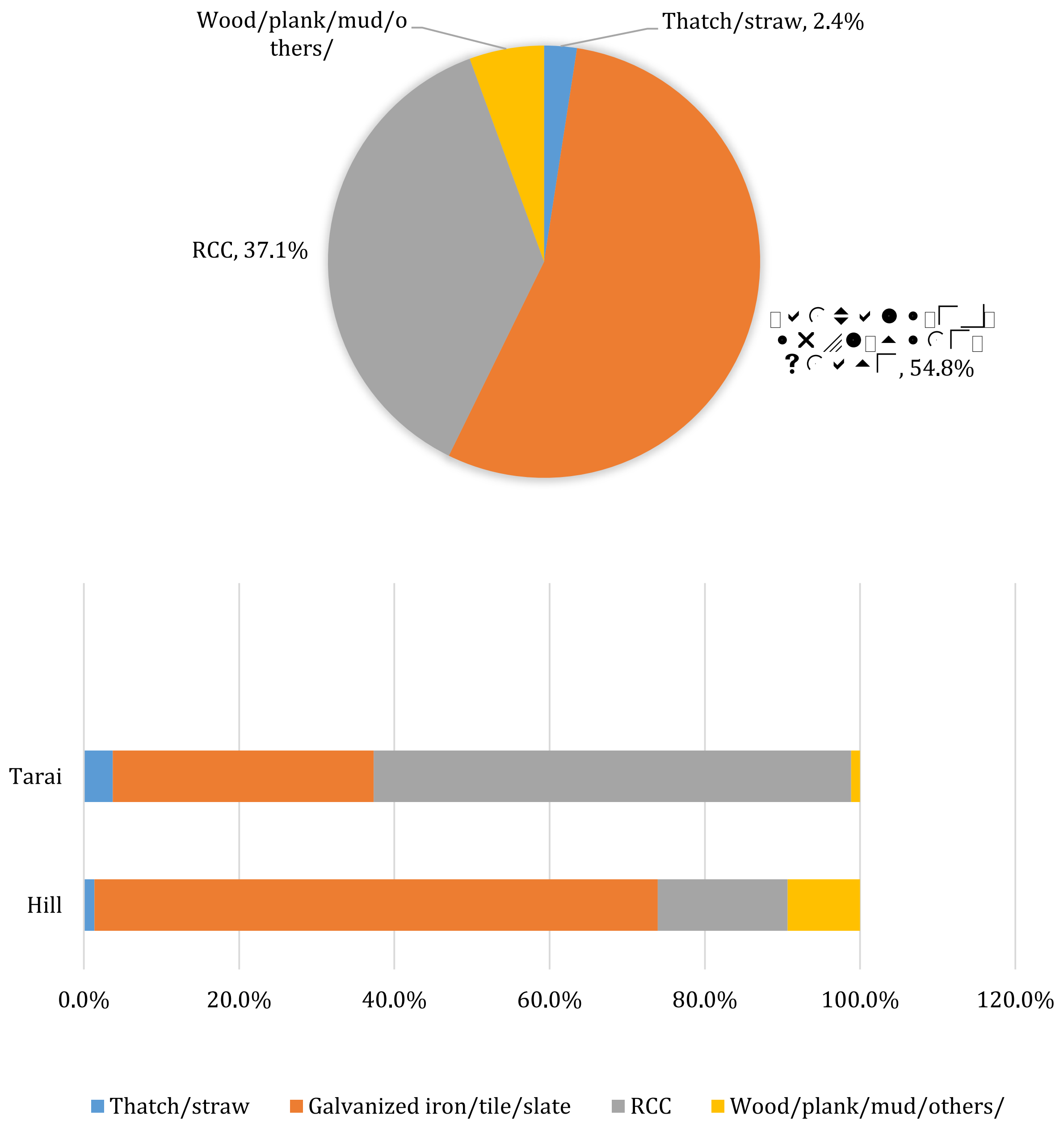


Figure 7-6: Mix of Respondent Households by Roof Type in Lumbini Province (top) and Ecological Regions (bottom)

7.1. Respondents by Gender

Figure 7-7 shows the mix of respondents and the respective household heads by gender. Although the respondents are as nearly same as for both genders, there is majority in male being the household head. It can denote that the male is economically active outside the house, while females are engaged in household activities, mainly in rural and remote areas of the province.

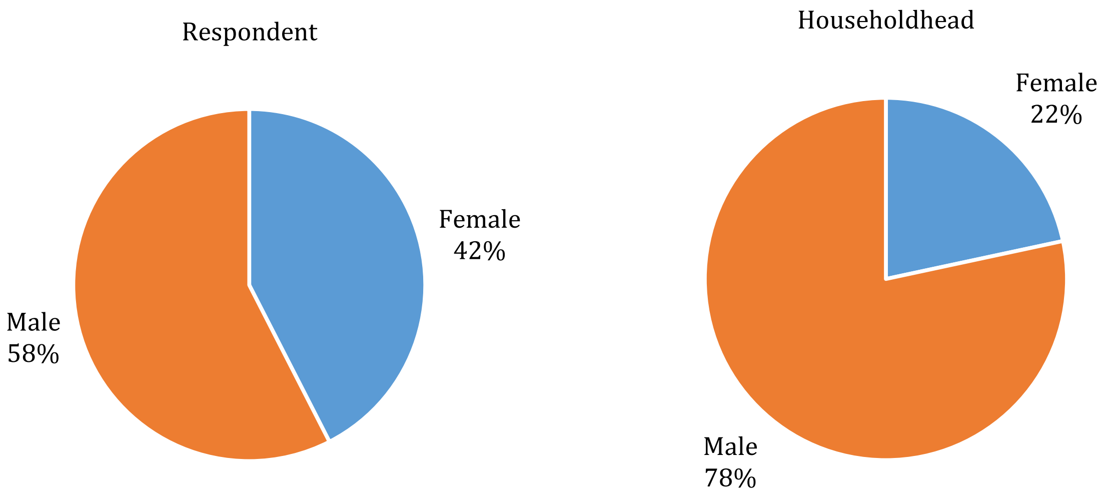
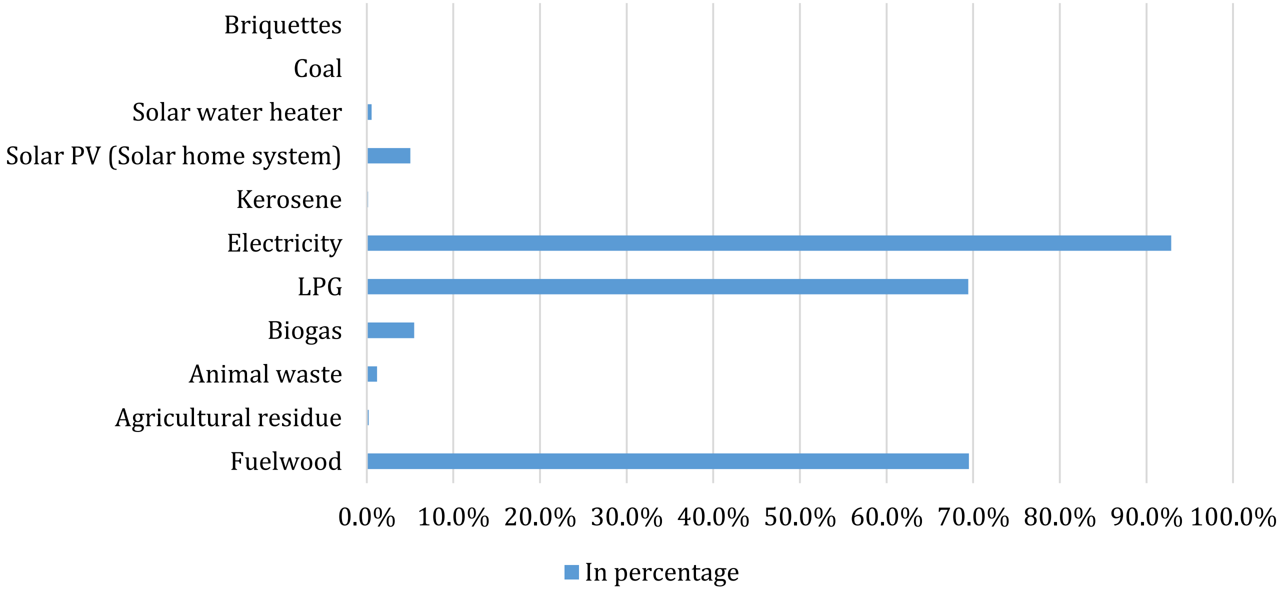


Figure 7-7: Mix of Household Respondents and the Household Head by Gender

7.2. EnergyAccesstoSociety

Figure 7-8shows the penetration of energy types in the Lumbini Province. Over 95% of the population has access to electricity. Second to that is the use of fuelwood, where nearly 70% of the respondents still use fuelwood as a source of energy. LPG is used by almost 70% of the population. This energy mix shows that although the access to electricity is good, the residents in Lumbini Province are still in the phase of energy transition from traditional to modern fuels. Even though the reach of electricity is higher than fuelwood but in energy terms, the use of fuelwood and other biomass is higher 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 the opportunity cost of fuelwood collection is not considered. Thus, people tend to use these sources more often. **Figure 7-8**highlights fuel stacking in Lumbini Province, and it is normal practice in developing countries as consumers cannot depend on one source of energy due to affordability, fuel security, and reliability of supply.



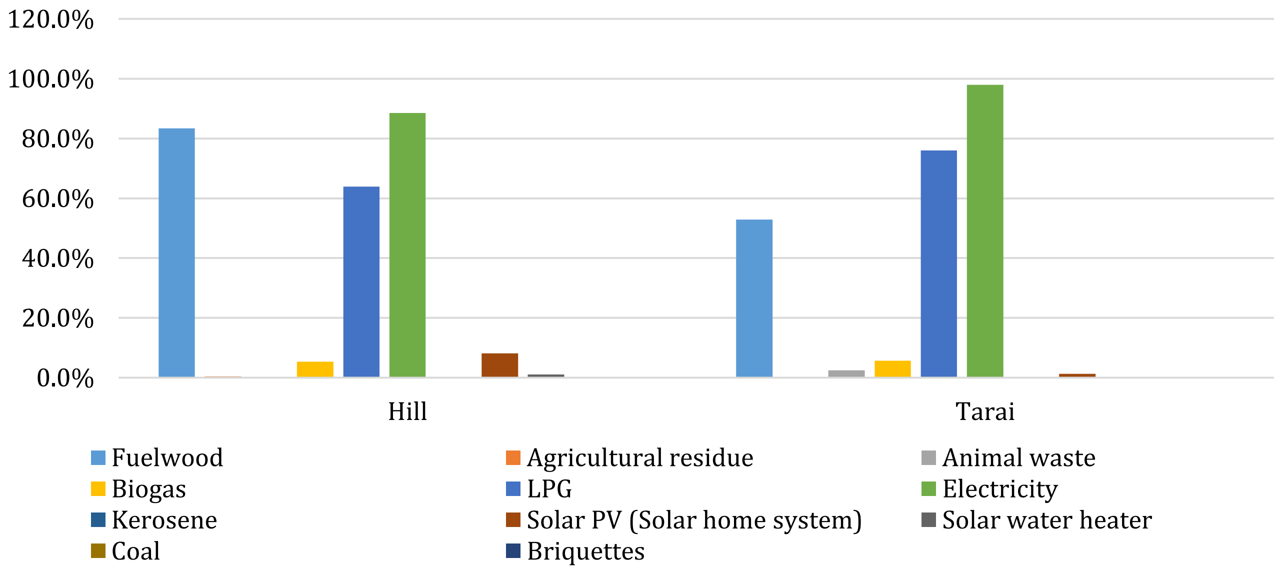


Figure 7-8: Penetration of Energy Types in Lumbini Province (top) and Ecological Regions (bottom)

Table 7-1 shows how much people paid for commercially traded energy sources. At current times, even fuelwood is being traded at an average rate of NRs. 425 per bhari (around 40 kg) on average, with the highest in Terai, and the lowest in the Hill region. Meanwhile, the LPG in Lumbini Province costs around NR 1,813 per cylinder, with transportation costs. Thus, the upfront cost of commercial energy still seems high. But if we consider energy efficiency, the cost of useful energy would be much lower for commercial energy.

Table 7-1: Cost of Commercially Traded Fuel in NRs in Lumbini Province

Fueltype	Unit	Lumbini Province		Hill	Terai
Fuelwood	40Kg	425		334	571
Kerosene	Liter	157		154	167
LPG	Cylinder	1813.3		1865.2	1761.2
Coal	Kg	54		35	67

		Districts											
	unit	Rukumeast	Rolpa	Pyuthan	Gulmi	Arghakhanchi	Palpa	Parasi	Rupandehi	Kapilvastu	Dang	Banke	Bardiya
Fuelwood	40Kg	508	396	258	438		272	551			1112	493	363
Kerosene	Liter				150		172		153		180		
LPG	Cylinder	1821.4	1935.6	1753.5	2121.8	1916.9	1686.5	1704.2	1770.7	1723.1	1798.9	1721.9	1867.8
Coal	Kg		10				60		67				

Figure 7-9shows the share of electricity connection as per ampere capacity of households who have electricity. It was observed in the survey that less than 50% of the households lie within minimal amperage capacity of 5A and around 35% of households are using 6-15 A**.** Compared to other Provinces, higher amperage connection is available in the Lumbini Province. For electric cooking, it is essential to have an electricity connection of 15 A.

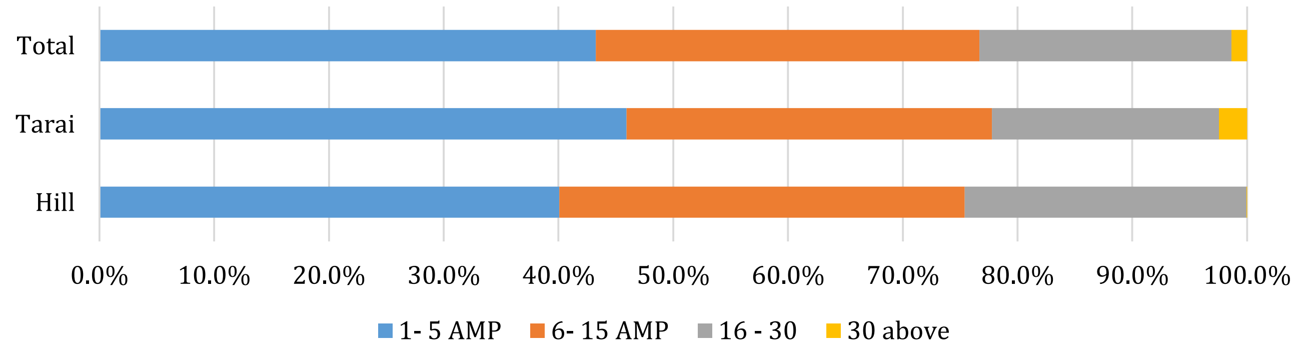


Figure 7-9: Mix of Ampere Capacity of Households with Electricity Access of Lumbini Province

It seems for enhancing the electricity connection provincial and local level governments need to coordinate with the federal government for development of distribution infrastructure and household wiring systems.

8. Energy Scenario Analysis

8.1. Scenario Development

A large-scale bottom-up partial-optimization modelling framework developed collaboratively by IEA-ETSAP program is used for energy scenario development in Nepal. It allows for a unique set of analytical capacities in energy markets, technology trends, policy strategies and investments across the energy sector that would be critical to achieve sustainable energy development and climate goals in the provinces of Nepal. It covers all sectors across the energy system with dedicated bottom-up modelling for:

- Final energy demand, covering economic sectors - industry, transport, residential (buildings), agriculture, commercial (services), and construction and mining. This is driven by detailed modelling of energy services and material demands.
- Energy transformation, including electricity generation and heat production, the production of biofuels, and other energy-related processes, as well as related transmission and distribution systems, storage, and trade.
- Energy supply, including solid biomass collection, fossil fuels trade, and availability of renewable energy resources in the provinces.

Further, this Integrated Energy – Economy - Climate (IEEC) Model is designed to analyze a diverse range of aspects of the energy system, including:

- Global, national, and provincial energy prospects: these include trends in demand, supply availability and constraints, international trade, and energy balances by sector and by fuel in the projection horizon.
- Environmental impact of energy use: this includes CO2 emissions from fuel combustion, GHG emissions from final energy demand and energy transformation.
- Effects of policy actions and technological changes: scenarios analyze the impact of a range of policy actions and technological developments on energy demand, supply, trade, investments, and emissions.
- Investment in the energy sector: this includes investment requirements in the fuel supply chain to satisfy projected energy demand and demand-side investment requirements.
- Modern energy access assessments: these include trends in access to electricity and clean cooking facilities, and the additional energy demand, investments, and CO_2 emissions due to increased energy access.

The IEEC model uses a scenario approach to examine future energy trends. The IEEC Model is used to explore various scenarios, each of which is built on a different set of underlying assumptions about how the energy system might respond to the current global energy crisis and evolve thereafter based on the national energy and climate -related plans and programs, and Nepal's commitment and pledges to the international energy and climate related programs. By comparing them, the reader and concerned policymakers can assess what drives the various outcomes, and the opportunities and pitfalls that lie along the way. These scenarios are not predictions – IEEC Model scenarios do not contain a single view about what the long-term future might hold. Instead, what the scenarios seek to do is to enable readers and policymakers to compare different possible versions of the future and the levers and actions that produce them, with the aim of stimulating insights about the future of provincial energy and taking a pathway for sustainable energy development in the provinces for a long-term period.

Provincial energy demand projections from the Model for Analysis of Energy Demand (MAED) – a freely available software developed at the International Atomic Energy Agency (IAEA) - are input exogenously into the IEEC modelling framework to analyze the supply, environmental and economic implications. Economic and population growth rates are taken as main drivers for energy demand projections.

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 (REF) Scenario*
- *Low Economic Growth (LOW) Scenario*
- *High Economic Growth (HIH) Scenario*

In addition to these three, an additional scenario has been explored to analyze the impact of strategic interventions in the energy sector. The scenario is primarily based on the Sustainable Development Goals and Nationally Determined Contribution targets.

- *Sustainable Energy Development (SED) Scenario*

For combined policy analysis, reference case is taken as the policy intervention scenario called Sustainable Energy Development (SED)Scenario and its results werecompared with those of the Reference Economic Growth Scenario.

The major strategic interventions taken in the Sustainable Energy Development (SED) Scenario 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 hydrogen for thermal purpose in cement industries
- Intervention of mass transportation system
- Introduction of new electric transportation technologies

The detailed interventions in policy scenario are given in sections below.

8.1.1. Low Economic Growth (LOW) Scenario

The following are the major assumptions of this scenario:

- Average GDP growth rate of 6.18%
- The shares of each demand technology in the energy supply in future years will be same as in the base year.

Table**8-1** illustrates the comprehensive energy demand projections for various fuel types in the low growth scenario, spanning from the base year to the year 2050. Anticipated within Lumbini Province, this analysis reveals a noteworthy surge in energy requirements, transitioning from the current level of 77 PJ in 2022 to 95 PJ by 2030 and a staggering 255 PJ by the year 2050. This implies that energy demand is poised to nearly triple over a span of three decades, with an average annual growth rate of 4.36%. Simultaneously, the per capita energy demand is slated to ascend from 15 GJ in 2022 to 35 GJ in 2050 in this scenario, signifying that energy consumption in the future is set to outpace population growth. This growth is primarily concentrated within the economic sectors, underlining the increasing energy needs associated with economic activities.

Table 8-1. Fuel Demand in Low Economic Growth Scenario (PJ)

BAU				2022	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	32.63	33.46	34.67	38.16	48.16	59.52	85.35
			Charcoal	0.04	0.01	0.01	0.01	0.01	0.02	0.03
		Modern biomass	Biogas	2.22	2.33	2.48	2.65	2.83	3.01	3.21
			Bio briquettes	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	New Renewables		Solar PV	0.13	0.15	0.18	0.24	0.32	0.45	0.64
			Grid Electricity	5.53	7.36	9.90	13.12	17.62	23.96	33.25
Non-renewable			Petrol	3.58	3.73	4.00	4.30	4.65	5.05	5.54
			Diesel	20.18	19.24	24.81	33.15	45.17	62.83	89.21
			Kerosene	0.01	0.01	0.01	0.01	0.02	0.02	0.03
			Furnace Oil	1.41	0.86	1.13	1.53	2.10	2.93	4.19
			ATF**	0.22	0.23	0.24	0.26	0.27	0.29	0.31
			LPG	4.98	4.49	4.94	5.51	6.22	7.17	8.45
			Coal	6.31	10.33	12.97	16.90	16.88	23.45	25.14
Total				**77.26**	**82.18**	**95.35**	**115.83**	**144.26**	**188.71**	**255.35**

Figure 8-1 depicts the growth of primary solid biomass, encompassing fuelwood, agricultural residue, and animal dung, has shown a sustained upward trajectory in recent years. However, this trend is expected to change soon, as the utilization of petroleum products is projected to experience a remarkable surge, potentially surpassing the demand for biomass post-2030. Notably, even though the demand for electricity is set to increase at a robust rate of 6.6% annually, its proportion within the overall energy mix is anticipated to remain relatively low. Nonetheless, there is a significant shift expected, with the share of electricity likely to nearly double by 2030 and increase nearly six foldby 2050. This analysis underscores the evolving dynamics in the energy sector, where the dominance of traditional biomass may decreasegiven the growing petroleum product consumption and the increasing importance of electricity as an energy source.

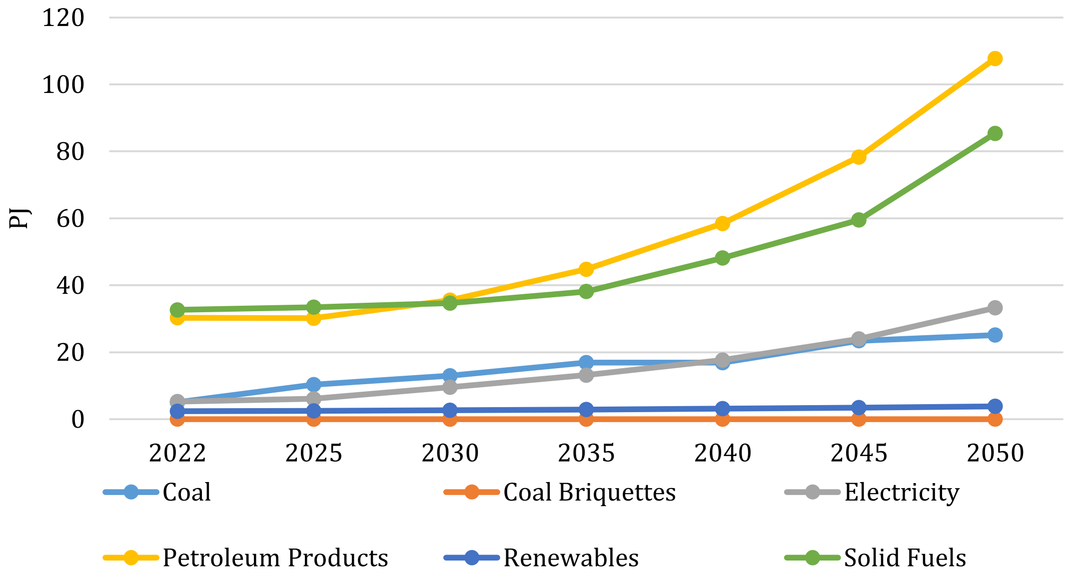
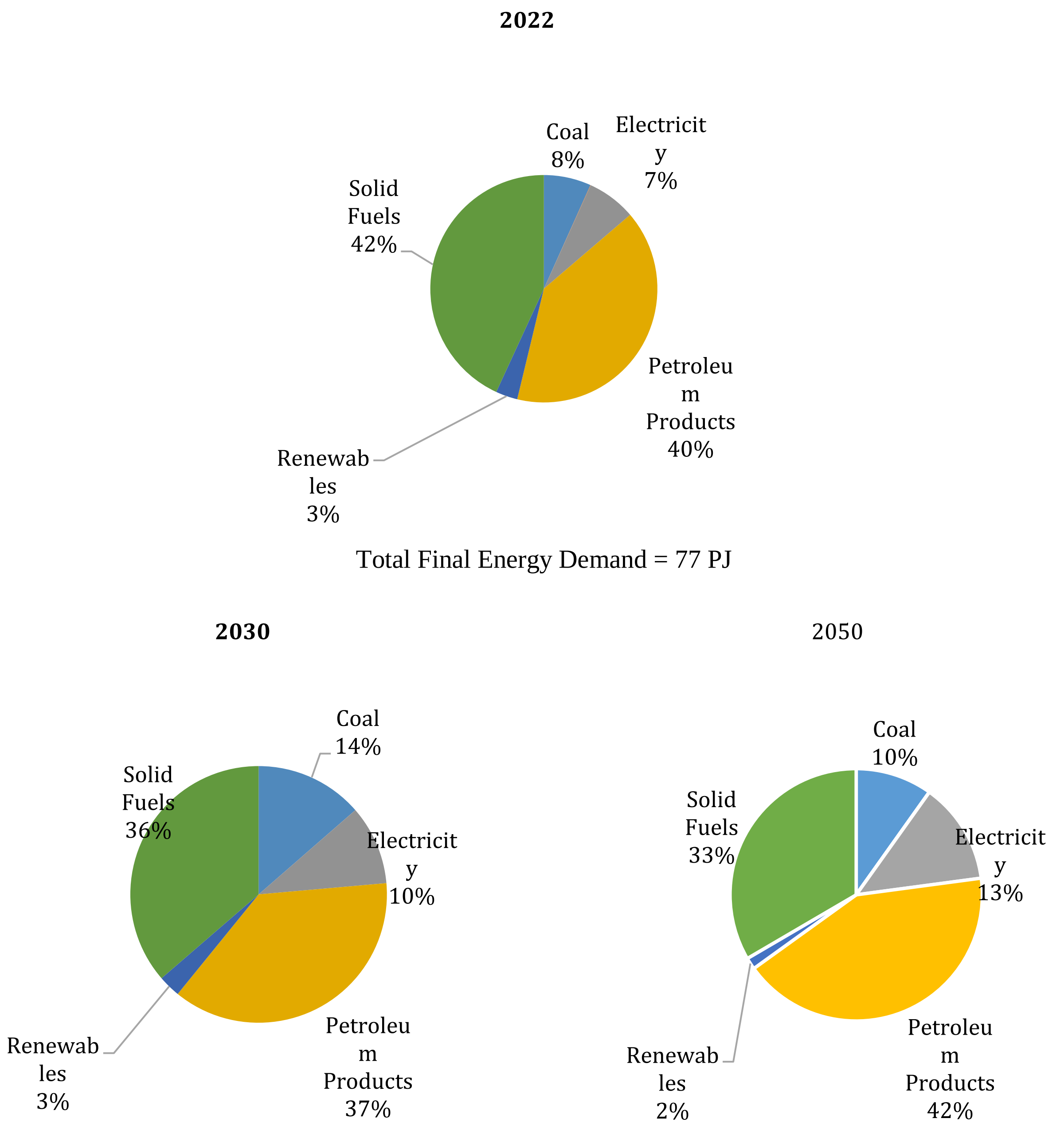


Figure 8-1. Fuel Demand Trend at Low Economic Growth Scenario

Figure 8-2 the energy mix within the overall fuel demand is depicted, revealing significant shifts in the coming years. The data indicates a decline in the demand for solid biomass, which is projected to drop to 36% in 2030 and to 33% by 2050as other commercial energy demand increases. In contrast, the demand for petroleum products is anticipated to increase to 42% by 2050 compared to the 2022 baselineextensively consumed in industry sector. Additionally, electricity's share in the energy mix is expected to rise from 10% in 2030 to 13% by 2050. These findings underscore the pressing need for interventions aimed at promoting electrification and renewable energy sources to address the changing landscape of energy demand and its environmental implications.



(b) Total Final Energy Demand = 95 PJ (c) Total Final Energy Demand = 255 PJ

Figure 8-2. Fuel Mix at Low Economic Growth Scenario

Table 8-2 illustrates the distribution of energy demand across different economic sectors. Notably, there is a significant transformation in the composition of energy consumption by 2050. The residential sector's share of energy demand sees a substantial decline, plummeting from 37%of the total final energy demand in 2022 to just 10% in 2050. This shift can be attributed to the adoption of more energy-efficient technologies within households. Conversely, the industrial sector experiences a noteworthy increase in its share of energy demand, rising to 44% in 2030 and further to 59% in 2050. This surge is primarily due to an increase in manufacturing activities, although the lack of adequate energy efficiency measures plays a role. Lumbini Province has major industrial hubs in the country. The commercial sector's share of energy demand remains relatively constant over the studied period. At the same time, the transport sector sees a modest decrease in its share. Importantly, these alterations in the energy distribution within the commercial and transport sectors are not driven by reduced energy demand but are a consequence of the heightened energy demand in the industrial sector. As a result, it becomes imperative to prioritize and enhance energy efficiency initiatives within the industrial sector to achieve a more sustainable and balanced energy landscape in the future. This analysis underscores the need for targeted interventions to optimize energy usage and emissions across different sectors, with a focus on industrial efficiency as a crucial element in achieving long-term sustainability goals.

Table 8-2. Sectoral Demand at Low Economic Growth Scenario (PJ)

	2022	2025	2030	2035	2040	2045	2050
Agriculture	5.28	6.01	7.93	10.69	14.68	20.54	29.32
Commercial	5.35	5.74	6.70	8.19	10.35	13.50	18.12
Construction and Mining	2.48	2.82	3.71	5.01	6.88	9.63	13.74
Industry	28.47	32.13	42.13	56.62	75.58	105.73	150.89
Residential	28.88	28.27	26.60	25.63	25.14	24.97	25.05
Transport	6.79	7.22	8.28	9.70	11.64	14.34	18.23
Total	**77.26**	**82.18**	**95.35**	**115.83**	**144.26**	**188.71**	**255.35**

Figure 8-3, shows the installed power plant capacity needed with 30% planning reserve on expected peak load for the study period. In 2022, an installed power plant capacity of 421 MW was necessary. However, the demand for power is expected to increase significantly, reaching approximately 1,400 MW in 2030 and a substantial growth to4,697 MW in 2050, including 30% reserve margin. These increases are in response to the growing energy consumption, which is projected to reach approximately 6,132GWh and a staggering 20,571GWh in 2030 and 2050, respectively. This data highlights the escalating demand for energy over time, emphasizing the importance of robust infrastructure and sustainable energy solutions to meet the future needs of society.

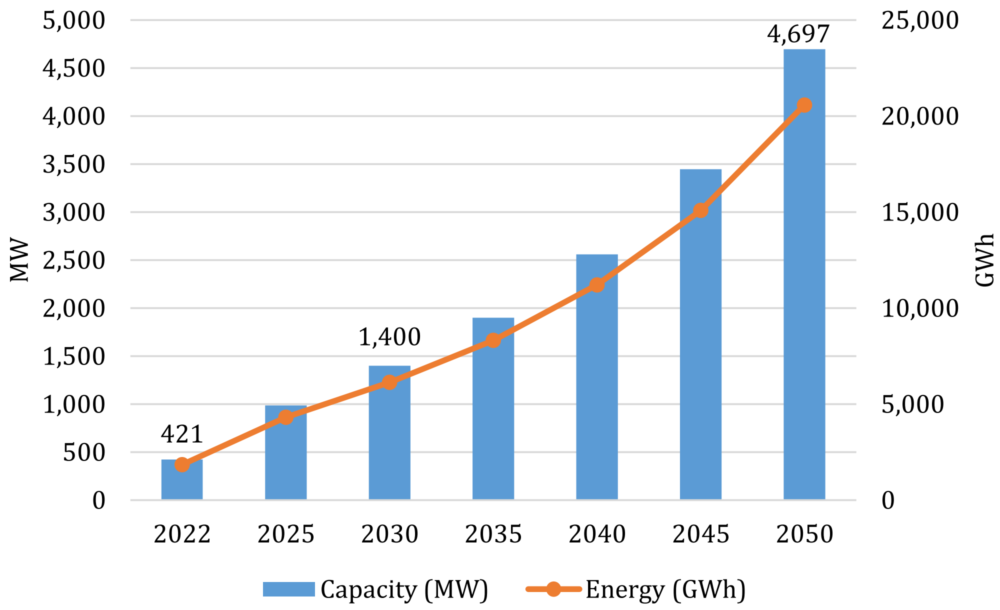


Figure 8-3. Installed Power Plant Capacity Requirement Low Economic Growth Scenario

GHG emissions trend in Low Economic Growth Scenario is as shown in **Figure 8-4.** The scenario illustrates a concerning trajectory. From 2022 to 2030, GHG emissions are projected to rise from 2,864kt to 3,956kt, and this alarming trend will persist, with an anticipated surge to 10,566kt by 2050. This represents an average annual growth rate of 4.8% over the 2022-2050 period, primarily driven by an escalation in the consumption of fossil fuels. Notably, GHG emissions in 2050 are expected to be nearly four times higher than the base year, largely stemming from the heightened demand for fossil fuels within the Lumbini Province. This data underscores the urgent need for measures to curb emissions, as such a trajectory has significant implications for climate change and its associated impacts on the environment and society.

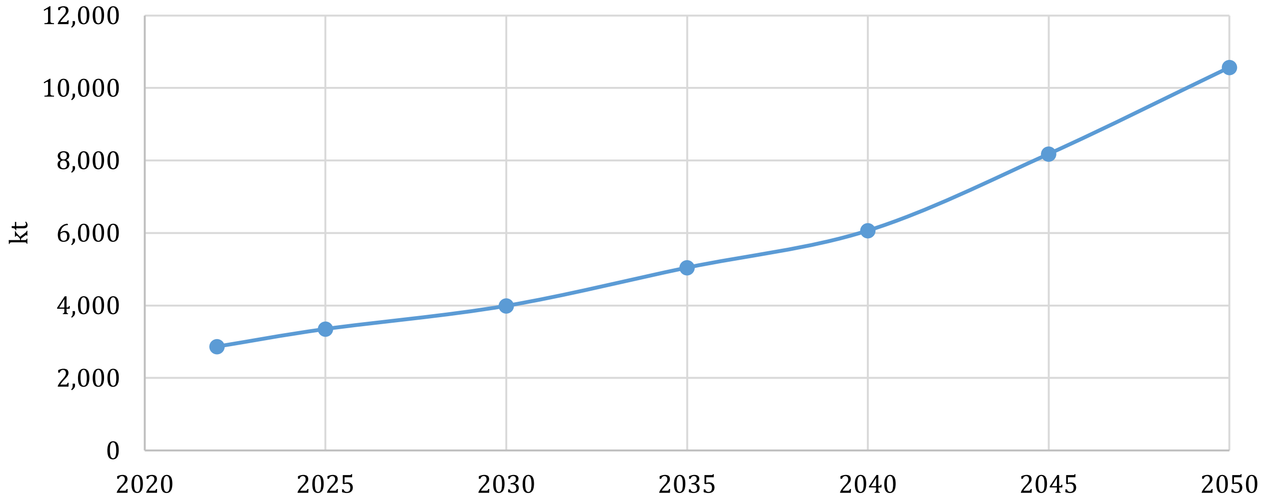


Figure 8-4. GHG Emissions at Low Economic Growth Scenario

- **Energy Indicators in the Low Economic Growth Scenario**

Table 8-3 presents energy indicators for a Low Economic Growth Scenario, revealing that without any policy interventions in the energy sector, per capita energy demand is projected to more than double by 2050 compared to the current levels. Furthermore, the proportion of renewable energy sources is expected to show a slight increase in the coming years. However, there is a concerning trend in the net import of fossil fuels, which is predicted to rise from 47% in 2022 to 52% in 2050. This is primarily driven by an increasing demand for fossil-based energy and conventional technologies. Consequently, the use of imported carbon-based fuels is anticipated to significantly raise per capita greenhouse gas (GHG) emissions, nearly tripling by 2050 from the current baseline values. This analysis highlights the urgent need for policies and strategies to reduce reliance on fossil fuels and mitigate the associated environmental impacts to achieve a more sustainable energy future.

Table 8-3. Energy Indicators in Low Economic Growth Scenario

		2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Final energy demand/capita	GJ/capita	15.08	15.46	16.87	19.27	22.56	27.75	35.30
Final electricity demand	kWh/capita	307	392	496	617	780	997	1,301
Final energy demand	GJ/million NRS	130	121	107	96	87	82	77
Final Electricity Demand	kWh/million NRS	2,641	3,080	3,138	3,082	3,015	2,930	2,850
Total Electricity Used/household	kWh/HH	480	480	480	480	480	480	480
Share of renewable energy in final total energy demand (solar, biogas, hydro, etc.)	per cent	10.2%	12.0%	13.2%	13.8%	14.4%	14.5%	14.5%
The ratio of net import to total primary energy supply	per cent	47.5%	47.3%	50.4%	53.2%	52.2%	53.9%	52.0%
GHG emissions	GHG in Kg/capita	559	608	700	838	948	1,202	1,461

8.1.2. High Economic Growth (HIH) Scenario

The following are the major assumptions of this scenario:

- Average GDP growth rate of 8.13%
- The shares of each demand technology in the energy supply in future years will be same as in the base year

In **Table 8-4,** the total energy demand for the High Economic Growth scenario is presented, covering various fuel types from the base year through 2050. In Lumbini Province, the projected energy demand is set to experience substantial growth, increasing from its 2022 level of 77 PJ to 100 PJ in 2030, and a significant increase to 411 PJ by the year 2050, marking a fivefold increase. This surge in energy consumption reflects a notable average annual growth rate of 6% in the High Economic Growth case, surpassing the LOW scenario. The rationale behind this higher growth rate is the increased economic activities, driving a greater need for energy resources. This data highlights the critical relationship between economic development and energy demand, emphasizing the importance of sustainable energy planning and management to accommodate this robust growth in energy requirements in Lumbini Province.

Table 8-4. Fuel Demand in High Economic Growth Scenario (PJ)

HIGH				2022	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	32.63	33.72	35.83	41.39	56.96	79.41	134.92
			Charcoal	0.04	0.01	0.01	0.01	0.02	0.03	0.05
		Modern biomass	Biogas	2.22	2.33	2.48	2.65	2.83	3.02	3.23
			Bio briquettes	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	New Renewables		Solar PV	0.13	0.15	0.20	0.28	0.41	0.65	1.09
			Grid Electricity	5.53	7.48	10.47	14.77	21.72	33.42	54.43
Non-renewable			Petrol	3.58	3.73	4.01	4.34	4.73	5.25	5.98
			Diesel	20.18	19.58	26.46	37.92	56.99	90.09	150.28
			Kerosene	0.01	0.01	0.01	0.02	0.02	0.03	0.04
			Furnace Oil	1.41	0.87	1.21	1.75	2.66	4.23	7.09
			ATF**	0.22	0.23	0.24	0.26	0.27	0.29	0.31
			LPG	4.98	4.50	5.00	5.68	6.66	8.18	10.72
			Coal	6.31	10.51	13.82	19.36	21.38	33.83	42.62
Total				**77.26**	**83.13**	**99.75**	**128.43**	**174.66**	**258.43**	**410.76**

The proportion of primary solid biomass, including fuelwood, agricultural residue, and animal dung, consistently remains high over the specified time frame, with an annual growth rate of 5%. Projections indicate that there will be an increase in demand for petroleum and coal by approximately 6.5% and 8%, respectively, while electricity demand is expected to rise at an annual rate of 8.5%, as depicted in **Figure 8-5.** In this High Industrialization (HIH) scenario, the demand for petroleum products is anticipated to outpace the demand for solid biomass, albeit at a faster rate compared to the LOW scenario. This heightened demand for petroleum products primarily stems from the industrial sector, where increased economic activities drive the need for more fossil fuels, highlighting the necessity for intervention to mitigate the environmental impact.

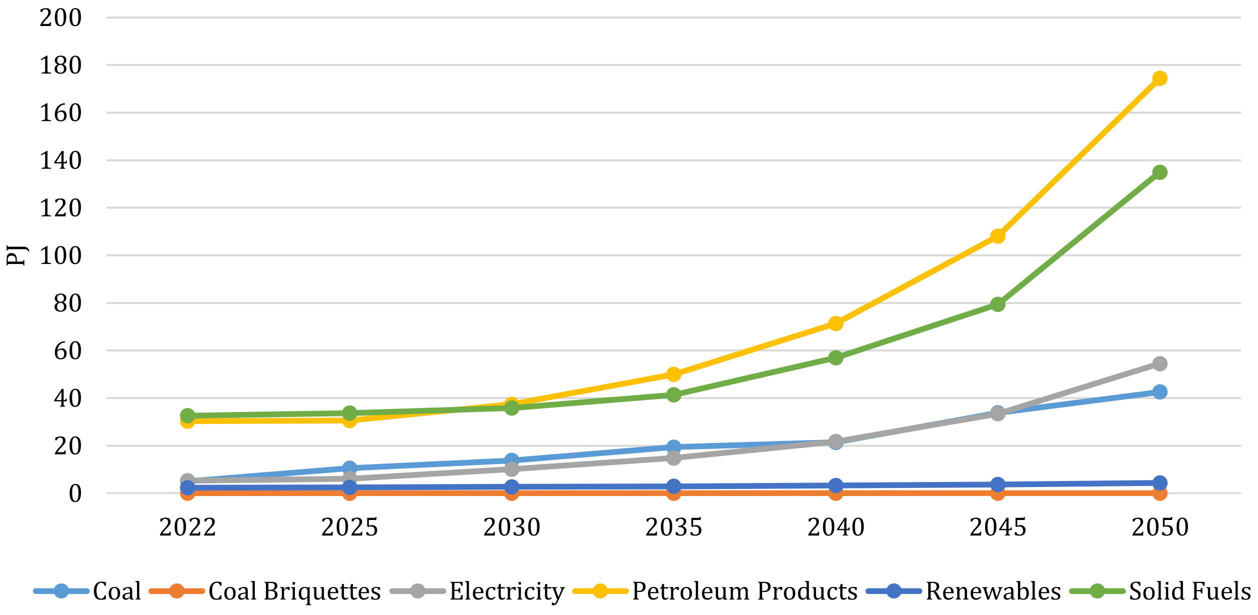
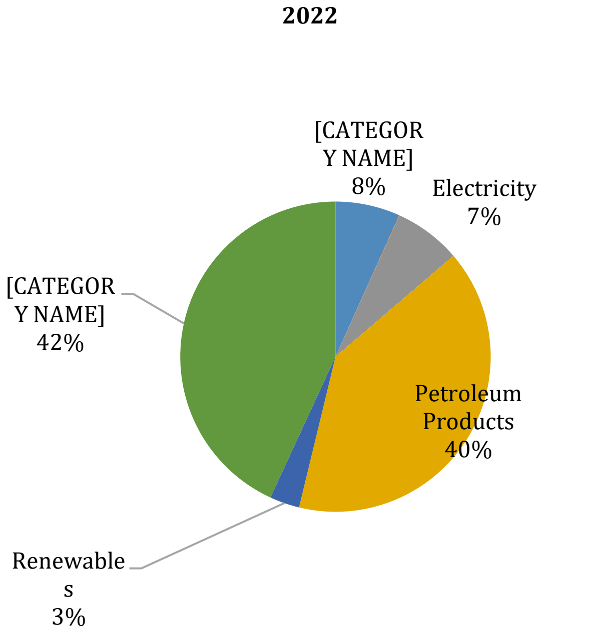
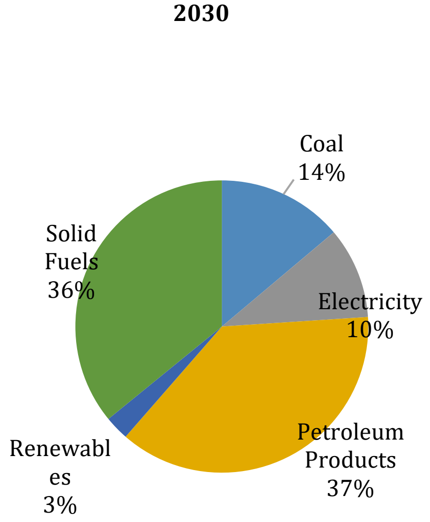


Figure 8-5. Fuel Demand Trend at High Economic Growth Scenario

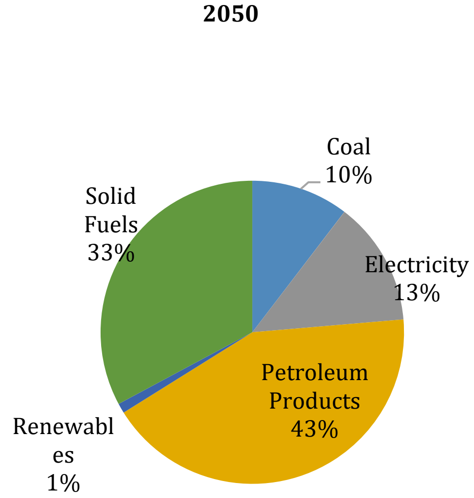
In **Figure 8-6** the energy mix for total fuel demand in 2022, 2030, and 2050 is depicted. It is noteworthy that the demand for solid biomass is anticipated to decline, reaching 36% in 2030 and 33% in 2050. Conversely, petroleum products are poised for substantial growth, with their share in demand increasing to 43% by 2050, in contrast to 2022. Furthermore, electricity demand is projected to see a modest rise, accounting for 10% in 2030 and 13% in 2050. This data underscores a notable shift in energy sources and highlights the growing importance of petroleum products in the future energy landscape to meet the growing energy demand if energy transition measures were not implemented.



a) Total Final Energy Demand = 77 PJ



(b) Total Final Energy Demand = 100 PJ



(c) Total Final Energy Demand = 411 PJ

Figure 8-6. Fuel Mix at High Economic Growth Scenario

Table 8-5 illustrates the sectoral energy demand in the given scenario, offering intriguing insights into changing energy consumption patterns. Notably, the residential sector's share of energy demand experiences a significant decline, plummeting from 37% in 2022 to a mere 6% by 2050. In stark contrast, the industrial sector make substantial growth, with its share of energy demand surging from 45% in 2030 to a dominant 62% by 2050. The commercial sector also sees a notable uptick, with its energy demand share reaching 7% in 2050. Interestingly, the transport sector's energy demand grows at a comparatively slower rate of 5%, while the overall energy demand exhibits a more robust growth rate of 6.1%.

Table 8-5. Sectoral Demand at High Economic Growth Scenario (PJ)

	2022	2025	2030	2035	2040	2045	2050
Agriculture	5.28	6.12	8.48	12.28	18.62	29.64	49.70
Commercial	5.35	5.85	7.16	9.39	13.10	19.41	30.60
Construction and Mining	2.48	2.87	3.97	5.76	8.73	13.89	23.30
Industry	28.47	32.74	45.04	65.03	95.87	152.55	255.77
Residential	28.88	28.27	26.60	25.63	25.14	24.97	25.05
Transport	6.79	7.27	8.50	10.34	13.21	17.97	26.35
Total	**77.26**	**83.13**	**99.75**	**128.43**	**174.66**	**258.43**	**410.76**

In **Figure 8-7** the installed power plant capacity required with 30% planning reserve on expected peak load for the study period. is depicted, revealing significant changes in future power requirements. The analysis projects a substantial increase in electricity demand, with an anticipated rise from the current 421 MW to 1,471MW by 2030, and a further surge to 7,326 MW by 2050. This growth is primarily attributed to 11% annual increase in demand, driven by the expected expansion of economic activities. It is evident that substantial infrastructure and capacity upgrades will be necessary to meet these escalating energy needs, and careful planning and investment will be crucial to ensure a reliable and sustainable power supply in the coming decades.

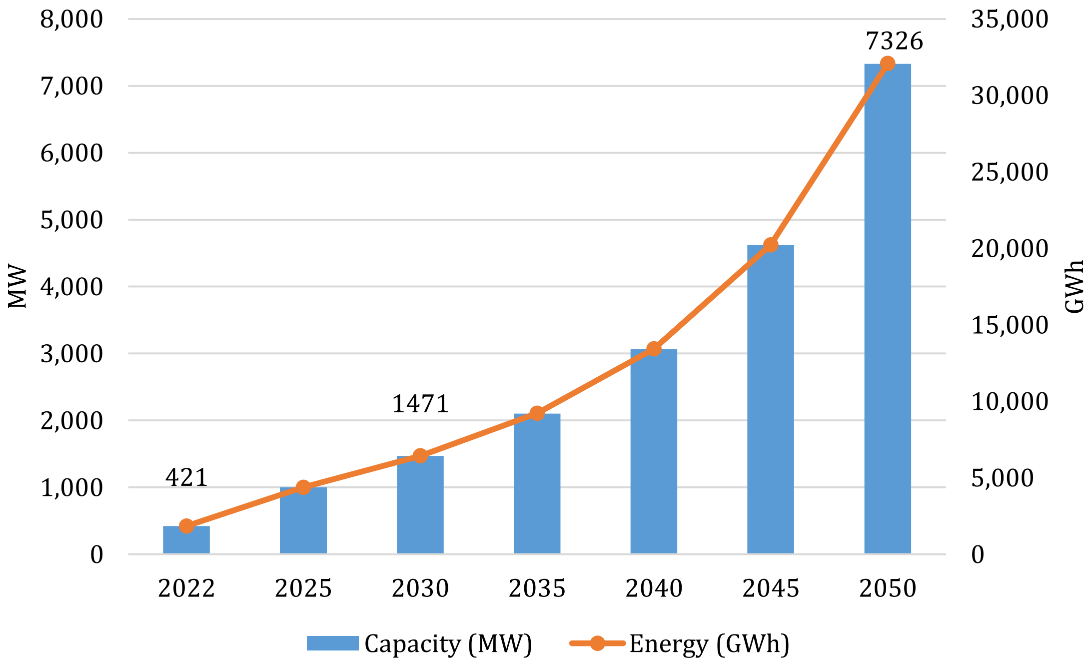


Figure 8-7. Installed Power Plant Capacity Requirement High Economic Growth Scenario

In **Figure 8-8** the trendof greenhouse gas (GHG) emissions in a scenario characterized by high economic growth is depicted. The data reveals a substantial increase in GHG emissions, projecting an elevation to 4,173kilotons in 2030 and a staggering potential rise to 17,229 kilotons by 2050. This translates to an average annual growth rate of 6.6% between 2022 and 2050, culminating in emissions six times higher than the current levels by 2050. The primary driving factor behind this sharp escalation is the pronounced demand for fossil fuels in the Lumbini Province. This data underscores the critical need for targeted strategies and policies to mitigate GHG emissions, especially in regions with rapid economic development, to combat the associated environmental challenges.

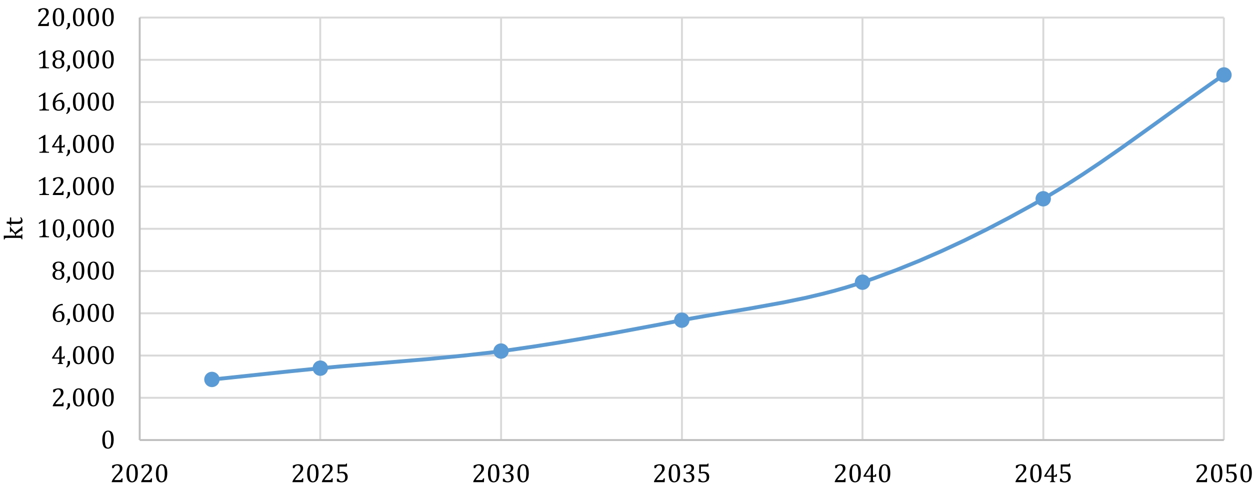


Figure 8-8. GHG emissions at High Economic Growth Scenario

- **Energy Indicators in the High Economic Growth Scenario**

Table 8-6 presents energy indicators for the High Economic Growth Scenario, revealing that without any energy sector policy interventions, per capita energy demand is projected to increase almost fourfold by 2050 compared to the current levels. Although there is a slight uptick in the share of renewables, the scenario also anticipates a rise in net fuel imports, climbing from 47% in 2022 to 53% in 2050. This increase in carbon-based energy demand and conventional technologies will be the driving force behind the surge in imported carbon-based fuels and their utilization, significantly amplifying per capita greenhouse gas emissions by more than fourfold by 2050, as compared to the baseline values. This analysis underscores the urgency of implementing effective policies to address the growing energy demand and its associated environmental consequences.

Table 8-6. Energy Indicators in High Economic Growth Scenario

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	15.08	15.64	17.65	21.36	27.32	38.00	56.79
Final electricity demand	kWh/capita	307	399	524	695	961	1,391	2,132
Final energy demand	GJ/million NRS	130	120	104	93	83	77	73
Final Electricity Demand	kWh/million NRS	2,641	3,071	3,104	3,022	2,931	2,834	2,754
Total Electricity Used/household	kWh/HH	480	480	480	480	480	480	480
Share of renewable energy in final total energy demand (solar, biogas, hydro, etc.)	per cent	10.20%	11.97%	13.18%	13.77%	14.28%	14.34%	14.29%
The ratio of net import to total primary energy supply	per cent	47.51%	47.45%	50.88%	53.98%	53.09%	54.91%	52.84%
GHG emission	GHG in Kg/capita	559	616	738	943	1,168	1,679	2,389

8.1.3. Reference Economic Growth (REF) Scenario

The following are the major assumptions of this scenario:

- Average GDP growth rate of 6.96%
- The shares of each demand technology in the energy supply in future years will be same as in the base year.

In **Table 8-7** the total energy demand for different fuel types in the reference growth scenario is presented, spanning from the base year to 2050. In Lumbini Province, this demand is projected to undergo significant expansion, rising from 77 PJ in 2022 to 96 PJ by 2030, and ultimately reaching 309 PJ by 2050, marking a fourfold increase in the reference scenario. This growth represents an average annual growth rate of 5.1% for the reference case, with electricity emerging as the fastest growingenergy category, followed by petroleum products. This data highlights the region's escalating energy needs, development of hydropower plants and petroleum products underscore driving this demand surge, which has implications for energy planning and resource allocation in the coming decades.

Table 8-7. Fuel Demand in Reference Economic Growth Scenario (PJ)

REF				2022	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	32.63	33.50	34.87	38.84	50.50	65.72	102.45
			Charcoal	0.04	0.01	0.02	0.01	0.02	0.02	0.04
		Modern biomass	Biogas	2.22	2.32	2.47	2.64	2.83	3.02	3.22
			Bio briquettes	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	New Renewables		Solar PV	0.13	0.15	0.19	0.25	0.35	0.51	0.80
			Grid Electricity	5.53	7.38	10.00	13.47	18.71	26.91	40.55
Non-renewable			Petrol	3.58	3.73	4.00	4.31	4.67	5.11	5.69
			Diesel	20.18	19.28	25.09	34.16	48.32	71.33	110.27
			Kerosene	0.01	0.01	0.01	0.01	0.02	0.02	0.03
			Furnace Oil	1.41	0.86	1.14	1.57	2.25	3.34	5.19
			ATF**	0.22	0.23	0.24	0.26	0.27	0.29	0.31
			LPG	4.98	4.60	4.95	5.54	6.34	7.48	9.23
			Coal	6.31	10.37	13.12	17.43	18.08	26.68	31.17
Total				**77.26**	**82.33**	**96.11**	**118.52**	**152.36**	**210.44**	**308.95**

The share of primary solid biomass (fuelwood, agri-residue and animal dung) will not remain high throughout the period but will be surpassed by highly growing petroleum products which are expected to grow at the rate of 5.4% whereas electricity demand would grow at higher rate of7.6% per annum **Figure 8-**9. The demand of electricity, however, will remain below the demand of petroleum and biomass in absence of interventions.

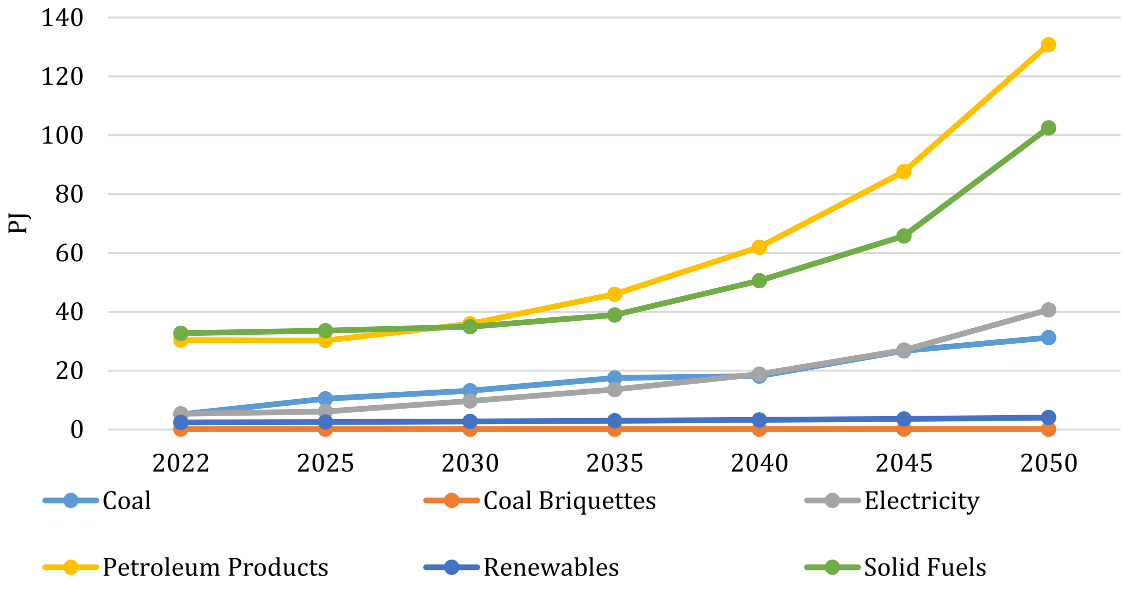
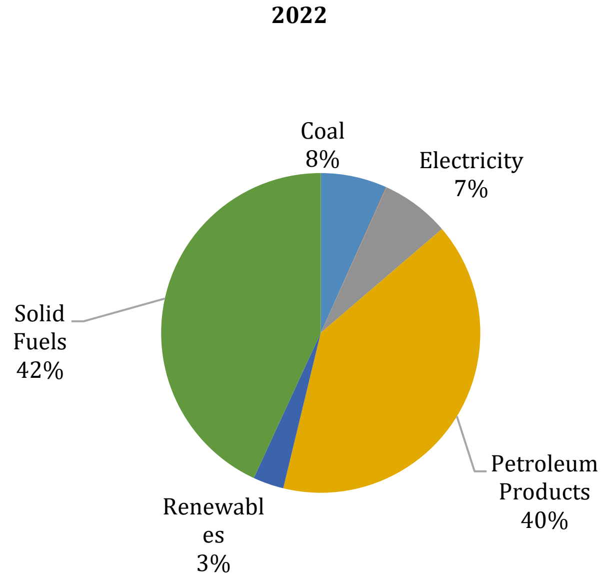
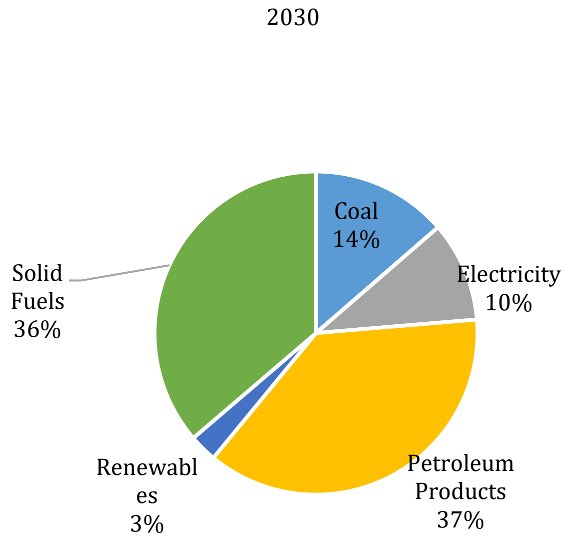


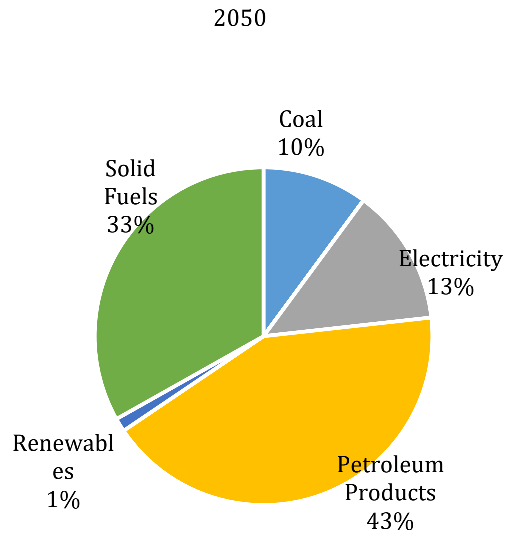
Figure 8-9. Fuel Demand Trend at Reference Economic Growth Scenario

Figure 8-10 shows the energy mix in the total fuel demand for 2022, 2030 and 2050 years. The demand of solid biomass is expected to decrease to 36% in 2030 and 33% in 2050 respectively. Compared to 2022, the demand of petroleum products would reach 43%. The electricity demand share would be 10% in 2030 and 13% in 2050 respectively.



Total Final Energy Demand = 77 PJ





(b) Total Final Energy Demand = 96 PJ (c) Total Final Energy Demand = 309 PJ

Figure 8-10. Fuel Mix at Reference Economic Growth Scenario

Table 8-8 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 8% in 2050 from 37% in 2022. Meanwhile, the industrial sector's share of energy demand will increase to 44% in 2030 and 61% in 2050. Whereas the share of Energy demands in the commercial sector will increase to 7.3% from its base year value of 6.9%. Although there will be an overall increase in energy demand, the share of energy demand in the transport sector will decrease, while the actual demand reaching nearly 3 folds in 2050 with respect to 2022.

Table 8-8. Sectoral Demand at Reference Economic Growth Scenario (PJ)

	2022	2025	2030	2035	2040	2045	2050
Agriculture	5.28	6.03	8.02	11.03	15.73	23.38	36.35
Commercial	5.35	5.76	6.78	8.44	11.08	15.34	22.42
Construction and Mining	2.48	2.83	3.76	5.17	7.37	10.96	17.04
Industry	28.47	32.23	42.64	58.41	80.99	120.32	187.06
Residential	28.88	28.27	26.60	25.63	25.14	24.97	25.05
Transport	6.79	7.21	8.31	9.84	12.06	15.47	21.03
Total	**77.26**	**82.33**	**96.11**	**118.52**	**152.36**	**210.44**	**308.95**

The data presented in **Figure 8-11** provides a clear insight into the energy landscape of Lumbini Province, emphasizing a continued dependence on biomass energy sources in the absence of policies promoting clean and renewable alternatives. This trajectory is expected to result in a notable surge in the demand for fossil fuels by 2050. The sustainability of relying heavily on biomass energy raises apprehensions, particularly concerning the finite forest resources in Lumbini Province. Moreover, there are uncertainties about the long-term economic feasibility of supporting the substantial importation of fossil fuels required under this scenario.

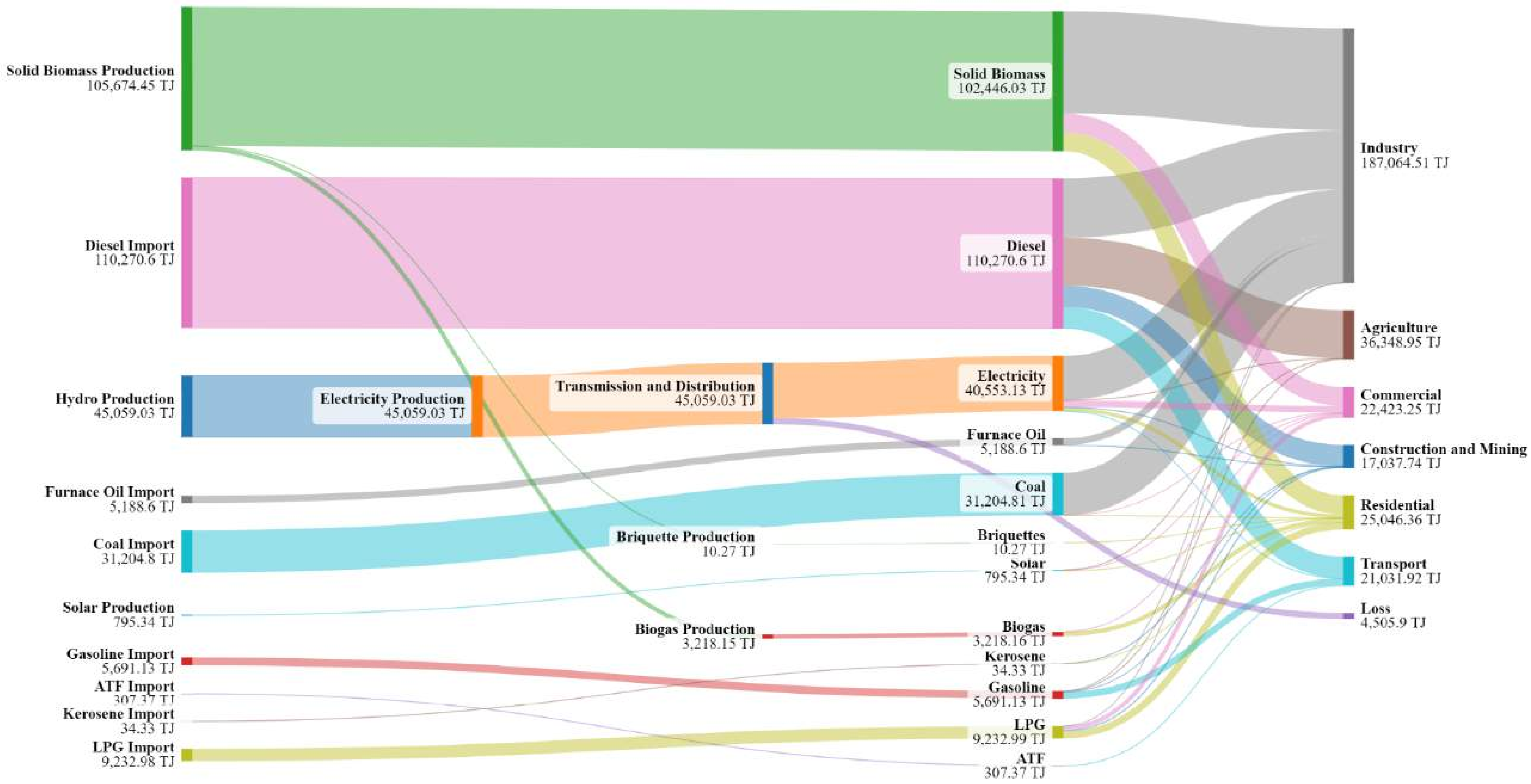


Figure 8-11. Sankey Diagram for Flow of Energy in Lumbini Province for the Reference Economic Growth Scenario in 2050

Figure 8-12 shows the installed power plant capacity required with 30% planning reserve on expected peak load for the study period. The future power requirement would be 1,412 MW in 2030 and 5,604 MW in 2050. The electricity demand will be 6,186 GWh in 2030 and 24,544GWh in 2050.

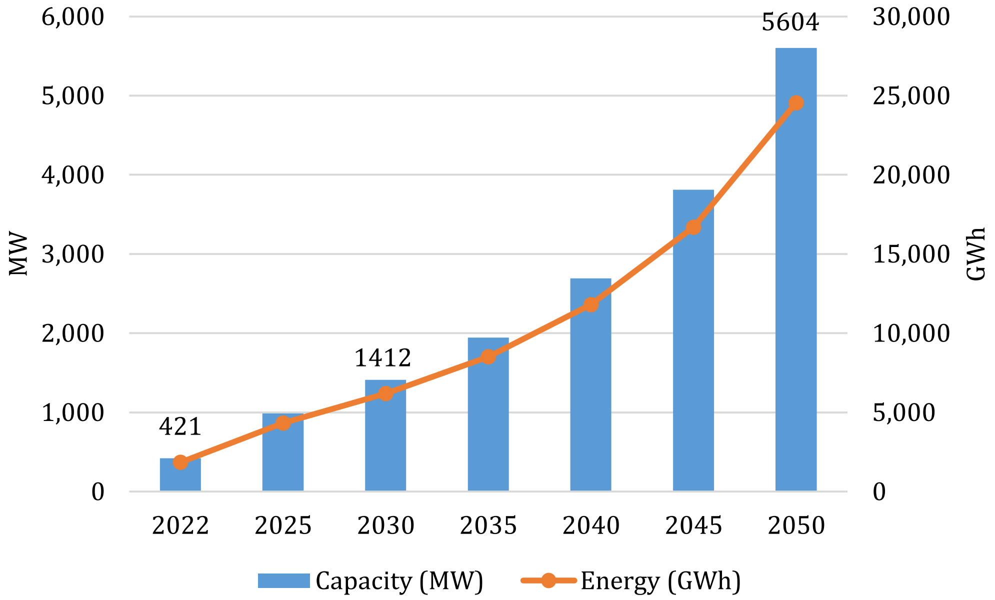


Figure 8-12. Installed Power Plant Capacity Requirement Reference Economic Growth Scenario

GHG emissions trend in Reference Economic Growth Scenario is as shown in **Figure 8-13.** GHGemissions would increase from 2,864kt in 2022 to 3,993kt in 2030 and will reach 12,881kt in 2050. The GHG emissions would grow at an average growth rate of 5.5% during 2022-2050. There will be 4.5 times growth in GHG emissions in 2050 from its base year and it is mainly attributed to the high demand in fossil fuels in the Lumbini Province.

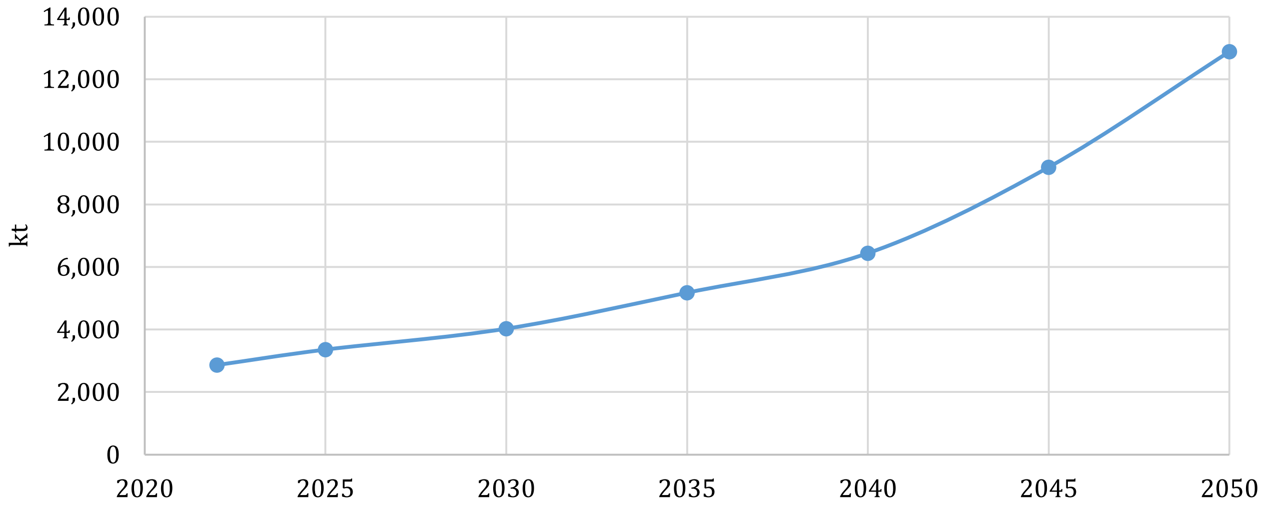


Figure 8-13. GHG Emissions at Reference Economic Growth Scenario

Energy Indicators in the Reference Economic Growth Scenario

Table 8-9 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 - by 4%, in years coming by, but in the other hand the net import of fuel in also seen to reach 53% in 2050 from 47% in 2022, all due to increase in carbon-based energy demand and the conventional demand technologies. The imported carbon-based fuels and their uses are also going to impact per capita GHG emissions reaching almost three times by 2050 from the current baseline values.

Table 8-9. Energy Indicators in Reference Economic Growth Scenario

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	15.08	15.49	17.00	19.71	23.83	30.94	42.72
Final electricity demand	kWh/capita	307	393	501	634	828	1,120	1,588
Final energy demand	GJ/million NRS	130	121	106	95	86	80	75
Final Electricity Demand	kWh/million NRS	2,641	3,079	3,132	3,068	2,988	2,892	2,805
Total Electricity Used/household	kWh/HH	480	480	480	480	480	480	480
Share of renewable energy in final total energy demand (solar, biogas, hydro, etc.)	per cent	10.2%	12.0%	13.2%	13.8%	14.4%	14.5%	14.4%
The ratio of net import to total primary energy supply	per cent	47.5%	47.3%	50.5%	53.4%	52.5%	54.3%	52.4%
GHG emissions	GHG in Kg/capita	559	609	706	861	1,007	1,351	1,781

8.1.4. Sustainable Energy Development (SED) Scenario

In this scenario all combined policy measures are considered at an average annual GDP growth of 6.96% for various technology Interventions – same as in the REF scenario. 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, NPC's SDG roadmap, NDC 2020 targets for 2030, Nepal's Long-Term Strategies for Net Zero Emission by 2045 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. 6.96%.
- The shares of energy technologies vary in line with intervening strategies which are given below.

Agriculture:

- 60% Electrification,40% solar in water pumping by 2050
- 50% electrification in farm machineries by 2050

Commercial sector

- 100% electrification in lighting and electrical appliances by 2050
- 50% electric, 30% LPG in cooking and water boiling
- 20% electric in space heating

Transportation

- Intercity transport
  - 20% electric car
  - 50% electric bus
  - 10% electric motorcycle
  - 10% fuel cell electric car
  - 10% fuel cell electric bus
- Intercity transport
  - 40% electric bus
  - 20% electric car
  - 30% electric train
  - 10% airplane
- Freight
  - 40% electric train
  - 60% electric vehicles

Industry:

- Boiler
  - 50% electric boiler
- Motive power and other end-uses
  - 100% electrification by 2050
- Process Heat
  - 30% electrification including 5% hydrogen, 70% alternative clean fuel by 2050
  - Intervention of hydrogen (5%) for cement industry

Residential sector:

- Rural cooking and water heating: 40% electric, 30% ICS and 30% LPG by 2050
- Rural others: 40% electrification, 30% LPG, 30% fuelwood by 2050
- Rural: 100% electrification in rest
- Urban cooking and water heating: 60% electrification, 30% LPG by 2050
- Urban others: 60% electrification, 305 LPG by 2050
- All others to be fully electrified by 2050.

The final demands of various fuels in this scenario have been given in **Table 8-10.** The total energy demand in 2030 and 2050 is expected to be 83 PJ and 274 PJ respectively. Per capita energy demand is expected to be 38 GJ in 2050 in the Sustainable Energy Development Scenario (SEDS), whereas it would be 43 GJ in the Reference Economic Growth Scenario. Thus, there is clear indication of improvement in energy efficiency, along with intervention of cleaner technologies.

Table 8-10. Fuel Demand Sustainable Energy Development Scenario(PJ)

				2022	2025	2030	2035	2040	2045	2050
Renewables	Conventional renewable	Traditional biomass	PSF*	32.63	28.03	24.50	29.98	42.02	58.20	96.61
			Charcoal	0.04	0.01	0.01	0.01	0.01	0.00	0.00
		Modern biomass	Biogas	2.22	2.21	2.14	2.07	1.97	1.85	1.70
			Bio briquettes	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	New Renewables		Solar PV	0.13	0.18	0.29	0.47	0.79	1.36	2.40
			Grid Electricity	5.53	8.47	13.76	21.48	33.54	53.48	88.47
Non-renewable			Petrol	3.58	3.37	2.97	2.51	1.96	1.32	0.54
			Diesel	20.18	18.51	22.24	27.78	35.67	47.21	64.52
			Kerosene	0.01	0.01	0.01	0.01	0.01	0.02	0.03
			Furnace Oil	1.41	0.83	1.04	1.35	1.80	2.50	3.59
			ATF**	0.22	0.23	0.24	0.26	0.27	0.29	0.31
			LPG	4.98	4.41	4.71	5.09	5.60	6.32	7.40
			Coal	6.31	9.90	11.47	13.48	11.84	14.84	8.75
Total				**77.26**	**76.15**	**83.39**	**104.49**	**135.49**	**187.39**	**274.32**

In this scenario, the final energy demand would grow at the rate of 4.6% per annum whereas electricity demand grows at an average rate of 10% per annum during 2022-2050. Compared to other energy carriers, electricity demand will be surpassing other demands after 2045. The primary solid biomass (wood, agri -residue and animal dung) demand is expected to grow within the rate of 4% during the same period due to clean energy technology intervention in all major sectors. Policy intervention to reduce petroleum demand mainly in commercial and residential sectors significantly shows reduction of its demand in future years. Modern renewables, excluding grid electricity, are expected to grow at the rate of 2% per annum during the analysis period. The energy demand trends are highlighted in **Figure 8-14.**

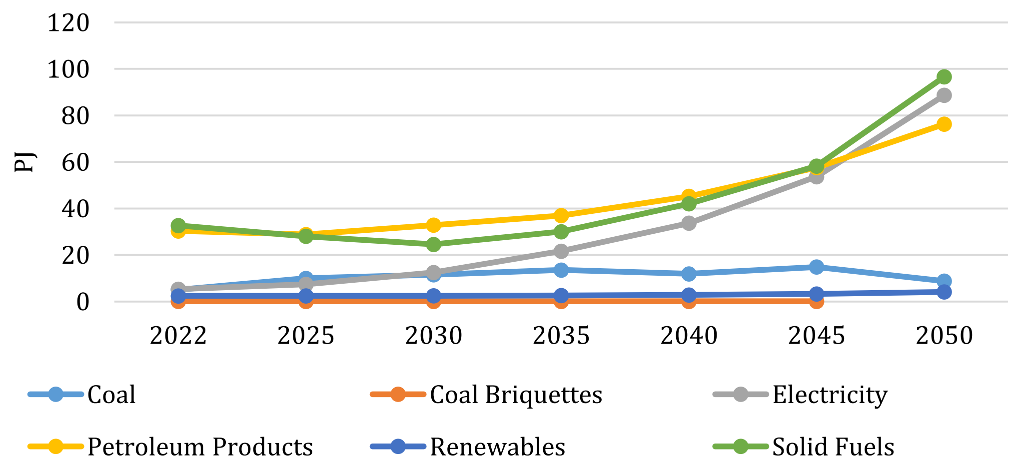
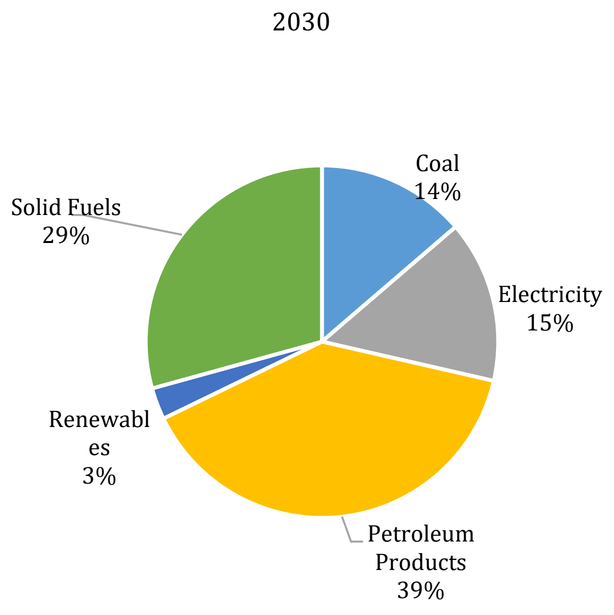
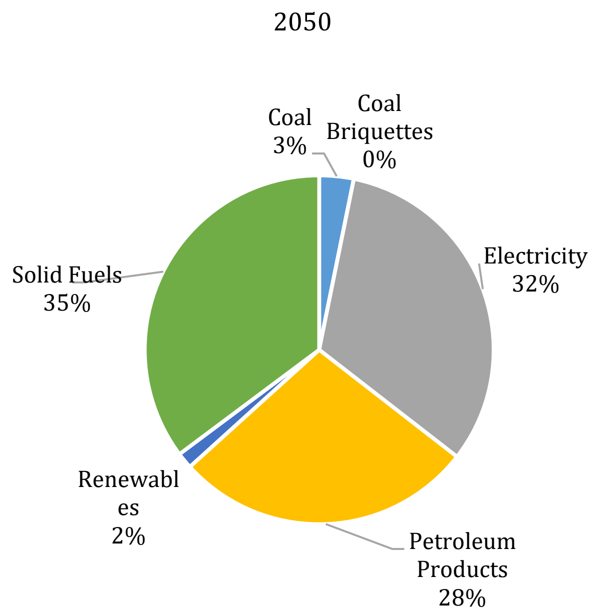


Figure 8-14. Fuel demand trend at Sustainable Energy Development Scenario (SEDS)

Figure 8-15 show the energy mix in the total energy demands for 2030 and 2050 years. The demand of fuelwood is expected to reach29% in 2030 and 35% in 2050 respectively. However, this increase is not solely due to increase in demand, but due to lowering of energy intensity.Meanwhile, electricity demand would be 15% in 2030 and 32% in 2050 respectively. While the petroleum products' demand also will be reducing causing lowering in share to 28% in 2050 from 39% in 2030.



(a) Total Final Energy Demand = 84 PJ



(b) Total Final Energy Demand = 274 PJ

Figure 8-15. Fuel mix at Sustainable Energy Development Scenario (SEDS)

Table 8-11 shows the sectoral energy demand in this scenario. The share of residential sector decreases to 7% in 2050 from 37% in 2022. Meanwhile, the industrial sector's share of energy demand will increase to 50% in 2030 and 64% in 2050 respectively, whereas the share of energy demands in the commercial, agriculture, and transport sectors will be 6%, 10% and 8% respectively in 2050 and remaining demand comes from construction and mining sector. Thus, the agriculture sector in this province is going to be one of the major sectors after industry.

Table 8-11. Sectoral Demand at Sustainable Energy Development Scenario (SEDS) (PJ)

	2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Agriculture	5.28	5.85	7.38	9.60	12.92	18.04	26.24
Commercial	5.35	4.80	4.54	5.88	7.85	10.86	15.63
Construction and Mining	2.48	2.83	3.76	5.17	7.37	10.96	17.04
Industry	28.47	32.03	41.90	56.69	78.12	114.87	176.76
Residential	28.88	23.65	18.00	18.10	18.15	18.12	18.02
Transport	6.79	7.00	7.81	9.05	11.08	14.53	20.63
Total	**77.26**	**76.15**	**83.39**	**104.49**	**135.49**	**187.39**	**274.32**

The Sankey diagram depicted in **Figure 8-16**indicates a noteworthy transformation in Nepal's energy sector under the SED Scenario. By 2050, there is limitation in the use of solid biomass and a minimal dependence on imported fossil fuels. This signifies a pivotal shift towards cleaner, renewable sources for electricity generation, marking a significant stride in enhancing energy security and sustainability within the region. This transition not only underscores a reduced environmental impact but also heralds a more resilient and ecologically responsible energy future for Nepal.

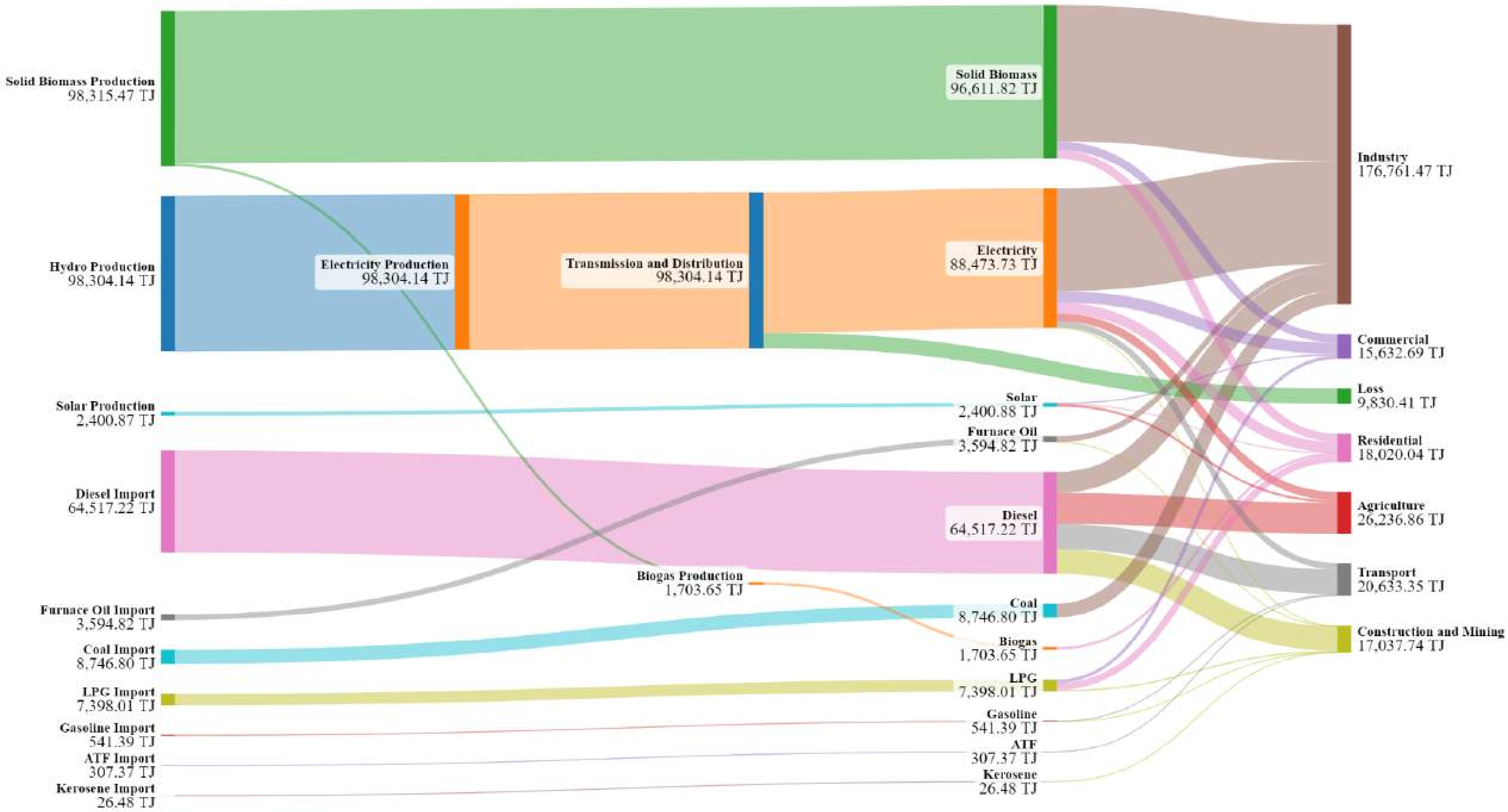


Figure 8-16. Sankey Diagram for Flow of Energy in Lumbini Province for the Sustainable Energy Development Scenario in 2050

The installed power plant capacity requirement in this scenario with 30% planning reserve on expected peak load for the study period is as shown in **Figure 8-17.** The power plant requirement for Lumbini Province in 2030 will be 1,879 MW, and it will be 11,530 MW by 2050. This is almost twice the requirement in the reference case in 2050. The electricity demand will be 8,229GWh in 2030 and 50,503 GWh in 2050.

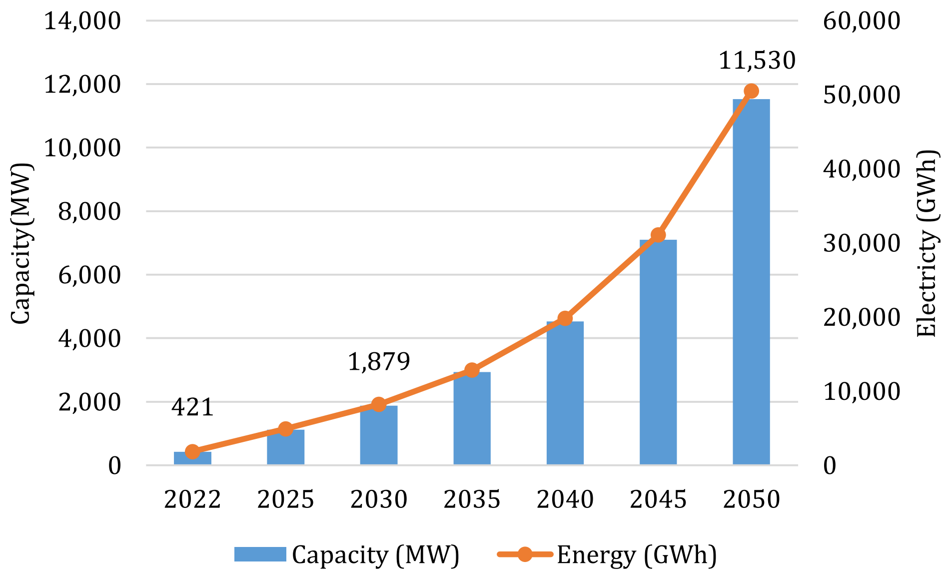


Figure 8-17. Power Plant CapacityRequirement in Sustainable Energy Development Scenario (SEDS)

GHG emissions trend in Sustainable Energy Development Scenario (SEDS) is shown in **Figure 8-18.** GHG emissions would increase from 2,864kt in 2022 to 3,458kt in 2030 and to 6,672kt in 2050. The GHG emissions would grow at the average rate of 3.1% during 2022-2050. Compared to the Reference Economic Growth Scenario, GHG emissions in SEDS would be reduced by nearly 50% in 2050. Lumbini Province will have the industrial sector as a prominent energy intensive 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).

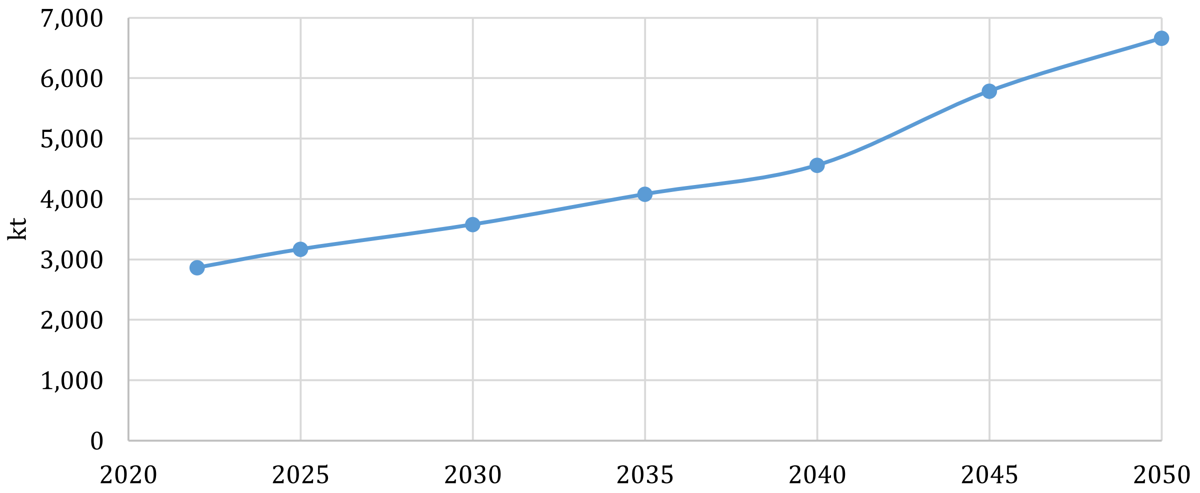


Figure 8-18. GHG Emissions at Sustainable Energy Development Scenario (SEDS)

Energy Indicators in the Sustainable Energy Development Scenario (SEDS)

Table 8-11 shows the **energy** indicator for policy scenario i.e., SEDS which clearly presents the impacts of strategic interventions in energy sector. Per capita final energy demand is 90% of that in Reference Economic Growth Scenario in 2050, while the electricity – which comes from clean renewable resources – increases to 3,500 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. GDP energy intensity improves from 0.39 toe/US$1,000 in 2022 to 0.21 toe/US$1,000 in 2050. The current GDP energy intensity in the South Asia region is 0.3 toe/US$1,000, whereas in the emerging developing countriesit is 0.28 toe/US$1,000[7]. Due to energy transition envisaged in the SED scenario, GDP energy intensity has decreased by almost 50% by 2050 compared to 2022. In addition to this, the share of fuel imports decreases to 31% of total energy from52% in reference scenario in 2050. On other hand, use of national resources increases with increase in use of renewables to 34% in 2050 as compared to only 14% in the REF Scenario.

Table 8-12. Energy Indicators in Sustainable Energy Development Scenario (SEDS)

		2022	2025	2030	2035	2040	2045	2050
Final energy demand/capita	GJ/capita	15.08	14.33	14.75	17.38	21.19	27.56	37.93
Final electricity demand	kWh/capita	307	452	690	1,014	1,491	2,240	3,490
Final energy demand	GJ/million NRS	130	112	92	84	76	71	67
Final Electricity Demand	kWh/million NRS	2,641	3,538	4,319	4,910	5,382	5,784	6,165
Total Electricity Used/household	kWh/HH	480	556	684	812	940	1,068	1,196
Share of renewable energy in final total energy demand (solar, biogas, hydro, etc.)	per cent	10.2%	14.3%	19.4%	23.0%	26.8%	30.3%	33.7%
The ratio of net import to total primary energy supply	per cent	47.5%	48.9%	51.2%	48.3%	42.2%	38.7%	31.0%
GHG emissions	GHG in Kg/capita	559	577	612	680	714	852	923

8.2. Comparative Analysis

Figure 8-19 shows the final energy demand for the reference and policy (SEDS) scenarios which clearly shows the impact of fuel switching and energy efficiency. With lower growth rate of 4.6% in the SED scenario instead of 5.1% in REF scenario, the total final energy demand could be reduced by nearly 13% in 2030 and by 11% in 2050. Although the energy saving does not look as significant, it is to be noted that the energy mix changes significantly – from imported petroleum fuels to indigenous clean energy.

[7]https://databank.worldbank.org/source/world-development-indicators/Series/EG.EGY.PRIM.PP.KD

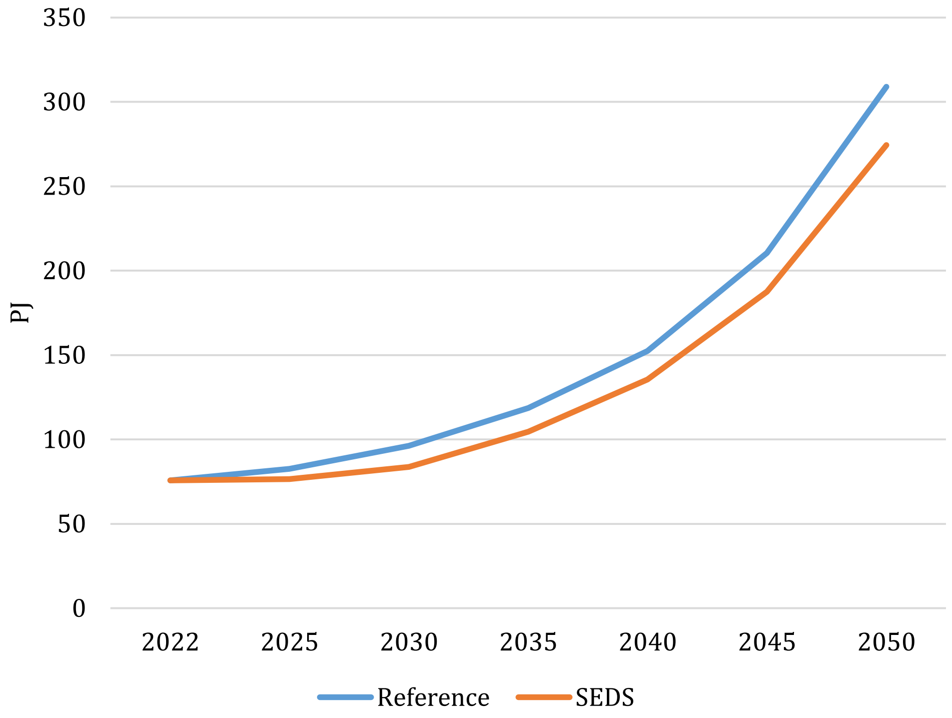


Figure 8-19. Total Final Energy Demand in Lumbini Province

A comparable pattern in per capita energy demand is seen in **Figure 8-20,** withthesimilar reduction in energy intensity as a result of penetration of energy efficient technologies. The major factors in decreasing the energy intensity arefrom use of cleaner technologies, which are more efficient in industrial, commercial,and residential sectors.

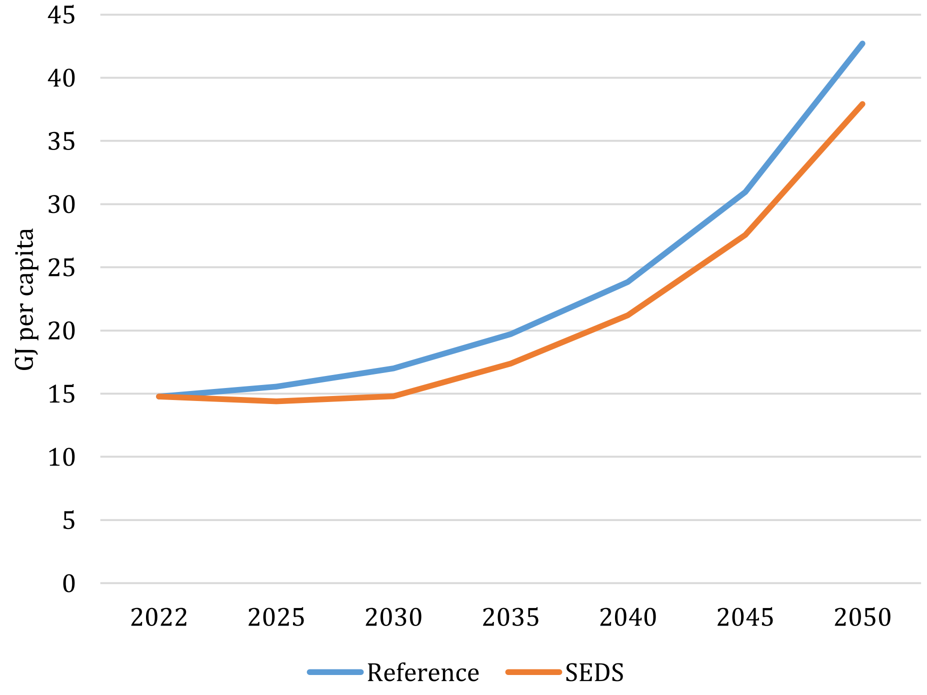


Figure 8-20. Final Energy Demand per capita in Lumbini Province

Figure 8-21 depicts the electricity demand in compared scenarios which shows that in the SEDS. The total electricity consumption will grow at very high rate reaching 3,500 kwh per capita in overall due

to electrification in almost all possible areas. Meanwhile, the household electricity demand reaches 684 kWh/HH by 2030 and 1,200 kWh/HH by 2050 which is still far from the Tier-5 criteria of 3,000 kWh/HH by the World Bank (WB/ESMAP, 2019). However, the growth in access to electricity means an increase in demand for nationally available hydroelectricity production.

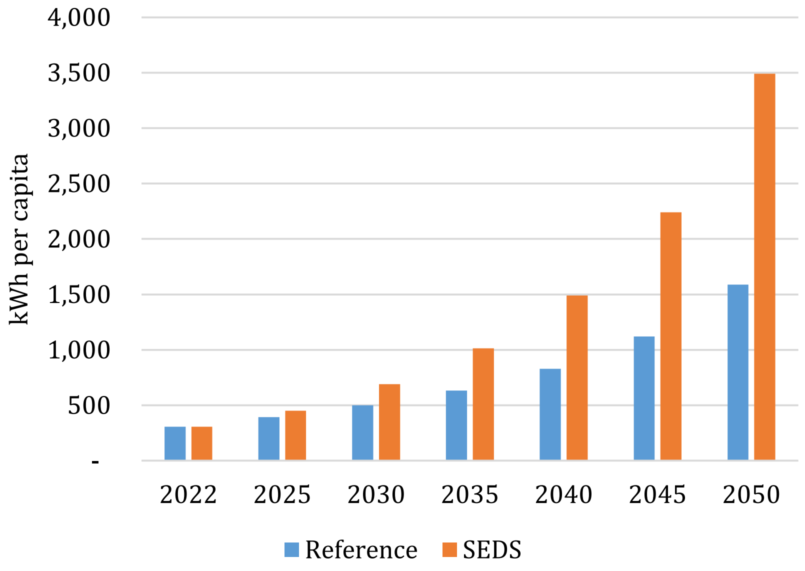


Figure 8-21. Electricity Demand Per Capita in Lumbini Province

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 8-22.** The share of clean renewable energy would increase from 10% in 2022 to 34% in 2050, provided that enough hydropower and power from solar PV are developed provincially and nationally.

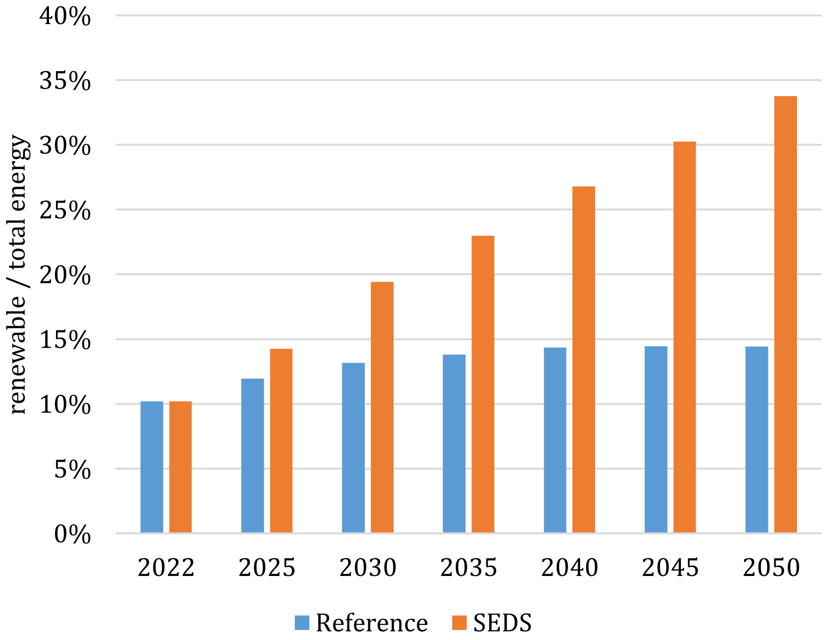


Figure 8-22. Renewable Energy to Total Energy Demand Ratio in Lumbini Province

The effect of energy development and production from indigenous resources reduces the pressure on fuel dependency which is depicted in **Figure 8-23.** There seems to be no improvement in thenet fuel import to total energy ratio till 2030 because of rapid intervention of ICS. Meanwhile, the ratio of 52% in the Reference scenario would come down to 31% in the SEDS in 2050 with the enforcement of energy transition policy actions and thus, strengthening the energy security of the country and reducing outflow of foreign currency. Consequently, it can enhance the balance of the payment of the Lumbini Province and the country.

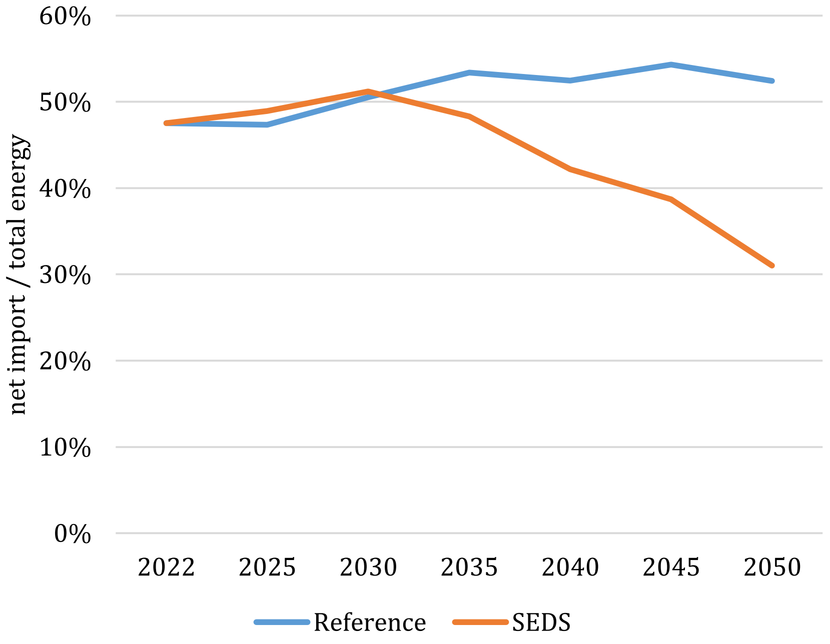


Figure 8-23. Petroleum Import to Total Energy Ratio in Lumbini Province

Figure 8-24shows the impact in GHG emissions due to policy interventions of clean energy. Emissions which were growing at the rate of 6% in the Reference Economic Growth Scenario would increase at the rate of only 3% resulting in the GHG emissions reduction of 13% in year 2030 and up to 48% in 2050. This reduction in GHG emissions is not only beneficial for climatic reasons, but also (a) for health perspective – since use of carbon-based fuels emit other pollutants that directly affect health of local population and users, and (b) for economic perspective -by monetizing the emission reduction through carbon trading.

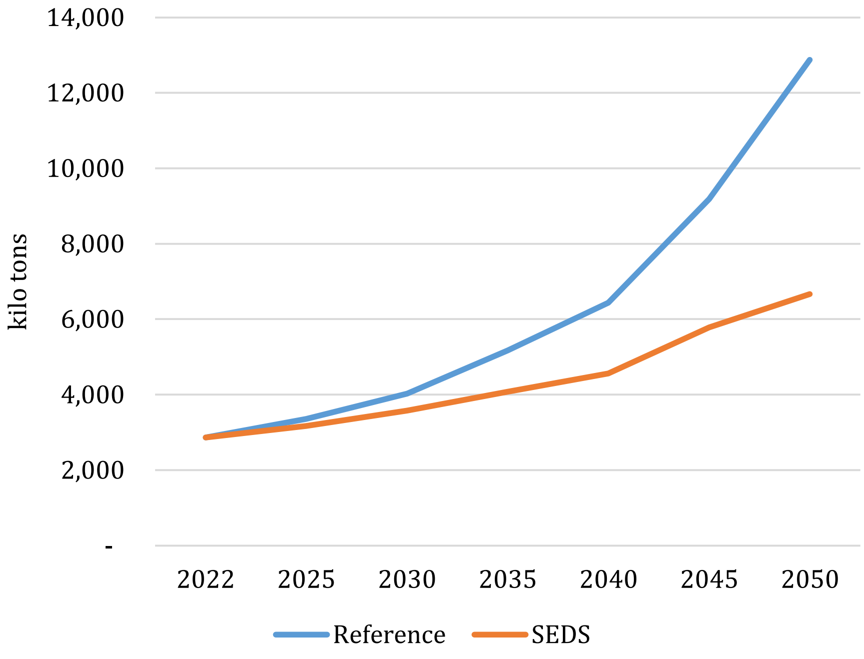


Figure 8-24. GHG Emissions in Lumbini Province

To meet the larger share of the energy requirements in the SEDS and to achieve the sustainable development goals the development of hydropower plants is essential. The hydropower plant capacity requirement in the SEDS is estimated to be 1,943 MW i.e., 33% more than in the reference scenario in 2030 and the capacity requirement goes up to 11,530 MW i.e. double the requirement in the reference scenario (**Figure 8-25).**

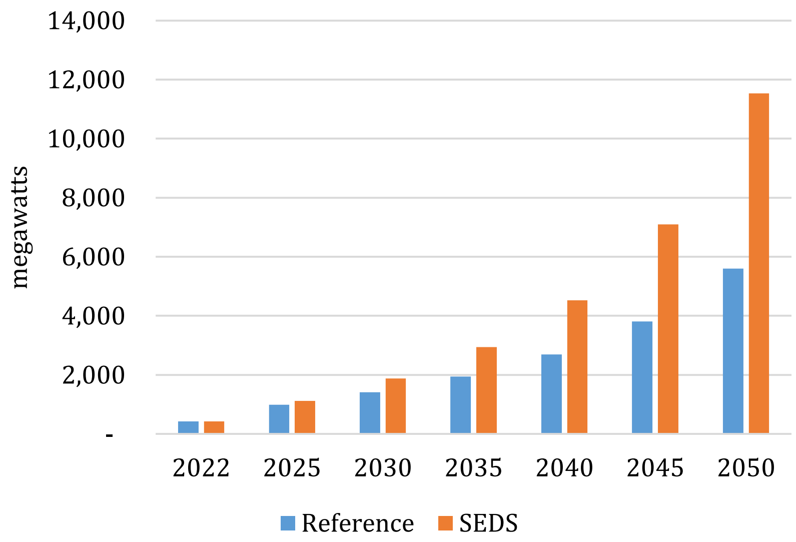


Figure 8-25. Hydro Power Plant Capacity Requirement in Lumbini Province

8.3. Provincial Comparison

Comparing the energy consumption of Lumbini Province with the rest of the province, the total consumption of the province is 2nd highest among the seven provinces. One of the major reasons for higher consumption in Lumbini Province is the large number of industries here in compared to other provinces that have higher energy consumption. Moreover, the overall population of the province is also high, causing a higher demand for energy (**Figure 8-26**).

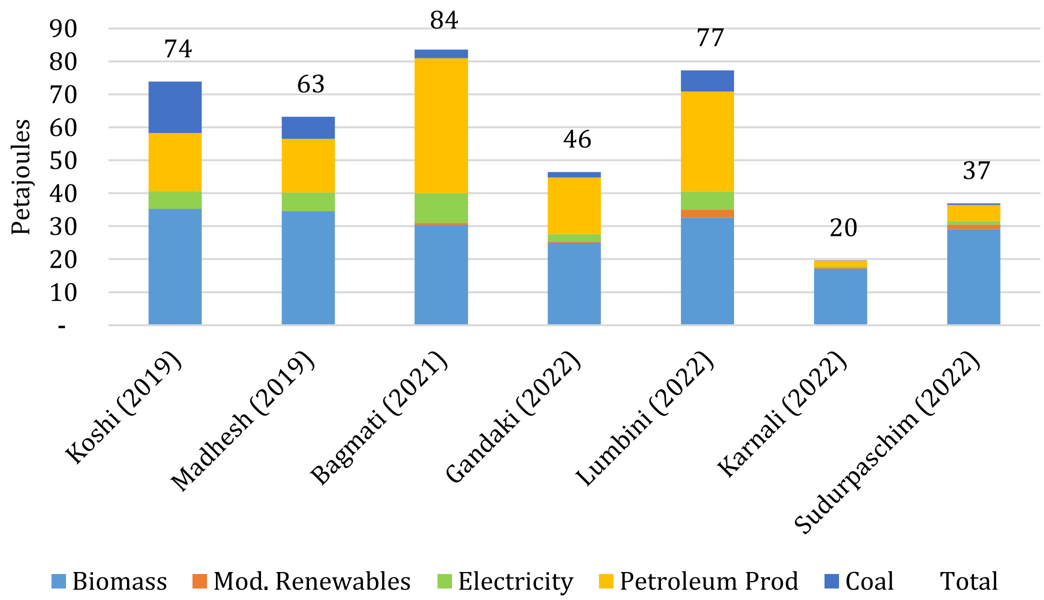


Figure 8-26. Provincial Comparison of Energy by Fuel Types

The comparison of energy consumption per GVA of all seven provinces is shown in **Table 8-13**. It shows that Gandaki has the highest industrial energy per GVA showing lower energy efficiency as well as the use of diesel generators for electricity. Meanwhile, Lumbini has the least industrial energy per GVA indicating lower energy-intensive industries in the province. Similarly, commercial energy per GVA of GandakiProvince and that of Lumbini Province is comparable and is high compared to the other provinces indicating the lower efficiency owing to a large share of primary solid fuels used in the commercial sector. Comparing the agriculture energy intensity, Lumbini has the highest intensity showing energy-intensive activities compared to the other provinces. Similarly, energy consumption per capita in residential sector is the highest in Sudurpashchim Province due to the large share of primary solid fuels used for cooking and other residential activities. Energy consumption per capita in the transport sector of Koshi Province is the highest and is comparable to Bagmati, Lumbini, and Gandaki.

Table 8-13. Comparison of Energy Consumption per GVA / per Capita Among Different Provinces

	Energy consumed per provincial gross value addition (KJ/NR of GVA)						
Economic sector	**Koshi**	**Madhesh**	**Bagmati**	**Gandaki**	**Lumbini**	**Karnali**	**Sudurpashchim**
Agriculture	2.74	4.39	4.85	11.46	29.33	4.40	9.98
Commercial	7.78	9.18	7.23	18.18	16.22	11.07	8.20
Industrial	871.98	602.51	444.4	1,304.09	738.55	183.01	441.93
Construction & mining	14.5	11.3	14.59	19.89	53.26	14.85	24.92
	Energy consumed per capita (GJ/capita)						
Residential	5.97	6.37	5.03	7.84	5.64	9.93	10.04
Transport	1.48	0.94	1.44	1.28	1.33	0.53	0.46

9. Economic Analysis

There are strong interactive linkages among energy, economics and the environment. A comparative analysis has been conducted between these segments in the Reference scenario and the SEDS. This kind of analysis is essential for the policymakers to take necessary implementation actions in the energy sector of Lumbini Province. **Table 9-1**shows the total investment cost for supply technologies in 2022 constant prices compared to the GDP under respective years.

9.1. Capital Investment

In REF scenario, the gross investment share in supply technologies is around 0.88 % of GDP on average. In SED scenario, new and efficient technology interventions are done. To achieve the sustainable developments goals, capital investment should increase from current 1% of GDP to 14% by 2030 and to 25% by 2050 respectively. The high investment in SED scenario is mainly due to the investments required in hydropower 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 9-1).**

In the case of Lumbini Province, which has limited resources and feasibility for development of hydropower plants, the province can invest on infrastructural development for power transmission development and also focus on large solar power plants. Thus, the capital investment as given in **Table 9-1,** would be required to develop the power plants in the province.

Table 9-1. Total Technology Cost for Different Scenarios

	2022	2025	2030	2035	2040	2045	2050
Investment in the REF scenario in NR billion	2.61	18.00	30.68	45.87	67.64	101.63	158.60
Capital Investment as % of GDP	0.88%	5.36%	6.86%	7.47%	7.72%	7.80%	7.83%
Investment in the SEDS scenario in NR billion	2.61	26.08	63.91	112.38	184.70	301.35	503.30
Capital Investment as % of GDP	0.88%	7.76%	14.30%	18.29%	21.08%	23.14%	24.85%

Development of large hydropower plants comes under the purview of the federal government of Nepal, and even for the federal government, the power plant development costs are huge. As per policy research working paper of the World Bank for infrastructure development in emerging markets and developing countries, investment costs come around 6% of the GDP in the energy sector in the South Asia region (Ruiz-Nunez, F. and Wei, Z., 2015). As GHG emissions will be decreased by almost 50% in 2050 in the SED scenario, the Government of Nepal must seek international climate grants and finance funds, international financial institutions, and domestic private finances for the development of power plants required in the country.

9.2. The Marginal Abatement Cost

GHG emissions for reference scenario and SEDS scenario is shown in **Figure 9-1**. 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 15%, and 48% in 2050. This considerable reduction of GHG emission accounts for efficient and modern technology.

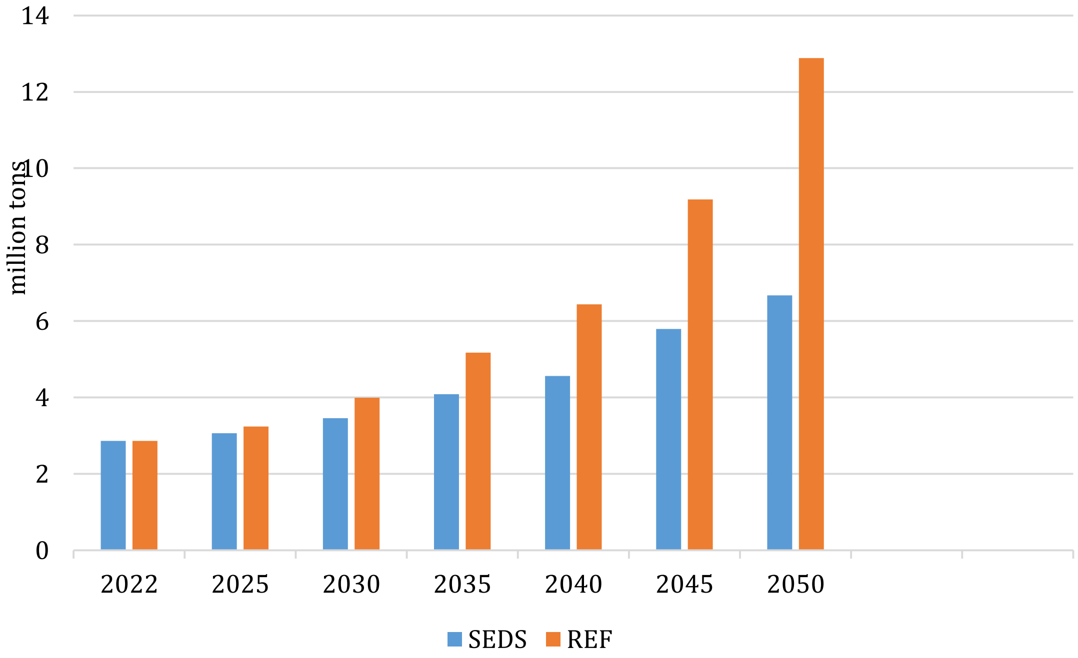


Figure 9-1. GHG Emission for Different Scenarios

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 plants and solar power plants. Thus, it is essential to measure the investments required to understand the applicability of the strategic actions for reduction of emissions. **Table 9-2**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 (Wang et. al, 2022).

Table 9-2. Marginal Abatement Cost

	2025	**2030**	**2035**	**2040**	**2045**	**2050**
Incremental Investments (Billion Rs.)	8	33	67	117	200	345
GHG abated (kt)	172	535	1,088	1,871	3,393	6,209
MAC ('000 NPR/ton of CO2e)	47	62	61	63	59	56

9.3. Net Fuel Import Cost

Figure 9-2 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 19billion NRs in 2030 and 476 billion NRs in 2050 from that of REF scenario. All the costs incurred are at constant price of 2022. These 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 59% of the investment required in

2030 for clean power plant development, while in 2050 the saving can contribute all of the investment required. This indicates a 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 the need for proper energy policy in the future. Furthermore, detailed analysis of 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.

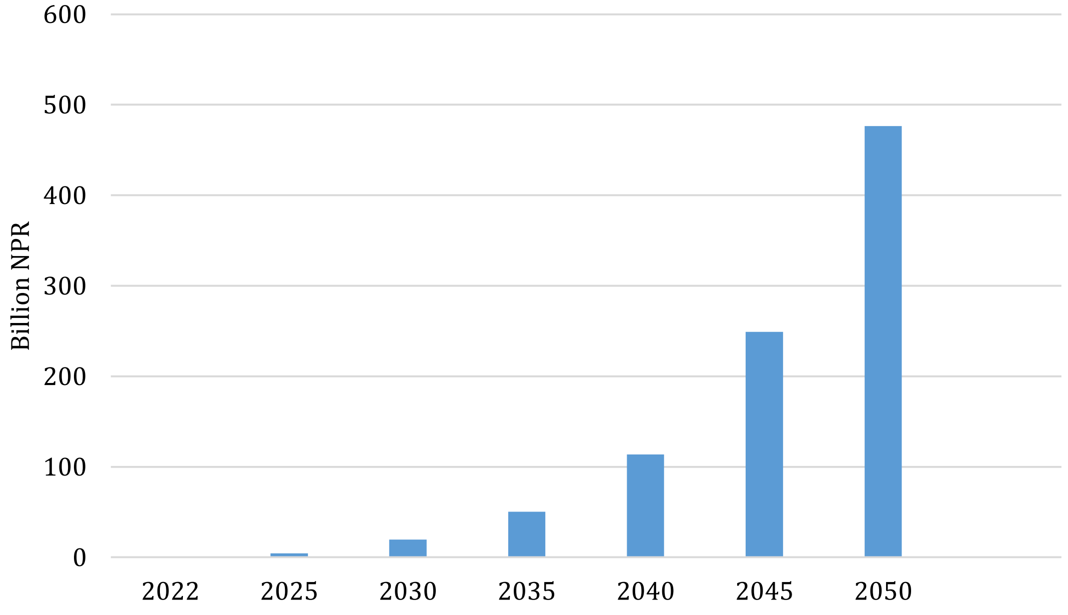


Figure 9-2. Net Fuel Import Cost Savings

9.4. Carbon trading

In addition to savings from imports of fuels and the value addition to national economy by trading of electricity produced within the nation's boundary, additional economic benefits can also be obtained from carbon trading. 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 9-3.**

Table 9-3. Carbon Trading Benefits

	2025	2030	2035	2040	2045	2050
Carbon trading benefits (Billion Rs)	1.74	3.87	9.05	21.37	15.07	35.59

Fuel costs saving and carbon certificate trading can provide the huge capital investments required for energy transition to clean renewable energy, if the Lumbini provincial government/Nepal government undertake the pathway for the sustainable energy development.

10. Limitations and Constraints of the Survey

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

- The primary and secondary data on the current situation of the province were not available at the most, which is needed during the pre-planning phase of the study and also required for the post-analysis of the energy consumption – such as the population of the sector; the gross value added of each type of economic sector and subsector; the number of vehicles by type and registration; the types of household; the actual number of functioning institutions, as well as the supply database.
- Many respondents were reluctant to give information due to hesitation, mistrust, and unwillingness to share personal information, and even dissatisfaction with the current situation as one of the major hurdles.
- Although the surveyors were technically sound and of the same geographical background – which aided a fluent workout during the survey, the social situation, mainly in the rural area posed some problems. The residents would either be hesitant and/or have no idea about the specific questions asked.
- The economic sectors such as the commercial and industrial sectors were reluctant to share their information. Either they refused to give information or had to have multiple visits. In industries, data collection was the most difficult. Sometimes access to industrial premises and information was denied even at the requests of experts by telephone. The unavailability of concerned persons, no knowledge of required information, and even not having the authority to provide information were the major responses posed by the respondents.
- In addition, some information provided by respondents was too dubious. Such data had to be adjusted by expert judgment.
- The information provided by some of the respondents were not as accurate as they had to give them on hunch or based on their memory and in many cases such as residential, agricultural, and small commercial entities do not keep a record of their energy uses.
- The newly added construction and mining sector also had major difficulties in the collection of data. This sectorial entity is not locally based and/or brings the equipment from other regions when necessary for the limited time as per requirements. Thus, their energy consumption had to be based more on overall yearly energy consumption than on each end-use activity.

Despite all the limitations and constraints faced, the survey was conducted with realistic means to retrieve the required energy and other information.

11. Conclusion and Policy Recommendations

The updated database of energy consumption is essential 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 is related to energy consumption determined through primary sample surveys and the energy supply situation is based on secondary resources in the Lumbini Province. It 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 - except residential, is gross value added while that of residential sector is taken as population. In addition to that, a situational analysis of macroeconomic indicators of Lumbini Province and socio-economic analysis in the residential sector based on the survey have been carried out.

In 2021/2022, the primary sample survey shows that the total final energy consumption of the Lumbini Province was 77 PJwhich accounts for 15 GJ per capita. This energy consumption per capita seems to be in line with the averages from previous studies. The shares of energy consumption in economic sectors of the Lumbini Province indicate some differences from the national level energy consumption pattern. Residential and Industrial sectors consume almost equally 37% of total energy consumption. However, the share of energy consumption in the industrial sector, compared to national level, is quite high due to industry bases in the province. This is primarily because Lumbini Province, like Koshi Province, is an economic hub for industry. Transport sector demand is 9% and commercial 7% respectively. One prominent feature is the final energy consumption in the agriculture sector, and it stands at also 7% which is quite high compared to the figure for the national level. It is because agriculture is a major activity in flat lands of terai and the mechanization in agriculture sector is also very predominant due to easy accessibility of agri-machines in flat lands. Meanwhile in the commercial sector, which is already less energy intensive due to availability and less interruption of electricity supply recently, the overall energy intensity is lower due to higher efficiency of electrical appliances. As for energy consumption by fuel types, the use of biomass is still prevalent at around 42%. Petroleum products are 40% of the total energy consumed in the province, coal is 8% and electricity is 7%. Modern renewables account for 3% of the total energy and they are mostly from biogas plants.

As per ecological regions, Lumbini Province has only two regions – Terai and Hilly regions. Terai region has the highest consumption with 65% of the total consumption in the province, which is followed by hilly region at 23% and the rest is consumed in the transport and construction and mining sectors, which is at 12% of the total consumption. Terai and Hilly regions consume fuelwood at 22% and 16% respectively of the total energy consumed in the province, while fossil fuels and electricity consumptions in the Terai region are high with 47% and 10% respectively of the total which is understandable with the concentration of industries in the region. Fossil fuel consumption in the hilly region is 21% of the total provincial consumption. LPG consumption in Terai region is around 8% of the total, followed by 5% in the hilly region, respectively.

The forest area and potential fuelwood production in the current status show potential production of 1,438 kilo tons in Lumbini Province. As per projection done in the forestry sector, the volume of fuelwood can reach 2,276 kilo tons in 2040. There is potential production of 7,263TJ of energy from

Biogas in the province while the total potential energy produced from agricultural waste is 48,279 TJ. Almost 57% of this energy comes from paddy straw, and about 24% comes from maize. As for the supply of petroleum products, the province depends entirely on the import of petroleum products. There was a supply of 106 million liters of gasoline, 419 million liters of diesel, around 5.7 million liters of kerosene and 117,000 MT of LPG respectively in the province. Meanwhile, the total sales of electricity in the Lumbini Province are 1,487GWh. In the renewable energy sector, there are 2.9 MW of micro-hydro plants installed in Lumbini Province. Approximately 572 kW_p of institutional Solar PV systems are installed, and152,300 numbers of SHS were installed in the province. Most of the biogas plants are sized 4 cubic meters in the province. There are 67,600 domestic biogas plants with 20 numbers of large biogas plants, 211,000 mud ICSs, and 6,926 metallic ICSs in the province.

Lumbini Province is industrially and commercially active. Therefore, there is higher usage of commercial energy sources such as fossil fuels and electricity. In the residential sector there is seemingly transition from traditional to modern fuels while the agricultural sector has taken a significant leap forward towards renewable energy. 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.

The primary survey and the subsequent supervisory visit by the WECS officials and the study team members indicated evidence and palpable signs of energy transition to clean energy from fossil fuels even in the industrial sector where the management was reluctant to shift to electricity because of power reliability and voltage fluctuations. With the upgradation of transmissions and distribution systems by the NEA and the GoN's massive plan to revamp the infrastructure, Nepal can move forward with the targets set by the Long-Term Strategy (LTS) for net-zero emissions by 2045, and the NDC 2020, and the roadmap to achieving the SDGs by 2030.

Therefore, overall, the total energy consumption in Lumbini shows an energy transition in residential sectors and productive sectors like industry, transport, commerce and services and agriculture. The impact of energy efficiency is evident from the consumption shift to modern form of energy and clean energy. However, there is still a huge potential of intervention of more energy efficient technologies along with inclusion of indigenous modern renewable clean energy technologies.

A large-scale bottom-up partial-optimization modelling framework developed collaboratively by IEA-ETSAP program is used for energy scenario development in Nepal, encompassing provincial economy, energy consumptions based on primary survey and secondary data, and climate issues - especially GHG emissions. Further, this Integrated Energy – Economy - Climate (IEEC) Model is designed to analyze a diverse range of aspects of the energy system. The IEEC model uses a scenario approach to examine future energy trends. The IEEC Model is used to explore various scenarios, each of which is built on a different set of underlying policy assumptions about how the energy system might respond to the current global energy crisis and evolve thereafter based on the national energy and climate -related plans and programs, and Nepal's commitment and pledges to the international energy and climate related programs. Four scenarios – Low Economic growth (LOW), High Economic growth (HIH), Reference (REF), and the Sustainable Energy Development (SED) Scenarios were developed.

The projected final energy demand in the REF scenario anticipates a substantial growth, escalating from 77 PJ in 2022 to 309 PJ in 2050, reflecting a fourfold increase in demand. While the proportion of solid biomass in the total final energy is expected to decline from 42% in 2022 to 33% in 2050, petroleum products' share is forecasted to slightly rise from 40% to 43% during the same period. Despite this, the absolute demand for petroleum products is set to experience a significant surge. Additionally, electricity demand is poised to climb to 13% of total final energy by 2050, up from 7% in 2022, necessitating a substantial increase in installed power capacity from 420 MW in 2022 to 5,600 MW in 2050.

In the SED scenario, characterized by diverse energy transition policies, the projected final energy demand for 2050 is 274 PJ. Solid biomass fuels are anticipated to constitute 35% of the total final energy, while petroleum products are expected to decrease to 28%. Notably, electricity is poised to represent 32% of the total energy, driven by strategic measures like sectoral electrification. The envisaged power plant capacity required by 2050 is 11,530 MW. The GDP energy intensity exhibits a positive trend, improving from 0.39 toe/US$1,000 in 2022 to 0.21 toe/US$1,000 in 2050. This marks a substantial 50% reduction in GDP energy intensity, contributing to enhanced energy security and sustainability. The electricity intensity of GDP is projected to reach 6,165 kWh/NR million in 2050, a notable increase from the 2,805 kWh/NR million in the Reference (REF) scenario. Additionally, per capita greenhouse gas (GHG) emissions are anticipated to decrease to 923 kg in 2050, in contrast to the 1,781 kg in the REF scenario, reflecting a significant 50% reduction. This outlook aligns favorably with the country's energy security and sustainability objectives.

Policy Recommendations

- **Energy Generation Capacity Development**

  The study shows that the province does not have enough capacity of electricity generation plant from hydro resources. The demand is going to increase at a higher rate if sustainable energy development goals are to be achieved. The under construction and planned plant capacity are supportive, but in the long run, it will not be enough to cater for the electricity demand within the province. Thus, the province should focus on more plant capacity development – with integration of utility scale variable renewable energy generation plants like Solar, waste to energy etc.

  - *Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province;Ministry of Forest, Environment and Soil Conservation – Lumbini Province;Ministry of Agriculture Land Management – Lumbini Province; Lumbini Province Planning Commission; Alternative Energy Promotion Center; Nepal Electricity Authority – Lumbini Province*

- **Energy Infrastructure Development**

  It is crucial to increase accessibility and reliability of energy – mainly electricity. Given that the province has very limited hydropower resource, limited accessibility in remote areas and reliabilities issues even in urban areas, the electricity infrastructure needs to be expanded as well as upgraded. Increasing accessibility and reliability will increase the consumer confidence in its use itself. Thus, it will also support the demand creation. Furthermore, expansion of road infrastructure also supports to increase the accessibility to modern technologies and services.

  - *Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province; Ministry of Physical Infrastructure Development – Lumbini Province;Lumbini Province Planning Commission; Nepal Electricity Authority – Lumbini Province*

- **e-Cooking Promotion**

  Given that the province has very low penetration of electric cooking technology users, the province should promote the use of e-cooking wherever possible. In short term, the commercial sectors can be motivated to adopt eCooking, while with expanded reach and capacity for technology, electricity, and awareness, full-fledged electrification in cooking e can be promoted. E-cooking can have multitude of impactful benefits – it is a clean cooking solution, it creates internal demand for electricity, it reduces LPG imports, it is the most efficient of all cooking technologies and also it is economically cheaper.

  Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province;Alternative Energy Promotion Center; Nepal Electricity Authority – Lumbini Province

- **EnergyDemand Creation**

  In the province, the potential energy demand would come from industrial, agricultural, commercial and transportation sector by mechanization and electrification. Currently, there's excess electricity production in the nation in wet seasons, risking wastage if demand isn't stimulated. By fostering demand, in fore mentioned sectors, the province can boost economic output and enhance its overall status. Increasing energy demand aligns with broader development goals, ultimately contributing to the prosperity and advancement of the province.

  Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province; Ministry of Agriculture and Land Management – Lumbini Province; Ministry of Industry and Transportation Management – Lumbini Province; Lumbini Province Planning Commission; Alternative Energy Promotion Center; Water and Energy Commission Secretariat; Nepal Electricity Authority – Lumbini Province

- **Energy Efficiency Regulations**

  In Lumbini Province, the energy-intensive activities come mainly from industries. It is crucial to prioritize energy efficiency that enhances productivity, minimizes energy waste, and reduces economic losses. Therefore, implementing energy efficiency regulations in the long term is essential. These regulations will ensure that energy-consuming activities in the province are conducted in the most resource-efficient manner possible, leading to not only economic benefits but also environmental sustainability. By promoting energy efficiency alongside demand creation, Lumbini Province can optimize its energy use, spur economic development, and contribute to a greener future.

  Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province; Ministry of Industry and Transportation Management – Lumbini Province; Lumbini Province Planning Commission; Alternative Energy Promotion Center; Water and Energy Commission Secretariat

- **Clean Energy Regulations**

  The integration of clean energy regulations within the broader energy demand creation strategy is paramount for fostering sustainable development in Nepal. While stimulating economic activities and meeting escalating energy demands, a cautious approach must prioritize the adoption of clean energy sources in the short term, with a view towards mandating their use in the long term. An effective regulatory framework can facilitate this transition by incentivizing the deployment of small-scale solar photovoltaic (PV) systems to power equipment initially, with provisions for capacity upgrades to larger systems over time. Furthermore, promoting the clean and efficient utilization of biomass in thermal processes within industries and commercial activities is imperative. By enacting and enforcing such regulations, the province can accelerate the transition towards a low-carbon economy, reduce reliance on fossil fuels, and mitigate the adverse impacts of energy consumption on public health and the environment.

- *Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province; Lumbini Province Planning Commission; Ministry of Forest, Environment, Tourism and Drinking Water – Lumbini Province; Alternative Energy Promotion Center; Water and Energy Commission Secretariat*

- **Renewable Energy Commercialization**

The findings highlight a concerning trend of underutilization and inefficient utilization of renewable energy sources in Nepal, particularly in the case of biomass. Despite its abundance, biomass predominantly fuels traditional open stoves in the residential sector, contributing to health hazards, environmental degradation, and resource depletion. This represents a non-productive use of energy and underscores the urgent need for intervention. By transitioning to clean energy alternatives for cooking in residential areas, such as improved cookstoves or biogas systems, there exists a significant opportunity to commercialize the forest sector as an energy resource for industrial sector. This shift not only addresses the pressing issues of health and environmental sustainability but also unlocks economic potential by creating markets for renewable energy technologies. Thus, promoting renewable energy commercialization emerges as a strategic imperative for fostering sustainable development and mitigating the adverse impacts of traditional biomass use.

- *Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province; Ministry of Forest, Environment, Tourism and Drinking Water – Lumbini Province; Ministry of Agriculture Land Management – Lumbini Province; Ministry of Industry and Transportation Management – Lumbini Province; Lumbini Province Planning Commission; Alternative Energy Promotion Center; Water and Energy Commission Secretariat*

- **Database Management**

Effective database management is critical for informed decision-making in energy planning and policy formulation. A comprehensive database serves as evidence and benchmark for developing strategies and initiatives. Therefore, it is recommended to establish a reliable and robust database management system - encompassing all facets of energy and related matters, providing stakeholders with access to accurate and up-to-date information. The recommendations outlined in this report underscore the need for provincial governments to take proactive steps in setting up database management systems, particularly at the provincial level. By leveraging the newly developed National Energy Information System (NEIS) and the provincial reports as reference points, such systems can streamline data collection, storage, and analysis, facilitating evidence-based decision-making and fostering transparency and accountability.

- *Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province; Lumbini Province Planning Commission; Water and Energy Commission Secretariat*

- **Awareness Creation and Capacity Building**

  The provincial government can play a pivotal role in fostering awareness creation and capacity building initiatives. Given the nation's transition towards sustainable energy sources and the pressing need to address environmental and energy security concerns, it is imperative for provincial governments to spearhead efforts in raising awareness and building capacity among stakeholders. Such initiatives are essential to instill a deeper understanding of the benefits and importance of clean energy adoption. Moreover, capacity building programs aimed at enhancing technical skills can catalyze innovation and entrepreneurship, driving economic growth and job creation in the province. Ultimately, by investing in awareness creation and capacity building for the clean energy sector, provincial governments can foster a culture of sustainability, unlock socio-economic opportunities, and pave the way for a greener, more prosperous future.

  - *Actors: Ministry of Energy, Water Resources, and Irrigation – Lumbini Province; Alternative Energy Promotion Center; Water and Energy Commission Secretariat*

Overall, the energy consumption analysis in the base year 2022 and the policy measures taken in the future energy development in the Lumbini Province indicate that a sustainable pathway based on renewable energy, and energy efficiency is the best option for its provincial energy development, and the sustainable energy development in the national context. The total consumption of the province is 2^{nd} highest among the seven provinces due to large number of industries compared to other provinces and the overall population of the province is also high, causing a higher demand for energy. This study also indicates that with the core focus on energy security, reliability, and sustainability, Lumbini Province/Nepal’s energy development should be geared towards 5 energy transition 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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